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GREEN TECHNOLOGY ADOPTION IN MALAYSIA: WHERE ARE WE NOW? WHAT IS LACKING? & WHAT SHOULD WE DO NEXT?

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Abstract:

There have been numerous studies on the adoption of green technology, particularly in the manufacturing industry. Nevertheless, the evidence of green technology being used by firms in Malaysia is still limited. The research objective is to investigate green technology adoption in Malaysia from the literature in order to understand what green technology has been adopted. This study performed a systematic literature review and bibliometric analysis to answer the research objective. The database chosen to undertake this study is Scopus, Web of Science and Lens.org. Findings show that i) most studies in the literature is still focusing on the adoption or acceptance of green technology by firms, ii) most studies are written for management focus, and iii) energy and construction industry being the most investigated area of research. The literature gaps are showing that Malaysia green technology adoption is still in the infant stage. Currently, the literature is stagnant with many conceptual papers only contributing to the first level of green technology perception. Future research should focus on providing empirical evidence of green technology adoption.

Keywords:

Green Technology, Technology Adoption, Environmental Management, Systematic Literature Review, Bibliometric Analysis, Malaysian Firm

Introduction

Green technology is one of the enablers for increasing environmental performance for firms and reducing environmental threats. There have been numerous studies on the adoption of

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green technology, particularly in the manufacturing industry (Peng, Zheng, Wei, & Elahi, 2020; Mishra, Polkowski, Borah, & Dash, 2020; Lin, & Liu, 2020). The industry of producing goods is known to be one of the largest polluters of air pollution and waste. Various studies have been found to promote green practices at the firm level (Chang, Wan, Lou, Chen, & Wang, 2020; Kruse, Mohnen, Pope, & Sato, 2020), and green supply chain practices at the supply chain level (Zhang, & Yousaf, 2020; Shahzad et al., 2020). One of the main practices is to substitute conventional technology consisting of equipment and machinery to greener technology. Firms in the developed countries are more accepting the adoption of green technology in order to adhere to the regulations and customer requirements (Guo, Nowakowska-Grunt, Gorbanyov, & Egorova, 2020).

However, investment of green technology is expensive and require firms to allocate its resources and support from the top management. There is also a question of transferring the technology to other firms, especially firms in developing countries. Firms in developing countries such as Malaysia are serving as the contract manufacturer to other manufacturing firms, and sharing technology is considered as sensitive. Literature had shown that scholars are keen on investigating green technology in Malaysia (Vaka, Walvekar, Rasheed, & Khalid, 2020; Show, Thangalazhy-Gopakumar, & Foo, 2020), and this topic is no stranger in Malaysia with several policies have been enforced by policymakers to provide incentives to manufacturing firms adopting green technology (Shaharudin, Fernando, Jabbour, Sroufe, & Jasmi, 2019).

Malaysia is aiming to become a sustainable nation by 2020 through green technology. The Malaysian government understood that for Malaysia to become sustainable, it must adopt green technology in the whole supply chain network of firms and government agencies. Thus, the Malaysian policymakers are proposing green technology initiatives for renewable energy, energy efficiency and conservation, and green tax incentive (MIDA, 2019). For each green initiative, green technology is emphasized. For example, renewable energy can be adopted throughout Malaysia through initiatives such as Feed-in-Tariff (FiT), the Net Energy Metering (NEM), and Large-Scale Solar (LSS) Photovoltaic plant schemes. These initiatives are focus for society and firms. On the other hand, to improve energy efficiency or conservation, green technology adoption among energy service firms (ESCOs) were aimed by the government. Furthermore, green tax incentives were given to firms converting to green technology machinery and equipment.

Nevertheless, the evidence of green technology being used by firms in Malaysia is still limited (Yao, Song, Yu, Guo, 2020; Chan, Okumus, & Chan, 2020). Therefore, the research objective is to investigate green technology adoption in Malaysia. The research objective is guided by PICo which stands for Population (the targeted population is firm in Malaysia), Interest (the interest of this study is the adoption of green technology), and Context (Malaysia).

The contribution of this study is that it paves the understanding of green technology adoption in Malaysia. Through the understanding of current literature of green technology adoption, gaps in the literature and future research can be identified. Furthermore, determining the gaps will increase the understanding of green technology adoption that is useful for policymakers to provide incentives. Moreover, firms are able to identify current practice regarding green technology and the improvement needed.

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The next section will discuss on the green technology with its features, current literature on green technology and Malaysian context. The methodology section will thoroughly describe the process of searching, filtering, selecting, and synthesizing the articles. The section followed by analysis section by presenting the bibliometric findings based on the systematic literature review and end with discussion and conclusion. These parts cover what is the current understanding of the literature regarding green technology adoption, what is lacking in the literature and what should be the future direction for scholars to address green technology adoption.

Literature Review

Green Technology can be defined as a technology complied with environmental regulation. The significant effect of compliance is that a non-compliance of environmental regulation will lead firms to receive penalties (Thimm, & Rasmussen, 2020). The advantage of adopting green technology is that there is attainment such as green incentive by the government (Lartey et al., 2020), meeting customer requirement (Nguyen, Onofrei, Truong, & Lockrey, 2020), positive brand image to the firm (Zameer, Wang, & Yasmeen, 2020), receives support from environmental Non-Governmental Organizations (Guo, Cheng, & Liu, 2020), and competitive advantage in the industry (Somjai, Vsuvanich, Laosillapacharoen, & Jermsittiparsert, 2020). Nevertheless, green technology requires inspection to be carried out by the firm periodically to ensure that the attainments are sustained (Shaharudin, & Fernando, 2017). Similarly, the firm also need to deploy the latest green technology to ensure efficiency in environmental protection and performance (Shanmugan, Shaharudin, Ganesan, & Fernando, 2019). This mean that the firm need to exploit potential technology and use it throughout the firm's operations and supply chain (Fernando, Wah, & Shaharudin, 2016).

The literature for green technology can be divided into management literature and engineering literature. Currently for management literature is discussing on green technology as innovative firm's process (Lizi, Zhu, & Yuan, 2020; Peng, Zheng, Wei, & Elahi, 2020), effect of adoption to the policy (Hussain, Pan, Ali, & Xiaofang, 2020) and country (Perruchas, Consoli, & Barbieri, 2020). On the other hand for engineering literature is discussing on sustainable product (Yousef, et al., 2020), carbon reduction technology (Yang, Zha, Wang, & Chen, 2020), supply chain network (Zhen, Wu, Wang, & Laporte, 2020), and product enhancement (Debnath et al., 2020; Zheng, Hu, Feng, Wang, & Zhang, 2020). The literature shows that green technology is still a hot topic among management and engineering scholars. In addition, the literature also shows that that empirical evidence is limited with firm-specific green technology adoption is only a few.

In Malaysia, green technology study is focusing on improving aquaculture wastewater (Jusoh, Nasir, Yunos, Jusoh, & Lam, 2020), green information technology (Anthony, Majid, & Romli, 2020; Islam, Muthaiyah, & Yong, 2020), product improvement (Nawi et al., 2020; Halimatul et al., 2020), green technology adoption (Sa'adi, & Zainordin, 2020; Lin, Alam, Ho, Al-Shaikh, & Sultan, 2020; Vinathan, 2020;), and behavioral research (Lau et al., 2020; Ogienwonyi, & Harun, 2020). Surprisingly, the latest literature of green technology in Malaysia is more on management literature with adoption of green technology and behavioral research were the main interest of scholars. Even though empirical evidence and adoption of green technology studies are plenty, there is still gap in the literature for Malaysian context such as how green technology impact the firms' in term of policies and sustainable performance.

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Research Methodology

This study performed a systematic literature review and bibliometric analysis to answer the research objectives. The database chosen to undertake this study is Scopus, Web of Science and Lens.org. The reason for considering these databases is due to these databases have comprehensive collections of abstracts, and scholars widely use it. The keywords used to answer the research objectives are “green technology” and “adoption.”

The Boolean operator of AND was used to ensure that more relevant results were included. Also, the truncated operator of * was used to ensure that both singular and plural words are included in the search as shown in Table 1. Table 2 shows an early search had resulted in 721 manuscripts. After filtering with the latest ten years of publication, only selecting articles and investigation in Malaysia, the total number of manuscripts falls to 44. By eliminating duplicates, the result is 29 manuscripts. The next stage is to filter based on the relevancy of the title, abstract, and keywords. Based on the filter, only 20 articles were relevant to answer the research objectives. The last stage is to check the quality of the manuscript. These 20 manuscripts were assessed by each research team member to ensure the bias is minimum, and only the best manuscripts will be included. Each member will provide evidence on whether to include or exclude the manuscript. Justification is required when the manuscript failed to get a consensus agreement among all team members. There are 17 manuscripts selected to be discussed in the findings.

Table 1: Search String

Database	Search String
Web of Science	TOPIC: ("green technolog*” AND "adoption*") Refined by: COUNTRIES/REGIONS: (MALAYSIA) AND PUBLICATION YEARS: (2019 OR 2017 OR 2015 OR 2012 OR 2013 OR 2018 OR 2016 OR 2014 OR 2011 OR 2010) AND DOCUMENT TYPES: (ARTICLE)
Scopus	TITLE-ABS-KEY ("green technolog*" AND "adoption*") AND (LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMITTO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011) OR LIMIT-TO (PUBYEAR , 2010)) AND (LIMIT-TO (AFFILCOUNTRY , "Malaysia")) AND (LIMIT-TO (DOCTYPE , "ar"))
Lens.org	Scholarly Works (12) = (Title: green technology OR (Abstract: green technology OR (Keyword: green technology OR Field of Study: green technology))) AND ((Title: adoption OR (Abstract: adoption OR (Keyword: adoption OR Field of Study: adoption))) AND ((Title: green technologies OR (Abstract: green technologies OR (Keyword: green technologies OR Field of Study: green technologies))) AND (Title: adoptions OR (Abstract: adoptions OR (Keyword: adoptions OR Field of Study: adoptions)))))

Table 2: Data Mining Phases

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Filter	Detail	Count
1st stage: Identification		
Database search	Scopus	238
	Web of Science	174
	Lens.org	309
	Total	721
2nd stage: Screening		
Year	2010-2019	
Country	Malaysia only	
Document Type	Article only	
Result	Scopus	17
	Web of Science	15
	Lens.org	12
	Total	44
	Remove Duplicates	29
3rd stage: Eligibility	Title, Abstract, Keywords, & Full-text assessment	20 (9 unrelated)
4th stage: Quality	A quality appraisal based on full text regarding green technology adoption in Malaysia	17

Result

After performing the search based on the search string as shown in Table 1 and following the method underlined in Table 2, this study is able to identify 17 articles related to green technology adoption. There is a difference between green technology and green technology adoption. When searching for articles related to green technology, there are plenty of articles available in all databases. However, when selecting articles related to the adoption of green technology, the number of paper decreases as the phrase green technology adoption can be defined as a practice, or useable technology. Thus, in this study all 17 articles selected were related to green technology adoption in Malaysia.

Table 3 shows the top journal publications for all 17 articles selected. Based on the result, it shows that Modeling electric vehicle has the highest citation of 140 followed by Determinants and environmental outcome of green technology innovation (50), and empirical investigation of green initiatives (26). In terms of the journals, the highest number of published articles were from Environmental Science and Pollution research with two outputs as shown in Table 4. The title of articles and journals showed most of the studies are related to environmental science. However, it is worth noting that most titles were focusing on the management aspect and less on engineering or technical aspect. In addition, the identified journals were not purely business management discipline, but it is more of business management and environmental science discipline.

Table 3: Top Journal Publications Related to Green Technology in Malaysia

No	Journal Title	Citation
1	A possible resolution of Malaysian sunset industry by green fertilizer technology: factors affecting the adoption among paddy farmers	0

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2	A Qualitative Study of Green Building Indexes Rating of Lightweight Foam Concrete	9
3	A state-of-the-art review on facilitating sustainable agriculture through green fertilizer technology adoption: Assessing farmers behavior	11
4	An empirical investigation of green initiatives and environmental sustainability for manufacturing SMEs	26
5	An Integrative Approach to Study on Consumer Behavior towards Plug-In Hybrid Electric Vehicles Revolution: Consumer Behavior towards Plug-In Hybrid Electric Vehicles	14
6	An overview of biomass thermochemical conversion technologies in Malaysia	18
7	An Overview of Electric Vehicle Technology: A Vision Towards Sustainable Transportation	23
8	Analysis of natural gas vehicle acceptance behavior for Klang Valley, Malaysia	0
9	Assessing the adoption of green technology among the contractor in central region of Sarawak (Mukah, Sibu and Bintulu)	0
10	Consumers' Acceptance towards Green Technology in Automotive Industries in Malacca, Malaysia	11
11	Determinants and environmental outcome of green technology innovation adoption in the transportation industry in Malaysia	50
12	Environmental knowledge, awareness, and business school students' intentions to purchase green vehicles in emerging countries	35
13	Green Initiatives adoption: Perspective of E&E manufacturing SMEs sustainability	2
14	Green is clean: the role of ICT in resource management.	21
15	Low Carbon Footprint: The Supply Chain Agenda in Malaysian Manufacturing Firms	6
16	Modelling electric vehicle usage intentions: An empirical study in Malaysia	140
17	The effects of knowledge transfer on farmers decision making toward sustainable agriculture practices in view of green fertilizer technology	12
	Total	**378**

Table4: Top Journals

No	Journal	Total Paper
1	Applied Behavioral Economics Research and Trends	1
2	Asian Journal of Technology Innovation	1
3	Environmental Science and Pollution Research	2
4	Intelligent Transportation and Planning: Breakthroughs in Research and Practice	1
5	International Journal of Business Administration	1
6	International Journal of Economic Research	1
7	International Journal of Sustainable Transportation	1

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8	Journal of Cleaner Production	1
9	Journal of Manufacturing Technology Management	1
10	Journal of Sustainable Development	1
11	Malaysian Construction Research Journal	1
12	Renewable and Alternative Energy: Concepts, Methodologies, Tools, And Applications	1
13	Science of The Total Environment	1
14	Sustainability (Switzerland)	1
15	Trends in Food Science and Technology	1
16	World Journal of Science Technology and Sustainable Development	1
	Total	**17**

Table 5 shows the top authors from 17 articles regarding adoption of green technology. The finding shows that there were 67 authors contributing to green technology adoption with Adnan (3 articles), Nordin (3 articles), Rahman (2 articles), and Yacob (2 articles) were the most productive scholars. This shows that green technology adoption is still growing in number in Malaysia and more studies need to take place.

Table 5: Top Authors

No	Author	Total Name in Paper
1	Adnan N.,	3
2	Ahmad Hussen Tareq	1
3	Al Mamun A.,	1
4	Alaa Mohamd Shoukry;	1
5	Alamzeb Aamir;	1
6	Alonge O. Richard;	1
7	Arshian Sharif;	1
8	Bekhet H.A.	1
9	Chan Y.H.,	1
10	Cheah K.W.,	1
11	Eng L.K.,	1
12	Fared M.	1
13	Fernando, Y	1
14	Fong Y.C.,	1
15	Ghani W.A.W.A.K.,	1
16	Hong B.H.,	1
17	How B.S.,	1
18	Iranmanesh M.,	1
19	Jaganathan M.,	1
20	Jumadi H.B.	1
21	Kansha Y.,	1
22	Khalid Zaman;	1
23	Khoo, HL	1
24	Khor S.C.	1
25	Lam H.L.,	1
26	Loy A.C.M.,	1
27	Mahyudin B. Ramli	1

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28	Masud M.M.,	1
29	Mohamad Ariff bin Bahruddin;	1
30	Mohamed A. Sharkawy;	1
31	Mohiuddin M.,	1
32	Nadia Adnan;	1
33	Ngan S.L.	1
34	Nikbin D.,	1
35	Nodeson S.,	1
36	Noor, A	1
37	Noor, MA	1
38	Nordin S.M.,	3
39	Nurul Zarirah Nizam;	1
40	Nusaibah Mansor;	1
41	Rahman, I;	2
42	Rambli J.,	1
43	Rasli A.M.	1
44	Rubeena Batool;	1
45	Sa'adi N.,	1
46	Sang Y.-N.,	1
47	Sanil S. Hishan	1
48	Shaharudin, MS;	1
49	Shahbaz M.,	1
50	Shahrina Md Nordin;	1
51	Showkat Gani;	1
52	Shuhaili A.F.A.,	1
53	Singh H.K.G.,	1
54	Siti Norbaya Yahaya;	1
55	Su Z.	1
56	Syed F.A.,	1
57	Talat Islam;	1
58	Teoh, LE;	1
59	Vasant, P;	1
60	Wong L.S.,	1
61	Yacob P.,	2
62	Yasuo Hoshino	1
63	Yusuf N.R.,	1
64	Yusup S.,	1
65	Zailani S.,	1
66	Zainordin N.	1
67	Zakaria N.,	1

Table 6 shows the top keywords extracted from the author's keywords. These are key terms identified by the scholars regarding green technology adoption. Based on the result it shows that widely used keyword is green technology (7), green building (2), and wavelet coherence (2). While it was no surprise that green technology keyword is the top keyword, the green building on the other hand shows that most articles have addressed green building when discussing green technology adoption. However, surprisingly enough that a technical term for

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correlation using wavelet coherence was used among 17 articles. This finding shows that not all articles were management focus and other keywords also pointing toward technical aspect.

Table 6: Top 30 Keywords

Rank	Frequency	N-Gram
1	7	green technology
2	2	green building
3	2	wavelet coherence
4	1	acceptance regression
5	1	adoption decision
6	1	advanced multi
7	1	and bioenergy
8	1	and industrialization
9	1	and medium
10	1	auto rickshaw
11	1	behavior business
12	1	behavioral intention
13	1	biochemicals and
14	1	bioenergy biomass
15	1	biomass commercialization
16	1	brunches fiber
17	1	building green
18	1	building lean
19	1	building system
20	1	buildings malaysia
21	1	business students
22	1	carbon emission
23	1	change economic
24	1	climate change
25	1	co emissions
26	1	coherence partial
27	1	coherence south
28	1	commercialization thermochemical
29	1	composites empty
30	1	condition urbanization

Table 7 shows the top publishers for these 17 articles. Elsevier has the highest number of articles (3) followed by Emerald (2), Springer (2), and WIT Press (2). Since Emerald and Springer have more business management studies, it is understandable that studies regarding green technology adoption published by them were focusing on business management discipline while Elsevier and WIT Press were more of multidisciplinary studies. The finding of journal title, keywords used, and publishers show that even Emerald and Springer were shifting to accepting multidisciplinary research.

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Table 7: Top Publishers

No	Publisher	Total
1	Elsevier Ltd	3
2	Emerald Group Publishing Ltd.	2
3	Springer Verlag	2
4	WIT Press	2
5	Construction Research Institute of Malaysia	1
6	MDPI AG	1
7	Universita Putra Malaysia	1
8	Serials Publications	1
9	Canadian Center of Science and Education	1
10	Routledge	1
11	Undisclosed	2
	Total	**17**

Discussion

Where Are We Now?

The literature has more management focus literature regarding green technology adoption. The published journals were multidisciplinary in nature. Thus, scholars should attempt to contribute to the literature from multiple point of study such as integrating business management discipline with environmental science or supply chain management and environmental science.

There are 67 authors working to contribute to green technology adoption in Malaysia. However, these number is still growing, and more studies are expected since all the studies identified have limited empirical evidence. While there is no dispute that management scholars dominating the result, the keyword analysis on the other hand showing that preferable keywords mostly are technical terms but insignificant in terms of frequency. This finding shows that either scholars are misusing the technical terms to boast the article, or the overlapping of definition is inevitable.

What Is Lacking?

Engineering aspect is lacking due to lack of empirical evidence of firms reporting its result of green technology adoption. Clear definition for management focus and technical focus should be underlined as shown in the overlapping used of keywords.

What We Want to Do Next?

Scholars need to investigate more of green technology adoption by providing empirical evidence. Moreover, scholars contributing to the literature is expected to increase as the current scholars publishing on green technology adoption is still growing. In the future, there should be scholars in Malaysia that has established as key scholar for green technology adoption with at least more than five papers. Moreover, studies of green technology adoption should also focus on addressing the different school of thought for green technology adoption. Is there any difference between management scholars and engineering scholars as shown in the result of keyword analysis?

This study shows that green technology adoption is not belonging to management only or engineering only, but it is a multidisciplinary in nature. Future research for green technology

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and other related studies of environment should not be a single discipline as the findings showed that publishers were accepting multidisciplinary research more than management aspect alone.

Conclusion

Findings show that i) most studies in the literature is still focusing on the adoption or acceptance of green technology by firms, ii) most studies are written for management focus, and iii) energy and construction industry being the most investigated area of research. This study significantly contributes to the literature by identifying the literature gaps. The literature gaps are showing that Malaysia green technology adoption is still in the infant stage. Currently, the literature is stagnant with many conceptual papers only contributing to the first level of green technology perception. Future research should focus on providing empirical evidence of green technology adoption.

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