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A SOLUTION TO VIETNAM'S WASTE PROBLEM

: Focusing on waste segregation and method of waste disposal

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Abstract

Vietnam's rapid economic growth has led to a surge in waste emissions. After implementing the Doi Moi economic reform and opening strategy in the mid-1980s, the country became one of the biggest contributors to plastic pollution in Southeast Asia and one of a number of nations that failed to effectively manage and dispose of waste. Vietnam generated 38,000 tons of municipal waste per day in 2017, and according to the Vietnam Environment Agency, the amount of solid waste generated in Vietnam is increasing by 10 to 16% annually. Additionally, improper waste disposal negatively affects the health and environment of low-income households. In the past, when economic development was a top priority, these difficulties were difficult to manage carefully. However, now that Vietnam's economic status in the international community has changed, it is inevitable for the government to take steps toward a new Vietnam. This paper presents solutions that can create synergy with the government's environmental policy in two stages, assuming that the Vietnamese government is taking an active stance on environmental issues, such as introducing separate collection policy and environmentally friendly waste treatment methods. First, along with the Vietnamese government's mandatory separate collection, it is proposed to introduce a separate collection platform that shortens the adaptation period and provides incentives to the public for separate collection. Second, solutions such as rPET (recycled polyester terephthalate) fibers, pyrolysis oil, and plastic bricks are offered to enable the current traditional and uneconomical plastic waste treatment procedures to achieve economic benefits and be disposed of in a future-oriented manner. Nephron, a circulating resource collection machine developed by Korean social enterprise SuperBin, has become a model for a separate collection platform implemented in consideration of various circumstances such as economic and technological conditions in Vietnam. This recycling platform and waste plastic treatment technology will propel Vietnam's domestic waste management towards a more streamlined, sanitary, eco-friendly, and sustainable direction, and with this platform, Vietnam will become a recycling and environmental leader.

Keywords: Recycling, Waste, Waste plastic, Circular resource

Contents

1. Introduction

With Vietnam's strong economic growth over the past decades, the country's solid waste production has increased by nearly 10% annually. According to the World Economic Forum, only 10-15 % of the waste collected in Vietnam is reused or recycled, the rest being transported to landfills and incinerators. Therefore, a sustainable approach to solid waste management, waste collection, transportation, and disposal technologies in Vietnam is a priority. According to the National Environmental Status Report by Vietnam's Ministry of Natural Resources and Environment, average daily solid waste emissions grew by almost 46%, from 44,400 tons in 2010 to 64,658 tons in 2019. Vietnam's daily waste emissions are between 0.35 and 0.80 kg. Vietnam generates around 25 million tons of household solid trash annually, of which more than 50 percent is generated in urban areas. As Vietnam progresses with industrialization, urbanization, and economic and population expansion, the amount of garbage generated in urban centers also increases. According to a 2018 research by the World Bank, solid waste generation in Vietnam's metropolitan regions is expected to increase by 8.4% per year over the next few years, while garbage generation in Vietnam as a whole will increase by 5% per year, reaching 54 million tons by 2030. Three-quarters of 63 provinces and cities dispose of more than 1,000 tons of garbage every day, and as of 2019, Hanoi and Ho Chi Minh City, Vietnam's two largest cities accounted for 33.6% and 33.5% of total waste emissions nationwide, respectively. With urbanization, waste emissions are increasing rapidly each year, making it difficult to manage. As a result, the waste disposal issue continues to be a topic of discussion in Vietnam.

Table 1. Solid Waste Emissions by Region (2010-2019)

Region	**Waste volume (ton/day)**			**Per capita waste volume (kg/day)**		
	2010	2015	2019	2010	2015	2019
Northern part						
- Hà Nội	5,000	5,515	6,500	0.95	0.76	0.81
- Hải Phòng	1,250	1,000	1,982	0.67	0.51	0.98
- Quảng Ninh	-	805	1,539	-	1.02	1.17
- Hải Dương	-	-	1,072	-	-	0.57
Central part						
- Thanh Hóa	-	-	2,175	-	-	0.6
- Nghệ An	-	-	2,464	-	-	0.74
- Đà Nẵng	805	900	1,100	0.83	0.87	0.97
Southern part						
- Hồ Chí Minh	7,081	8,323	9,400	0.96	1.02	1.05
- Bình Dương	378	-	2,661	0.22	-	1.1
- Đồng Nai	773	-	1,885	0.28	-	0.61

Sources: Yunjin, K. (2022)

Vietnam's central government and local governments in each province and city are facing

numerous challenges in collecting, transporting, and managing the rapidly rising amount of garbage. As noted earlier, waste emissions are rising rapidly with Vietnam's economic expansion, making it impossible to manage this problem with the current labor-intensive and inefficient waste treatment infrastructure. Vietnam's Ministry of Natural Resources and Environment reported that, as of 2019, the average rate of household solid garbage collection in urban regions was 92%, compared to 66% in rural areas. The majority of Vietnam's garbage is currently disposed of in landfills or incinerators using relatively primitive waste treatment methods. Classification and separate collection of household waste, which are generally practiced in Korea, are being conducted on a trial basis in some of Vietnam's major cities, but it is anticipated that it will take some time for these practices to become widespread, as adaptation requires considerable time. Therefore, most household waste in Vietnam is collected all together, transported to landfills, and disposed of unsorted. Separate collection is not widely used in ordinary households in Vietnam for two reasons: first, there is no legal requirement that individuals separate their garbage; second, because it has not yet been mandated, common houses may lack space for waste separation and may be expensive.

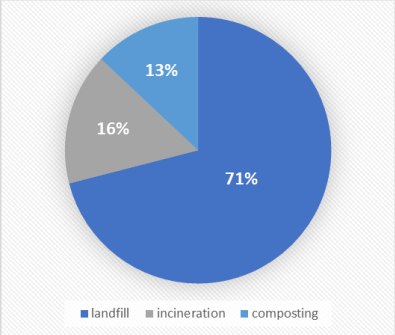

Figure 1. Percentage by waste disposal method in 2019
Sources: *Yunjin, K. (2022)*

It is not that the Vietnamese government has not made efforts to promote separate collection. In 2007, Hanoi and the Japanese governments implemented the "3Rs Hanoi" program to collect and identify solid garbage from waste sources in certain locations. However, the program's separation movement was not maintained after the project's conclusion, and although similar initiatives were subsequently undertaken, they did not scale nationwide due to inadequate responses from authorities, garbage collectors, and local communities. In addition, the Vietnamese government amended the Environmental Protection Act (Agreement 45/2022/NĐ-CP) last year to make the separate discharge of household waste mandatory. The law came into effect on August 25, 2022, and solid household waste must be disposed of in bags or face a fine of 1 million VND. Thus, it can be stated that the absence of required legal requirements, one of the reasons why separate collection is not practiced, has been rectified. However, it is not strictly regulated in practice, and given that the Vietnamese people are unfamiliar with the recycling system, it will take a considerable amount of time before the policy is fully implemented and expanded.

In urban areas, the collection and transportation of solid trash have traditionally been mostly managed and handled by government-owned and state-operated organizations, although recently the private sector has also begun to execute this function. In rural areas, the garbage

problem is largely handled by cooperatives, and in many rural areas, due to problematic transportation and low population density, individuals dispose of waste on their own or in rivers and vacant lots. Due to a lack of environmental awareness and access to public garbage collection and recycling facilities, waste is frequently illegally dumped into canals, lakes, rice paddies, beaches, and the ocean.

On November 17, 2020, the amended Environmental Protection Act (Law No. 72/2020/QH14) established the cornerstone for Vietnam's transition from a "linear economy" to a "net environmental system." The cyclical economy is an economic model that integrates sustainable development while reducing environmental impact throughout design, production, consumption, and service activities, with the goal of reducing raw materials, extending product life, minimizing waste generation, and minimizing negative environmental impacts. Vietnam is currently in a critical position to transition from a linear economy to a cyclical economy for the reasons listed below. First, Vietnam's resource depletion and ecosystem destruction have been exacerbated by economic expansion so far. As mentioned earlier, Vietnam's two largest cities, Hanoi and Ho Chi Minh, are currently among the most polluted cities in Southeast Asia. Vietnam, according to the World Bank's 2021 forecast, ranks fourth in the world in terms of yearly plastic waste emissions, with about 2.62 million tons. Vietnam's plastic waste emissions account for 6% of global marine plastic waste emissions. Plastic and nylon account for between 8 and 12% of solid trash in Vietnam, with each household using an average of 1 kg of plastic bags every month. Every day, around 80 tons of plastic and nylon packaging materials are discarded in Hanoi and Ho Chi Minh City. Additionally, the COVID-19 outbreak has increased the amount of waste generated by plastic packaging for masks, disinfectants, and hand sanitizers. In addition, due to the increase in non-face-to-face e-commerce, the use and disposal of non-recyclable packaging materials have increased. Due to the increasing urbanization rate and the number of middle-income households, Vietnam has experienced rapid growth in plastic consumption and demand in the retail, construction, and automobile industries, as well as in the production of everyday consumer goods. The second problem is the rise in the amount of money that is wasted due to the improper disposal of recyclable plastic packaging materials. According to the World Bank, Vietnam's plastic resin package recycling rate in 2019 was just 33%. Every year, 2.62 million tons of plastic are thrown away, which results in economic losses ranging from $2.2 billion to $2.9 billion. According to the World Bank, 75% of the value of PET, PP, HDPE, and LDPE materials consumed in Vietnam in 2019 was lost due to low recycling levels in Vietnam. These materials include plastic. The recycling of plastic packaging is expected to provide a value of around $3.4 billion each year if everything goes smoothly. Only 872 million, or 33% of the total amount of plastic garbage generated annually in Vietnam, are recycled, while the remaining 677 million, or 67%, are thrown away.

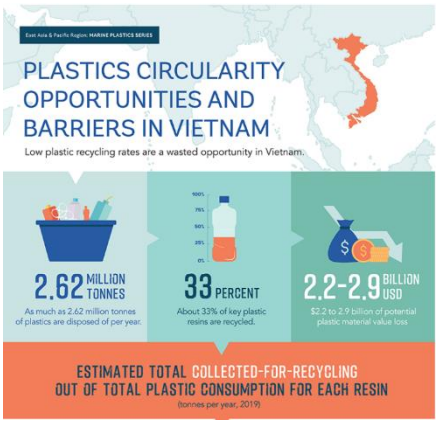

Figure 2. Recycling rate of plastic waste and financial loss due to plastic waste in Vietnam
***Sources**: World Bank Group (2021)*

The last reason is the United Nations Convention (COP26) in 2021. At the 2021 United Nations Climate Change Conference (COP26) held in Glasgow, Scotland, Vietnam committed to "Net Zero," reducing net carbon emissions to zero by 2050. Given Vietnam's present environmental protection legislation and garbage recycling rate, reaching net zero by 2050 appears difficult. However, Vietnam has signed a major international pact to demonstrate its responsibility and desire to engage in international efforts to tackle future climate change challenges. In line with the global trend in green economic development, cyclical economy, and digital economy, Vietnam's implementation of the Convention at COP26 is congruent with the current shift of national economic policy from a linear economy to a cyclical economy.

This study examines the Vietnamese government's attempts to reduce and efficiently manage waste, focusing on separate garbage collection, and proposes strategies for creating synergies with government programs. Vietnam is the world’s fourth-largest producer of plastic garbage as of 2019, and economic losses associated with the disposal of recyclable plastic packaging are increasing. So, it presents a more efficient and environmentally beneficial method to make recyclable plastic out of the many types of waste collected in Vietnam.

2. The establishment of a separate collection platform

In the first half of 2018, there was a refusal to collect waste vinyl from apartments in the Seoul metropolitan area, which was called the "waste crisis." The incident occurred when China stopped importing some recycled solid waste, including waste vinyl. As the export route to China was blocked, domestic recycling companies refused to collect recycled waste such as waste vinyl, which became a problem. The garbage crisis clearly demonstrated problems in the domestic recycling process. Currently, recycling waste collection methods in Korea are largely divided into two types: those in which the local government directly manages a separate collection site and those in which a private company voluntarily contracts and collects recycled waste selected by residents. The garbage crisis of 2018 can be attributed to the second method, the collection by private companies. It is difficult to make a big profit because the recycling waste sorting work is labor-intensive and requires human hands to go through it one by one. Therefore, if recycled products can be sold to other countries, such as China, public expenditure can be reduced and recycled products can be efficiently managed, but if not, there is a limit to the capabilities of private companies, so other alternatives are needed. In order to fundamentally

solve the garbage crisis, it is necessary to improve the resource circulation structure consisting of a linear economic system of 'production-consumption-incineration/landfill'. Under the current system, garbage separation is not aimed at increasing recycling rates but rather at reducing the burden of incineration and landfills, so the actual recycling rate is low and the quality of recycled waste is inevitably low. SuperBin, a social enterprise launched in 2015 to solve this problem, manufactures and sells "Nephron," an artificial intelligence-based empty container recovery device that recovers recycled waste (a circular resource). Among them, high-valued wastes are called "circular resources," and despite their usefulness, many circulating resources on the planet are not recognized for their value and are treated vulgarly and discarded. Nephron is the world's first robot that collects circulating resources and returns the value to people through total data on household waste and smart artificial intelligence technology, creating the world's first market where garbage can be traded.

The garbage collection stage of the separate collection platform presented in this paper is designed to suit the situation in Vietnam based on SuperBin's Nephron. In the case of Nephron, recyclable waste resources are collected well, but the current resource recovery methods are not easy to incinerate or landfill, and the recycling platform proposed in this paper is intended to shorten the introduction period. Furthermore, through this platform, waste management infrastructure can be built in each city in Vietnam, allowing cities to be managed and designed in a sustainable and future-oriented way. This separate collection platform is configured and operated as shown in Figure 3.

Figure 3. Superbin's Waste Trading Platform
***Sources**: https://www.superbin.co.kr/company/nephron*

The stage of collecting and selling waste consists of a waste discharger (seller), a separate collection platform (collector), and a waste buyer (buyer). Simply, the seller puts the recyclable waste into a machine such as a nephron and receives compensation through points. Machines use AI to recognize the type of garbage and classify it by type. Classified waste is purchased by waste purchasers, mainly recycling and upcycling companies. In addition, this process consists of interactions of devices, control systems, and app services.

2.1 Seller-to-Collector

First, explaining the first stage, the seller-to-collector stage, the seller, waste discharger, must classify the waste they wish to dispose of as recyclable and not possible at home. In this process, Vietnamese users are not familiar with recycling, so they will have difficulty sorting due to lack of related information or knowledge. To address this, it plans to include information recycling-related information in the app service provided. As shown in <Figure 4>, we plan to provide information by type of garbage, such as paper, plastic, vinyl, cans, and bottles, and provide examples of recyclables and non-recyclable to make it easier to set separate collection standards. If the information provided is insufficient, the user can post the question on the Q&A bulletin board of the application and have the administrator manage each question.

Figure 4. Examples of garbage separation and discharge assistance applications
***Sources**: GOOGLE PLAY*

Once an individual has completed the separate collection, they can move on to the collection stage. Users, i.e., sellers, should take the sorted garbage and move it to the place where the garbage collection machine is located. Collection machines will be mainly placed in parks, squares, apartment complexes, and inside buildings. It is a system that allows users to recognize the user's ID by reading the application's QR code or ID card into the machine, and this is a technology that can be easily accessed in Korean food collection machines. When the user is recognized, the inlet of the machine opens and trash can be put into it. When garbage is put in, the image sensing artificial intelligence in the machine identifies whether it is a circulating resource and rewards the user with points if it meets the criteria, and returns the trash if it does not meet the criteria. The artificial intelligence used in this process is image sensing artificial intelligence that can identify even if the form or barcode of garbage is damaged, and accuracy can be improved through deep-learning, which increases as the number of users increases. In addition, the points provided as compensation will be paid differently according to certain criteria such as resource type, weight, and suitability. Users can check accumulated points through the application, and users who have collected more than a certain amount of points can apply for cash conversion.

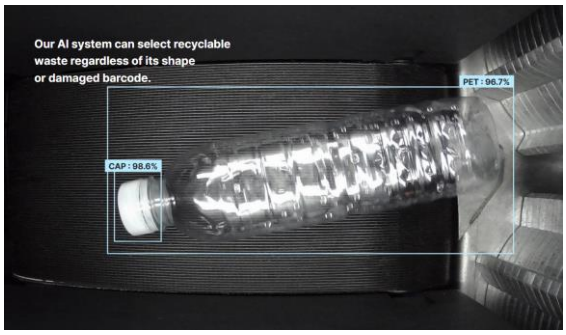

Figure 5. Application of Nephron's Image Sensing AI Technology
Sources: *https://www.superbin.co.kr/company/nephron*

2.2 Collector-to-Buyer

The process of managing the circulating resources collected by the garbage collection machine involves three stages of screening. Initially, the waste discharger conducts the first screening and delivers the waste to the machine, which then performs a second screening during the input process. Subsequently, a final screening takes place within the machine, categorizing the waste based on its type and quality. The classified garbage is then sold to buyers, namely waste disposal and recycling companies, who acquire resources based on contractual agreements that align with their specific needs and quantities.

Despite the well-established waste classification system implemented in this process, challenges persist regarding the utilization of waste. While numerous companies specialize in upcycling and recycling materials such as plastics, paper, glass, and cloth, there is a scarcity of companies capable of processing waste in a reusable form. Furthermore, the absence of clear treatment and quality evaluation criteria leads to the production of subpar waste-processed products, with each company producing different variations. Consequently, this hampers profitability and efficiency. Moreover, relying solely on domestic demand for waste-processed products in Vietnam proves challenging, necessitating their exportation to the international market. Meeting elevated Environmental, Social, and Governance (ESG) standards and competing with waste-processed products from other countries requires a focus on high-quality output. Thus, it is crucial for the government to establish standards for assessing the quality of waste-processed products and implement regular screenings to address these concerns.

3. Utilization of Recycled Waste: Focusing on Plastic

The main purpose of the separate collection platform is to make people feel familiar with the separate collection and provide economic incentives and venues for separate collection, thereby breaking down barriers to separate collection and promoting individual motivation. However, the secondary purpose is to effectively manage Vietnam's waste problem, and for this purpose, not only the separate collection but also the waste disposal process after separate collection is important. Until now, most of Vietnamese waste disposal methods have been traditional and labor-intensive methods such as landfill and incineration. These methods are neither economical nor eco-friendly, nor sustainable. Therefore, it can be said that eco-friendly and sustainable changes in waste treatment methods are needed.

The wastes collected through the platform are of various types, such as plastic, glass, cans,

and aluminum. However, in this paper, we would like to present a solution to the recycling method of plastic among various wastes. This can be said to be related to Vietnam's national loss caused by the inefficient recycling of plastic waste described in the introduction. Specifically, according to the report "Market Study for Vietnam: Plastics Circularity Opportunities and Barriers" released by International Finance Corporation (IFC), 3.9 million tons of plastic were consumed in Vietnam in 2019, but 1.28 million tons were recycled, accounting for only 33% of total consumption. As 2.62 million tons of plastic are discarded without being recycled, about 75% of the material value of plastic is lost, resulting in a loss of 2.2-2.9 billion per year.[1]

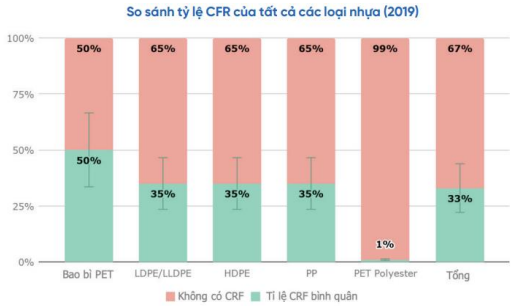

Figure 6. Collected for Recycling (CFR) rates of plastic
Source: *World Bank Group (2021)*

To reduce the enormous economic and environmental losses under these circumstances, we propose to use the waste plastics collected through the separate collection platform as recycled fibers, pyrolysis oils, and plastic bricks. Since plastic waste can be used for many purposes, demand is guaranteed as long as the separate collection is done properly. Therefore, it is possible to make profits by exporting the collected waste plastic to overseas companies that run businesses using waste plastic. However, large and small costs are unavoidable in the process of exporting, and if waste plastics are used in various ways in the country, greater economic value can be created than when exporting. Therefore, we propose to attract and encourage businesses that utilize waste plastics so that waste plastics collected through the platform can be used autonomously in Vietnam, and to provide active support in establishing factories. Eventually, the collected waste plastics are distributed in Vietnam.

3.1 Recycled fibers

Recycled fibers refer to fibers produced by chemically and physically grinding and refining collected waste plastics. Recycled fibers are as good as ordinary fibers in quality and manufacturing processes, and have high added value. In addition, it is so versatile that it is used to make bags and shoes as well as down jackets, fleece jackets, and hoodies. Many leading fashion brands such as Patagonia, The North Face, Black Yak, and Polo are already making

[1] International Finance Corporation. (2021). Market Study for Vietnam : Plastics Circularity Opportunities and Barriers. https://www.ifc.org/wps/wcm/connect/5438568a-83bd-4ac2-843d-bae3b4adabba/Market-Study-for-Vietnam-Plastics-Circularity-Opportunities-and-Barriers.pdf?MOD=AJPERES&CVID=nMQU7AH

various categories of clothing using recycled fiber. In addition, recycled fibers are produced through a process that significantly reduces energy usage and carbon dioxide generation compared to general chemical fibers, so they are very eco-friendly and sustainable materials. In the current situation where ESG management and sustainability have become trends, the demand for recycled fibers is also expected to continue to increase. In fact, the scale of the global eco-friendly fiber market is growing significantly every year. In addition, since European countries are scheduled to stop importing clothing that has not been certified as recycled fiber from 2025, it is essential to use waste plastic as recycled fiber for competitiveness in the export market to Europe.

3.2 Pyrolysis Oil

Pyrolysis oil refers to oil made by directly or indirectly applying high heat (300 to 800°C) to waste plastic in an anaerobic state. It can be recycled as a raw material for petrochemical processes such as naphtha and diesel by replacing crude oil and can be used to make various plastic products. Pyrolysis technology is particularly meaningful in that it enables recycling by recovering raw materials from non-recyclable waste such as disposable cups, razors, and toothpaste tubes made of polyolefin, a mixed plastic. In addition, current recycling is centered on a single material, making it difficult to recycle plastics mixed with multiple materials. However, pyrolysis technology improves the level of recycling by enabling recycling without distinguishing the type or color of plastic. In addition, pyrolysis technology is eco-friendly and sustainable because it has the effect of high energy replacement and greenhouse gas reduction compared to other energy technologies such as incineration and landfill.

Table 5. Energy replacement and greenhouse gas reduction effects for each technology

Sortation	The effects of energy substitution			Other reduction effects	Total (TC/TON)
	Energy substitution effect (TOE/TON)	Emission coefficient (TC/TOE)	Reduced amount of greenhouse gases (TC/TON)		
Simple incineration	0	1.05	0	-	0
Solid fuel	0.2	1.05	0.21	-	0.21
Pyrolysis emulsification	0.57	0.84	0.48	-	0.48
Gasification	0.26	1.05	0.27	0.2	0.47
Use of incineration heat recovery	0.18	1.05	0.19	-	0.19

Sources: Kyunghwan, L. (2022)

3.3 Plastic brick

Plastic bricks refer to bricks made by recycling waste plastic as a raw material for bricks. The process for making these plastic bricks is as follows: First, the collected waste plastic is

put into a crusher and crushed into very small pieces. After melting these crushed pieces with hot water or heat, plastic bricks are completed by putting them in an appropriately sized mold and hardening them.

Plastic consists of complex molecular structures that are difficult to decompose. Due to the solid nature of these plastics, there is an environmental problem in that they do not break down easily, but because of this property, plastic bricks do not crack or break like ordinary bricks. Therefore, plastic bricks are suitable for making retaining walls or soundproof walls that support the ground at construction sites and can be used not only for warehouse and terrace construction but also for landscaping.

Unlike ordinary bricks, adhesives, additives, and chemicals are not used in the manufacturing process of plastic bricks. In addition, it is eco-friendly because it emits significantly less greenhouse gas than ordinary bricks, and it is very economical because of its low manufacturing period and cost. Also, since it can be made from almost any type of plastic, including non-recyclable plastics, the effort and cost of sorting or cleaning waste plastics can be saved.

4. Conclusion

Currently, Vietnam lacks technology to process recycled waste on its own, recycling and upcycling have not been activated, and related companies have not grown significantly. Under these circumstances, the proposal to make recycled fiber and pyrolysis oil from waste plastic is very expensive and requires a high degree of technology, so it is not suitable for solving the waste problem by applying it directly to Vietnam. On the other hand, making bricks out of waste plastic does not require advanced technology. Therefore, making bricks with waste plastic collected through the platform can be a way for the Vietnamese government to solve the waste problem on its own.

The proposals in this paper have different expected effects from the perspective of sellers, collectors (platform operators), buyers, and society as a whole. First of all, from the sellers' point of view, the introduction of the platform will make the living environment of sellers more pleasant and clean than before by increasing the recycling rate of waste and lowering the landfill rate. In addition, as recycling becomes easier, environmentally conscious sellers will be able to save the environment with less effort than before. In addition, the points accumulated through the platform can be cashed out to obtain economic benefits.

In terms of collectors, they can use the platform as a source of revenue to obtain economic benefits. They can insert advertisements into applications, receive direct sponsorship, and make profits by selling waste plastics to businesses. In addition, in a circumstance where ESG management is becoming a hot topic, the platform can provide many advantages to the community, increasing competitiveness and customer loyalty in the market. This will also be of great help to future business expansion. The waste problem is a problem that needs to be addressed at the government level and has plagued the Vietnamese people for quite some time. Therefore, collectors will be able to achieve organic cooperation with the government by receiving full support from the government in the process of operating the platform. In addition, if a collector creates a successful case through collaboration with the government or local government, he or she can get an opportunity to expand business to other regions.

On the buyer's side, they can save time and effort in obtaining waste by signing contracts with the collector through the platform. Also, they can get good quality raw materials at low prices.

On the social front, the platform can accelerate the development of an effective recycling system and greatly increase the recycling rate of waste, which can greatly contribute to preventing the loss of material value of waste and realizing a green society. In addition, the introduction of the platform can have many positive effects on society as a whole, such as increasing the employment rate by creating many jobs related to the recycling industry and platform in Vietnam.

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<Reference list>

Jongyeong, L. (2020), "Producing Yarn from PET Bottles... The Rise of Recycled Fibers", *KBS NEWS*, Available at: https://news.kbs.co.kr/news/view.do?ncd=5033234 (Accessed: 19 January 2023).

Juwon, N. (2022), "Architects and Designers Embrace the Transformative Power of Recycled Plastic Waste", *Newspenguin*, Available at: https://www.newspenguin.com/news/articleView.html?idxno=10610 (Accessed: 19 January 2023).

KOTRA. (2022), "Vietnam's Circular Economic Policy and Consultative Body for Net Zero in 2050", Available at: https://dream.kotra.or.kr/kotranews/cms/news/actionKotraBoardDetail.do?SITE_NO=3&MENU_ID=410&CONTENTS_NO=1&bbsGbn=242&bbsSn=242&pNttSn=195305 (Accessed: 11 January 2023).

Kyunghwan, L. (2022), "Thermal Decomposition Oil from Plastic Waste: Environmental Friendliness Equals Economic Prosperity", *Energy & Environment News*, Available at: http://www.e2news.com/news/articleView.html?idxno=241268 (Accessed: 20 January 2023).

Ministry of the Environment of Japan. (n.d.), "Ha Noi 3R Declaration-Sustainable 3R Goals for Asia and the Pacific for 2013-2023", Available at: https://www.env.go.jp/recycle/3r/en/declaration/hanoi-declaration.html (Accessed: 20 January 2023).

Minjeong, K. (2022), "Global chemical companies leading the 'circulating economy' with waste plastic pyrolysis oil production", *ESG Economy*, Available at: http://www.esgeconomy.com/news/articleView.html?idxno=2659 (Accessed: 18 January 2023).

Namhee, Y. (2019), "Recycling resources are selected from the collection stage of PET bottles and cans. The cost of waste disposal thus reduced is 'social value'", Available at: http://dbr.donga.com/article/view/1101/article_no/9079/ac/a_view (Accessed:18 January 2023).

World Bank Group. (2021), "Market Study for Vietnam: Plastics Circularity Opportunities and Barriers", *Marine Plastics Series*, pp. 20-85, Available at: http://hdl.handle.net/10986/36313 (Accessed: 20 January 2023).

Yugyeom, K. (2021), "Who recycles products made of recycled fiber?", Available at: http://www.fpost.co.kr/board/bbs/board.php?bo_table=special&wr_id=619 (Accessed: 20 January 2023).

Yunjin, K. (2022), "Status and Policy of Waste Disposal in Vietnam", *KOTRA*, 11 March. Available at: https://dream.kotra.or.kr/kotranews/cms/news/actionKotraBoardDetail.do?SITE_NO=3&MENU_ID=180&CONTENTS_NO=1&bbsGbn=243&bbsSn=243&pNttSn=193373 (Accessed: 20 January 2023).