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*Review Article*

# Waste to Energy Sustainability Model as a Waste Power Plant: A Bibliometric and Visualization Analysis

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## Abstract
More than half of the world's population lives in cities, so the increase in urban waste production globally is mainly due to population growth, urbanization, and economic development, in the past decade, the utilization of waste to energy has provided positive benefits in terms of energy generation. By 2040 power generation will increase globally by 49%. By 2040, renewable energy sources are expected to meet 8% of the total global energy demand, With the development of the economy, waste management goes through several stages to reach the level of high technology as seen today. A sophisticated collection system, combined with an efficient separation process, enables high recovery and recycling rates. The method used in this study is qualitative with a literature study approach. The findings in this study show that China is the country that researches the most about wasto to energy, then the process carried out in the PLTSa Waste to Energy Policy Model recommendations in this study involves several related actors such as Business Entities, authorized Local Governments, and communities. In this case, waste to energy needs attention by local governments that have the authority to manage electricity by establishing provincial regulations in the electricity sector, establishing general electricity plans, and determining business licenses for providing electricity to business entities.

**Keywords**: Waste; energy; power plant; bibliomatric

## 1. Introduction

More than half of the world's population lives in cities, so the increase in urban waste production globally is mainly due to population growth, urbanization, and economic development (Kumar & Samadder, 2017). In the last decade, the use of waste in energy has provided positive benefits in terms of energy generation. Waste can be converted into useful energy (Kothari et al., 2010). Waste to Energy (WtE) It is interesting that many countries are making Waste to Energy an effective waste management solution (Toufaili et al., 2023). Regardless of the energy source, it is estimated that by 2040 electricity generation will increase globally by 49%. By 2040, renewable energy sources are expected to meet 8% of the total global energy demand (International Energy Agency, 2020).

In line with economic development, waste management went through several stages to achieve the level of high technology as seen today. A sophisticated collection system, combined with an efficient separation process, enables high recovery and recycling rates. This is in line with the research conducted (Rahim, 2020) Discussing the waste management system in developed countries, there are several stages, starting from reducing waste production from the source, then recycling and reusing, processing the waste into energy resources, and minimizing waste disposal to landfill. Research from (El Toufaili et al., 2023) discusses how to select WTE under urban solid waste management in the Greater Beirut Area

(GBA). Protecting the environment and public health is mandatory, but there is also an urgent need for new sources of electrical energy that are economically viable. Then research is done (Traven, 2023) Examining how to elaborate on the current methods of energy recovery from urban solid waste (MSW), including incineration, pyrolysis, anaerobic digestion, and landfill gas recovery and utilization, gas utilization in landfills emerged as the most prominent option for energy recovery from urban solid waste, the study also underscores the importance of matching technology choices to waste characteristics and highlights the importance of tailored approaches in general and comprehensive waste management.

Based on previous research that has been done. Research focuses more on identifying research developments, contributions of specific authors or groups of researchers, and comparisons between emerging research topics. This not only provides a broad picture of the current state of affairs but also highlights knowledge gaps that may need to be filled in future research. Using bibliometric analysis, this study will produce recommendations and practical guidance to see trends in processing waste into energy. This approach allows us to detail significant research trends, identify key concepts that predominate, as well as describe the network of cooperation between authors, institutions, and countries in related literature.

The purpose of this study is to analyze the portrait of the development of waste to energy studies. This research is very important to be carried out as a form of reflection and understanding of how so far the study of waste to energy. The author suspects that there have been two waste-to-energy studies so far. First, waste to energy is seen from the side of opportunities, second, waste to energy is seen as a challenge Therefore, this study analyzes bibliometrics on waste processing processed into energy to create sustainable urban development by utilizing waste as energy by providing concepts related to the Waste to Energy Policy Model in landfill.

## 2. Methods

The method used in this study is qualitative method with a literature study approach. In bibliometric studies, data can be obtained from primary, secondary, or tertiary journals covering a period and analyzed from various angles to determine whether the data displayed are documents by country or region, documents by type, and documents by year, etc. (Subekti et al., 2022). The keywords used in this study are Waste To Energy “TITLE-ABS-KEY ( "Waste To Energy" ) AND PUBYEAR > 2014 AND PUBYEAR < 2023 AND ( LIMIT-TO ( PUBSTAGE, "final" ) ) AND ( LIMIT-TO ( OA, "all" ) ) AND ( LIMIT-TO ( DOCTYPE, "ar") ) AND ( LIMIT-TO ( LANGUAGE, "English" ) ) AND ( LIMIT-TO ( SRCTYPE, "j" ) )”. This study used the Scopus search engine to identify research related to Waste To Energy from 2014 to 2023. The publication of research related to Waste To Energy from 2014 to 2023 is 524 documents. The Scopus database has become the primary source of studies for evaluating scientific research. As one of the largest data centers in the world, Scopus can index scientific literature to provide accurate information about the metadata of each scientific article, including publication date, abstracts, references, and other fields (Herawati et al., 2022). Figure 1 shows the stages in data collection and data processing analysis obtained in the Scopus database.

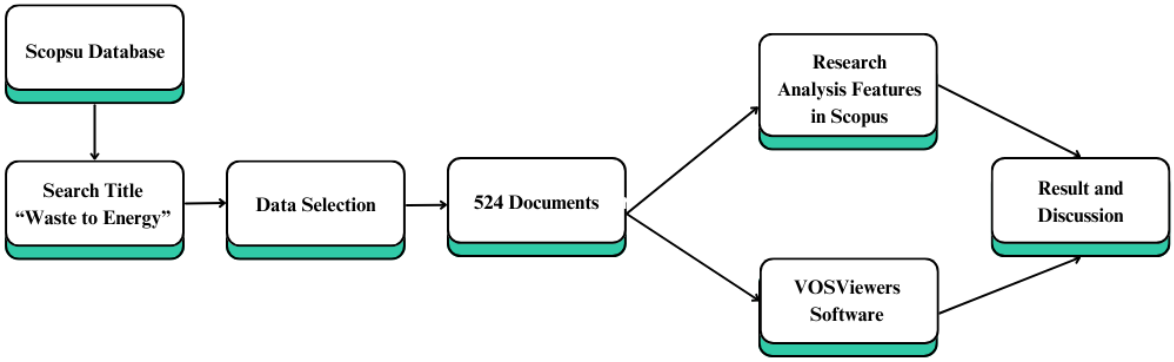


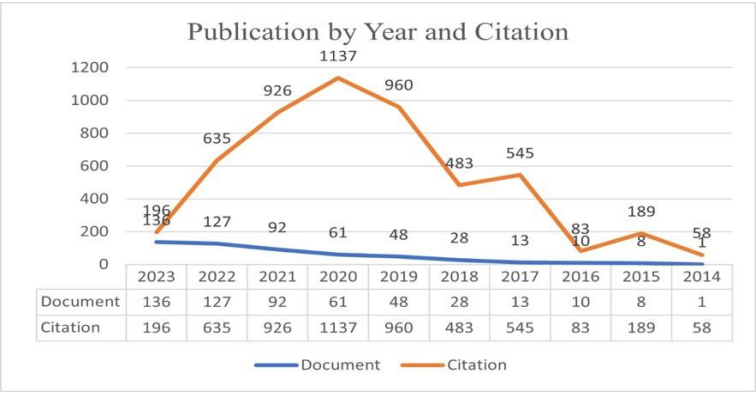

**Figure 1.** Flowchart of data collection, data analysis, and data visualization.

In mapping the publication of scientific research Waste To Energy using Vosviewer tools for visualization analysis of publications in co-occurrence analysis. VOSviewer is a software tool for building and visualizing bibliometric networks (Soesanto & Handalani, 2023). VOSviewer pays special attention to the graphical representation of bibliometric maps. VOSviewer functionality is useful for displaying large bibliometric maps in an easily interpreted way (Soesanto & Handalani, 2023). This study sends research map information using export data to RIS Export file format, which is then processed using VOSviewers to determine big data to be analyzed to obtain the results of comparative data of this research with previous research.

## 3. Result and Discussion

From the results of an analysis of 524 scientific publications obtained from the Scopus database which produces diverse and varied data. Scientific publications related to Western energy from 2014 to 2023 have diverse points of view. The study analyzes and classifies data starting from the year of the document, identifying trends and patterns of interest. Not only that, but this analysis also identifies countries that contribute the most scientific publications, the most frequently used journal sources, the most prolific authors as well as institutions active in the study. This diverse data provides rich insights into the research dynamics in this review, which can help us understand how research develops and how various related aspects interact in influencing future research direction.

### 3.1. General Information and Annual Publication Output




| | 2023 | 2022 | 2021 | 2020 | 2019 | 2018 | 2017 | 2016 | 2015 | 2014 |
|---|---|---|---|---|---|---|---|---|---|---|
| Document | 136 | 127 | 92 | 61 | 48 | 28 | 13 | 10 | 8 | 1 |
| Citation | 196 | 635 | 926 | 1137 | 960 | 483 | 545 | 83 | 189 | 58 |

**Figure 2.** Global trends in publications on digital maturity from 2014 to 2023 and average article citations per year.

Based on the picture above, we can see the progress of the Waste To Energy study in the period from 2014 to 2023. It can be seen from the number of documents each year has increased significantly over time. In 2014, it can be seen that there was 1 published document indexed by Scopus, then in 2015, there were 8 documents this marks a good start for understanding related to waste to energy because there have been several researchers who have studied the theme, since then the number of published documents has increased continuously. Starting in 2016 there were 10 documents, while we saw in 2017 there were 13 documents. The positive trend continued in 2018, by recording 28 documents, then continued in 2019 there were 48 documents, this increase continued in 2020 with a total of 61 documents, then in 2021, there were 92 documents. The increase is evident in 2022 with the number of publications of 127 documents, while in 2023 it will increase drastically by 136 documents. This positive trend reflects the growing interest and focus in waste-to-energy research, marking an increasingly important role from an academic and scientific perspective. These drastic improvements may also reflect responses to technological developments or important issues that motivate further research in this field.

### 3.2. Publication by Country

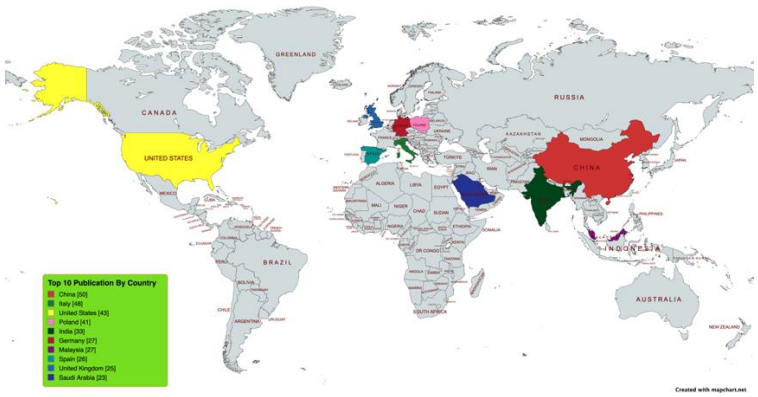



**Figure 3.** Countries contribute the most in the field of waste to energy.

Figure 3 shows that China is the country with the most scientific research publications indexed by Scopus with the theme Waste to Energy from 2014 to 2023. From the data obtained China ranks noticeably by contributing as many as 50 documents, second position, Italy by contributing significantly by contributing 48 documents, followed by the United States with as many as 43 documents. Poland also contributed 41 documents, in addition, India also contributed 33 documents, showing their important role in knowledge in this field. Then Germany and Malaysia both contributed by contributing 27 documents, Spain also contributed by contributing 26 documents, while the United Kingdom contributed 25 documents, and no less importantly Saudi Arabia also contributed by contributing 23 documents, scientific research throughout the period 2014 to 2023, adding to the diversity of knowledge sources in the theme of waste to energy.

**Table 1.** Most global cited by country

| Author/Year | Tittle Article | Total Citations | Country |
|---|---|---|---|
| (Azam et al., 2020) | Status, characterization, and potential utilization of municipal solid waste as renewable energy source: Lahore case study in Pakistan | 95 | China |
| (Marzorati et al., 2018) | Green corrosion inhibitors from natural sources and biomass wastes | 176 | Italy |

| Author/Year | Tittle Article | Total Citations | Country |
|---|---|---|---|
| (Ramaswami et al., 2017) | An urban systems framework to assess the trans-boundary food-energy-water nexus: Implementation in Delhi, India | 124 | United States |
| (Dudek et al., 2019) | The effect of biochar addition on the biogas production kinetics from the anaerobic digestion of brewers' spent grain | 59 | Polandia |
| (Malode et al., 2021) | Recent advances and viability in biofuel production | 148 | India |
| (Schneider et al., 2017) | Solid waste management in Ho Chi Minh City, Vietnam: Moving towards a circular economy? | 48 | Germany |
| (Ghaleb et al., 2020) | Response surface methodology to optimize methane production from mesophilic anaerobic co-digestion of oily-biological sludge and sugarcane bagasse | 54 | Malaysia |
| (Hoehn et al., 2019) | Energy embedded in food loss management and in the production of uneaten food: Seeking a sustainable pathway | 26 | Spain |
| (Yaqoob et al., 2021) | Current status and potential of tire pyrolysis oil production as an alternative fuel in developing countries | 35 | Unitetd Kingdom |
| (Ouda et al., 2017) | Waste-to-energy potential in the Western Province of Saudi Arabia | 86 | Saudi Arabia |

### 3.3. Documents by Author

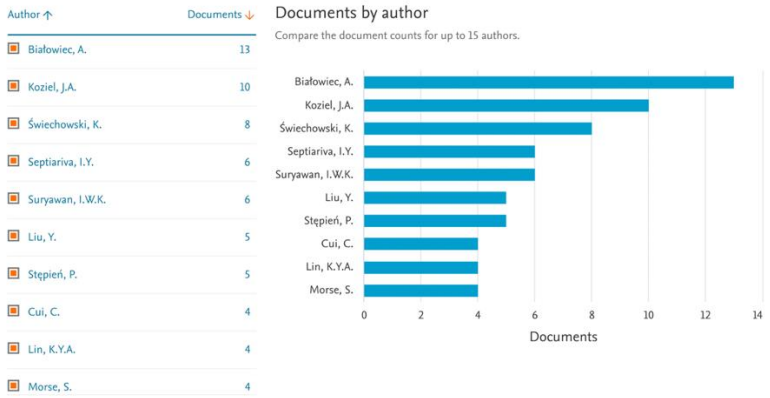



**Figure 4.** Most contributing authors in the field of waste to energy.

Figure 4 reveals the extraordinary dominance shown by author Biatowiec, A. in scientific research on the theme of waste to energy from 2014 to 2023 indexed by Scopus. In that period Biatowiec, A managed to contribute as many as 13 significant documents in the study of waste to energy, this shows the important and consistent war of Biatowiec, A in enriching our insights related to waste sampa that can be processed into energy. In addition, Koziel, J.A. also managed to contribute as many as 10 documents, followed by Swiechowski, K. by contributing 8 documents, while several other researchers such as Septiariva, I.Y and Suryawan, I.W.K both contributed 6 documents. Liu, Y. and Stepie, P. also contributed 6 documents each, while Cui, C, Lin, K.Y.A., and Morse, S. each contributed 4 documents. This shows that several researchers have succeeded in making substantial contributions to developing insight and understanding of waste that can be used to become energy.

### 3.4. Linkage and Clustering of Keywords in Waste to Energy

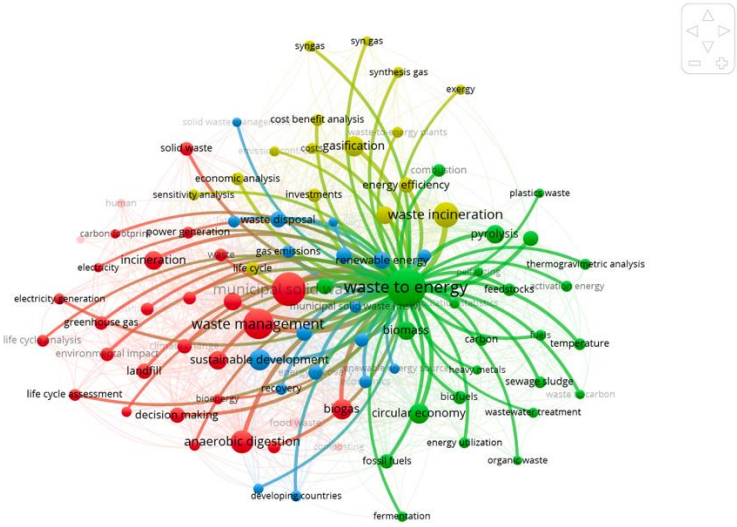



**Figure 5.** The relationship between concepts in waste to energy.

The image above shows a concept map of waste to energy from keywords or terms that often appear, on also shows the biggest keywords that indicate the larger the keyword node, the greater the frequency of the keyword, the wider the link, the more. The great relationship between the two keywords (Liu et al., 2015; Wang & Chai, 2018). Figure 5 shows that the large node size or keyword is a Waste of energy. Waste to Energy is the focus of discussion and deep attention in the context of research on waste to energy, The keywords that have relevance related to waste to energy are renewable energy, waste incineration, sustainable development, waste management, carbon, biogas, and there are several other keywords. The difference in the color of the connecting lines in the picture above shows the relationship of each cluster on the theme of waste to energy.

### 3.5. An Overview in Waste to Energy (2014-2023)

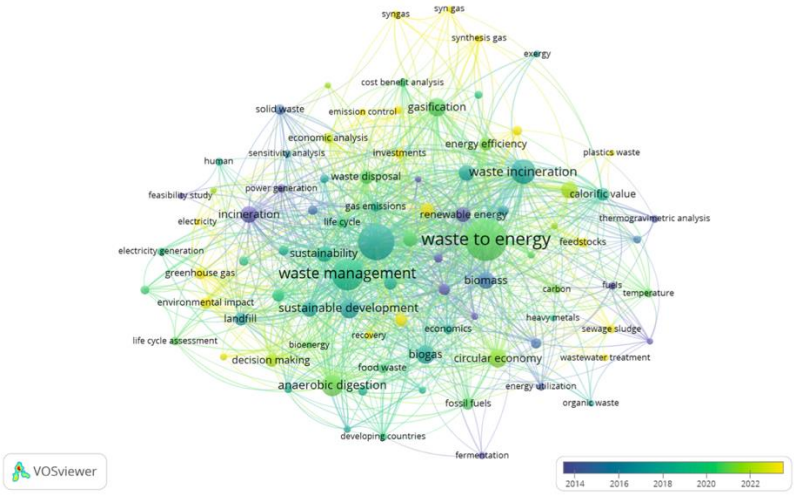



**Figure 6.** Portrait of the development of waste to energy studies (2014-2023)

The data in the figure above shows the progress of studies in the last decade related to waste to energy, from 2014 to 2023 there has been a significant increase in research. It can be seen that from 2014 to 2016 waste to energy was widely studied in terms of incineration, renewable energy, sustainability, and waste management. Then from 2018 to 2020 a lot of studies were conducted in terms of gas emissions, , carbon, then in 2022 until now many studies have in terms of economic analysis, energy recovery, and investment. So the development of this study can encourage researchers in developing studies related to waste to energy.

### 3.5. Linkage in Waste to Energy for Future Research

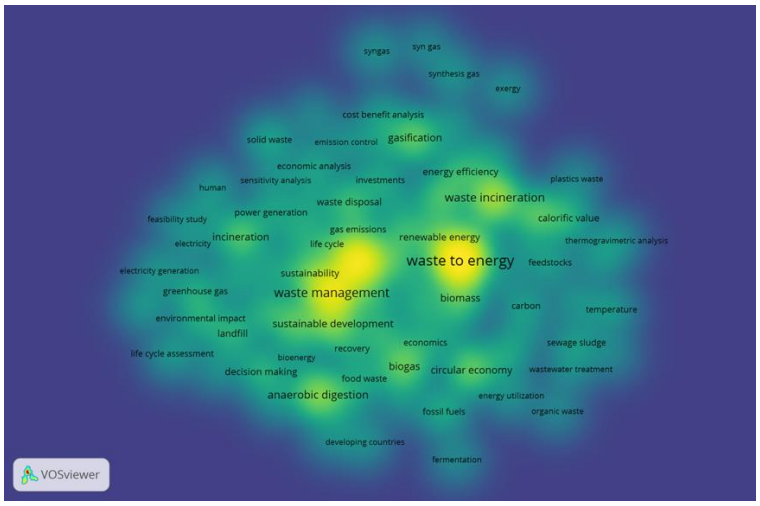



**Figure 7.** Visualization overlay waste to energy (2014-2023)

The picture above shows the results of VOSviewer analysis using phyto density visualization by looking at topics ranging from those that are most often studied to topics that have not been studied by many researchers so that it has the opportunity to be studied further related to the theme of waste to energy. In other words, the results of density visualization are used to find the novelty of further research related to the theme of waste to energy. In the concept of using density in VOSviewer, it can be seen that yellow indicates the most frequently discussed topic, while green is a topic that has not been studied much, which can then be a finding for further research.

Figure 7 shows that the yellow topics are waste to energy, waste management, sustainability, life cycle, and renewable energy showing that these topics have become the main topics in waste to energy studies. On the other hand, the green color includes solid waste, organic waste, wastewater treatment, and synthesis gas. This green color indicates that this topic has not been studied much in waste to energy research. In other words, the outermost and green part is a part that can be used for further research. So that it can make a new contribution to understanding waste to energy because this can provide further insight into implementing waste that can be developed into energy.

It was found in this study that China is the country that studies the most about Waste to energy, this can be seen from the documents that have been successfully published and indexed in the Scopus database, making China rank first with the country that studies the most about Waste to energy. This study also explains that it is interesting to see the publicity trend every year, that the theme of waste to energy research is relatively high. Even 2023 is the year that has the highest publicity in the last 10 years. This shows that waste to energy has become a topic of interest for researchers and academics.

Furthermore, shared event analysis is used to display visualization networks based on keywords to determine research direction and popular themes, and has been shown to help track the progress of research and science programs (Gao et al., 2017). This study featured 8 clusters with different colors. Image labels indicate keywords or terms that appear frequently, while colors indicate groups. Clustering

is used to get a better picture or understanding of bibliometric networks (S. Liu et al., 2018). Thus, this study found that scientific research publications with the theme of waste to energy from 2014 to 2023 indexed by Scopus have a strong relationship with renewable energy, waste incineration, sustainable development, waste management, carbon, biogas.

Vosviewer can be used to visualize the level of density or number of problems studied in a field of study. This visualization of density can provide a better understanding of trends, focus, and relationships between concepts and research topics. The more nodes are yellow, the more research on the subject is conducted. On the other hand, the greener or knot, the less research is done on the topic. As a result, this study also explains that subjects such as organic waste, wastewater treatment, and synthesis gas renewable energy still have a very good chance to become research material in the future related to the theme of waste to energy.

The research explains that waste-to-energy plays an important role in the face of the rapid and far-reaching changes brought about by waste-to-energy technologies have several advantages. First, this process can help reduce the amount of trash that accumulates in landfills. By burning garbage, its amount is significantly reduced. Second, the energy produced from this waste can reduce the need for fossil fuels, which are a limited source of energy and have a negative impact on the environment. This process uses special technology to burn garbage and generate heat. This heat can then be used to generate electricity or to heat buildings and homes. In this way, waste that usually only becomes waste can be used as a useful source of energy. By understanding the level of readiness and maturity in adopting and utilizing waste-to-energy technologies, researchers can help organizations, institutions and communities to face challenges and seize opportunities that arise in this digital age more effectively. This includes the development of models, strategies and practices that can improve the processing of shampoo so that it can have a positive impact as a useful energy source. Thus, research on waste to energy in the context of organic waste, wastewater treatment, and synthesis gas is not only relevant, but also important to be studied significantly in future research. This research review is recommended as an effort to understand and deal with the ongoing changes in an increasingly digitalized environment.

In addition, this study offers a model of waste to energy policy concepts that can be applied to landfills. This model was conceptualized through previous research by looking at emerging topics in the literature on sustainable urban development with waste that can be used as an energy source:

1. *Input*

In the recommendations of the Waste to Energy Policy Model, the inputs in this study are Business Entities which include State-Owned Enterprises (BUMN), Regional-Owned Enterprises (BUMD), private business entities in the form of Limited Liability Companies (PT), foreign legal entities, or cooperatives. This is in line with Presidential Regulation Number 12 of 2018 Amendments to the Regulation of the Minister of Energy and Mineral Resources Number 39 of 2017 concerning the Implementation of Physical Activities for the Utilization of New and Renewable Energy and Energy Conservation.

2. *Proses*

The process carried out in the recommendations of the Waste to Energy Policy Model as PLTSa in this study involves several related actors such as Business Entities, authorized Local Governments, and the community. In this case, the Regional Government has the authority in electricity management by establishing provincial regulations in the electricity sector, establishing a general electricity plan, and establishing business licenses for providing electricity to business entities. In this case, the sense of ownership becomes the authority of the Regional Government, namely the Environment and Forestry Service in collaboration with Business Entities. In the construction of PLTSa, two technologies refer to laws and regulations, namely Sanitary Landfill and Zero Waste. If the technology used in PLTSa is not in the legislation, further adjustments need to be made. To realize TPA into PLTSa requires effective and efficient funding aspects. So the Government Cooperation with Business Entities (KPBU) scheme was

prepared, The selection of waste used is such as biomass waste, which has various types such as agriculture, livestock, and organic waste.

***3.*** *Output*

*The output* or results obtained in this study are the construction of a Waste Power Center, but to run this program requires community involvement. The role of the community here as community *empowerment* will not only have an impact on PLTSa alone, on the other hand, it will improve the economic level. People tend to be willing to participate if there are incentives or perceived benefits. This can be done by creating a Waste Bank with the principle of "From the Community, By the Community, and For the Community" which is integrated with the Piyungan Landfill, or there is no third party. So that it can reduce the dependence of the community on those who usually sell the sorted products to third parties, and can improve the survival of the community around the landfill. In addition, a form of community empowerment can also be carried out to improve the economy by further exploring the potential that exists in the landfill such as training on skills to process waste that can be recycled by the Tourism Office, cooperative development by the Cooperative Office and Small and Medium Enterprises.

*4.* *Outcome*

*The outcome* obtained in this study is the construction of a Waste to Energi. The PLTSa not only reduces the amount of waste that accumulates in the landfill but there are benefits felt by the community, both directly and indirectly. The benefits felt directly by the community are such as the ease of the community in accessing electricity.

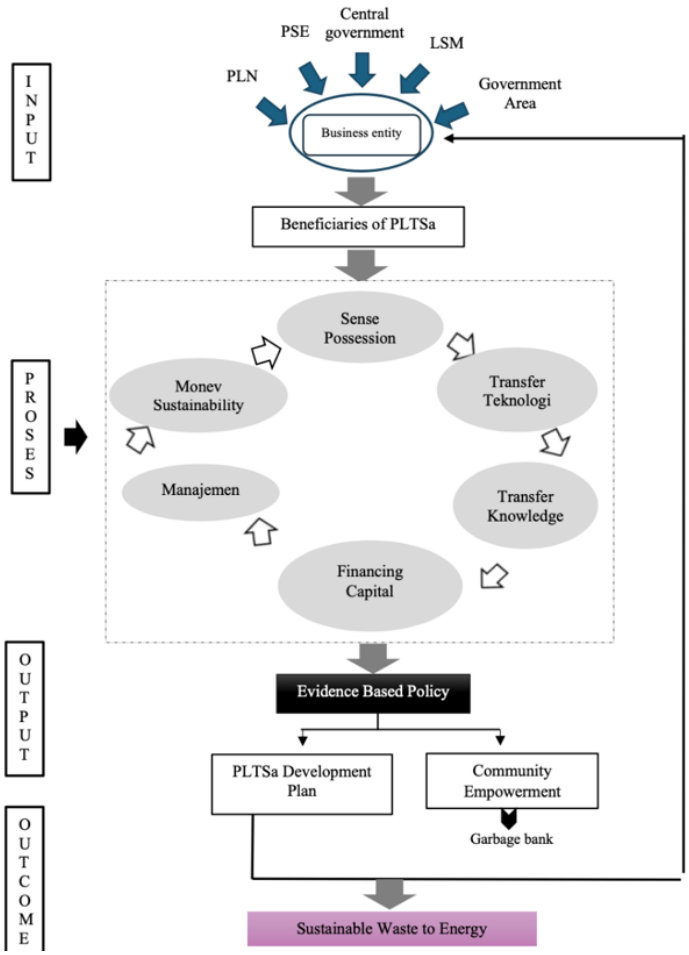



**Figure 8.** Recommendations for sustainable waste to energy development model based on community empowerment at PLTSA (results of research analysis developed from the hybrid energy institutional model of new renewable energy)
Source : (Rachmawatie, 2019).

## 5. Conclusions

The study of waste to energy in the last ten years is very dynamic and evolving with 524 scientific publications from 2014 to 2023 on waste to energy proving a significant growth in interest and research on this topic. The positive trend in the number of publications reflects a good response to technological developments in the digital era. China leads the way as the largest contributor with 50 documents covering various aspects of waste-to-energy. While authors such as Biatowiec, A managed to contribute as many as 13 significant documents in the study of waste to energy, this shows the important and consistent war of Biatowiec, A in enriching our insights related to waste sampa that can be processed into energy. and others make consistent contributions. Visual mapping shows that topics such as waste to energy, waste management, sustainability, life cycle, and renewable energy are the main studies in waste to energy research, but there are still several topics such as solid waste, organic waste, wastewater treatment, and synthesis gas that are open for further research. Research trends show an increasing focus throughout the decade. The increasing focus on waste to energy reflects a paradigm shift in understanding and dealing with the challenges and opportunities faced by communities in managing waste. This research provides rich insights into the direction and development of waste-to-energy research and shows the potential for further exploration in the various dimensions of this topic. These findings could help direct future research and contribute to our understanding of waste-to-energy.

Although this study succeeded in explaining the development map of research on "Waste to Energy", this study has limited data sources taken, namely the data analyzed is only taken from the Scopus database and has not used data sourced from Dimension, Web of Science. Thus, further research development needs to be studied more deeply using Dimension and Web of Science or comparison with data from the Scopus database, supported by the composition of other Vosviewer software that was not used in this study.

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