CURRENT UPDATE WASTE TO ENERGY IN DEVELOPING COUNTRY; A REVIEW AND BIBLIOMETRIC ANALYSIS

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Abstract

The concept of processing waste into energy has developed in the last few decades, especially in developing countries. This paper reviews a bibliometric overview of the waste-to-energy literature and related analyzes in developing countries in the last 10 years. The research method used is quantitative with bibliometric analysis on the Scopus database. Based on this method, the number of articles analyzed was 1,880 articles in the form of journals, conference papers, and scientific reviews. There are four stages of analysis, namely determining the source title, keywords, country, and selection literature. Data analysis using a bibliometric approach found 116 articles related to Waste-to-Energy Incineration in developing countries. This study uses VOSviewer software version 1.6.19 for data complexity. The results of this study indicate that the Waste to Energy was divided into five clusters with 56 keywords. The most powerful topics related to this Waste-to-Energy are Municipal Solid Waste and Technology. Research on related waste into energy has increased in developing countries since 2004. This study found keywords such as biofuel and electricity, indicating the current trends in Waste to Energy research in the visualization of research trend mapping.

Keywords: *waste-to-energy, bibliometric analysis, developing country*

Introduction

Effective Municipal Solid Waste Management (MSWM) is a goal to be achieved in developing countries. Rapid population growth and lifestyle changes are the highest factors in urban garbage. On the other hand, landfills are beginning to be threatened by problems of overcapacity, land constraints, and poor environmental impact. The landfill has remained the primary choice for waste management in some countries for decades (Jeswani et al., 2013; Monni, 2012). This problem has reached worrying conditions, so it requires a sustainable solution to waste management. One of the highlighting approaches is waste-to-energy technology (WtE), which has now been widely applied in developed countries due to the development of renewable energy sources with efficient land use (Nanda & Berruti, 2021). Some previous studies related to WtE from Asian countries, such as China, aimed in 5 years that electricity generated from waste combustion technology would increase by 10%, reaching a 30% share of the total energy mix (Zhou et al., 2014). In Japan, most of the Municipal Solid Waste (MSW) that is 80% is handle by incineration. In this process, energy recovery has been included in a certain proportion of waste incineration plants (Tabata, 2013). In South Korea, the amount of energy produced from mixed waste (combustion)

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contributes more than 23% of renewable energy production (Ryu, 2010).

Most recent research suggests that combustion, anaerobic digestion, and pyrolysis are the most dominant Waste to Energy (WtE) processing. However, the researchers focused on developing more efficient energy processes, the most popular in the economic and environmental fields (Boloy et al., 2021). It is also mentioned that WtE plants have significant environmental benefits and excellent external benefits (Lim et al., 2014; Tsai & Kuo, 2010) ,as well as significant impacts on society and the environment (Pavlas et al., 2010).

Bibliometric is useful for mapping literature and quantitatively analyzing developments and growth in scientific publications (Du et al., 2014). Bibliometric techniques have been applied in various research in energy-related fields such as alternative energy research (Mao et al., 2015), solar energy (Du et al., 2014), energy efficiency (Du et al., 2013), WtE technology (Boloy et al., 2021). Previous researchers have examined many methods of sustainable energy generation, considering factors such as cost (Fazeli et al., 2016), environmental impact using the Life Cycle Assessment (LCA) technique (Muis et al., 2023; Vandermeersch et al., 2014), and the Analytical Hierarchical Process (AHP) (Arafat et al., 2015; Toniolo et al., 2014).

The bibliometric study comprehensively analyzes waste-to-energy-related literature for effective municipal solid waste management in developing countries (Ndou & Rampedi, 2022). Also, to obtain various publication characteristics, such as publication types, subject categories, institutions, countries, year trends, and content analysis of keywords and titles.

The study will include a variety of relevant research articles, conference papers, and other scientific publications. The focus will be on exploring current knowledge about waste-to-energy technologies, their implementation in developing countries, and related environmental and socio-economic impacts.

The study aims to identify and evaluate research trends in the Scopus database using VOSviewer software in Developing countries that research WtE and influential publications in this field.

Research Methodology

Data Source

Data sources in this study are taken using Scopus Database. From previous research, Scopus was selected to obtain information from digital libraries and offer various queries through institutional subscriptions (Klapka & Slaby, 2018). The keywords used in this study are Waste Management, Municipal Solid Waste, Waste to Energy. The data used is the literature published over the last 10 years, from 2014 to 2023. The study stage can be seen in the flow chart image (Figure 1). Stage 1 is identifying papers, the number of articles analyzed was 1,880 in the form of journals, conference papers, and scientific reviews. The data distribution during the initial identification stage obtained a total of 707 literature documents. Stage 2 filtering on the title, abstract, subject area and type of literature results obtained 667 documents. The abstract filtering is done by selecting several components of methods, analysis, and results related to the reviewed article. The subject areas screening for filtering are energy, engineering, and environmental science topics. Stage 3 filtering (Keyword filtering developing countries), resulting in 237 documents. The final stage (stage 4) includes manually selecting documents that have relevance to Waste to Energy. The results were obtained from 116 documents to be analyzed using the VOSviewer software version 1.6.19.

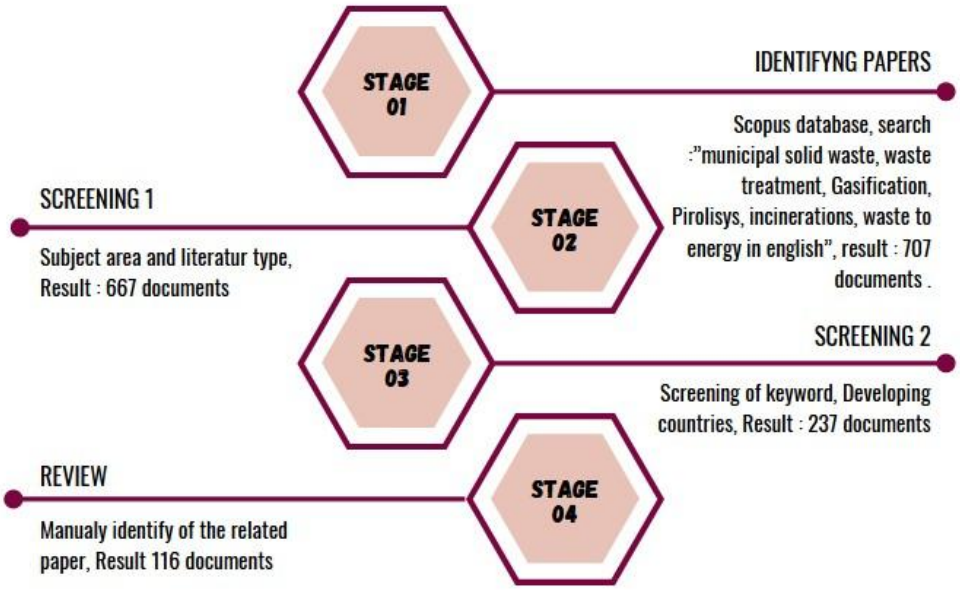


Figure 1. Flow Diagram for Article Selection Process

Data analysis

Documents selected in the Scopus database of 116 articles are then downloaded in the *ris format and inserted into the VOSviewer software. In bibliographic metadata, the term "keyword" contains important information in scientific work and is usually used for indexing purposes (Ramadan et al., 2022). Furthermore, VOSviewer is used to illustrate trends in the form of bibliometric (Effah et al., 2023), i.e. publication maps with keywords or terms (term co-occurrence maps) will form a network (co-citation) that is connected based on related research. The more links between keywords or terms, the stronger the relationship between the terms. In this study, the calculation method uses a binary approach to analyze text data and a fractional approach to analyze bibliographic data. Then, network visualization and overlay in the analysis qualitatively.

Results and Discussion

Bibliometric Analysis Result

In this section, the results are discussed based on the co-occurrence of keywords, with author keywords selected because they tend to be more specific, precisely describing what is being researched. From the analysis results, 56 keywords were identified, with a minimum occurrence threshold set at five occurrences per keyword. Approximately 56 keyword nodes met this threshold, as seen in Figure 2. The identified keywords were divided into five clusters and formed 1427 links. As shown in Table 1, the keywords in the five clusters that appeared most frequently were named accordingly. For example, in cluster 1, the keyword MSW management is closely related to waste to energy, which suggests that most of the research analyses municipal solid waste currently processed into energy. A different color represents each cluster in the bibliometric mapping. The correlation between the number of nodes in the bibliometric map is related to the keywords appearing in the research. The larger the nodes, the more keywords appear in the research. The number of co-occurrences of more than two keywords indicates the number of publications in which the keyword appears together in the title, abstract, or list of keywords (Van Eck & Waltman, 2010).

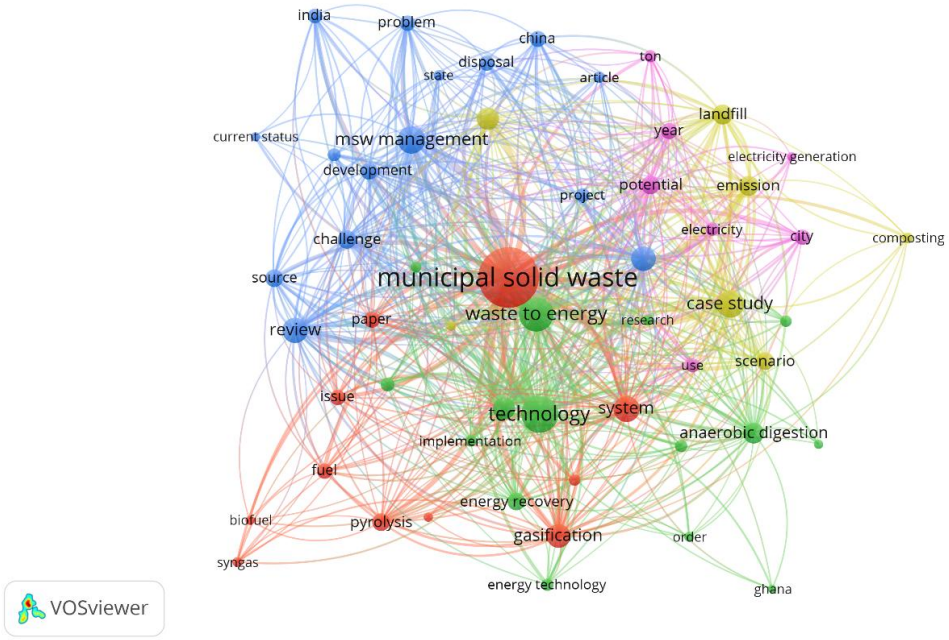


Figure 2. Co-occurrence of Author Keywords

Table 1. Number of co-occurrences and link of the keywords per clusters

Cluster	Keyword	Occurrences	Link
1 (15 items)	Article	16	49
	Challenge	41	53
	China	32	44
	Current Status	11	46
	Development	35	53
	Disposal	29	51
	Incineration	71	54
	India	26	47
	MSW Management	**88**	**53**
	Problem	29	51
	Project	22	46
	Review	76	53
	Source	36	54
	State	14	45
	World	21	52
2 (15 items)	Anaerobic Digestion	50	54
	Conversion	19	51
	Energy Recovery	37	54
	Energy Technology	19	53
	Ghana	9	28
	Implementation	17	49
	Life Cycle Assessment	17	43
	Opportunity	14	50
	Order	12	47
	Perspective	23	52
	Research	15	50
	Sensitivity Analysis	10	46
	Technology	156	54
	Treatment	57	53
	Waste to Energy	138	54
3 (11 items)	Addition	10	46
	Biofuel	10	39
	Environmental Impact	16	48
	Fuel	28	50
	Gasification	69	54
	Issue	29	53
	Municipal Solid Waste	429	54
	Paper	32	54
	Pyrolysis	38	52
	Syngas	12	40
	System	81	54
4 (8 items)	City	29	50
	Electricity	21	52
	Electricity Generation	11	41
	Potential	41	52
	Ton	19	52

Cluster	Keyword	Occurrences	Link
	Use	22	53
	Waste Conversion	32	53
5 (7 items)	Case Study	88	54
	Composting	14	43
	Emission	46	52
	Energy Production	12	47
	Generation	57	52
	Landfill	47	53
	Scenario	37	51

Density Visualization

As seen in Figure 3, the visualization of research distribution with the highest occurrence values is the keyword "Municipal Solid Waste" (429 occurrences) in cluster 3. This indicates that Municipal Solid Waste is relevant in waste-to-energy research. Municipal Solid Waste plays a crucial role in shaping a safe environment and is a potential renewable energy source. In recent years, Waste to Energy has become a trend implemented in developing countries in the Asia-Pacific region, especially in thermal processing (Alao et al., 2022). Occurrences of other keywords are related to technology in cluster 2, indicating an emerging trend in technology used in waste-to-energy research. In this study, several technologies were found mentioned in keywords such as Incineration (71 occurrences), Anaerobic Digestion (AD) (50 occurrences), Gasification (69 occurrences), Pyrolysis (38 occurrences), and Composting (14 occurrences). Thermal processes in Waste to Energy have been a focal point in research in developing countries in recent years.

In the co-occurrence analysis, in cluster 5, several keywords were found, namely case studies and emission factors in Waste to Energy, which are interrelated, along with environmental impact factors in cluster 3. These findings describe that Waste-to-Energy activities' emission factors and environmental impact are interesting research issues in developing countries and need further discussion. In cluster 2, the keyword "lifecycle assessment" was found to measure environmental impact. The lifecycle assessment method is an approach used to assess, identify, and analyze the potential environmental impact of various comparative scenarios (Ferronato et al., 2020).

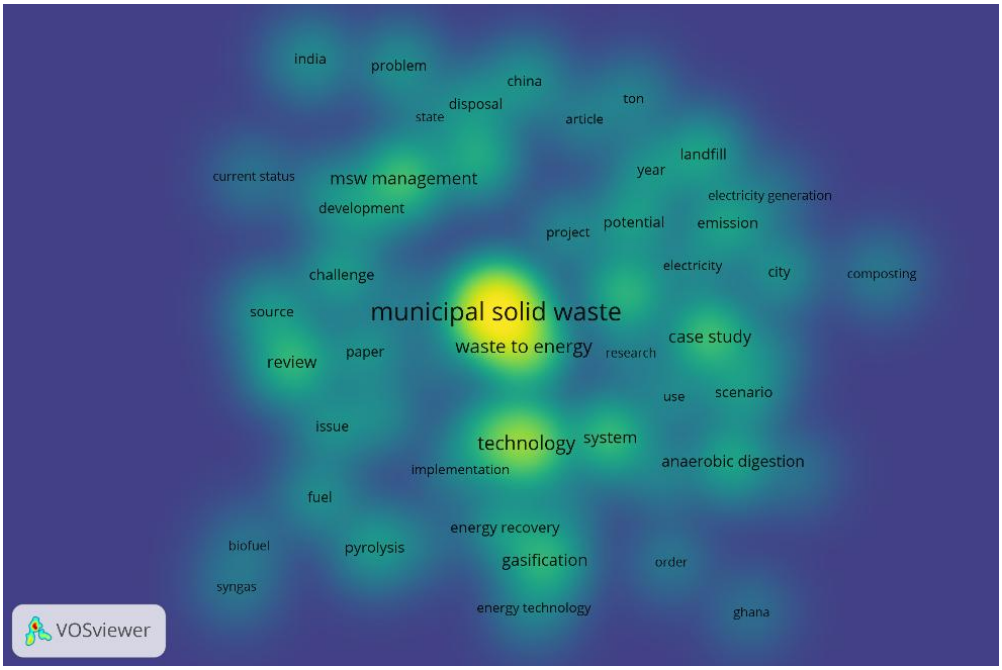


Figure 3. Density Visualization of Waste-to-Energy in Developing Countries.

Cluster analysis on bibliometric mapping.

The main topic in cluster 1 focuses on MSW (Municipal Solid Waste) management, which is interconnected with the review, country, incineration, problem, challenge, China, and India. According to Figure 4, these findings reveal that MSW management poses several problems and challenges in developing countries, and it currently attracts much attention in research, especially in countries like China and India. In cluster 2, the most frequently appearing keyword is related to waste to energy, strongly linked to technology, waste to energy, anaerobic digestion, energy recovery, and others (Figure 4).

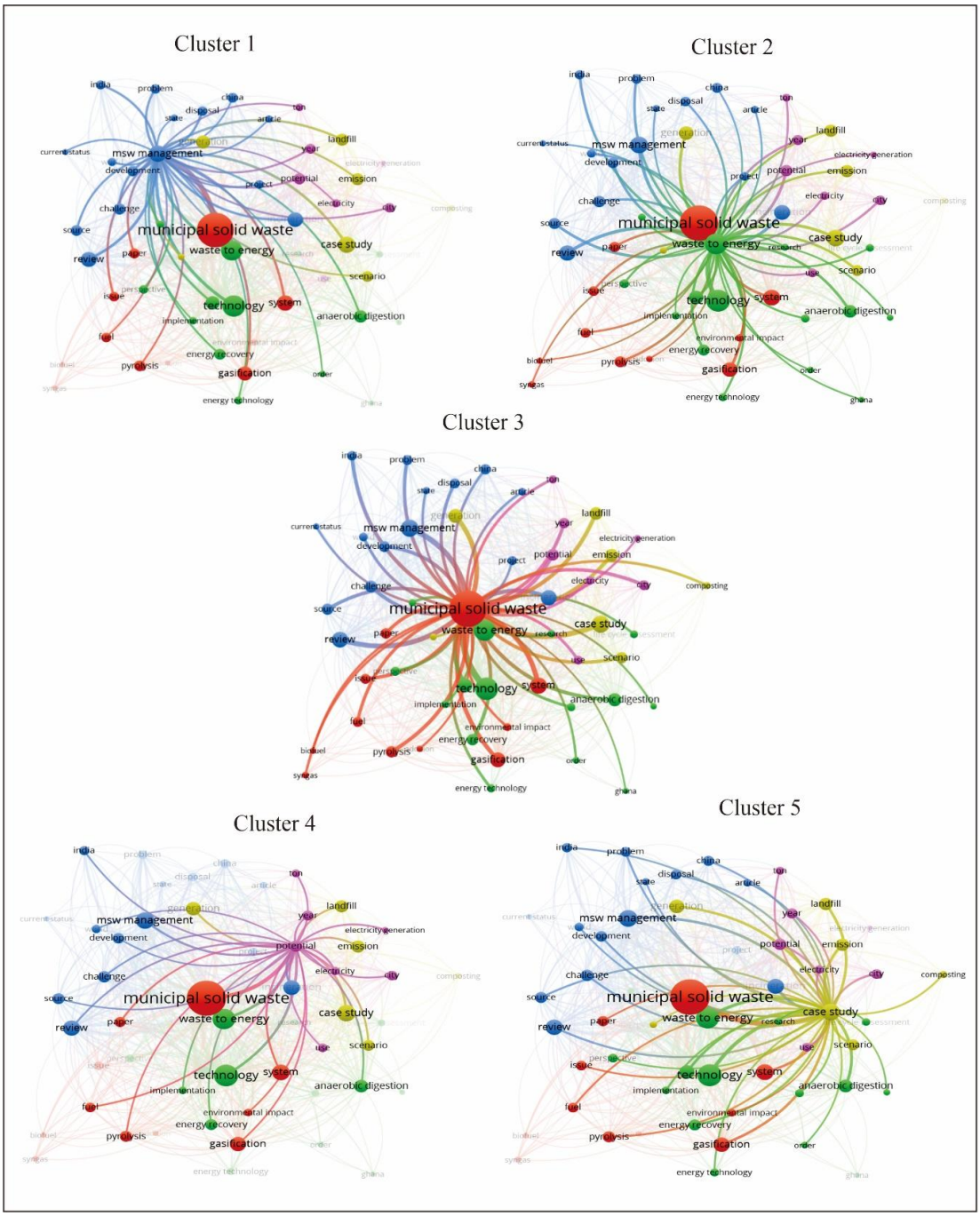
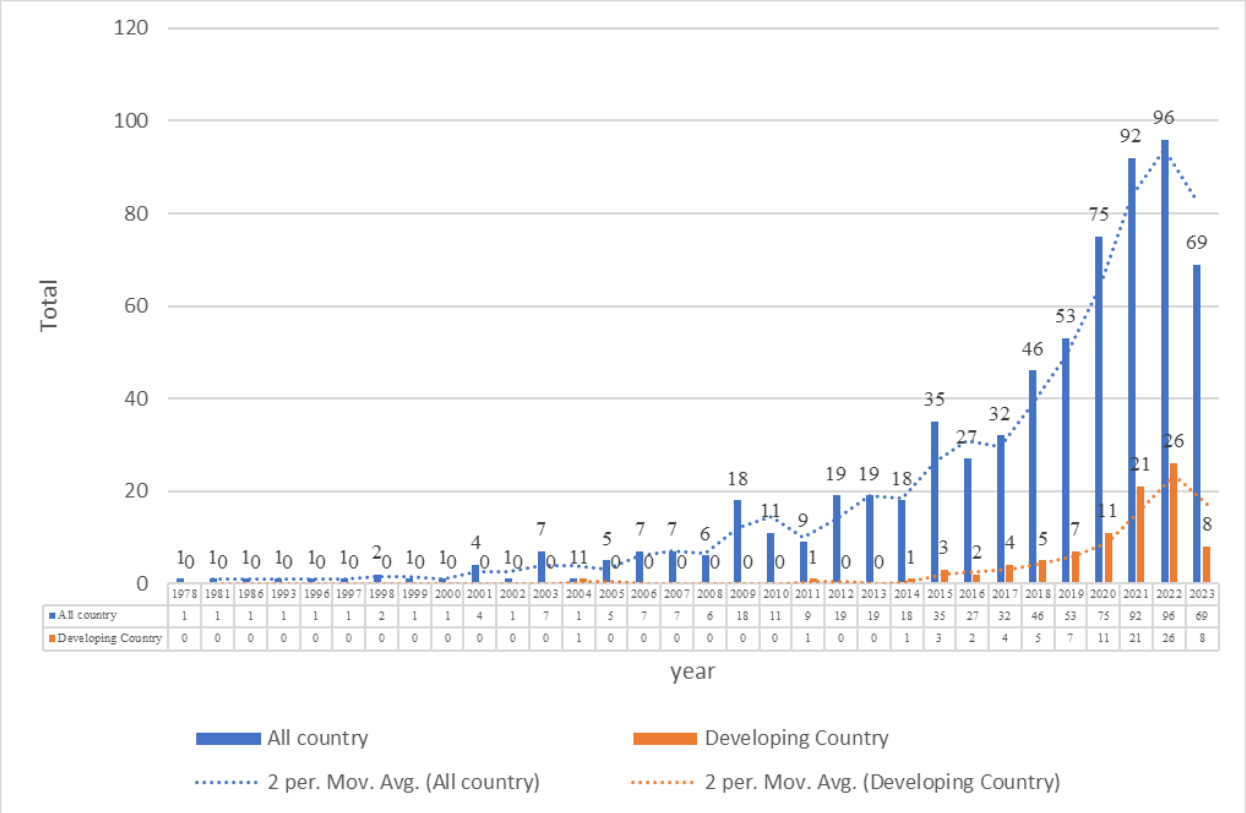


Figure 4. Keyword Cluster Map

These findings reveal that "Technology" in waste to energy is a significant aspect currently being applied in developing countries. In cluster 2, a strong association with life cycle assessment, the most used method for environmental impact analysis in waste-to-energy processes, is also found. In cluster 3, the mapping shows that keywords are centered around Municipal Solid Waste, related to processes used in waste treatment such as gasification, pyrolysis, biofuel, and others. In cluster 4, the focus is on the potential of Waste to Energy, linked to electricity, waste conversion, city, and other items. In cluster 5, the most frequently appearing keyword is "case study," which is interconnected with landfill, emission, and other items. In the case of Waste to Energy research, case studies are efforts to reduce emissions from the amount of waste ending up in landfills.

Trend of Waste to Energy Research

The increasing trend of Waste-to-Energy (WtE) research worldwide and in developing countries can be observed in Figure 5. Publications related to WtE first entered the Scopus database in 1978, while in developing countries, research about waste-to-energy was identified in 2004. The growth of WtE research has continued to experience significant increases up to the present, which holds for developing countries as well.



	1978	1981	1986	1993	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
All country	1	1	1	1	1	1	2	1	1	4	1	7	1	5	7	7	6	18	11	9	19	19	18	35	27	32	46	53	75	92	96	69
Developing Country	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	3	2	4	5	7	11	21	26	8

Figure 5. Number of WtE research in All country and Developing country

The research trends of the last five years can be observed in the bibliometric mapping visualization. As shown in Figure 6, the color gradient from blue, green, and yellow indicates research trends. The blue color in the figure represents research conducted before 2019, the green color indicates rapidly evolving research trends, and the yellow color signifies recent research trends after 2021. The figure illustrates the research potential related to Municipal Solid

Waste connected to converting Waste to Energy. Following that, research on technology in Waste to Energy becomes prominent, with some studies focusing on conversion processes such as gasification and anaerobic digestion. The technology in waste-to-energy represents a trending research pattern widely applied in developing countries. Meanwhile, the yellow color associated with keywords like biofuel and electricity indicates recent research in the field of Waste to Energy.

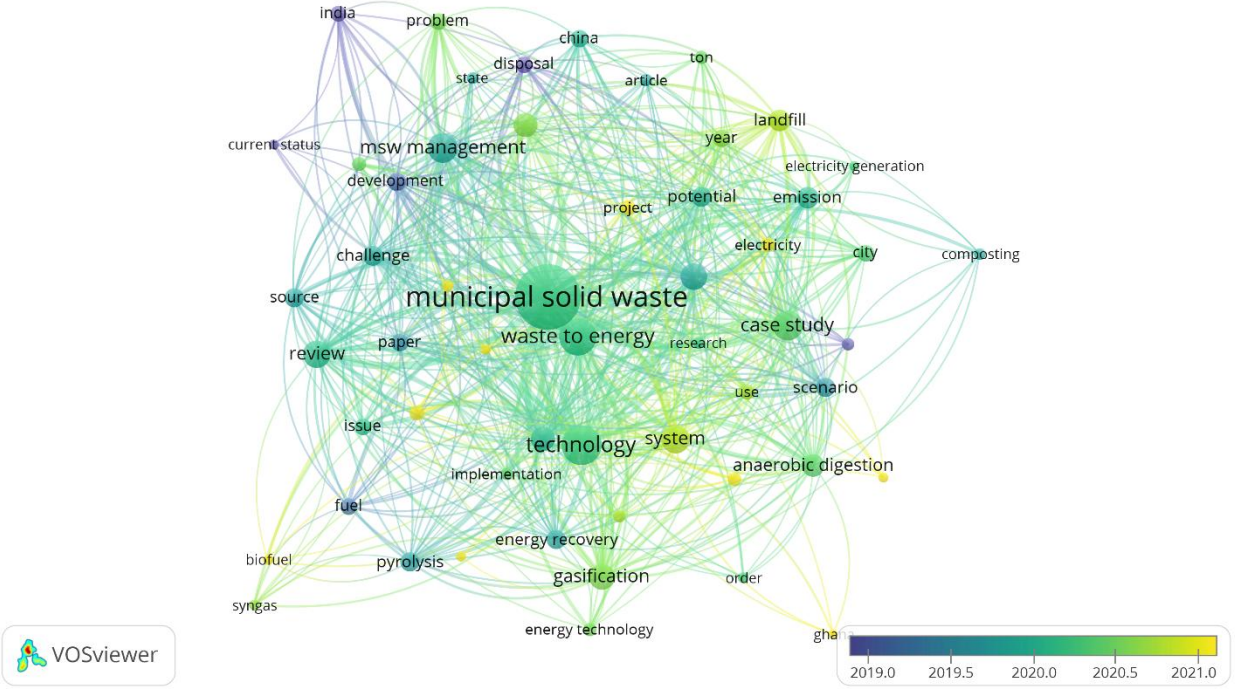


Figure 6. Visualization of Research Trend

Conclusions

The results of the bibliometric analysis reveal insightful patterns in waste-to-energy research. This research conducts a review and bibliometric mapping of scientific literature related to waste-to-energy (WtE) in developing countries. The article screening process in the Scopus database identified 116 articles related to Waste to Energy in developing countries. Based on the analysis results, keyword mapping was obtained and divided into 5 clusters. The analysis revealed keywords with the highest occurrence value, mainly related to "Municipal Solid Waste" in cluster 1. Another keyword with the most increased occurrence was related to "technology," indicating a technological trend in waste-to-energy widely used in developing countries, such as incineration, anaerobic digestion, pyrolysis, and composting. In another cluster, the keyword "life cycle assessment" was the most commonly used method for assessing environmental impacts in waste-to-energy research. On the other hand, based on research trends, it was found that global research on Waste to Energy began in 1978. However, waste-to-energy research started in developing countries in 2004 and has significantly increased since then. In the visualization of research trend mapping, keywords such as biofuel and electricity point to current research trends in the field of Waste to Energy.

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