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Evaluation of circular economy potential of plastic waste in Sri Lanka

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Abstract

With increasing industrialization and high growing coastal population in Sri Lanka, plastic waste in municipal solid waste has increased tremendously over the past few decades. Plastic consumption in Sri Lanka is increasing at 16% annually with a current consumption of 265,000 megagram (Mg) per annum. If the current trends continue, a large amount of plastics will end up in an open environment threatening natural ecosystems. An attempt was carried out to understand the plastic material flow within Sri Lanka in the year 2017. Through material flow analysis, plastic material flow cycle consisting of nine processes was categorized. The plastic collection and recycling efficiencies were found to be 33% and 3%, respectively. The total quantity of plastics washed into the sea could have been approximated to 69,427 Mg. The per capita contribution is about 3.3 kg. With the integration of the plastic waste circular economy to the Renewable Energy Development Plan (2019–2025) of Sri Lanka, various scenarios were developed for the year 2025. Source segregation of plastic wastes, landfill mining to recover nonrecyclable plastics for energy production, and integration of formal and informal sectors are the three key recommendations to transform to a more vibrant circular economy.

KEYWORDS
circular economy, marine plastic pollution, material flow analysis, plastic recycling, plastic waste management, plastics

1 | INTRODUCTION

Sri Lanka is a developing island country with an approximate population of 21 million. With the rapid population growth and urbanization, the municipal waste generation has increased tremendously in the past few decades. Sri Lanka generates 7000 megagram (Mg) of solid waste per day, and the Western Province alone accounts for nearly 60% of the total solid waste of the country. The per capita waste generation is in the range of 0.4–1.0 kg of waste per day (Basnayake et al., 2018). The barriers to the successful implementation of solid waste management (SWM) in Sri Lanka are poor segregation at source, lack of financial commitments, improper disposal of generated municipal solid waste (MSW), absence of a strong controlling body, and lack of infrastructure. The country is also plagued with frequent power outage plunging the country into darkness due to technical failures of major power plants and unreliable power transmission and distribution system. Ceylon Electricity Board (2019) said that the country had 4048 MW installed capacity, while the peak demand was about 2616 MW in 2018. However, there were nonconventional renewable energy plants with only a total capacity of 656 MW except larger hydropower plants, providing 1597 GWh of energy (10.6%) annually to the country's power generation system. In March 2019, the country was generating 1950 MW to the peak demand of 2400 MW (Aneez, 2019).

Japan International Cooperation Agency (2016) report states that waste surveys conducted by the University of Peradeniya in 2014 revealed that nearly three fourth of total waste was generated from kitchens and the composition of plastics (hard and soft plastics) totaled 5.1%. A similar study conducted by the Central Environmental

Authority (CEA) also pointed out that plastics constituted about 6% of the total waste fractions. The United Nations Centre for Regional Development Report (UNCRD, 2019) says that the proportion of plastic in MSW is around 8–12% across all the countries and is about 10% in Sri Lanka. However, the plastic consumption in Sri Lanka is growing above 16% annually with the current consumption of 265,000 Mg per annum. As of 2017, annual plastic use per capita is 13.5 kg. The packaging sector is the largest consumer (>50%) of the plastic industry (UNCRD, 2019). Most of the plastic recycling industries in Sri Lanka adopt manual washing of plastics. The effluents are discharged to the natural environment without treatment in comparison with the standard levels stipulated in the regulations by the CEA, Sri Lanka (Gunarathna, 2012).

UNCRD reports that the proportion of plastic in MSW is around 8–12% across all the countries.

Improper plastic waste management practices and high coastal population in the country have created major hot spots of accumulated floating plastics in the Indian Ocean. Sri Lanka ranks fifth among the top 11 countries with the highest mismanagement of plastic waste (Jambeck et al., 2015). To reduce the consumption of plastics, Sri Lanka has banned the use of plastic bags 20 μm or less, unless with written approval from the CEA (UNCRD, 2019). The closed-loop systems (like the circular economy, biomimicry, whole systems thinking, etc.) are based upon an understanding that the materials flow within the system. Currently, the plastics are produced, consumed, and disposed in a linear model (cradle to grave approach). The consequences of the current resource inefficient linear economic model of plastic waste management will be catastrophic in future. There are several short-term and long-term solutions which have to be implemented to improve the plastic waste management system. For sustainable consumption and production of plastics in the country, implementation of necessary regulations, laws, and policies at the national, regional, and city levels are required. It is highly imminent to transform the current system into a circular model to solve the plastic waste management issues and use plastic waste as a tool to reduce frequent power cuts due to power shortage. Previous studies related to plastic waste management in Sri Lanka severely lack the overall macroview of plastics flowing within the system and hence could not provide opportunities for legal, policy, and efficiency interventions. The plastic waste management issues were not addressed due to a lack of technical data for decision-making and planning. It is highly impactful for the developing countries like Sri Lanka to understand the current waste management practices where the environmental standards are often weaker, and the policy interventions made through scientific analysis can lead to sound environmental protection standards, economic resilience, and resource optimization (Millette et al., 2019). The country can capitalize on the current waste management issues to promote innovation and infrastructure grounded in new technologies from private and public sector.

RESEARCH HIGHLIGHTS

- Plastic waste contribution to marine plastic pollution was estimated.
- Baseline data of plastic waste were developed using Material flow analysis for 2017.
- Plastic waste collection and recycling efficiencies were 33% and 3%, respectively.
- Different scenarios were analyzed to improve plastic waste management for 2025.
- Plastic waste-based circular economic policies interventions were recommended.

Sri Lanka has banned the use of plastic bags 20 μm or less in the country.

In this study, an attempt has been made to understand the plastic material flow within Sri Lanka in the year 2017. It also discusses a holistic approach to the management of plastic waste. It involves improving the mechanical recycling facilities, cofueling in cement plants, municipal incineration, and sanitary landfilling methods to solve the current plastic waste management issues. It also improves the resilience of the power generation of the country. The plastic waste circular economic policy interventions are recommended to realize the circular economic potential for the year 2025.

2 | METHODOLOGY

2.1 | Data collection

The system boundary for the study is Sri Lanka. The temporal boundary for the analysis is the year 2017. The data were collected, compiled, extracted, and analyzed from both primary and secondary data sources. Colombo, Gampaha, Kegalle, and Kandy were the four locations selected for the data collection. The primary data collection involved plastic waste compositional analysis by field investigation in January 2019, stakeholder analysis by survey questionnaires, and field observations at manufacturing companies, waste shops, plastic recycling factories, plastic upcycling factories, cement companies, waste collection facilities, pyrolysis plant, and landfills during 2018 and 2019. A survey was carried out in both informal and formal sectors of plastic waste management. The sample groups were chosen from relevant

EXHIBIT 1 Definitions for each process in the plastic material flow with corresponding sources of data

S. No.	Process	Definition	Source
1.	The plastic product manufacturing industry	The plastic products are manufactured in factories by using virgin (imported masterbatch) and recycled plastic pellets as raw materials. A portion of the manufactured products is exported to other countries while the remaining portion is used for local consumption	Sri Lanka Customs, field survey, and statistic data analysis (Sri Lanka Customs [Board of Investment of Sri Lanka, 2018; SLC], 2018), Phoenix Industries Ltd (PIL), 2018)
2.	Interim users of plastic products	Locally manufactured and imported products with plastic content are used to produce end-use items in this process. Finally, the products with plastic content are supplied to the end-users of plastic products	Sri Lanka Customs, publicly available report analysis, field survey, and statistic data analysis (SLC, 2018), Central Bank of Sri Lanka (CBSL), 2017, PIL (2018), BOISL (2018)
3.	End users of plastic products	Plastic products which are manufactured locally and imported from other countries. These products are consumed domestically and commercially	Sri Lanka Customs, publicly available report and statistic data analysis (PIL, 2018; SLC, 2018), Asian Development Bank (2017)
4.	Waste collection and transport sector	Plastic waste is collected and transported to recycling facilities, landfill sites, and open dumping sites. In this process, a small portion of the collected waste is exported to other countries	Database of CEA of Sri Lanka, Waste Management Authority of Western Province, Ministry of Megapolis and Western Development, and Sri Lanka Customs (CEA, 2018), Ministry of Megapolis and Western Development (MMWD) (2018), Waste Management Authority of Western Province ([WMAWP], 2017)
5.	Cofueling in cement plant	Cement manufacturing facilities use plastic waste (mostly hazardous) as a supplementary fuel for heat generation	Database of INSEE Eco-Cycling Lanka Pvt Ltd. (INSEE, 2018)
6.	Recycling	Collected plastic waste is converted into recycled pellets at dedicated facilities	Field survey and statistic data analysis, the material balance of the process (WMAWP, 2017; PIL, 2018)
7.	Plastic to oil	Crushed plastic waste is converted to heavy oil	Field survey in Polipto Lanka (Pvt) Ltd
8.	Landfilling	Most collected municipal wastes are disposed at a landfill and landfilled plastic waste is stocked in the landfill for a long period	Literature review and statistic data analysis National Solid Waste Management Support Centre (NSWMSC, 2017; MMWD (2018)
9.	Open environment	Uncollected and collected plastic wastes (open burning and open dumping) are stocked in the environment. A portion of the plastic waste is burnt, and the other portion is washed into the ocean	Literature review and statistic data analysis (Basnayake et al., 2018; NSWMSC, 2017)

persons and organizations related to plastic waste management in Sri Lanka such as waste generators, waste collectors, waste buyers, waste recyclers, and responsible authorities, and field observations were carried in Municipal Council, Urban Council, and Pradeshiya Sabha. Plastic manufacturing and import of plastic materials in Sri Lanka were collected through secondary sources such as customs records, annual reports from industry associations, and Central Bank publications, etc. The use and disposal data of the plastic materials were collected from various published materials, reports, documents, presentations, interviews, surveys, and particularly those involving government and private institutions.

2.2 | Material flow analysis

The material flow analysis (MFA) is an analytical method to quantify flows and stocks of materials or substances in a well-defined system. By the law of conservation of mass, the mass that enters a system must, by conservation of mass, either leave the system or accumulate within the system. MFA has been widely applied for environmental education, particularly in waste management. MFA has been used as an analytical tool to make decisions on waste management policy such as SWM in Germany, solid waste management system in Lahore, Pakistan (Masood et al., 2014), and quantification and accumulation of tire waste in Thailand (Jacob et al., 2014). Exhibit 1 shows the definitions of nine different processes in the plastic material flow with corresponding sources of data. The mass balance for a system used in this study is given in Equation (1):

$$\sum W_{\text{input}} = \sum W_{\text{output}} + W_{\text{storage}}. \quad (1)$$

The STAN 2.6 software was used to create the plastic material flow for plastic substances or goods for the year 2017. Based on the

EXHIBIT 2 Plastic waste management scenarios in the year 2025

Scenarios	Composition of total plastic waste generation (%)				
	Mechanical recycling	Cofueling in cement plant	Municipal incineration	Sanitary landfilling	Open dumping
Scenario 1 (BAU)	2	1	6	6	85
Scenario 2	12.5	5	7.5	25	50
Scenario 3	12.5	5	15	17.5	50
Scenario 4 (best scenario)	25	5	15	5	50

results of the material flow of plastic in the year 2017, plastic waste collection and recycling efficiency were calculated. The contributions of mechanical recycling and thermal/cofueling process to the plastic recycling stream were determined. Furthermore, four scenarios were developed to forecast the plastic waste management situation in the year 2025.

Scenario 1 is business as usual (BAU). In this scenario, it was assumed that the plastic waste management practices in the year 2017 remain the same in the year 2025. In Scenarios 2 and 3, mechanical recycling is expected to collect and recycle 12.5% of the total plastic waste. Sanitary landfilling and municipal incineration are promoted minimizing open dumping of plastic waste. Scenario 4 denotes the ideal plastic waste management goals and vision for Sri Lanka considering the transformation of the current linear system to a more circular plastic waste management system. In this scenario, the development of proper waste management practices and necessary infrastructure facilities including municipal incineration plants, cofueling in cement plants, and mechanical recycling systems for handling plastic waste are considered. In 2025, the collection efficiency can be possibly increased to 50% if mandatory actions are taken (Basnayake et al., 2018). The European Commission has introduced a 50% target for recycling of waste by 2020 (European Commission, 2011). It is assumed that 50% of collected plastic will be recycled under the best-case scenario in 2025. In high-income and upper-middle-income countries, 15% of waste is treated through modern incineration (Kaza et al., 2018). Similar strategy on implementation will help in achieving the goals of the Renewable Energy Development Plan Phase I (2019–2025) envisioned by Sri Lanka Sustainable Energy Authority, Ministry of Power, Energy & Business Development. (MPEBD, 2019) and the country's pledge to use 100 % renewable energy by 2050 (UNDP, 2017). Therefore, all these criteria are expected to be realized in 2025. Exhibit 2 shows the developed plastic waste management scenarios in 2025.

3 | RESULTS AND DISCUSSION

3.1 | Plastic waste management of Sri Lanka in 2017

In this study, the wastes were segregated into biodegradable and nonbiodegradable wastes in some areas. The mixed wastes collected from

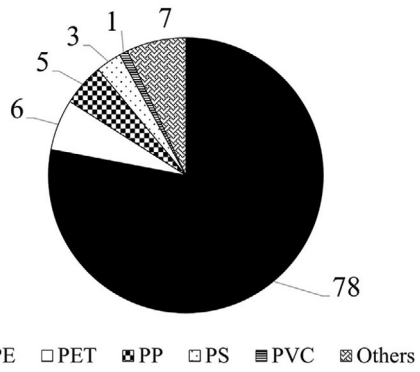

EXHIBIT 3 Plastic waste generation by polymer types (%)

the remaining areas in the Western Province were segregated at transfer stations. It is then taken to Kerawalapatiya waste park since the waste park only accepted segregated wastes. Plastic waste compositional analysis was carried out in Kerawalapatiya waste park on January 23–29, 2019, based on resin codes and sectoral categories. The plastics constituted about 41% of the total nonbiodegradable fraction. Exhibit 3 shows the plastic waste generation by types of polymers. Majority of the plastic waste generated was polyethylene (PE) (78%) followed by polyethylene terephthalate (PET) (6%). These PE, PET, and polypropylene (PP) wastes were generated from containers and packaging and dairy commodities. Generally, packaging waste containing PE and PP constitute more than 50% in plastic waste (UNCRD, 2019). Exhibit 4 shows the plastic waste generated from different product applications. Other plastic fractions polyvinyl chloride (PVC), polystyrene (PS), and other types of plastic fractions contribute very minor portions in plastic waste in Kerawalapatiya waste park. The data collection for developing the MFA was carried out during 2018 and 2019. The material flow of plastic in Sri Lanka in the year 2017 is presented in Exhibit 5. For the plastic-manufacturing process, the total weight of imported pellets used as raw material was about 317,000 Mg in 2017 and about 16,935 Mg of recycled plastics was also used.

About 39,059 Mg of plastic pellets was stocked by the end of 2017. Out of the total plastic products produced (333,506 Mg), about 50% is thermoplastic plastic products (168,137 Mg) and 11% thermosetting plastic products (36,999 Mg) were taken by end-users while about 36,000 Mg of plastic products was exported. The ratio of import to export is about 8.8 which refers to the import-driven plastic economy in Sri Lanka. About 26% (72,059 Mg of thermoplastics and 15,857 Mg

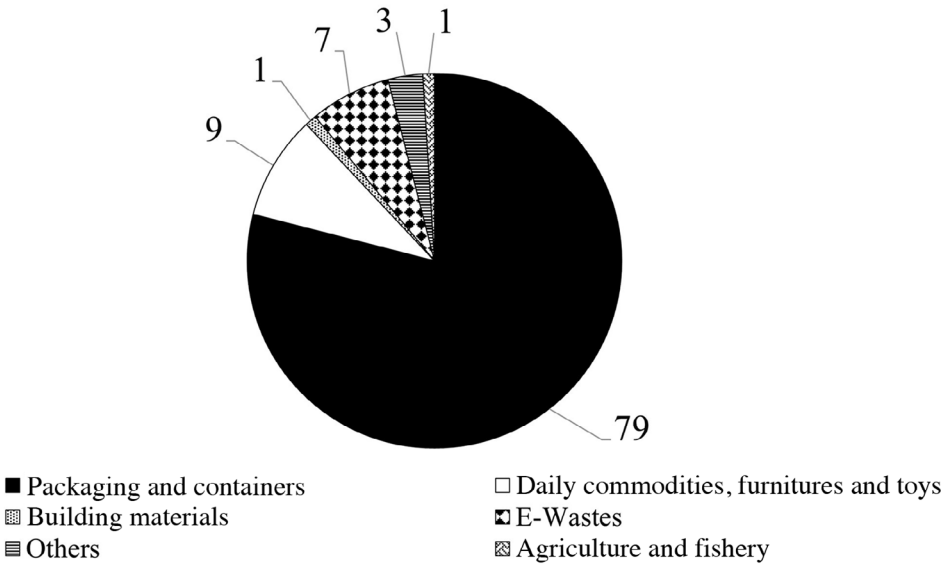

EXHIBIT 4 Plastic waste generation from different product applications (%)

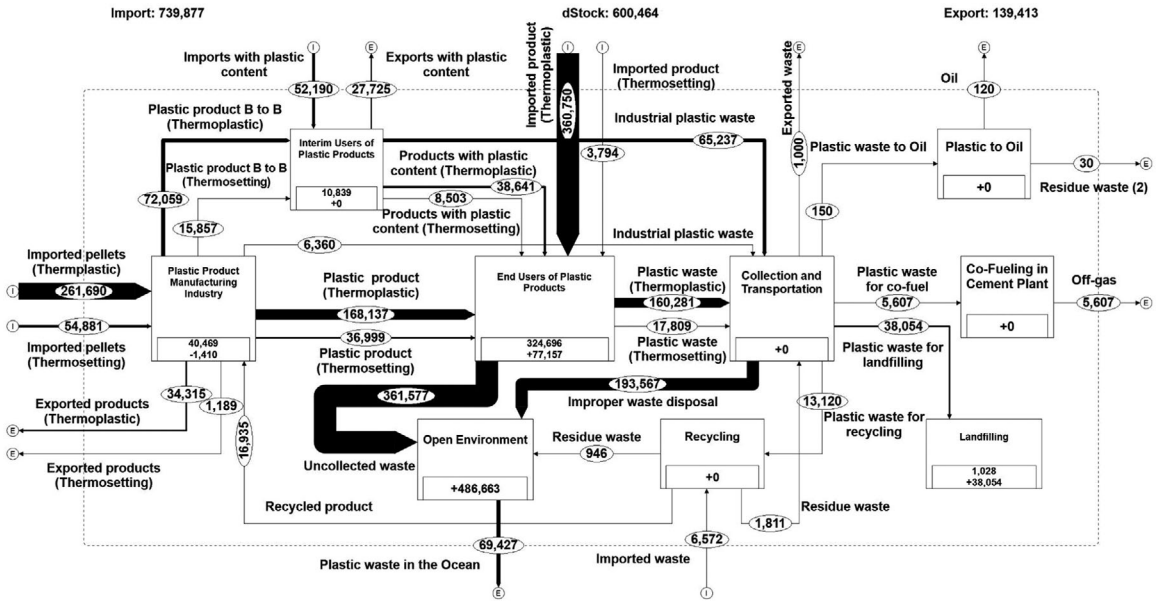

EXHIBIT 5 Plastic material flow in Sri Lanka, 2017 (units: flow, Mg/year; stock, Mg)

of thermosetting plastics) of the total manufactured plastics was supplied to interim users of plastic products. Out of 616,824 Mg of plastics consumed by end-users, about 77,157 Mg of plastic products is in stock while 539,667 Mg of plastics was generated as plastic waste. From the total plastic waste generated, only 33% (178,090 Mg) of the waste was collected and the remaining 360,000 Mg of plastic waste was added to the open environment as uncontrolled waste in the year 2017. Out of the collected plastic wastes, about 5607 Mg of plastic wastes was used for co-fueling in cement plants. A pyrolysis factory, which converts plastic waste to crude oil, takes about 150 Mg of plastic waste. About 38,054 Mg of plastic wastes had been sent to the landfills in 2017. In Sri Lanka, there are only two sanitary landfills, one in Kerawalapitiya waste park and the other is the Dompe landfill site. Moreover, 1028 Mg of plastic waste was stocked in the sanitary landfills by the end of 2016. In 2017, 1000 Mg of recyclable plastic waste had been exported to other countries. Out of the collected plastic waste, 13,120 Mg of plastic waste was collected separately by recyclable waste collectors of the government and private sectors. There are two main inflow streams such as imported plastic waste and plastic waste from the local consumption process. 6572 Mg of plastic waste was imported for the recycling process. Out of 19,692 Mg of plastic waste taken for recycling, 16,935 Mg of recycled pellets/products has been

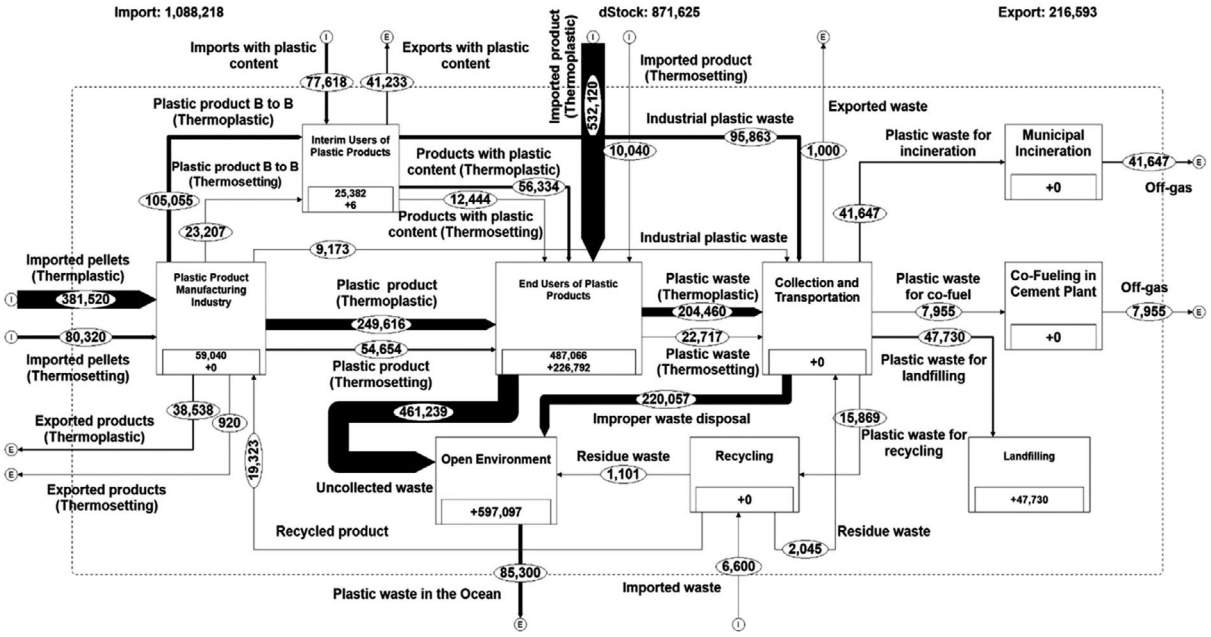

EXHIBIT 6 Plastic material flow in Sri Lanka, 2025—BAU scenario (units: flow, Mg/year; stock, Mg)

manufactured and sent back to the manufacturing process. In the open environment, uncollected waste and improper waste disposal contribute about 556,090 Mg of plastic waste including 946 Mg of residual waste from the recycling process. It is estimated from the data collected and analyzed that around 69,427 Mg of plastic waste could have been accumulated in oceans as plastic marine debris. This is in line with Jambeck et al. (2015) estimate of about 240,000–640,000 Mg/year. Assuming the total population of 21 million, the per capita disposal of plastic marine debris is about 3.3 kg in the year 2017.

3.2 | Future plastic waste management scenarios

3.2.1 | BAU scenario in 2025

Scenario 1 is the most probable BAU scenario of plastic waste management by 2025. In this BAU scenario, it is assumed that plastic waste management practices in 2017 remain the same in 2025. With an approximate population of around 23 million in 2025 (growth rate of 1.1%), MSW generation will be 11,571 Mg/day. The country will import 1,088,218 Mg of plastic materials in the form the plastic products and plastic pellets and export 39,458 Mg with the import/export ratio of 27.57. The total plastic waste generation will be 688,416 Mg in the year 2025. The collection efficiency is taken as 33%, and hence the total amount of uncollected plastic waste is 461,239 Mg in the year 2025. In 2017, 2% of generated plastic waste was recycled. Therefore, it is assumed that 2% of generated plastic waste is recycled in 2025. Thus, 15,869 Mg of generated plastic waste is supplied to the recycling process in 2025. 7955 Mg of off-gas will be used for the cofueling process, and 41,647 Mg of off-gas is generated from the incineration process. The total amount of improper plastic waste disposal is 220,507 Mg, and 85,300 Mg of plastic waste will be added to the ocean in the year 2025. Exhibit 6 shows the business as usual scenario in 2025.

3.2.2 | Best case scenario

The waste collection and transportation facilities are expected to collect about 50% of the generated plastic waste by 2025. About 309,788 Mg of thermoplastic waste and 34,420 Mg of thermosetting plastic waste will be collected from end-users of plastic products. Based on the BAU scenario, the amount of recycled plastic will increase by 10 times and about 198,363 Mg of plastic waste as estimated from BAU scenario expected to be openly dumped, will be fed to the mechanical recycling process. It is estimated that 13,200 Mg of plastic waste will be imported in 2025 and about 181,944 Mg of recycled pellets will be supplied to the plastic product manufacturing industry. About 42% of imported thermoplastic pellets can be replaced by the recycled plastic pellets and hence only about 218,899 Mg of thermoplastic pellets will be imported for the plastic-manufacturing process. About 41,154 Mg of plastic waste will be used for cofueling in cement plants and about 123,460 Mg of plastic waste will be incinerated in the municipal incineration plants. Thus, the incineration capacity should be increased by three times when compared with the BAU scenario. As a result of the plastic waste management plan of Scenario 4, the amount of plastic waste which will be openly dumped can be reduced up to 411,536 Mg. It is about 40% reduction of openly dumped plastic waste compared with the BAU scenario. However, about 51,442 Mg of plastic waste will be washed into the ocean in the year 2025. Exhibit 7 shows the best-case scenario for the year 2025.

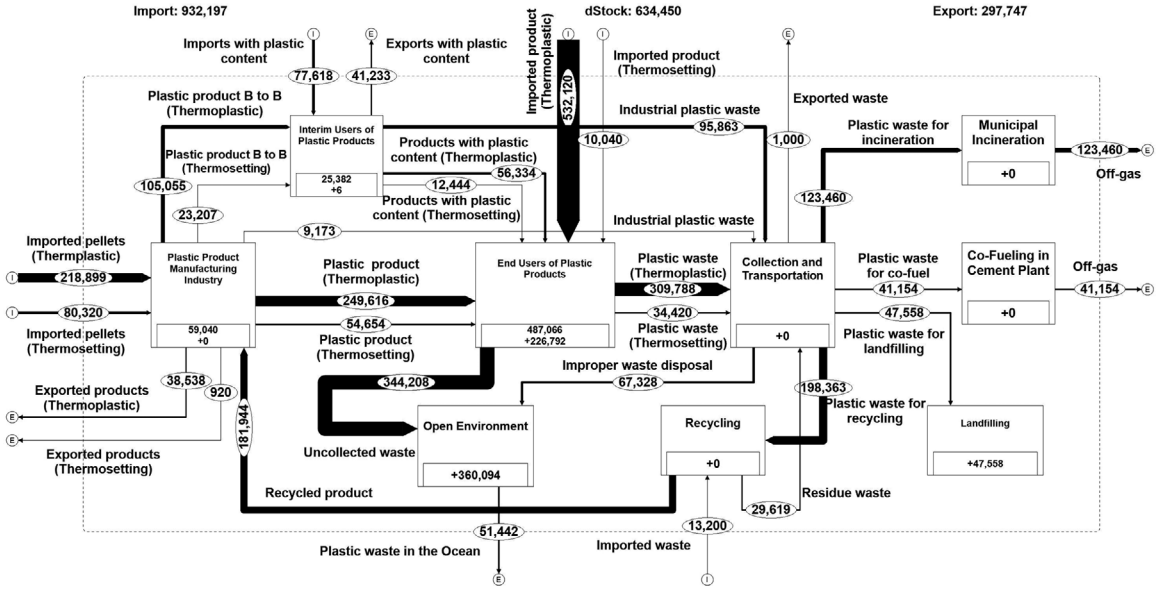

EXHIBIT 7 Plastic material flow in Sri Lanka, 2025—Scenario 4 (units: flow, Mg/year; stock, Mg)

3.3 | Identification of Circular Economy opportunities using policy interventions

The top-down and bottom-up approaches, ranging from source-based segregation to improving the public awareness, have to be put forth at the national, provincial, and local levels to realize the circular economy goals for plastic waste management. Sri Lanka's annual per capita contribution to plastic marine debris is about 1.5–3 kg when comparing with other lower-middle income countries such as Philippines (2.6–7 kg), Vietnam (2.9–7.7 kg), Egypt (1.5–4.2 kg), and Nigeria (0.6–1.7 kg) (Jambeck et al., 2015). Since the country is struggling with its current linear waste management system, three recommendations are provided. These recommendations are made with realistic targets These will shift the direction of waste management practices, capacity building, and improving the infrastructure towards a more systematic functioning ecosystem.

3.3.1 | Source-based segregation and involvement of information technology

By the stakeholder analysis carried out among 110 households in the selected sampling locations, it was evident that there was a lack of source segregation of MSW and lack of education and awareness on effective management of waste. Single-use plastic packaging waste is a major issue because of the lack of proper disposal facilities. Also, 60.9% of the interviewed households agreed that plastic packaging waste disposed of through curbside collection. As a result of the inefficient waste collection mechanism, it was common to resort to unscientific disposal methods. About 43% and 36% of the population practice open burning and unscientific dumping of plastic-packaging waste. Further, 9% of the population has dumped packaging waste in coastal areas and canals. With the holistic collaboration between the public sector, private sector, and industry, plastic waste can be handled scientifically and can be significantly reduced. Source segregation helps in resources recovery and easy collection of plastic waste. It can be achieved by the provision of specific bins for plastic waste disposal. On a positive note, about 31% of the interviewed households expressed their willingness to keep the plastic waste from MSW if they are provided with separate bins for disposal. Real-time monitoring of plastic waste collection time and truck route, special collection on request, and information regarding recycling centers and community bins can help in efficient plastic waste collection and recycling. The overall reduction of plastic consumption (kg) per capita has to reduce by introducing regulatory and financial instruments. The per capita plastic consumption of Sri Lanka is about 13.5 kg. This is higher in comparison with other countries such as India (11.6 kg), Indonesia (8.8 kg), Myanmar (4.6 kg), and Philippines (10 kg) (UNCRD, 2019).

3.3.2 | Landfill mining and waste to energy for Sri Lanka's energy sufficiency

From the field investigation and stakeholder interviews, it was evident that the lack of proper waste infrastructure facilities has resulted in rampant dumping of plastic wastes in open dumpsites. The disposal of plastic wastes in such areas had become a serious issue as the general public is unwilling and in some cases protest against the local authorities to dump the garbage. The existing regulatory mechanism in Sri Lanka for plastic waste management is not systematically functional. Many developing and developed countries like Thailand, India, United States, etc. have adopted landfill mining to recover old plastic waste dumped in landfills and dumpsites and generate revenue from the process. Landfill/dumpsite mining is the process of reclaiming land from the wastes dumped in landfills/dumpsites in addition to recovering valuables such as recyclable and combustible components. The

nonrecyclable plastic waste from the dumpsite has a high net calorific value. It can be recovered for generating energy by utilizing it in waste to energy plants in alignment with achieving the goal of 100% electricity generation through renewable energy by 2050. The plastic waste can also be used for cofueling in cement kilns with environmental safety precautions taken into account.

3.3.3 | Public and informal sector participation

Nearly 33% of the plastic wastes generated were collected. Lack of collection are due to lack of awareness among the types of waste, methods of recycling, the impact of recycling in a sustainable Plastic Waste Management system and the severity of impact by poor waste disposal methods, etc. In Sri Lanka, there are several plastic recycling businesses such as Yaal fiber, Katana upcycle, and Paalam products. These microlevel businesses help in achieving positive social, economic, and environmental impacts. At the same time, the plastic wastes are diverted from haphazard disposal practices through the development of value-added products (Conlon et al., 2019). Hence, public participation in microlevel businesses has to be encouraged in addition to addressing plastic awareness in Sri Lanka. Based on the stakeholder interview and data collection, about 106,863 repair centers of both formal and informal origin were established in Sri Lanka. It has accounted for 11.3% of total business establishments in the year 2016. It is the result of people's innate interests to repair products and the governments should motivate such sustainable product design and incentivize the public in this aspect. Awareness programs are needed to be conducted for different stakeholders. There are about 40,000 people involved in collecting recyclable waste and supplying to wholesalers in Sri Lanka. Integration of the informal sector to the formal sector along with the legal and professional recognition will reduce the overall MSW management costs, create job opportunities in addition to the provision of support to recycling industries (Peter et al., 2019).

Governments should motivate sustainable product design and incentivize the public.

4 | CONCLUSION

Macr view analysis of plastic material flow in Sri Lanka was carried out in this study. Through MFA, the plastic material flow cycle consisting of nine processes was categorized. The STAN 2.6 software was used to create the plastic material flow considering flows and stocks of goods for 2017. Out of 539,667 Mg of plastic waste generated, about 33% (178,090 Mg) of them was collected and only 3% (16,190 Mg) was recycled. The total quantity of plastics washed into the sea could has been approximated to 69,427 Mg. Thus the per capita contribution to plastic marine debris is about 3.3 kg. By MFA, four scenarios were developed for the year 2025 with a focus on improving the collection and treatment infrastructure. This will consequently be aiding the power demands of the country.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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