Utilization of *RVM* Technology as a Green Technology Innovation to Support a Sustainable Economy

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ABSTRACT

Background: The development of environmentally friendly technology has brought significant changes in various sectors, especially in efforts to achieve a sustainable economy. The application of green technology is an important step in addressing environmental issues arising from increased plastic consumption and low recycling rates. One innovation that has emerged in this context is the Reverse Vending Machine (RVM), an automated machine that accepts used plastic bottles or cans and exchanges them for certain incentives. This technology not only plays a role in waste management, but also encourages circular economic behavior in society. **Objective**: This study was conducted to examine the use of Reverse Vending Machine (RVM) technology as a form of green technology innovation in supporting the creation of a sustainable economy. Method: This study used a literature review method by examining various journals, scientific articles, and research reports related to the application of RVM and its contribution to plastic waste management and circular economy development. **Results**: The results of the study show that RVM has great potential in increasing community participation in recycling activities through an economic incentive system. The implementation of RVM in various countries has proven to be effective in reducing plastic waste, increasing environmental awareness, and opening up opportunities for green economy-based business innovation. In addition, the integration of RVM with digital technologies such as the Internet of Things (IoT) and electronic payment systems also strengthens the efficiency and sustainability of waste management systems. **Conclusion**: The use of Reverse Vending Machine (RVM) technology is one of the strategic solutions in realizing green technology that supports a sustainable economy. Collaboration between the government, the private sector, and the community is needed to expand the implementation of this technology. Further research can focus on RVM business models that are adaptive to local socioeconomic conditions, so that they can make a real contribution to sustainable development in Indonesia.

Keywords: Reverse Vending Machine (RVM), Environmentally Friendly Technology, Circular Economy, Plastic Recycling, Technological Innovation.

BACKGROUND

Technological developments in the era of the Fourth Industrial Revolution have brought significant changes to various sectors of life, including the environment and economy.[1] These developments are marked by increased integration between digital technology, automation, and sustainable innovation in economic and social activities. In the context of sustainable development, The implementation of green technology

[1] Klaus Schwab, The Fourth Industrial Revolution (World Economic Forum, 2016).

is crucial in addressing global challenges on issues of climate change, declining environmental quality, and increasingly complex waste management. [2]

One of the biggest environmental problems facing the world today is the increase in the volume of plastic waste. According to an OECD report (2022), global plastic production reaches more than 400 million tons per year, and only about 9% is successfully recycled.[3] Indonesia even ranks fourth in the world in terms of the amount of plastic waste entering the ocean.[4] This situation highlights the urgent need for technological innovations that can raise public awareness of plastic waste management and strengthen circular economy practices.

In an effort to overcome these problems, a technological innovation known as the Reverse Vending Machine (RVM) has emerged. An RVM is an automated machine designed to accept used packaging, such as plastic bottles or cans, and reward users with points or economic incentives.[5] This concept is a tangible implementation of green technology because it encourages recycling, reduces plastic waste, and creates new economic value from previously worthless waste.

Furthermore, the implementation of RVM plays an important role in supporting the transition to a sustainable and circular economy.[6] The circular economy emphasizes the importance of maintaining the value of products and materials for as long as possible through recycling, reuse, and waste reduction. The implementation of RVM in various countries, such as Germany, Norway, and China, has been proven to increase the collection rate of plastic bottles to more than 80%.[7] In addition to its environmental impact, this technology also provides economic benefits, such as creating new jobs, strengthening the recycling industry, and encouraging sustainability-based business innovation.

In the Indonesian context, the adoption of RVM technology is still relatively new and faces various challenges, ranging from low public awareness of recycling, limited infrastructure, to a lack of policy support that encourages waste-based incentive systems. Nevertheless, the opportunities for implementing RVM are enormous, especially with the increasing public and private sector attention to the sustainable development agenda and the national targets for reducing emissions and plastic waste by 2030.[8]

Given this urgency and potential, this study was conducted to identify and analyze the role of Reverse Vending Machine (RVM) technology as a green technology innovation in supporting a sustainable economy. Using a literature review approach, this study examines various findings and applications of RVM in various countries and its potential application in Indonesia. The results of this study are expected to provide theoretical and practical contributions to the

[2] Morrar, R., Arman, H., & Mousa, S., "The Fourth Industrial Revolution (Industry 4.0): A Social Innovation Perspective," Technology Innovation Management Review, 7(11), 2017.
[3] OECD, Global Plastics Outlook: Policy Scenarios to 2060 (Paris: OECD Publishing, 2022).
[4] Jambeck, J. R., et al., "Plastic Waste Inputs from Land into the Ocean," Science, 347(6223), 2015, 768–771.
[5] Hahladakis, J. N., et al., "An Overview of Chemical Additives Present in Plastics: Migration, Release, Fate and Environmental Impact," Journal of Hazardous Materials, 344, 2020.
[6] Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J., "The Circular Economy – A New Sustainability Paradigm?," Journal of Cleaner Production, 143, 2017, 757–768.
[7] Hopewell, J., Dvorak, R., & Kosior, E., "Plastics Recycling: Challenges and Opportunities," Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1526), 2009, 2115–2126
[8] UNEP, Turning Off the Tap: How the World Can End Plastic Pollution and Create a Circular Economy (United Nations Environment Programme, 2023).

development of policies, business innovations, and implementation strategies for sustainable environmentally friendly technologies in the future.

Research Objectives

This study aims to analyze the role and potential of Reverse Vending Machine (RVM) technology as a form of green technology innovation that can support plastic waste management and encourage the implementation of a circular economy in society. Through a comprehensive literature review, this study seeks to identify how the implementation of RVM can contribute to the achievement of a sustainable economy, particularly in terms of resource efficiency, reduction of environmental impact, and increased economic value from recycling activities.

In addition, this study also focuses on reviewing various empirical and theoretical literature discussing the implementation of RVM in various countries, to understand the patterns of success and challenges faced in its application as an economic incentive-based waste management model. Through this approach, it is hoped that this study can explain the relationship between development environmentally friendly technology with increased public awareness of sustainable consumption and production practices. Ultimately, this research is expected to provide conceptual recommendations for the development of similar policies and technological innovations in Indonesia as a strategic step towards creating a green and sustainable economy.

LITERATURE REVIEW

Technological innovations have brought significant changes to environmental conservation efforts and sustainable resource management. One form of technology that supports these sustainability principles is the Reverse Vending Machine (RVM), an automated machine designed to efficiently collect and manage plastic bottles or used cans. This machine works on the opposite principle of a conventional vending machine: users do not purchase products, but instead insert waste into the machine and receive rewards in the form of points, tickets, or cash in return.[9] Through this mechanism, RVM not only serves as a waste management tool, but also functions as an educational tool that encourages community participation in protecting the environment and supporting recycling behavior.[10]

The use of RVM is a tangible manifestation of the application of green technology or environmentally friendly technology. According to Ottman, green technology is innovation that focuses on resource efficiency and reducing negative impacts on the environment.[11] This technology focuses not only on energy savings and emission reductions, but also on creating social and economic value through sustainable innovation. Hall and Vredenburg explain that green innovation requires a balance between business interests and ecological responsibility in order to provide long-term

[9] Handoko, P., Hermawan, H., & Jaya, S. (2018). Reverse Vending Machine Penukaran Limbah Botol Kemasan Plastik dengan Tiket Sebagai Alat Tukar Mata Uang. Seminar Nasional Sains dan Teknologi, Universitas Muhammadiyah Jakarta.

[10] Nurmelasari, E. E., & Ridho, W. F. (2023). *Pemanfaatan Mesin Otomatis Pengelolaan Sampah Botol Plastik (RVM) pada Masyarakat Berbasis Ekonomi Sirkular di Kota Yogyakarta*. *JPPMI*, 2(2), 121–129.

[11] Ottman, J. (2017). The New Rules of Green Marketing: Strategies, Tools, and Inspiration for Sustainable Branding. Berrett-Koehler Publishers.

benefits to society.[12] In this context, RVM serves as a form of green innovation because it integrates digital technology, economic incentive systems, and environmental sustainability goals into a single interconnected ecosystem.[13]

Furthermore, the concept of circular economy is an important basis that strengthens the implementation of RVM. Circular economy emphasizes the reuse of resources through the principles of reduce, reuse, recycle, replace, and repair, so that the material cycle can be closed and does not produce new waste. This model contrasts with the linear "take-make-dispose" economic paradigm that has long dominated production systems. Gertsakis and Lewis assert that circular systems aim to maximize the economic value of products through resource efficiency and sustainable design engineering. Thus, RVM is an important instrument in realizing a circular economy because it is capable of collecting plastic bottles After consumption, it is recycled into new raw materials, while also providing economic value to the communities involved in the recycling process.

Meanwhile, the concept of sustainable economy serves as the ultimate goal of implementing green technology and circular economy. Goodland defines sustainable economy as an economic system that balances economic, social, and environmental dimensions in order to maintain intergenerational sustainability. This principle is in line with Pearce and Turner's view that the use of natural resources must take into account the preservation of ecosystems and the welfare of future generations. In this context, the use of RVM is one of the concrete steps in building a sustainable economy because this system not only reduces waste but also creates economic added value through incentive mechanisms and community participation.

Theoretically, the relationship between RVM, green technology, circular economy, and sustainable economy forms a synergistic relationship. RVM functions as a concrete application of green technology that supports the implementation of circular economy principles through an automated recycling process. Through this approach, the community can play an active role in maintaining environmental sustainability while also gaining economic benefits. Thus, the application of RVM technology can be understood as a mechanism that connects environmentally friendly technological efficiency and a sustainable economic system oriented towards a balance between economic, social, and ecological values.

In other words, the use of RVM as part of green technology strengthens the implementation of the circular economy through automatic material recycling, ultimately resulting in a sustainable economy system that is in line with the Sustainable Development Goals (SDGs), particularly points 12 (Responsible Consumption and Production) and 13 (Climate Action).[14]

Previous Reseach

Based on the theories described above, the use of Reverse Vending Machines (RVM) as part of green technology has great potential in supporting the implementation of a circular economy towards a sustainable economic system. To strengthen this

[12] Hall, J., & Vredenburg, H. (2020). The Challenges of Innovating for Sustainable Development*. MIT Sloan Management Review, 61(4), 1–10.

[13] Zia, H., Jawaid, M. U., & Fatima, H. S. (2022). Plastic Waste Management through the Development of a Low-Cost and Lightweight Deep Learning Based Reverse Vending Machine*. Recycling. 7(5), 70.

[14] United Nations. (2015). Transforming Our World: The 2030 Agenda for Sustainable Development. United Nations General Assembly.

conceptual basis, this section reviews several relevant previous studies and shows the position of this study among existing studies. From the initial search, 25 scientific articles were found, which were then filtered based on theme relevance, journal quality, and availability of full text. After going through a selection and content analysis process, five main articles were obtained that were most relevant and credible. These articles are presented in Table 1 below.

Tabel 1 Results of Reviewing 5 Journals

Penelitian & tahun	Title	Theoretical concept	Theory Description / Key Findings	Research Results
Handoko, Hermawan & Jaya (2018)	Reverse Vending Machine Penukaran Limbah Botol Kemasan Plastik dengan Tiket Sebagai Alat Tukar Mata Uang	Experimentation and system design	Developing an automated machine that detects plastic bottles and issues tickets as a form of exchange.	Focus on technical aspects and machine mechanisms; no review of links to green technology and sustainable economy
Zia, Jawaid & Fatima (2022)	Plastic Waste Management through the Development of a Low-Cost and Lightweight Deep Learning Based Reverse Vending Machine	Deep learning-based technology design and system testing	Demonstrating the efficiency of the plastic waste classification system through the application of AI and automatic sensors.	Focus on technical innovation; not yet linked to the context of the circular economy and sustainable economy.
Nurmelasari & Ridho (2023)	Pemanfaatan Mesin Otomatis Pengelolaan Sampah Botol Plastik (RVM) pada Masyarakat Berbasis Ekonomi Sirkular di Kota Yogyakarta	Deskriptif kualitatif	RVM raises public awareness and participation in value-based recycling.	Emphasizing local social and economic aspects; has not yet discussed integration with green technology on a sustainable policy scale.

Gertsakis & Lewis (2020)	Design + Environment: A Global Guide to Designing Greener Goods	Literatur / konseptual	Promoting the principles of resource efficiency and environmentally friendly design in product innovation.	Providing a theoretical basis for the development of RVM as a form of green design and technology; not discussing the direct application of RVM.
Goodland (1995)	The Concept of Environmental Sustainability	Konseptual / teoretis	Explaining the relationship between the economy, society, and the environment within the framework of sustainable development.	It serves as the theoretical basis for interpreting sustainable economy; it does not yet discuss the contribution of technology as an implementation tool.

Based on the theories described above, the use of Reverse Vending Machines (RVM) as part of green technology has great potential in supporting the implementation of a circular economy towards a sustainable economic system. To strengthen this conceptual basis, this section reviews several relevant previous studies and shows the position of this study among existing studies.

Research conducted by Handoko, Hermawan, and Jaya developed an RVM machine that exchanges plastic bottle waste for tickets as a means of currency exchange.[15] This study focuses on the technical aspects and operating mechanisms of automatic machines that can detect types of plastic bottles and provide rewards in the form of tickets. The research makes an important contribution to the development of incentive-based recycling technology, but has not yet examined its integration with the concepts of green technology and sustainable economy.

Meanwhile, research conducted by Zia, Jawaid, and Fatima focused on plastic waste management through the development of a low-cost deep learning-based Reverse Vending Machine.[16] The results of this study indicate that the application of artificial intelligence technology can improve the efficiency of plastic bottle classification and

[15] Handoko, P., Hermawan, H., & Jaya, S. (2018). Reverse Vending Machine Penukaran Limbah Botol Kemasan Plastik dengan Tiket Sebagai Alat Tukar Mata Uang. Seminar Nasional Sains dan Teknologi, Universitas Muhammadiyah Jakarta.

[16] Zia, H., Jawaid, M. U., & Fatima, H. S. (2022). Plastic Waste Management through the Development of a Low-Cost and Lightweight Deep Learning Based Reverse Vending Machine. Recycling. 7(5), 70.

reduce errors in the recycling process. However, this study focuses more on the aspects of system engineering and has not yet reviewed its relationship with the circular economy or economic sustainability in a comprehensive manner.

Another study by Nurmelasari and Ridho examined the use of RVM in a social context with a circular economy approach in the city of Yogyakarta.[17] This study shows that the presence of automatic waste management machines can increase public awareness of sorting and exchanging plastic waste for economic value. This research provides an important basis for understanding the social and economic aspects of RVM implementation, but its focus is still limited to strengthening community behavior, rather than integrating the concept of green technology into sustainable policy.

In their research on environmentally friendly product design, Gertsakis and Lewis emphasize the importance of resource efficiency and sustainable innovation in every aspect of production.[18] Although this study does not specifically discuss RVM, the concepts presented provide a strong foundation for the development of green technology that can be applied in automated recycling systems. This reinforces The position of RVM as a tangible form of green design and technology implementation in solid waste management.

Furthermore, Goodland explains the concept of environmental sustainability as the basis of a sustainable economy that demands a balance between economic, social, and ecological aspects.[19] This view serves as a theoretical basis linking the application of environmentally friendly technologies such as RVM with the long-term goal of sustainable development. The study provides a framework for thinking that every technological innovation must be assessed in terms of its contribution to ecosystem sustainability and community welfare.

From these five studies, it can be concluded that the majority of previous studies focused on two main aspects: (1) technical development and efficiency of the RVM system; (2) application of RVM in the local social and economic context. Although each study has made a significant contribution, there is still a research gap in efforts to integrate RVM as a form of green technology that supports the circular economy system and generates sustainable economic impacts. Therefore, this study aims to strengthen the conceptual relationship between environmentally friendly technological innovation and the creation of green economic value oriented towards long-term sustainability.

In addition to reviewing academic literature, this study also strengthens its analysis by linking empirical data related to the actual conditions of plastic waste management in Indonesia, as shown in Table 2 below.

[17] Nurmelasari, E. E., & Ridho, W. F. (2023). Pemanfaatan Mesin Otomatis Pengelolaan Sampah Botol Plastik (RVM) pada Masyarakat Berbasis Ekonomi Sirkular di Kota Yogyakarta.JPPMI, 2(2), 121–129.

[18] Gertsakis, J., & Lewis, H. (2020). Design + Environment: A Global Guide to Designing Greener Goods. Greenleaf Publishing.

[19] Goodland, R. (1995). The Concept of Environmental Sustainability. Annual Review of Ecology and Systematics, 26, 1–24.

Tabel 2. Data on Plastic Waste Generation and Plastic Bottle Consumption in Indonesia

No	Data Type	Value / Amount	Description	Source
1	Total national plastic waste per year	± 7,8 juta ton	Including household and industrial packaging plastics	World Bank (2021)
2	Mismanaged plastic waste	± 4,9 juta ton	Open dumping or leakage into the sea	World Bank (2021)
3	Total national waste (organic & non-organic)	± 64 juta ton/tahun	Including all types of solid waste	BPS dan INAPLAS (2020)
4	Plastic recycling rate	± 10 %	Only a small portion of plastic is formally recycled	Zero Waste Center (2022)
5	Proportion of plastic bottles in total waste (example of a campus area study)	± 26%	Dominated by single-use bottled water	Jurnal Matrix Teknik Sipil, UNS (2022)
6	Volume of plastic bottled water products in Indonesia	± 226 ribu ton/tahun	Equivalent to 7.06% of total single-use plastics	Detik News (2022)
7	Proportion of the population using single-use plastic bottles	± 9 %	Consumers who rely on bottled water	Eco-Bussiness Report (2023)

The empirical data above shows that Indonesia still faces major challenges in plastic waste management, especially from single-use plastic bottles. Although only about 9% of the population consumes drinking water from single-use bottles, the scale of production and disposal of packaging remains enormous. Plastic bottles account for more than a quarter of urban waste volume in various local studies. The low recycling rate of only about 10% of total plastic that is successfully reprocessed indicates the need for innovative approaches to bridge the gap between high plastic consumption and low recycling capacity.

In this context, the reviewed literature (Table 2) shows that Reverse Vending Machine (RVM) technology can serve as a concrete solution through an incentive-based automatic bottle collection mechanism.

Metode Penelitian

This study uses a literature review research method to answer two predetermined research questions. The first research question is: "How is the concept and application of Reverse Vending Machine (RVM) technology as a green technology innovation in supporting the circular economy?" and the second research question is: "How is the

relationship between the application of RVM, green technology, circular economy, and sustainable economy in current scientific literature?"

To collect data for this study, a literature search was conducted through several online scientific databases such as Google Scholar. These databases were selected based on the consideration that these platforms provide access to various scientific publications relevant to the topics of Reverse Vending Machines, green technology, and the circular economy.

The search was conducted using keywords relevant to the research topic, including: "Reverse Vending Machine," "Green Technology," "Circular Economy," "Sustainable Economy," and "Recycling Innovation." The literature search process focused on articles published in the last five years as well as previous studies used for comparison to ensure that the results of this study reflect the latest developments and trends related to the application of green technology in sustainable economic systems from year to year.

During the search process, researchers selected and screened literature based on criteria relevant to the research focus. The selected articles were scientific publications discussing the development, application, or impact of RVM technology in environmental, social, and economic contexts. In addition, literature highlighting the relationship between RVM and the principles of green technology and circular economy was also included as key study material.

The next step is to read, record, and group the research results into relevant thematic categories. The analysis was conducted by identifying key concepts that emerged from the literature, such as green technology principles, resource efficiency, circular economy models, and the contribution of technology to economic sustainability. Each article was analyzed to see how RVM was used as a green technology innovation that could provide economic added value while reducing environmental impact.

In the analysis process, researchers also compared various findings from previous studies to identify similarities, differences, and research gaps that remain open. This approach aims to build a comprehensive synthesis of the position of RVM in the framework of a sustainable economy. The results of this analysis are then presented in the form of a narrative description and a summary table of previous research, so that readers can understand the overall developments in research in this field.

From the results of this study, researchers developed a conceptual framework as a basis for understanding the logical relationship between the main variables used in this study. This conceptual framework illustrates how the application of RVM as a form of green technology plays a role in strengthening the circular economy system, which ultimately contributes to the achievement of a sustainable economy as follows.

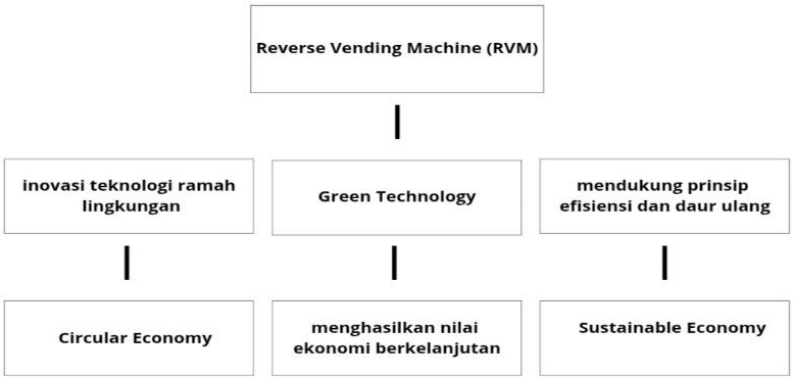

Figure 3. Conceptual framework

The research framework describes the conceptual relationship between four main elements, namely Reverse Vending Machines (RVM), Green Technology, Circular Economy, and Sustainable Economy. This relationship shows a logical direction in which the application of RVM technology acts as a bridge that integrates technological innovation with the principles of economic and environmental sustainability.

1. Reverse Vending Machines (RVM) serve as an environmentally friendly technological innovation designed to automatically manage plastic bottle waste through an exchange and recycling mechanism. The existence of RVMs represents the application of smart technology that is not only oriented towards efficiency, but also towards changing people's behavior towards waste management.
2. RVM is a tangible form of green technology implementation because it promotes the principles of energy efficiency, waste reduction, and sustainable use of resources. This green technology emphasizes a balance between economic benefits and ecological responsibility, which is the foundation for modern environmentally friendly innovation.
3. The application of green technology through RVM reinforces the principle of circular economy, where resources do not end up as waste, but are continuously reused in the production and consumption cycle. In this context, RVM creates added value through a recycling incentive system that encourages community participation in the circular economy chain.
4. The integration of green technology and the circular economy through RVM contributes to the creation of a sustainable economy, which is an economic system that balances economic, social, and environmental interests in a sustainable manner. By reducing environmental impact and creating new economic value, RVM has become a tangible symbol of the synergy between innovative technology and sustainable development.

Overall, this framework shows that the higher the application of RVM as a form of green technology, the greater its contribution to strengthening the circular economy, which ultimately promotes the realization of a sustainable economy. Thus, RVM not only serves as a technological device, but also as an instrument of transformation towards a sustainable green economy.

Methods

The selection of the literature review method in this study was based on the main objective of the research, which focused on conceptual analysis and the synthesis of previous research results relevant to the topics of Reverse Vending Machines (RVM), green technology, circular economy, and sustainable economy. This method was considered the most appropriate because it allowed researchers to build a comprehensive theoretical understanding without collecting primary data in the field.

According to Snyder, a literature review is a systematic and planned research method for identifying, evaluating, and interpreting all research results relevant to a specific research question.[20] Melalui metode ini, peneliti dapat memperoleh gambaran menyeluruh mengenai tren research, key concepts, and research gaps that remain open for further study. This opinion is reinforced by Okoli, who explains that literature studies not only serve as summaries of previous research, but also as scientific methods that can be used to generate new theories through the process of analyzing and synthesizing various sources of information.[21] This approach helps researchers develop a body of knowledge in their field of study and discover new directions for future research.

Webster and Watson also emphasize that conceptual research requires a literature review method because its purpose is not to measure empirical phenomena, but rather to understand the structure of knowledge and the interrelationships between concepts that have been discussed in previous literature.[22] Thus, this method is suitable for research oriented towards theoretical integration, such as the relationship between environmentally friendly technological innovation and economic sustainability.

Other methods such as quantitative or experimental approaches were not used in this study because the focus of the study was not on testing hypotheses or measuring numerical variables. Instead, this study aimed to explore existing concepts and theories in order to produce a deep qualitative understanding.[23] In addition, qualitative field approaches such as interviews or case studies were not chosen because this study did not require exploration of subjective experiences or social phenomena in the field. Literature studies were considered more efficient for analyzing conceptual relationships between variables and identifying thematic patterns from previous studies.[24]

Through a descriptive qualitative literature review approach, this study aims to produce a systematic scientific synthesis of how Reverse Vending Machines (RVM) serve as a green technology innovation that strengthens the circular economy and contributes to a sustainable economy.

[20] Snyder, H. (2019). Literature Review as a Research Methodology: An Overview and Guidelines. Journal of Business Research, 104, 333–339.
[21] Webster, J., & Watson, R. T. (2002). Analyzing the Past to Prepare for the Future: Writing a Literature Review. MIS Quarterly, 26(2), xiii–xxiii.
[22] Okoli, C. (2015). A Guide to Conducting a Systematic Literature Review of Information Systems Research. Sprouts: Working Papers on Information Systems, 10(26).
[23] Creswell, J. W., & Creswell, J. D. (2018). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches (5th ed.). Sage Publications.
[24] Jesson, J., Matheson, L., & Lacey, F. M. (2011). Doing Your Literature Review: Traditional and Systematic Techniques. Sage Publications.

RESULTS AND DISCUSSION

Results

According to Gertsakis & Lewis (2020), green technology is the application of technical innovations that aim to improve resource efficiency and reduce environmental impact through sustainable design systems. This principle is the main basis for the development of Reverse Vending Machine (RVM) technology, which is an automatic machine used to collect used plastic bottles in exchange for certain incentives, such as points, coupons, or digital money.

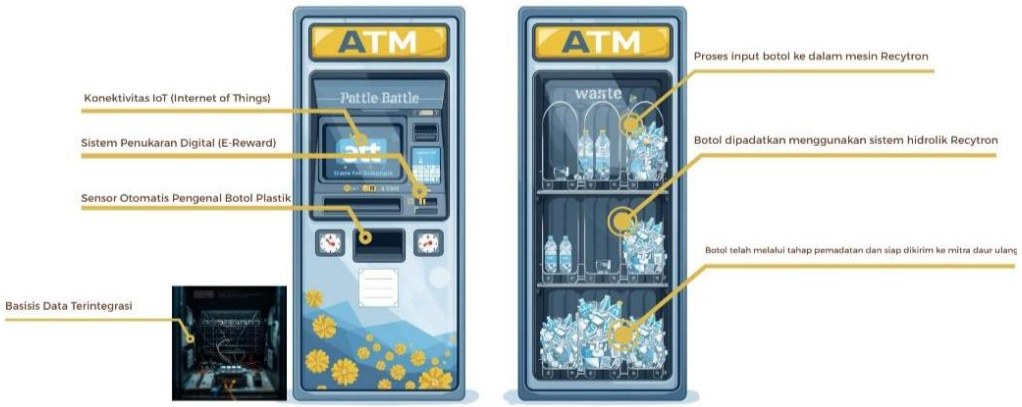

Figure 4 Example of an RVM (Reverse Vending Machine)

The results of the literature review and visualization of the RVM machine above show that the Reverse Vending Machine (RVM) is an effective form of green technology innovation in supporting circular economy practices and strengthening the transition to a sustainable economy. Based on the five main studies analyzed (see Table 1), several complementary key findings were discovered. (1) RVMs play an important role in encouraging community behavior to participate in recycling. Research by Nurmelasari & Ridho (2023) shows that the implementation of RVM machines in the Yogyakarta community has increased environmental awareness and citizen participation in plastic waste sorting. This technology not only functions as a waste collection tool but also as a means of environmental education that provides direct economic incentives. (2), Technically, research by Handoko, Hermawan, & Jaya (2018) proves that RVM can operate effectively in the local Indonesian context. The prototype of an automatic plastic bottle exchange machine that they developed proves that such a system can be implemented at the community level. (3) International research by Zia, Jawaid, & Fatima (2022) broadens the perspective by adding artificial intelligence (AI) technology to the RVM mechanism. The use of deep learning in RVM sensors and cameras has been proven to increase the accuracy of plastic material identification to over 95%. These results show that the application of advanced technology can reduce detection errors and facilitate efficient waste management. (4) Conceptual literature from Gertsakis & Lewis (2020) and Goodland (1995) reinforces the theoretical dimension of this research. Gertsakis emphasizes that green technology is not only related to energy and material efficiency, but also to system design that can minimize waste from the beginning of the production process. Meanwhile, Goodland places economic sustainability within the framework of balancing resource efficiency and long-term environmental sustainability.

This is also reinforced by a World Bank study (2021) which reports that Indonesia produces around 7.8 million tons of plastic waste per year, with 4.9 million tons of it not being managed properly. The low recycling rate (around 10%) indicates that the conventional waste management system is not yet effective. Therefore, the application of technologies such as

RVM is a potential solution to reduce waste generation and increase the collection of plastic bottles in a measurable manner, as shown in the diagram below.

Figure 5 Diagram of plastic waste and used plastic bottles in Indonesia

The results of these studies show that the application of RVM technology can be grouped into several main aspects, namely:

1. Technical aspects, including the use of detection sensors and AI recognition for automatic bottle identification.
2. Economic aspects, in the form of incentives that encourage recycling behavior among the community.
3. Socio-educational aspects, through increasing public awareness and participation in the importance of waste management.
4. Environmental aspects, which emphasize reducing plastic waste and pollution through an integrated collection system.

According to Gertsakis & Lewis (2020), innovations classified as green technology not only include energy efficiency or material recycling, but also create a symbiotic relationship between humans and technology. In this case, RVMs reflect the integration of social behavior and automated technology.

Collectively, these studies show that Reverse Vending Machines (RVMs) are a tangible representation of the application of green technology in a circular economy system. RVMs support the loop economy by closing the plastic material usage cycle, reducing waste, and creating economic incentives that encourage public participation.

The relationship between RVM, Green Technology, Circular Economy, and Sustainable Economy

Based on the results of the literature review, the relationship between the four main concepts of this study can be explained sequentially as follows:

1. Reverse Vending Machines (RVM) function as environmentally friendly technological innovations that utilize automation systems to manage plastic bottle waste efficiently.
2. Green Technology is the philosophical and technical foundation of RVMs, where technology is used to achieve energy efficiency, minimize waste, and support ecological balance.
3. Circular Economy is implemented through a reverse logistics system that allows materials to be reused in the production chain, reducing the need for new raw materials and extending the life cycle of materials.

4. Sustainable Economy is the ultimate goal of the integration of these three concepts, where resource management is carried out in a productive, socially equitable, and environmentally conscious manner.

Thus, the results of this study confirm that RVM is an integrative model of green technology application that supports the circular economy and strengthens the sustainable economic system.

Discussion

This study shows that the implementation of Reverse Vending Machines (RVM) as part of green technology innovation has a significant impact on increasing environmental awareness, improving the efficiency of plastic waste management, and strengthening the circular economy system. RVM machines have proven to be effective in automatically collecting used plastic bottles in exchange for monetary rewards, which encourages the community to participate more actively in recycling.

Critically, these findings confirm that the main problem with plastic waste management in Indonesia lies not only in limited infrastructure, but also in low community participation and a weak recycling incentive system. With the introduction of RVM technology, this gap can begin to be bridged, as the system changes the community's paradigm from waste disposers to contributors to the circular economy.

However, challenges still arise in terms of technology adoption and implementation costs. Previous studies (such as Handoko et al., 2018) highlight that the initial cost of procuring RVM machines is quite high and requires institutional support in order to operate sustainably. These findings show that although RVM technology is promising in concept, its success still depends on social factors, policies, and economic support from the government and plastic manufacturers.

CONCLUSION

This comprehensive literature study confirms that the use of Reverse Vending Machine (RVM) technology is a strategic and innovative solution that contributes significantly to the realization of green technology in support of a sustainable economy. RVM serves as a concrete implementation of green technology because it applies an efficient automation system in the management of plastic bottle waste, while promoting resource efficiency and reducing negative impacts on the environment. The presence of RVMs reinforces the principle of the circular economy by creating an incentive-based reverse logistics mechanism, which significantly increases public participation in recycling activities and closes the plastic material cycle back into the production chain. The interconnection between RVMs, green technology, and the circular economy logically leads to the achievement of a sustainable economy, namely an economic system that balances economic, social, and environmental interests. Although proven effective in raising environmental awareness and offering solutions to the massive plastic waste problem in Indonesia, the implementation of RVM in Indonesia still faces major challenges such as high initial procurement costs and the need for strong policy support, such as a structured incentive system, to ensure its operational sustainability. Thus, RVM not only serves as a technological device, but also as an instrument of transformation towards a sustainable green economy system in the future.

Recommendations

The success of RVM implementation as a sustainable green technology innovation is highly dependent on tripartite synergy; (1) Regulators (Government) must take the lead by adopting and implementing a strong incentive policy framework, such as the Deposit-Refund System (DRS), as well as providing adequate fiscal and infrastructure support to overcome high initial costs; (2) Practitioners (Industry Players) are advised to innovate in low-cost and locally adaptive RVM business models, including partnering with waste banks, and improving system efficiency through the integration of smart technologies such as Artificial Intelligence (AI); (3) Academics should focus their research on investment cost analysis, sustainable financing models, and studies on the synergy between RVM policies and sustainable development goals (SDGs), in order to provide strong conceptual recommendations for future policy development.

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