Resource Efficiency Potential Assessment in Plastic Packaging

Final Report | Resource Efficiency

PT. Kreasi Rekayasa Indonesia

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Abbreviations

3R	Reduce, Reuse, Recycle
ABOFI	*Asosiasi Biaxially Oriented Film Indonesia* - Indonesian Biaxially Oriented Film Association
ADUPI	*Asosiasi Daur Ulang Plastik Indonesia* - Indonesian Plastic Recycling Association
APSI	*Asosiasi Pengusaha Sampah Indonesia* - Indonesian Waste Entrepreneurs Association
ASEAN	Association of Southeast Asian Nations
Bappenas	*Badan Perencanaan Pembangunan Nasional* - Ministry of National Development Planning
BOPP	Biaxially-Oriented Polypropylene
CAGR	Compound Annual Growth Rate
CE	Circular Economy
CPP	Cast-Polypropylene
CO_2e	Carbon dioxide equivalent
EVOH	Ethylene-Vinyl Alcohol
F&B	Food and Beverage
GAPMMI	*Gabungan Pengusaha Makanan dan Minuman Seluruh Indonesia* - Indonesian Food and Beverage Entrepreneurs Association
GHG	Greenhouse gas
HDPE	High-Density Polyethylene
IKHF	*Industri Kimia Hilir dan Farmasi* - Downstream Chemical and Pharmaceutical Industry
INAPLAS	*Asosiasi Industri Olefin, Aromatik dan Plastik Indonesia* - Indonesian Olefin, Aromatic, and Plastic Industry Association
IPCC	Intergovernmental Panel on Climate Change
IPF	Indonesia Packaging Federation
KBLI	*Klasifikasi Baku Lapangan Usaha Indonesia* - Indonesian Standard Industrial Classification
LDPE	Low-Density Polyethylene
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MEMR	Ministry of Energy and Mineral Resources
MFA	Material Flow Analysis
MoEF	Ministry of Environment and Forestry
MoI	Ministry of Industry
MRF	Material Recovery Facility
NAMPA	Indonesian National Meat Processor Association
NPAP	National Plastic Action Partnership
OPP	Oriented-Polypropylene
PC	Polycarbonate
PDAM	*Perusahaan Daerah Air Minum* - Local Public Water Supply Company
PET/PETE	Polyethylene Terephthalate
PFD	Process Flow Diagram
PIH	*proper*
PLN	*Perusahaan Listrik Negara* - National Public Electricity Company
PP	Polypropylene
PROPER	*Program Penilaian Peringkat Kinerja Perusahaan dalam Pengelolaan Lingkungan Hidup* – Environmental Management Performance Rating Program for Company
PS	Polystyrene

PVC	Polyvinyl Chloride
RDF	Refuse Derived Fuels
RE	Resource Efficiency
RECP	Resource Efficient and Cleaner Production
SBR	Styrene-Butadiene Rubber
SC	Supply Chain
SIINAS	*Sistem Informasi Industri Nasional* - National Industry Information System
SIPSN	*Sistem Informasi Pengelolaan Sampah Nasional* - National Waste Management Information System
SWOT	Strengths, Weaknesses, Opportunities, and Threats
TOE	Ton of Oil Equivalent
TPS 3R	*Tempat Pengelolaan Sampah berbasis Recycle, Reuse, Reduce* - Waste Management Sites for Reduce, Reuse, and Recycle
TPS	*Tempat Penampungan Sementara* - Temporary Shelter
TPA	*Tempat Pemrosesan Akhir* - Final Processing Site
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization

0. Executive Summary

0.1. Plastic packaging in food and beverage sector

Plastic is a versatile material that is light in weight, hygienic, durable (with good impact absorption), low in production cost, sustainable and long-lasting; it has strong weatherability, resistance to rot, corrosion, chemicals, and water. Plastics can be molded in various ways and utilized in a wide range of applications. It takes less energy to produce and transport plastics compared to other materials. All these offering benefits make plastics the ubiquitous workhorse material of the modern economy [4]. Packaging accounts for about 40% (44.8% global market and 39.6% Europe market) of the plastic production demand and is the largest contributor segment for single-use plastics globally. The world consumes more than 100 million tons of plastic packaging annually [7], and about 40% of that plastic packaging is consumed to support the food and beverage sector.

F&B supply chains including production, processing, retail, and consumption involve transportation over long distances and multiple intermediary transits. Therefore, packaging plays a central role in the F&B system. Packaging is expected to not only facilitate safe transports and preserve the products during their shelf-life time but also to provide convenient and easy portioning and handling, provide information to the consumers, as well as facilitate promotion and marketing. During the development, several plastics resins have been considered safe for food and drink (food-grade) making plastic packaging a valuable resource for the sector.

PP is the largest volume commodity thermoplastic in the world, accounting for about 23% of the global plastics consumption. PP has a high melting point (able to withstand the hot-filling process), superior stress crack and temperature resistances, chemical inertness, and low-cost production. Common uses of PP include microwave-proof food containers, sweet and snack wrappers, hinged caps, and shrink sleeves labeling.

Levels of the popularity of polypropylene (PP) lead petrochemical organizations put into this business to deliver basic merchandise to mankind around the globe. As the largest polymer consumed in the F&B sector, polypropylene (PP) has many different types of packaging for different uses. Polypropylene's unique ability to be manufactured through different methods and into different applications started to challenge many of the old alternative materials, notably in the packaging, fiber, and injection molding industries. Its growth has been sustained over the years and it remains a major player in the plastic industry worldwide. Through major processes for plastic products such as injection molding, blow-up molding, and extrusion stretch, polypropylene (PP) is a core material in many advanced plastics that can be modified for better properties. A brief explanation of the polypropylene types can be found in **Figure 0.1**.

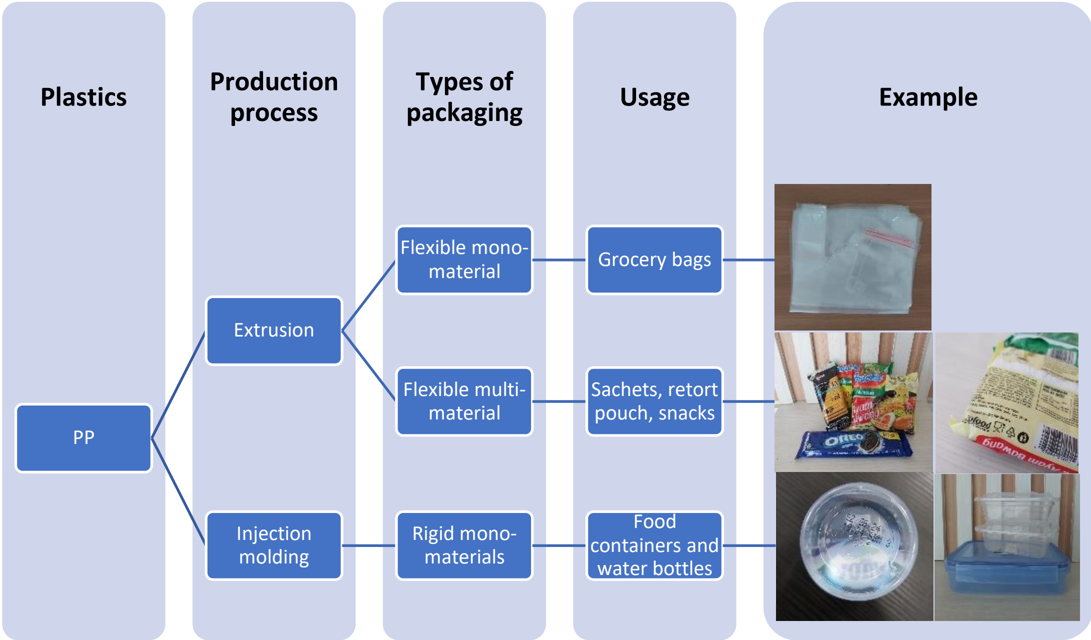


Figure 0.1 Polypropylene production process, type and usage in food and beverage sector

0.2. Resource efficiency for polypropylene plastic packaging

According to [2], Indonesia recycles only 12% of its plastic packaging waste (all resins). Currently, Indonesia recycles around 83% of its plastic waste open-loop (i.e., PET bottle to sheets or straps) and 17% in closed-loop processes (i.e., PET bottle to recycled PET bottle). From the data collected in the IPEN report, the Ministry of Industry recorded a 14% plastic recycling rate in 2019, while the Ministry of Environment and Forestry stated that the overall plastic recycling rate is 7%. Based on the study, approximately 4.2 million tons, or 61% of post-consumer plastic waste, are not collected by waste collectors or management systems and instead leaked into the environment. The remainder ended up in landfills [13]. Furthermore, the National Plastic Action Partnership (NPAP) report states that Indonesia's plastic recycling rate in 2020 will be around 10% of total plastic waste generation, or 6.8 million tons [4].

To this present date, there are no available studies regarding the recycling of PP. According to other studies conducted in ASEAN countries (Malaysia, Thailand, Philippines), recycling rate of PP is between 5 – 35% [14] [15] [16], lower than the recycling of PET which is around 20 – 65% [14] [15] [16]. These studies show that although PP is one of the most widely used plastic packaging materials in the world, the recycling of PP plastic is still low and not cost-effective if compared to other polymers. Most PP rigid plastic waste is recycled into flakes or pellets, while PP film plastic waste is most likely used for energy recovery.

Resource Efficiency stresses the importance of using all natural resources efficiently and prolongedly to narrow and slow resource cycles. Industries are able to optimize use of renewable resources, persistently pursue efficiency in the use of all natural resources and recover and recycle end of life products and industrial waste. This study will revolve around polypropylene (PP) but not specific in F&B due to the absence of resource efficiency indicator mapping and data unavailability in Indonesia.

0.3. Existing condition of plastic supply chain

Figure 0.2 shows the scope and limitations of this study. Resource efficiency data used in this study have been gathered from government databases (*Sistem Informasi Industri Nasional*/ National Industry Information System - SIINAS/NIIS and *Sistem Informasi Pengelolaan Sampah Nasional*/National Waste Management Information System - SIPSN/NWMIS) and industries. Meanwhile, additional information and insights about resource use and production have been gathered from associations, government and other local stakeholders. However, after consultation and data collection, resource efficiency data was found to have limited availability because RE data monitoring and reporting are still voluntary, not mandatory for some indicators. To overcome data scarcity, extrapolation has been done to gain a national overview. For example, to calculate the Indonesian recycling rate, an extrapolation of the national waste generation has been done to complete the remaining 50% cities/regions who have not submitted their data in SIPSN/NWMIS. Additional assumptions based on literature review were also carried out to complete the analysis. An assumption of PP production proportion for a polymer production industry has been done to calculate resource efficiency indicators. This proportion is derived from the total production of the respective industry. Due to limited data, only the conversion of PP to BOPP is considered in the plastic conversion and production of plastic products stage.

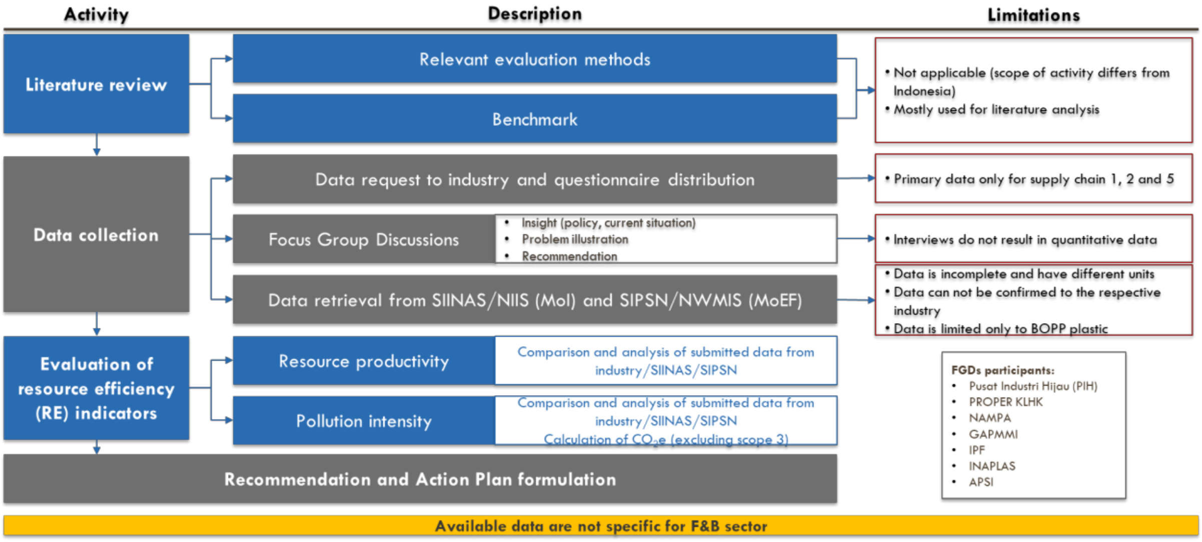


Figure 0.2 Scope and limitations of study

National benchmarks of RE indicators are only available for some industries who have participated in *Program Penilaian Peringkat Kinerja Perusahaan dalam Pengelolaan Lingkungan Hidup* (PROPER)/Environmental Management Performance Rating Program for Company and PIH. PROPER has published national benchmarks for several classification of industries. Meanwhile, the classification of industries is very general and does not include plastic industry. From all available benchmarks, only one industrial group (oil and gas refinery industry) could be compared to a supply chain covered in this study, i.e., polymer production industry (supply chain 1). Adjustments must be made in order to accurately compare calculated resource efficiency indicators (specific for PP) and total production in the oil and gas refinery industry. Supplemental analysis of polymer production industry, plastic conversion industry and recycling industry overseas (not on national level) derived from published scientific articles have also been done to complete the study.

The supply chain is divided into two categories namely upstream (supply chain 1/SC-1) and downstream (supply chain 2 – 6/SC-2 – SC-6). Nomenclature has been adapted from the industrial classification by the MoI.

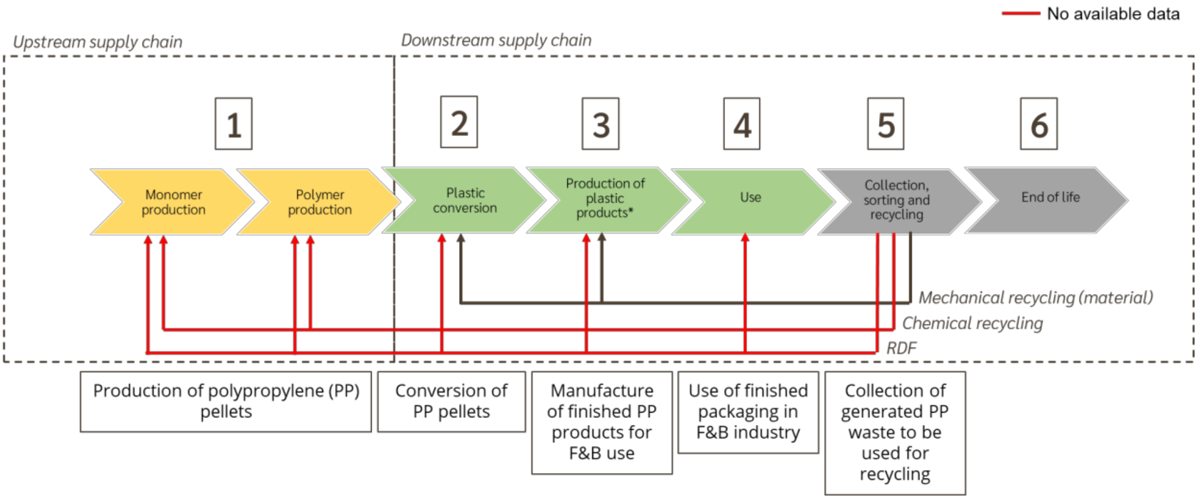


Figure 0.3 Plastic supply chain of polypropylene in Indonesia

A simplified material flow analysis of the plastic supply chain in 2020 is shown on **Figure 0.3** with a detailed scheme shown on **Figure 0.4**. Material flow analysis has been extracted from government data. The production process of plastic packaging begins with the production of monomer and polymer (SC-1). A dependency on imports (57%) can be observed to meet the demand for polymer production (raw virgin PP material in form of granules). A fraction of polymer product is also exported (7.5%). The production of polymer products is then followed by the plastic conversion (SC-2). Raw material in form of plastic granules enter this stage to be converted to film. Plastic film is further used in plastic packaging production process (SC-3).

SC-3 is divided into extruding and injection molding industries. Value of products from extrusion is assumed as BOPP film only. The production capacity of injection molding industry is assumed to be the value of products from SC-1 subtracted with exported products from SC-1 and plastic conversion products (through extruding) from SC-2 which is 87.3%. Based on gathered data, there are two classifications of industries present in BOPP film manufacture. Type A, which converts plastic PP granules through an extruding process until forming BOPP slit roll, and Type B, which converts BOPP jumbo rolls to finished BOPP plastic packaging products to be used by the next chain of industry (SC-4). A constant value of products has been assumed through all stages of Type A and B industries.

Used plastic packaging products enter either the collection, sorting and recycling stage (SC-5) or the end-of-life stage (SC-6). Used recyclable plastic packaging is re-introduced to the system in the form of plastic granules/scrap plastic/new products whilst others end up in landfills in the form of waste (SC-6).

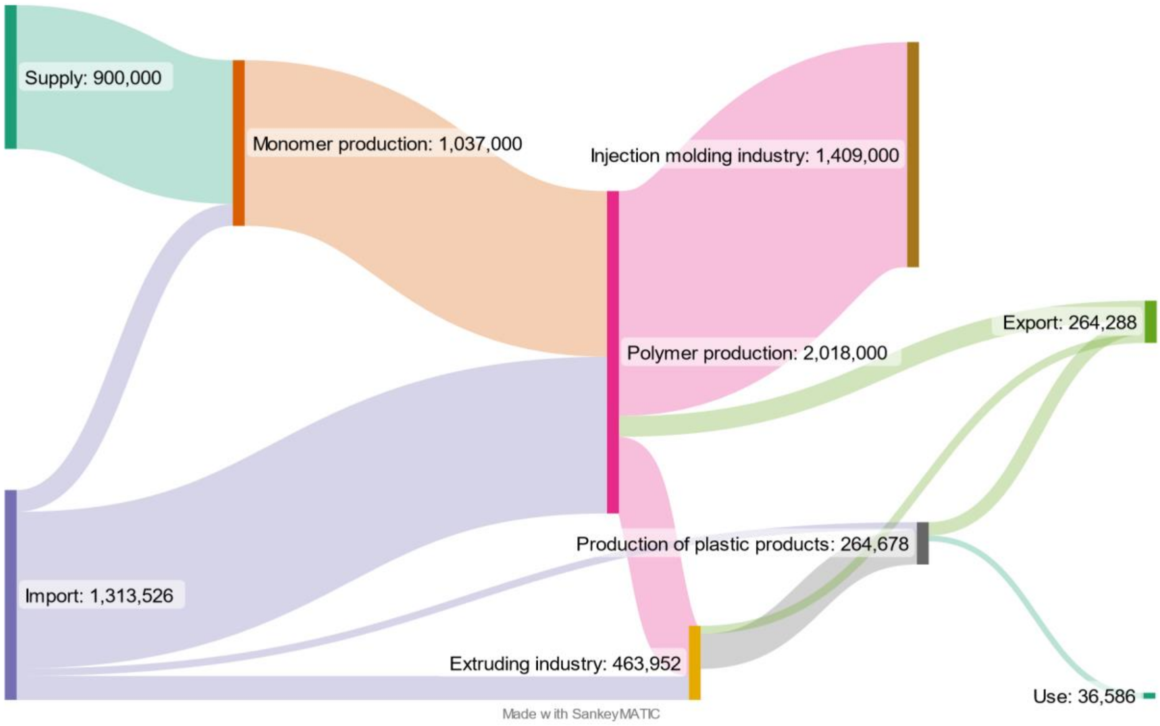


Figure 0.4 Simplified material flow analysis of PP plastic supply chain

0.4. Summary of resource efficiency indicator evaluation

0.4.1. Energy productivity and CO_2e emission intensity

Plastic producing industry still rely on fossil fuels for their energy sources. Fossil fuel usage results in a high CO_2e emission. Calculation of CO_2e emission intensity of each supply chain has found that SC-1 emits the highest amount of CO_2e emission. This finding is consistent with several literatures which have reported a high amount of emission in the upstream industry. Emission intensity (in decreasing order) is then followed by SC-2, SC-3, SC-5 and lastly SC-4 (**Figure 0.5**).

The scope of CO_2e emissions vary within supply chains. For example, industries in SC-1 have an almost equal proportion (if compared to other SC) of scope 1 and 2 emissions due to high energy requirement. High energy use requires industries to partly provide their own energy source. SC-1 industries are closely related to upstream oil and gas companies which enables them to produce and utilize less carbon intensive fuels such as LNG. On the other hand, industries in SC-2 through SC-5 mainly release emissions from scope 2 activity, which indicates electricity dependency to PLN (**Table 0.1**). According to INAPLAS, electricity dependency to PLN is also driven by economic factor (relatively low price). Not many industries have started calculating scope 3 emissions, since it is comprised of other indirect emissions (besides scope 1 and 2) from upstream and downstream activities (currently reported by only 1 industry in SC-2).

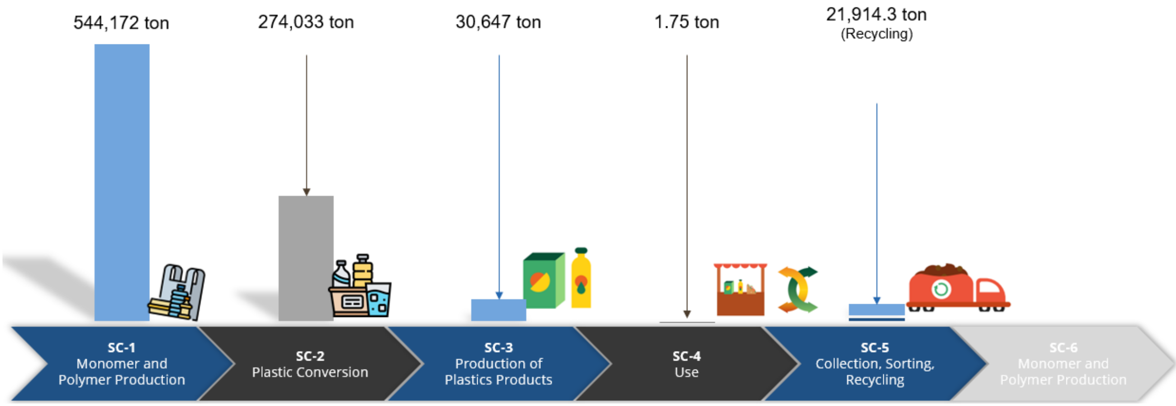


Figure 0.5 Total CO_2e emission intensity

Table 0.1 Emission source of supply chains based on scope of activity

Scope of activity	SC-1	SC-2	SC-3	SC-4	SC-5
Scope 1	46%	5.6%	0.49%	-	-
Scope 2	54%	94.2%	99.51%	100%	100%
Scope 3	*	0.2%	*	*	*

*Scope 3 emissions are not calculated for SC 1, SC 3-5

If 4 to 15% of PP plastic from the waste can be recycled, the range of avoided CO_2e emission in SC-3 will be up from 870 to 3,264 ton CO_2e. Regarding low energy productivity and high CO_2e emission intensity, two main issues have been identified in terms of management and technical aspects (**Figure 0.6**).

Industries do not put renewable energy as their priority since it is not a mandatory. Indonesia has pledged an unconditional 29% CO_2e emission reduction by 2030 (compared to BAU in 2020) based on Nationally Determined Contribution 2020. Manufacturing industries (including plastic producing industries) contribute 21.46% of GHG emissions from energy sector. However, the government has not yet issued a specific mitigation target to contribute towards said CO_2e emission reduction. Several policies have been issued for industries to manage CO_2e emissions although the basis is still voluntary participation, for instance, green industries (PP 29 Year 2018). Green industry is an industry which in its process prioritizes sustainable resource efficiency with respect to the environment to contribute towards society. Several programs in the green industry may contribute towards GHG emission reduction. Despite some ongoing and finished voluntary programs to minimize energy use and CO_2e emission, the increased use of renewables is highly encouraged.

Energy productivity and CO_2e emission intensity are also influenced by implementation and continuous improvement of cleaner production (CP). Limited CP implementation is caused by three main reasons: lack of management and individual awareness, lack of trained staff and limited energy sources choice. Based on collected data, awareness indicators are comprised of continuous evaluation and monitoring reports, which are still limited. Minimum staff training i.e., for energy saving campaign is also another contributor. Lastly, limited energy source in production process increases difficulty in CP implementation which will be further discussed in technical aspect.

In terms of technical problems, besides the use of fossil fuels, the non-competitive renewable energy installment cost, outdated production technology and gas flaring could lead to a high CO_2e emission intensity. The reliance on fossil fuel-based energy provided by PLN also adds to the problem. PLN predominantly uses coal as its source of energy, which produces a high emission intensity. Calculation of CO_2e emission by industries also considers purchased electricity from PLN (scope 2).

0.4.2. Material productivity and waste intensity

Regarding low material productivity and high waste intensity, three main issues have been identified in terms of management, technical as well as social aspect (**Figure 0.7**). This study has defined material as raw material in form of plastics (virgin and scrap) as well as chemicals and additives used in production.

In terms of management aspect, lack of cleaner production implementation may lead to a high amount of waste produced. This is further caused by irresponsible handling of pellets due to lack of management and individual awareness as well as lack of trained staff. This practice would lead to wastage of valuable plastic material. Researchers have reported that seabirds, turtles and fish have ingested a variety of plastic items which are comprised of used consumer products and resin pellets which enter the waste stream and oceans. The plastics industry should also play a part in managing plastic pellets in order to avoid them in entering waterways. This is done through employee training to handle and dispose plastic pellets [36] [37]. European Union and New Zealand have published guidelines to promote zero pellets loss.

Besides cleaner production, unreliable reported use of materials may also lead to an inaccurate material productivity which is caused by the absence of compulsory environmental report (SIINAS reporting is not mandatory) and lack of trained staff in resource efficiency data identification. For example, several industries have not yet implemented waste sorting, which could lead to loss of valuable material that can be reused/recycled either internally or externally.

Several industries in SC-3 have reported different units of manufactured products (by weight/piece/roll). These industries have been omitted from analysis. As for waste, some industries have still reported accumulated waste in different units (by volume/weight/trucks) which increases the difficulty in data analysis.

Lastly, FGD with APSI have found that recycling facilities are not equally distributed. According to our interview, this is mainly caused by the majority of plastic waste accumulation in Java. In addition, labor cost is also lower than other areas in Indonesia, creating a preferable investment. Waste management actors outside Java have reported difficulty in distributing their plastic scraps due to high cost of logistics.

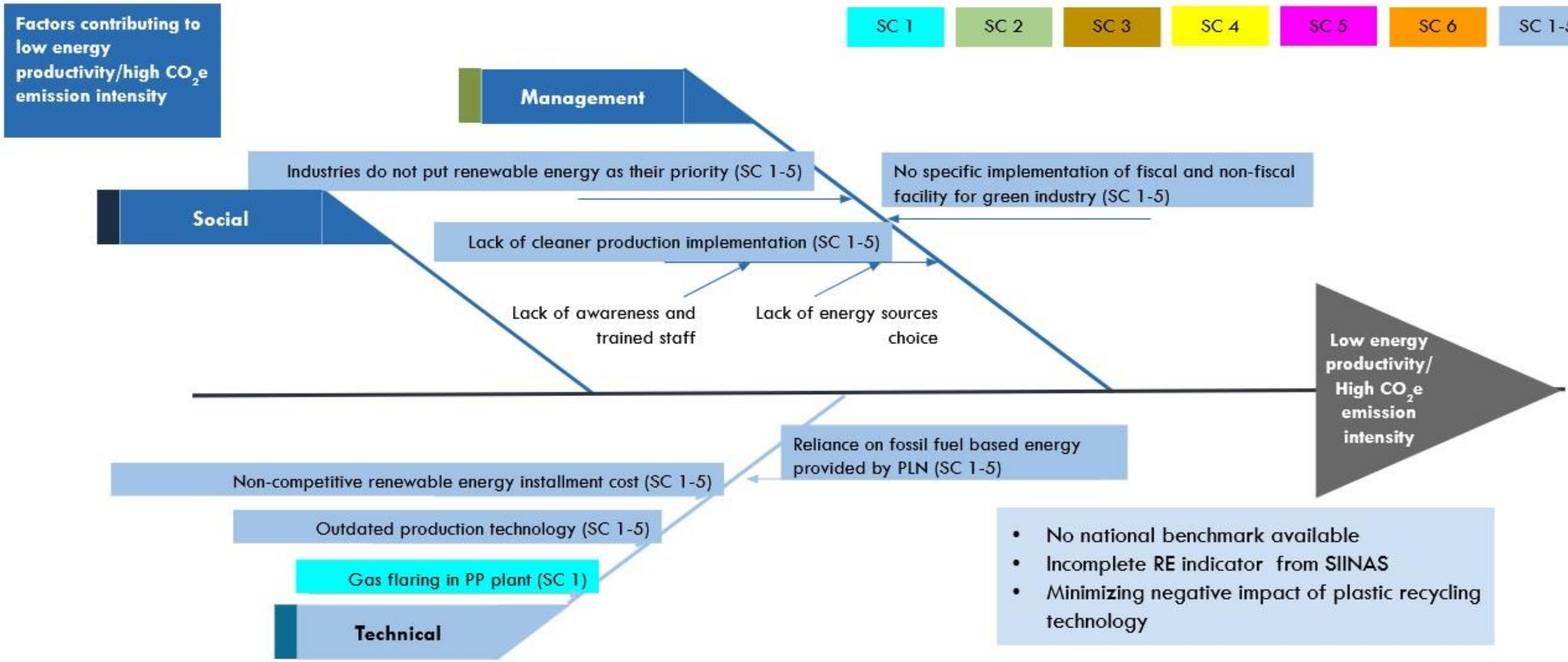


Figure 0.6 Energy productivity fishbone analysis

In terms of technical aspect, several problems have been identified. According to an interview with an industry in SC-1, outdated production technology has led to the inability of using environmentally friendly material in the production process. The use of this outdated production technology has also led to plastic product failure throughout SC-1 to SC-4. Several industries still do not optimize the use of recycled material, on the contrary, some recycling industries have reported using virgin material.

Lastly, most industries are still using multi-material and unnecessary packaging, which adds the level of difficulty in recycle. The use of multi-material and excess packaging by industries throughout SC-3 to SC-5 makes the recycling process difficult. Unused polypropylene usually ends up in landfills for energy production by RDF. According to GAPMMI, this is majorly caused by the low-cost fraction of plastic packaging production if compared to the actual product. Findings have shown that PP still remains an unfavorable material for recycling due to various reasons such as the use of multi-material, adhesives, color and lightweight characteristics. As a consequence, waste management actors would need to collect a high amount of waste to get a reasonable price. Despite present efforts in Indonesia, plastics are mainly recycled through an open-loop mechanism (IPF). Open-loop mechanism recycles food & beverage packaging to non-food-grade products. Striving towards an eco-design of packaging would increase the recyclability and enable close-loop recycling of PP plastics.

According to GAPMMI, low to middle income earners prefer to buy products in small quantities (in form of sachets). Sachets are composed of multi-material plastics (including PP), which is not preferred for recycle. Hence, low awareness and initiative of consumers in choosing environmentally friendly packaging are of concern in social aspect. According to Puspa [44], level of education and income has not a significant influence in determining preferences towards packaging products.

The GoI has already issued a Ministry of Environment and Forestry Regulation No. 75 of 2019 concerning Roadmap to Waste Reduction by Producers but implementation and detailed action plan are yet to be issued. Associations have expressed their concern towards this action plan.

0.4.3. Water productivity and wastewater intensity

Regarding water productivity and wastewater intensity, two problems have been identified in terms of management and technical aspect (**Figure 0.8**). As for technical problems, it has been identified that some industries still use water intensive technology if compared to other industries with similar production process.

In terms of management, the lack of water recycling implementation (SC-1 to SC-5) may lead to a low water productivity. High water use of material recycle purification in SC-5 is caused by the lack of dedicated public waste bins, low awareness of plastic waste sorting and lack of waste management system. This would ultimately lead to the mix of waste, thus needing a high amount of water to clean plastics before recycle. Several industries have already implemented water recycling programs in form of steam condensate recovery.

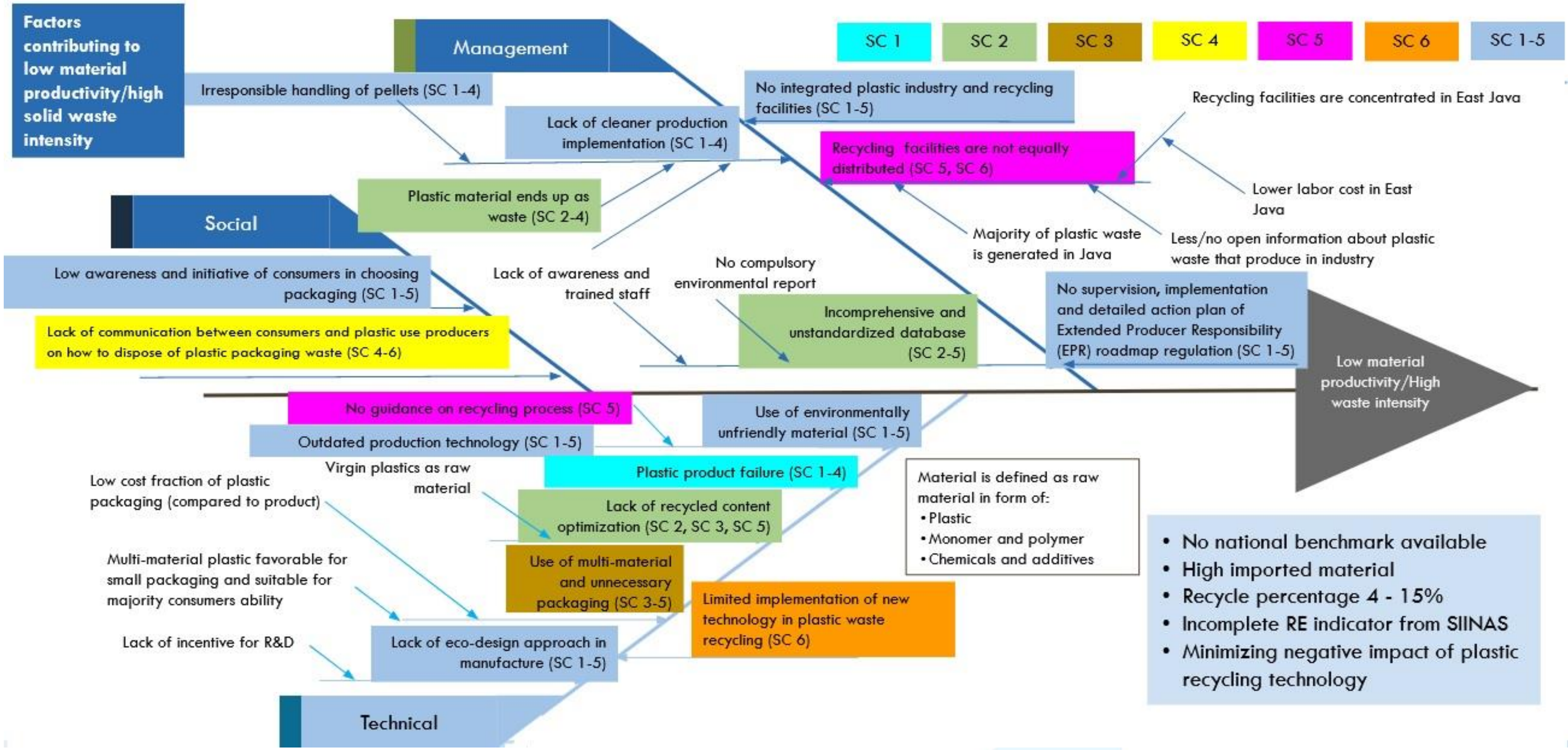


Figure 0.7 Material productivity fishbone analysis

The lack of cleaner production further adds up to this issue. Lastly, unstandardized reported water use is caused by lack of trained staff and no compulsory environmental report may also lead to an underestimate/overestimate of used water.

0.4.4. Implementation of resource efficient programs and activities

Based on sustainability reports published by industries in SC-1 through SC-3, several programs have been implemented to minimize the use of resources. Programs vary from technical, management as well as social aspects.

0.4.5. Recyclability of PP plastics

The Indonesian government plans to reduce 70% plastic wastes by 2025 [45] by creating regulations which states a 5% recyclability of produced plastic from total production capacity (upstream industry) as well as a 25% recyclability of plastics from total production capacity (downstream industry) [46].

Based on this conducted study, it has been found that most industries still heavily rely on imported raw materials in their production process. By reducing the number of imported materials and increasing local material consumption, the concept of a circular economy may be implemented. Substituting imported recycled material with collected polypropylene waste of recovery value should meet a proportion of imported recycled material demand of industries.

Collected for recycling rate (CFR) of PP in Thailand [15], Philippines [16], and Malaysia [14] is at 10 – 20%, 30% and 25 – 35% consecutively. The finding in Thailand is consistent with our findings of 4 – 15%. Low CFR in Thailand is analyzed by the behavior of consumer products and did not account for collection for recycling rates of industrial PP packaging which tend to be much higher [15].

To optimize plastic recycling in Indonesia, collection rate needs to be reinforced. Furthermore, sorting and separation from the waste source must be implemented to successfully meet the recycling rate target. Upgrading sorting and separation technology in waste management facilities can stimulate higher PP sorting rate from 31 to 81% each plant in EU, with the example of technology such as: trommel screen, Near Infrared (NIR), magnet, and etc. For mechanical recycling, recycling rate can be improved up to 53 to 72% each recycling plant in EU, with technological setup that also has additional sorting unit, such as: cascade screen, air classifier, density separator, and etc. For example, one of the recycling plants with 72% recycling rate using these unit operations: Feed hopper, film splitter, trommel, air classifier, NIR (5 times), wind sifter, manual sorting, baler, granulation, density separation (2 times), turbo wash, centrifuge dryer, air filter, and bagging [47]. Currently, available thermal recycling (energy recovery) in Indonesia options are RDF and waste power generation, such as incineration, gasification, and pyrolysis. The waste reduction potential of RDF is up to 75%, incineration is up to 80%, and both gasification and pyrolysis are up to 80 to 90% [48]. RDF is the best practice to address the limitation of multilayer plastic recycling at the moment. In addition, some of the industry in Indonesia has implemented RDF as part of their waste management efforts.

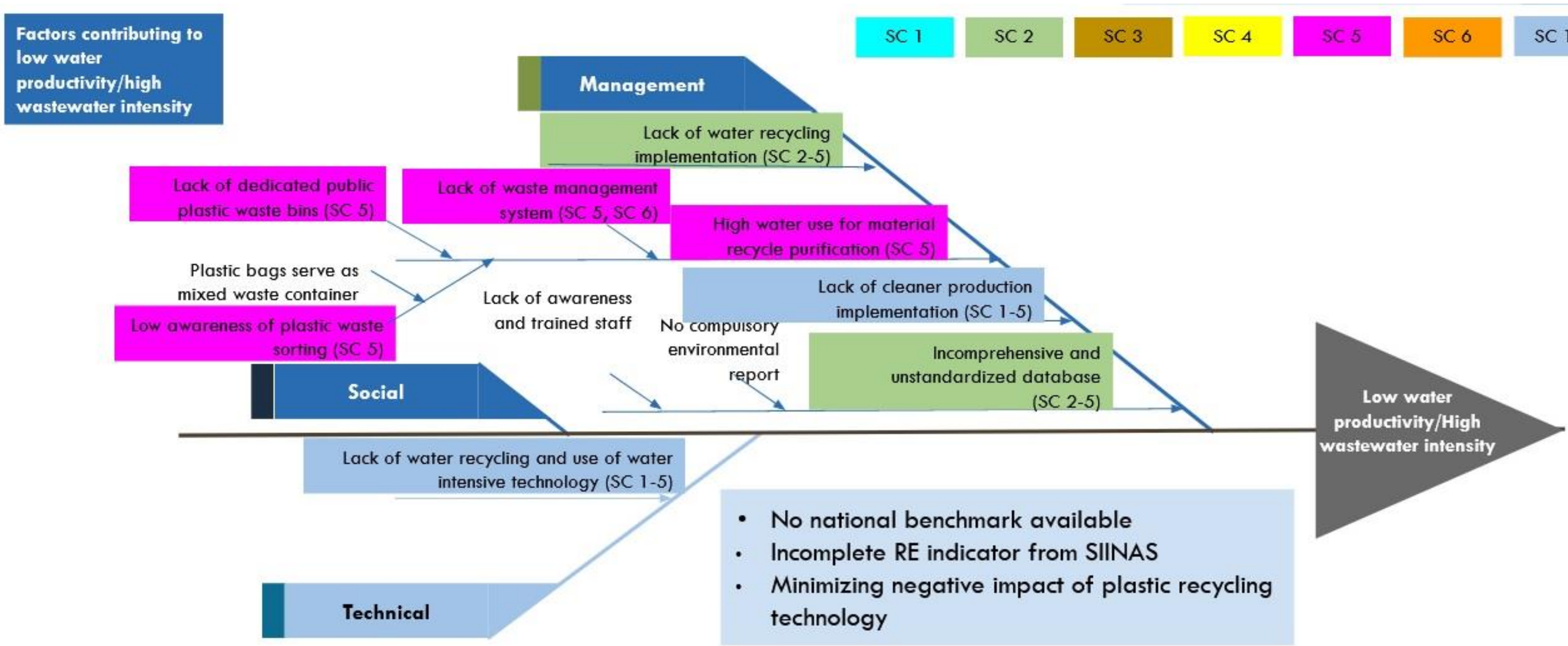


Figure 0.8 Water productivity fishbone analysis

0.4.6. Data as key strategy towards resource efficiency implementation

To implement a successful resource efficient process, a comprehensive and standardized database is required. Data variability in this study is caused by unavailable and inconsistent data. As the number of reported resource efficiency indicator varies from the analysis period (2018 – 2021), drawn conclusions may not give a completely accurate overview of the respective supply chain. Lastly, incomparable RE indicator data and reporting due to different scope of industry within the same industrial classification (KBLI) leads to the unavailability of national benchmark calculation. Data reported in SIINAS is collected based on KBLI, which is categorized by finished product (general classification). Ideally, data should be classified by type of resin and finished product. Lastly, three core recommendations (**Figure 0.9**) are proposed in this study are comprised of energy, resource efficiency (RE) data and recycle potential of PP waste.

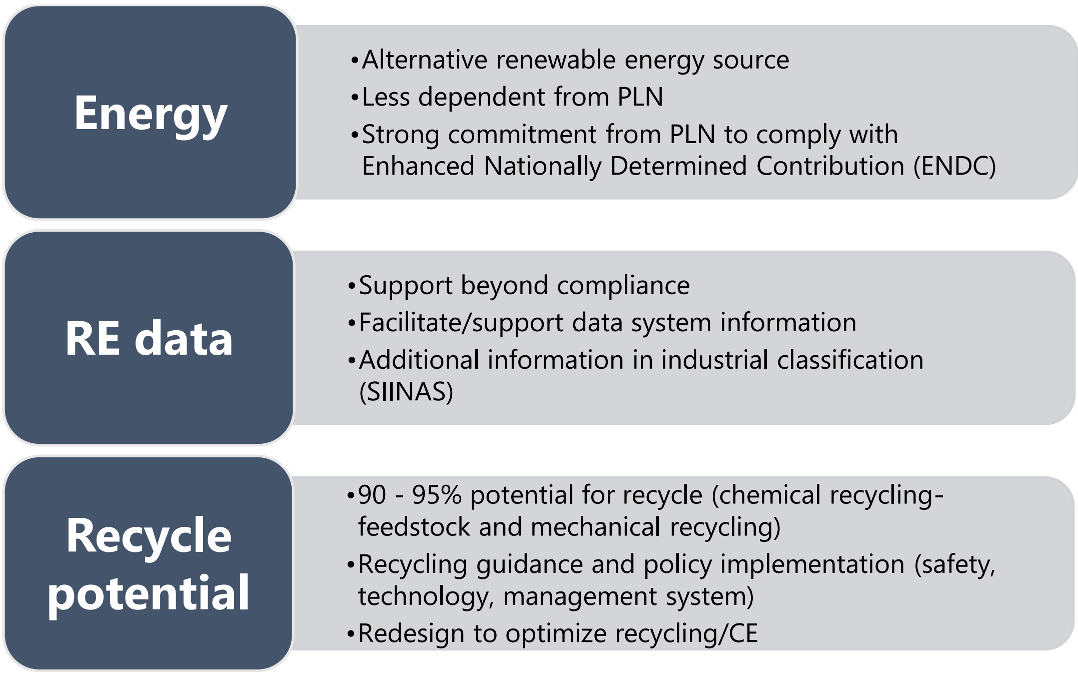


Figure 0.9 Core recommendations proposed in this study

1. Background of study

Resource efficiency according to [1], is improving economic performance while reducing pressure on natural resources through efficient use of them. Resource efficiency (RE) is related to circular economy (CE) from the perspective of reduction in the use of raw (virgin) inputs through increased materials circulation and minimization of losses. Previous studies have been done by The Ministry of National Development Planning of the Republic Indonesia titled "The Economic, Social and Environmental Benefits of a Circular Economy in Indonesia" and "Food Loss and Waste in Indonesia" in 2021. Five sectors were prioritized based on several criteria to understand the potential of the circular economy in Indonesia, which are as follows:

- Food and beverage, focus on food loss and waste
- Textiles, focus on textile waste
- Construction and environment, focus on construction and demolition waste
- Wholesale and retail trade, focus on plastic packaging waste
- Electric and electronic equipment, focus on e-waste

The food & beverage (F&B) sector is the most potential sector to apply the circular economy transformation. According to Bank Indonesia from [2], F&B measured 9.3% of total Gross Domestic Product (GDP) in 2019. F&B is also the largest sub-sector of manufacturing in Indonesia, the largest industry sector in Indonesia. Moreover, according to the [3] F&B is the biggest user of plastic in Indonesia. Unfortunately, plastic packaging in F&B is valued very low and hard to recycle, which leads to a lower recycling rate. These findings encourage this study to elaborate on plastic packaging in the F&B industry.

1.1. Plastic packaging in food and beverage sector

Plastic is a versatile material that is light in weight, hygienic, durable (with good impact absorption), low in production cost, sustainable and long-lasting; it has strong weatherability, resistance to rot, corrosion, chemicals, and water. Plastics can be molded in various ways and utilized in a wide range of applications. It takes less energy to produce and transport plastics compared to other materials. All these offering benefits make plastics the ubiquitous workhorse material of the modern economy [4]. Along with the demand, for the last decade, the worldwide production of plastics has been growing by almost 4 % annually (**Figure 1.1**) and has been projected to triple in 2050 [4].

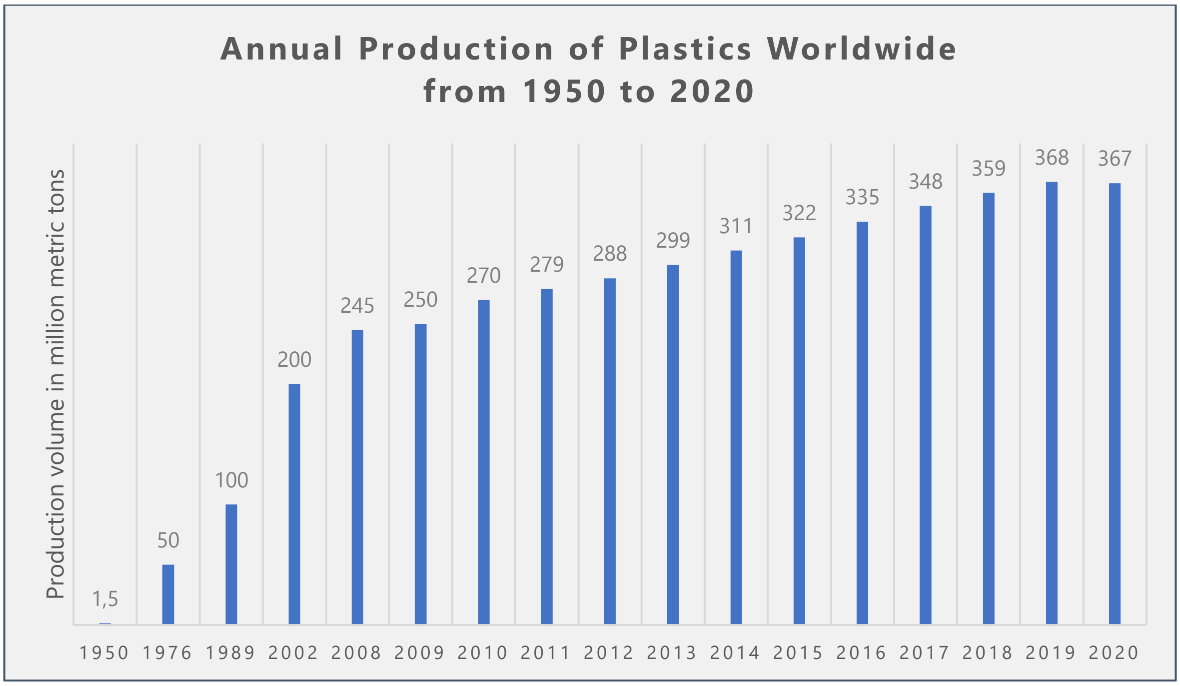
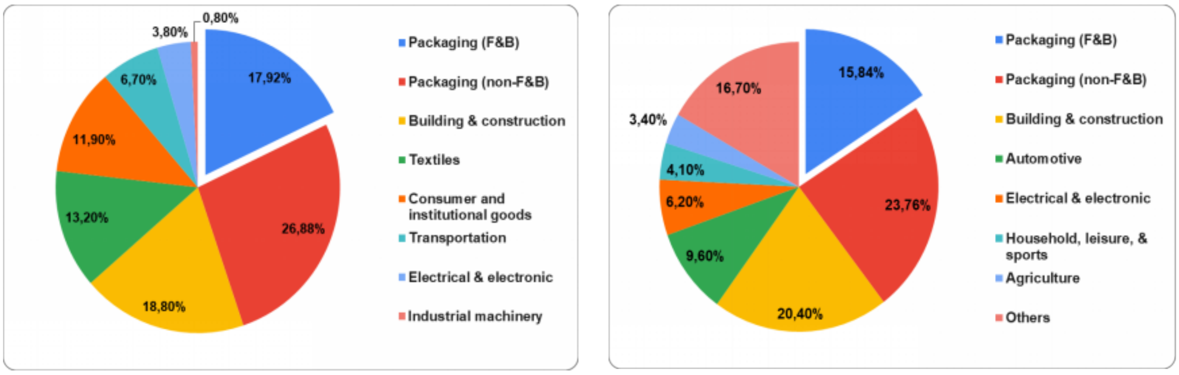


Figure 1.1 Annual production of plastics worldwide from 1950 to 2020, including thermoplastics, polyurethanes, thermosets, elastomers, adhesives, coatings and sealants, and polypropylene fibers [4]

Although research on bio-based plastics has increased for the last half a century, 99% of plastic production is still sourced from fossil fuels. In 2008, about 4% of fossil fuel (mostly in the form of a natural gas liquid fraction or low-value gaseous fraction from petroleum refining) is converted into 240 million tons of plastic [5]. The number has been increasing and it is predicted that by the year 2050, plastics manufacturing and processing may account for as much as 20% of petroleum global annual consumption and 15% of the annual carbon emissions budget [6].

Figure 1.2 pictures the distributions of the (a) global and (b) European plastic main market industrial sectors. Packaging accounts for about 40% (44.8% global market and 39.6% Europe market) of the plastic production demand and is the largest contributor segment for single-use plastics globally. The world consumes more than 100 million tons of plastic packaging annually [7], and about 40% of that plastic packaging is consumed to support the food and beverage sector. **Table 1.1** tabulates the annual household plastic packaging consumption in the six countries, i.e., China and 5 ASEAN countries (Indonesia, Vietnam, Malaysia, Philippines, and Thailand). In China and 5 ASEAN countries including Indonesia, the food and beverage (F&B) sector takes 59% of plastic packaging consumption, almost similar to the plastic packaging consumption in Indonesia itself (58%).



(a) (b)

Figure 1.2 Distributions of (a) global (calculated from data for Europe, the United States, China, and India) plastic main industrial market sectors and (b) European main industrial market sectors by segment in 2017 [8]

F&B supply chains including production, processing, retail, and consumption involve transportation over long distances and multiple intermediary transits. Therefore, packaging plays a central role in the F&B system. Packaging is expected to not only facilitate safe transports and preserve the products during their shelf-life time but also to provide convenient and easy portioning and handling, provide information to the consumers, as well as facilitate promotion and marketing. During the development, several plastics resins have been considered safe for food and drink (food-grade) making plastic packaging a valuable resource for the sector. **Figure 1.3** gives a mapping of plastic resins, their functionality in F&B packaging industries, and European converter demand in 2016.

Table 1.1 Annual household plastic packaging consumption in the six countries (China, Indonesia, Vietnam, Malaysia, Philippines, Thailand) in 2016 [9]

Total estimated annual household plastic packaging consumption (in 1000 tonnes)	**PET bottles**		**Other plastic bottles**		**Plastic film and bags**		**Plastic cups, cans, other containers**		**Other plastic packagings**		**Total packaging**	
	Indonesia	6 Countries	Indonesia	6 Countries	Indonesia	6 Countries	Indonesia	6 Countries	Indonesia	6 Countries	Indonesia	6 Countries
Beverage	814	7,296	6	50	45	367	14	79	92	785	971	8,576
Food	15	105	36	247	316	2,553	389	3,004	167	1,387	923	7,297
Detergent cleaning agent and personal care	14	183	60	749	8	110	32	358	55	515	170	1,916
Other	1	10	39	303	644	4,983	218	1,709	298	2,327	1,201	9,332
Total	845	7,594	141	1,350	1,012	8,013	654	5,150	612	5,015	3,265	27,122
Percentage of food and beverage to total consumption	98	97	30	22	36	36	62	60	42	43	58	59

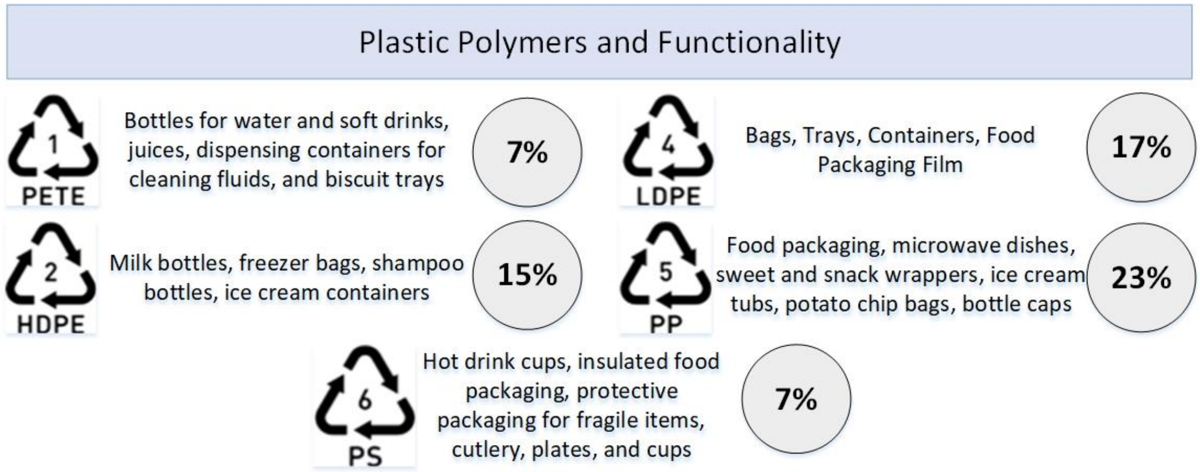


Figure 1.3 Plastic resins, their functionality in F&B packaging industries and by type percentage of world thermoplastics demand in 2015 [10]

Among those food-grade plastic resins, polypropylene (PP), polyethylene (PE), polyethylene terephthalate (PET) and polystyrene (PS or EPS) are dominating the F&B market sector.

1.2. Polypropylene use in packaging

PP is the largest volume commodity thermoplastic in the world, accounting for about 23% of the global plastics consumption. PP has a high melting point (able to withstand the hot-filling process), superior stress crack and temperature resistances, chemical inertness, and low-cost production. Common uses of PP include microwave-proof food containers, sweet and snack wrappers, hinged caps, and shrink sleeves labeling.

There are two major types of PE: low-density polyethylene (LDPE) and high-density polyethylene (HDPE). LDPE (including linear low-density polyethylene, LLDPE) is the cheapest thermoplastic accounting for 17% of the global plastic consumption. LDPE is less strong than HDPE but is more resilient, very flexible, and almost unbreakable; while LLDPE has similar strength as HDPE but is much more flexible due to the linear arrangement of a large number of short branches. Common uses of LDPE and LLDPE include squeezable containers, grocery bags, bubble packaging, overwrap and envelope films, shipping sacks, trays, and lids. HDPE accounts for about 15 percent of the global plastics consumption; it is strong, high density, rigid, and less permeable, and can withstand high temperatures and chemicals. Common uses include milk bottles, bottle caps, rigid containers, as well as shopping and freezer bags. These plastics are intended to be reusable and recyclable; they are distributed in the market with recycling symbols. However, after 40 years, only 14% of the global plastic packaging is collected for recycling; all the rest worth 80 to 120 billion USD every year is lost after one short use [11]. Factoring in the additional value losses in sorting and reprocessing, only 5% of material value is retained for subsequent use. The negative consumer attitudes and hesitancy to pay more, as well as the poor recollecting and recycling facilities, limit the number from progressing.

Levels of the popularity of polypropylene (PP) lead petrochemical organizations put into this business to deliver basic merchandise to mankind around the globe. As the largest polymer consumed in the F&B sector, polypropylene (PP) has many different types of packaging for different uses. Polypropylene's unique ability to be manufactured through different methods and into different applications started to challenge many of the old alternative materials, notably in the packaging, fiber, and injection molding industries. Its growth has been sustained over the years and it remains a major player in the plastic industry worldwide. Through major processes for plastic products such as injection molding, blow-up molding, and extrusion stretch, polypropylene (PP) is a core material in many advanced plastics that can be modified for better properties.

- Injection molding (thermoforming) is a method to obtain molded products by injecting plastic materials molten by heat into a mold, and then cooling and solidifying them, with product examples are rigid plastic such as food containers, pots, and tubs (for condiments, cold food items, etc.). Different from other rigid products such as bottles and caps (for soft drinks, cider, water, and oils), these products through a process called blow-up molding, a molding process used in the manufacturing industry to create hollow objects made of plastic.
- For extrusion stretch, it's a process of extruding the plastic through a circular die followed by expansion cooling. Product examples such as Biaxially Oriented Polypropylene (BOPP) flexible films (wide-ranging uses from snacks to confectionary to staples and fresh produces). Along with the times, technology, and food security that require extra protection, polypropylene packaging was also developed to be the main use in multi-layered materials packaging. Multi-layered material is composed of two or more materials joined together with adhesive or wax, divided into several layers with different function protection and become a favorite material for the food industry as it protects sensitive food products and hence longer shelf life. A brief explanation of the polypropylene types can be found in **Figure 1.4**.

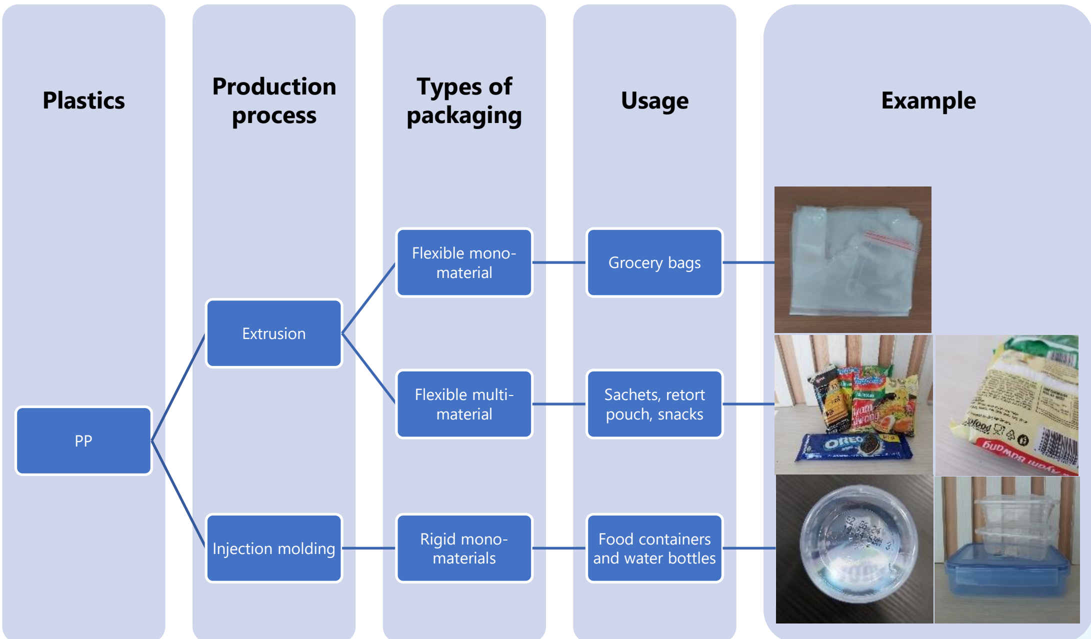


Figure 1.4 Polypropylene production process, type and usage in food and beverage sector

Applications of PP are unlimited including fibers, strapping, films, sheets, injection, and blow molding. **Figure 1.5** shows the global consumption of polypropylene (PP) plastic [12], which is primarily used in injection molding (39%). Polypropylene is majorly used for injection molding and is mostly available for this application in the form of pellets. Polypropylene is easy to mold, and it flows very well because of its low melt viscosity. In F&B sectors, thin-wall injection molding produces rigid packaging container applications. Rigid packaging containers are used in consumers' items such as food storage containers and water bottles. PP plastic film is claimed as the third most plastic use with 16.5%, which is mainly used to embrace food products. PP has good barrier properties for food packaging, high strength, good surface finish, and low cost. In Indonesia, around 50% of PP resin is produced locally.

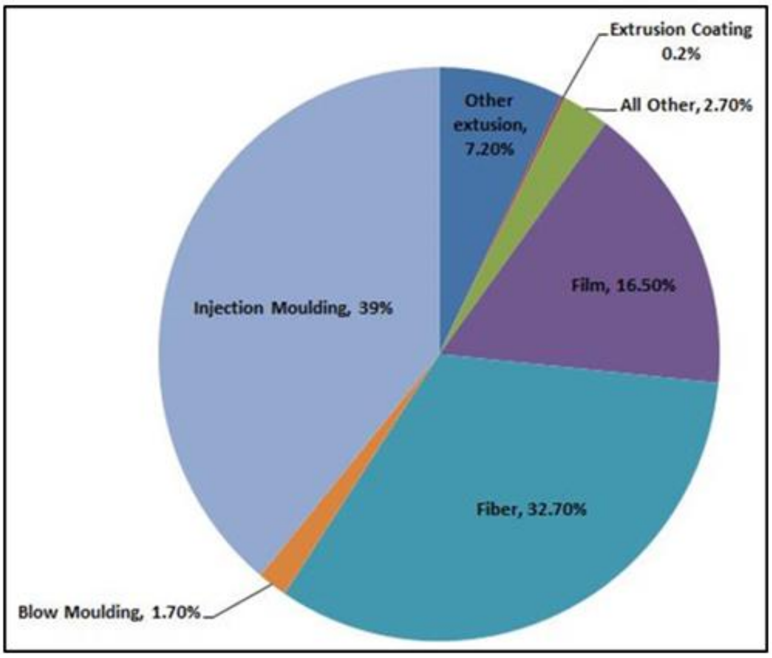


Figure 1.5 Global consumption of polypropylene [12]

1.3. Resource efficiency for polypropylene packaging

According to [2], Indonesia recycles only 12% of its plastic packaging waste (all resins). Currently, Indonesia recycles around 83% of its plastic waste open-loop (i.e., PET bottle to sheets or straps) and 17% in closed-loop processes (i.e., PET bottle to recycled PET bottle). From the data collected in the IPEN report, the Ministry of Industry recorded a 14% plastic recycling rate in 2019, while the Ministry of Environment and Forestry stated that the overall plastic recycling rate is 7%. Based on the study, approximately 4.2 million tons, or 61% of post-consumer plastic waste, are not collected by waste collectors or management systems and instead leaked into the environment. The remainder ended up in landfills [13]. Furthermore, the National Plastic Action Partnership (NPAP) report states that Indonesia's plastic recycling rate in 2020 will be around 10% of total plastic waste generation, or 6.8 million tons [4].

To this present date, there are no available studies regarding the recycling of PP. According to other studies conducted in ASEAN countries (Malaysia, Thailand, Philippines), recycling rate of

PP is between 5 – 35% [14] [15] [16], lower than the recycling of PET which is around 20 – 65% [14] [15] [16]. These studies show that although PP is one of the most widely used plastic packaging materials in the world, the recycling of PP plastic is still low and not cost-effective if compared to other polymers. Most PP rigid plastic waste is recycled into flakes or pellets, while PP film plastic waste is most likely used for energy recovery.

Resource Efficiency stresses the importance of using all natural resources efficiently and prolongedly to narrow and slow resource cycles. Industries are able to optimize use of renewable resources, persistently pursue efficiency in the use of all natural resources and recover and recycle end of life products and industrial waste. This study will revolve around polypropylene (PP) but not specific in F&B due to the absence of resource efficiency indicator mapping and data unavailability in Indonesia.

2. Methodology

Resource efficiency potential is evaluated with the resource efficiency indicator system developed by United Nations Industrial Development Organization (UNIDO) and United Nations Environment Programme (UNEP).

Resource Efficiency and Clear Production (RECP) is a preventive approach to improving resource use, reducing environmental pollution, and contributing to sustainable industrial development It is based on the continuous application of an integrated preventive environmental strategy to processes, products, and services in order to increase overall efficiency and to reduce risks to humans and the environment [17].

There are two different types of indicators namely (1) absolute indicators and (2) relative indicators. Absolute indicators measure yearly based data such as tons of carbon dioxide (CO_2), tons of generated waste, and annual production. Relative indicators on the other hand are a unit of absolute consumption or emission relative to the data being referenced. Productivity and intensity ratios are the key parameters for relative indicators.

Productivity ratios are the quantitative measure of a product output per unit of resource use whilst intensity ratios are the quantitative measure of emissions per unit of production. In a best-case scenario (sustainable production), productivity ratios are expected to increase over time whereas intensity ratios are expected to decrease. **Figure 2.1** shows the gate-to-gate boundary of an RECP system. The boundary of resource efficiency potential is given in the blue-colored box. On-site processes such as materials storage, processing, assembly, packaging, and storage are influenced by energy use, material use, and water use on the resource side. Each stage in the on-site process in turn will produce pollution such as air emissions, wastewater, and waste.

2.1. Resource Efficiency Indicators

The used system indicators proposed by UNIDO (2020) consist of six absolute indicators (three for resource use and three for pollution) and one reference indicator in the form of product output. These absolute indicators are then used to calculate three resource productivity and pollution intensity indicators.

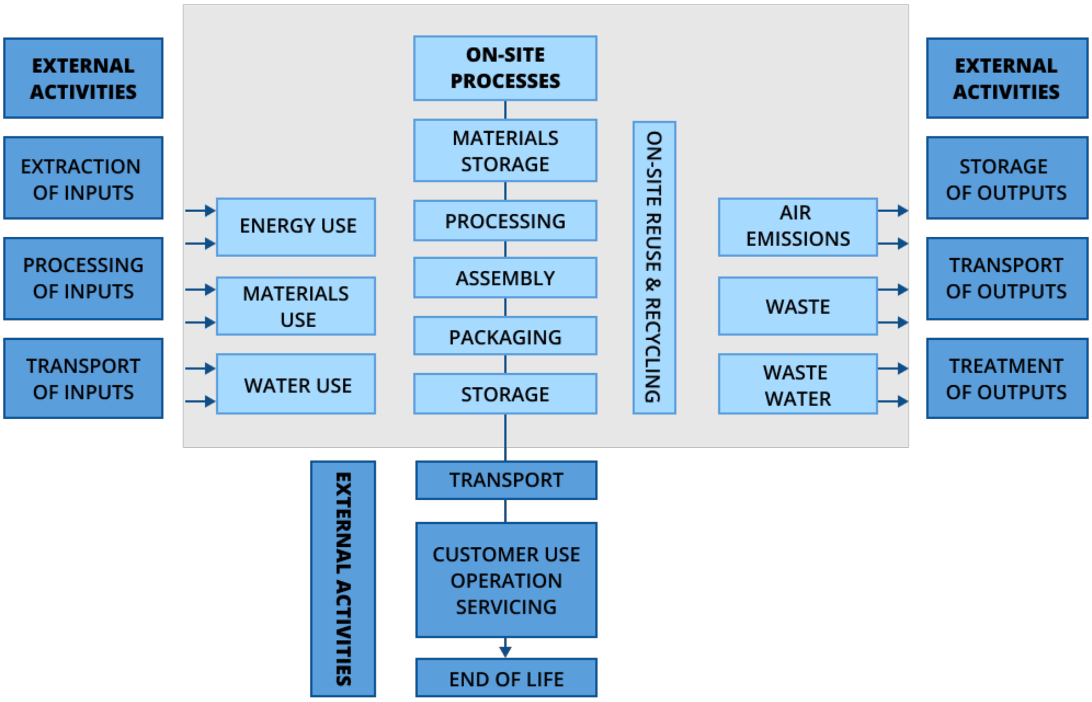


Figure 2.1 Gate-to-Gate boundary of an RECP system

2.1.1. Resource Use Indicators

Resource use indicators consist of energy use, materials use, and water use as described below.

- **Energy use** refers to the final energy use of the company measured in relevant units. This includes the energy content of fuels and gas used as well as consumed electricity
- **Materials use** refers to the total mass of materials used. This includes raw materials, packaging and distribution materials, and auxiliary materials but excludes the weight of fuels
- **Water use** refers to the total water consumption. This includes all water sources such as groundwater, tap/drinking water, surface water) and all applications (process water, cooling water, sanitary water)

2.1.2. Pollution indicators

Pollution indicators consist of air emissions, wastewater, and waste as described below.

- **Air emissions** refer to all air emissions but will be limited to greenhouse gases (GHGs). Greenhouse gas emissions cover on-site energy-related GHGs emissions, off-site energy-

related GHGs emissions and process-related GHGs emissions. Detailed calculation on air emission can be found on **Annex 4.**
- **Wastewater** refers to the total volume of contaminated water as a process result but excludes waste streams discharged without chemical/biological load
- **Waste** refers to the total value of waste transported, disposed and stored on the site. Waste is comprised of non-hazardous (i.e., plastic scraps, reject products, domestic waste, garden waste) and hazardous waste (i.e., additives, chemicals, lubricants).
- An absolute **production** indicator refers to the product output/value created by the respective industry

Figure 2.2 shows the relation between absolute indicators. The use of materials, energy, and water are in close relation with another. An increase in energy may affect the consumption of materials and water. Furthermore, the increase of material, energy, and water may lead to the increase of waste, air emissions, and wastewater generated in the industry. Improving a single parameter may lead to simultaneous system improvement as a whole. After all absolute indicator data has been collected, six relative indicators can then be calculated which comprises of:

- Energy productivity
- Materials productivity
- Water productivity
- Carbon intensity
- Waste intensity
- Wastewater intensity

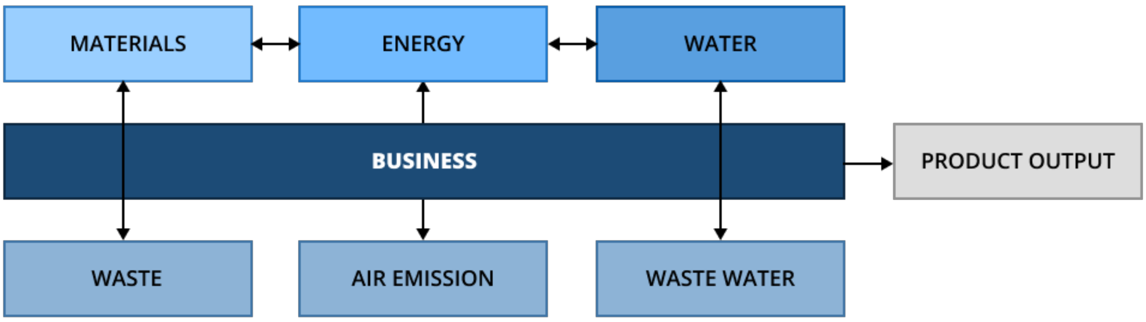


Figure 2.2 Relation between absolute indicators

2.2. Benchmarking and analysis

After gathering both absolute and relative indicators, results are benchmarked against national industries as well as industries in other countries. Benchmarking is only able to be carried out for similar scope of activity. However, indicators from different activities can be utilized as references and data comparisons. Evaluation is then done based on the previously calculated indicators. Lastly, recommendations related to plastic packaging (polypropylene) resource efficiency in the industry are formulated. A schematic view of the methodology can be seen in **Figure 2.3**.

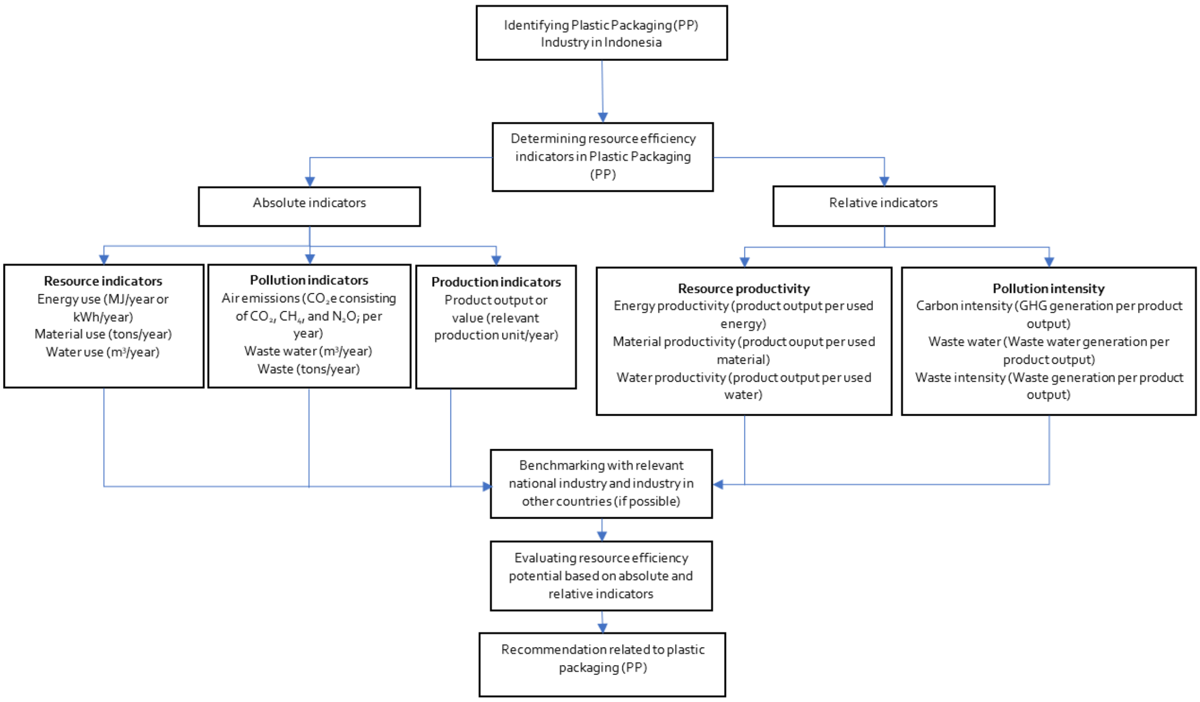


Figure 2.3 Resource efficiency potential methodology

2.3. Requested data

Data is collected through focus group discussions and questionnaires. According to the Directorate of Downstream Chemical and Pharmaceutical Industry, several industries are involved in the polypropylene supply chain process.

The list shown in **Table 2.1** below shows the categorization of industries involved in each supply chain based on the Ministry of Industry (MoI) nomenclature.

Table 2.1 List of plastic polypropylene manufacturing industries and related stakeholders

No.	Type of industry and related stakeholders	Supply chain (SC)	Additional information*
1	Polymer producing industries	SC 1	Upstream
2	Plastic conversion industries	SC 2	Downstream
3	Plastic production industries	SC 3	Downstream
4	Plastic usage industries	SC 4	Downstream
5	Collection, sorting and recycling industries and related stakeholders	SC 5	Downstream

*Based on MoI nomenclature

Several associations are also taking on a major role in the polypropylene supply chain. *Asosiasi Industri Plastik Indonesia* (INAPLAS) is involved in monomer production and polymer production. *Asosiasi Biaxially Oriented Films Indonesia* (ABOFI) is involved in the plastic film manufacturing process. As for plastic recycling, two major associations namely *Asosiasi Daur Ulang Plastik* (ADUPI) and Indonesian Plastics Recyclers take part in the process.

Table 2.2 shows the requested data for each industry and association in the polypropylene supply chain. Requested data may be adjusted according to the type of industry and association. For instance, more detailed data on manufactured packaging such as bottles, bottle caps, plastic labels, and gallons may be requested by industries specializing in plastic production and use.

Table 2.2 Requested data matrix

No	Data	Unit	Period
1	**Product (output)**	unit/year	2018-2020
		ton/year	
		kL/year	
		USD/year	
		Rp/year	
2	**Product outcome**	-	2018-2020
3	**Marketing leading to F&B industries**	-	2018-2020
4	**Energy use**		2018-2020
	Total energy consumption	MJ/year	
		kWh/year	
	Source of energy (detailed energy source such as PLN/privately owned generators/third party suppliers	-	
	Energy productivity	unit output/used energy unit	
5	**Material use**		2018-2020
	Material use	ton/year	
	Raw material source (import/export/recyclable/domestic)	quantity unit	
	Material productivity	unit output/used material unit	
	Raw material (raw material for packaging)	-	
6	**Water use**		2018-2020
	Total water use	kL/year	
		m^3/year	
	Water source (centralized provided/groundwater/stormwater/surface water/other wastewater use)	-	
	Water productivity	unit output/used water unit	
7	**Air emissions**		2018-2020
	GHGs emission from all industrial process	ton CO_2e/year	
	Carbon intensity	GHG emission/product output	
8	**Wastewater**		2018-2020
	Total wastewater	kL/year	
		m^3/year	
	Wastewater intensity	wastewater/product output	
9	**Waste**		2018-2020
	Total solid and hazardous waste	unit/year	
	Solid waste intensity	waste/product output	
	Waste sent to landfills/incinerators/recycling facilities and is still a part of the industrial on-site process or sent to a third party (including waste classification)	-	

During the period of study, relevant stakeholders including ministries, industries, and associations have taken part in the data collection process. Focus group discussions have been held in the past three months to collect national data besides secondary data from corresponding references. This is especially important to ensure an appropriate recommendation formulation in terms of plastic packaging. This study is supported by MoI - Downstream Chemical and Pharmaceutical Industry (IKHF) in facilitating focus group discussion (FGD) and data collection. The following **Table 2.3** summarizes past focus group discussions with relevant ministries, industries, and associations.

Table 2.3 List of focus group discussions

No	Name of ministry/industry/association	Date
1	MoI – Directorate of Beverages, Tobacco Products and Refreshments (MINTEMGAR)	29 October 2021
2	MoI – Downstream Chemical and Pharmaceutical Industry (IKHF) – Center for Green Industry (PIH)	10 November 2021
3	Polytama	15 November 2021
4	MoI – Downstream Chemical and Pharmaceutical Industry (IKHF) (kick-off meeting)	21 December 2021
5	GAPMMI	4 January 2022
6	IPF	13 January 2022
7	NAMPA	5 January 2022
8	• ADUPI • APHINDO • Indopoly Swakarsa Industry • PT Panverta Cakrakencana • ABOFI/PT Trias Sentosa • Rotokemas	17 February 2022
9	APSI	16 March 2022
10	Pertamina RU III Plaju	22 March 2022

3. Existing condition of plastic supply chain

3.1. Data limitations

Figure 3.1 shows the scope and limitations of this study. Resource efficiency data used in this study have been gathered from government databases (*Sistem Informasi Industri Nasional*/ National Industry Information System - SIINAS/NIIS and *Sistem Informasi Pengelolaan Sampah Nasional*/National Waste Management Information System - SIPSN/NWMIS) and industries. Meanwhile, additional information and insights about resource use and production have been gathered from associations, government and other local stakeholders. However, after consultation and data collection, resource efficiency data was found to have limited availability because RE data monitoring and reporting are still voluntary, not mandatory for some indicators. To overcome data scarcity, extrapolation has been done to gain a national overview. For example, to calculate the Indonesian recycling rate, an extrapolation of the national waste generation has been done to complete the remaining 50% cities/regions who have not submitted their data in SIPSN/NWMIS. Additional assumptions based on literature review were also carried out to complete the analysis. An assumption of PP production proportion for a polymer production industry has been done to calculate resource efficiency indicators. This proportion is derived from the total production of the respective industry. Due to limited data, only the conversion of PP to BOPP is considered in the plastic conversion and production of plastic products stage.

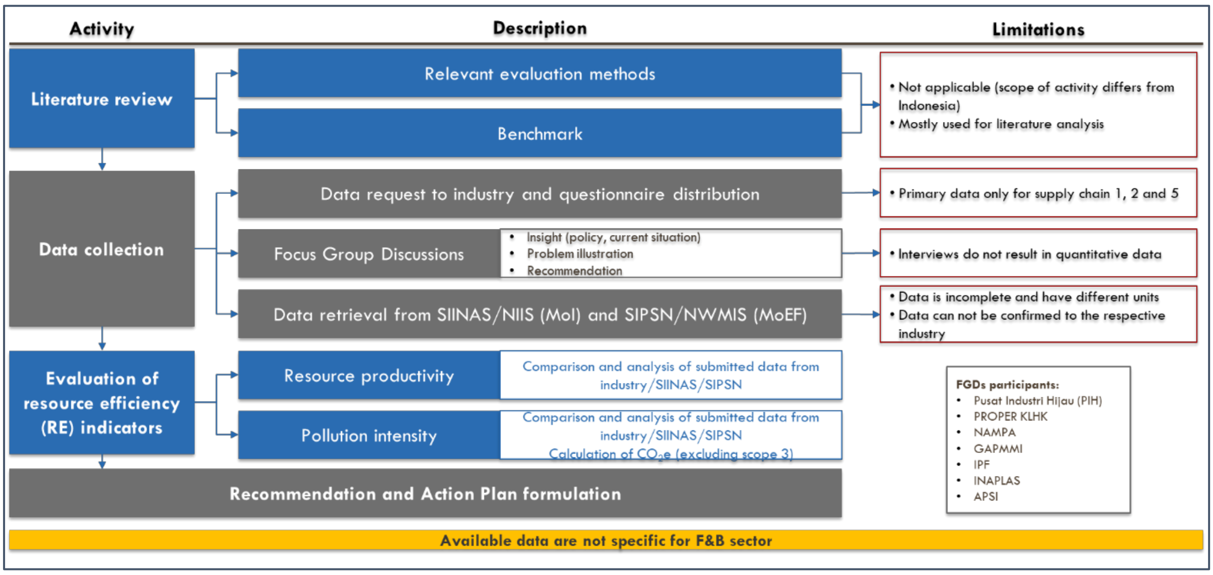


Figure 3.1 Scope and limitations of study

National benchmarks of RE indicators are only available for some industries who have participated in *Program Penilaian Peringkat Kinerja Perusahaan dalam Pengelolaan Lingkungan Hidup* (PROPER)/Environmental Management Performance Rating Program for Company and PIH. PROPER has published national benchmarks for several classification of industries. Meanwhile, the classification of industries is very general and does not include plastic industry. From all available benchmarks, only one industrial group (oil and gas refinery industry) could be compared to a supply chain covered in this study, i.e., polymer production industry (supply chain 1). Adjustments must be made in order to accurately compare calculated resource efficiency indicators (specific for PP) and total production in the oil and gas refinery industry. Supplemental analysis of polymer production industry, plastic conversion industry and recycling industry overseas (not on national level) derived from published scientific articles have also been done to complete the study.

3.2. Supply chain of plastic industry

Mapping of plastic industry supply chain has been done through literature review and focus group discussions with government, associations as well as other stakeholders. **Figure 3.2** shows the currently identified plastic supply chain of polypropylene in Indonesia. Black arrows indicate the mechanical recycling of material in form of plastics, whereas red arrows indicate chemical recycling and Refuse Derived Fuel (RDF) process. RDF has already been implemented in Indonesia, especially in cement industries. Chemical recycling is an alternative method which could also be implemented in the future.

The supply chain is divided into two categories namely upstream (supply chain 1/SC-1) and downstream (supply chain 2 – 6/SC-2 – SC-6). Nomenclature has been adapted from the industrial classification by the MoI.

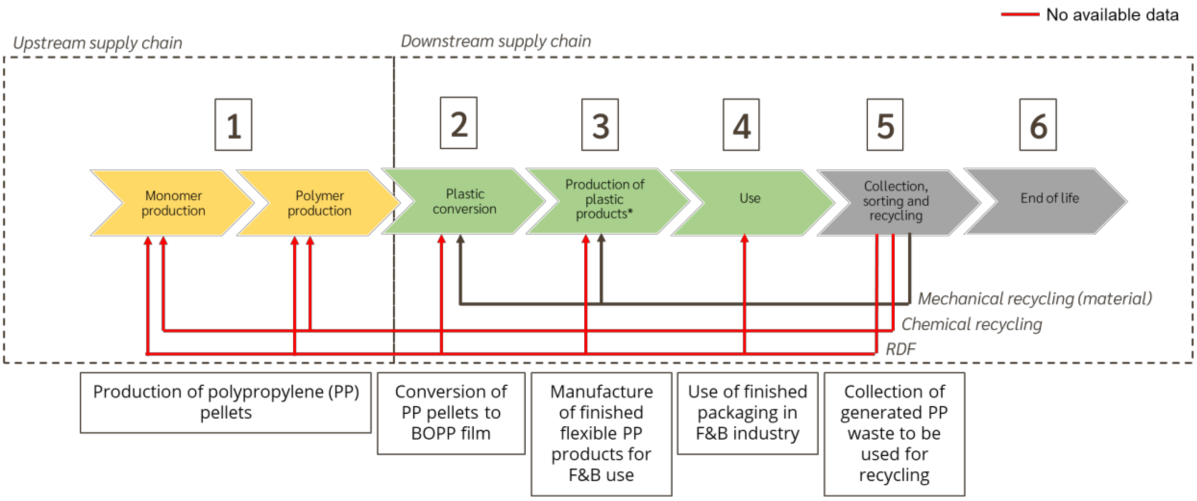


Figure 3.2 Plastic supply chain of polypropylene in Indonesia

A simplified material flow analysis of the plastic supply chain in 2020 is shown on **Figure 3.3** with a detailed scheme shown on **Figure 3.4**. Material flow analysis has been extracted from government data. The production process of plastic packaging begins with the production of monomer and polymer (SC-1). A dependency on imports (57%) can be observed to meet the demand for polymer production (raw virgin PP material in form of granules). A fraction of polymer product is also exported (7.5%). The production of polymer products is then followed by the plastic conversion (SC-2). Raw material in form of plastic granules enter this stage to be converted to film. Plastic film is further used in plastic packaging production process (SC-3).

SC-3 is divided into extruding and injection molding industries. Value of products from extrusion is assumed as BOPP film only. The production capacity of injection molding industry is assumed to be the value of products from SC-1 subtracted with exported products from SC-1 and plastic conversion products (through extruding) from SC-2 which is 87.3%. Based on gathered data, there are two classifications of industries present in BOPP film manufacture. Type A, which converts plastic PP granules through an extruding process until forming BOPP slit roll, and Type B, which converts BOPP jumbo rolls to finished BOPP plastic packaging products to be used by the next chain of industry (SC-4). A constant value of products has been assumed through all stages of Type A and B industries.

Used plastic packaging products enter either the collection, sorting and recycling stage (SC-5) or the end-of-life stage (SC-6). Used recyclable plastic packaging is re-introduced to the system in the form of plastic granules/scrap plastic/new products whilst others end up in landfills in the form of waste (SC-6). Text highlighted in red indicate unavailable (NA)/assumed data. (**Figure 3.4**).

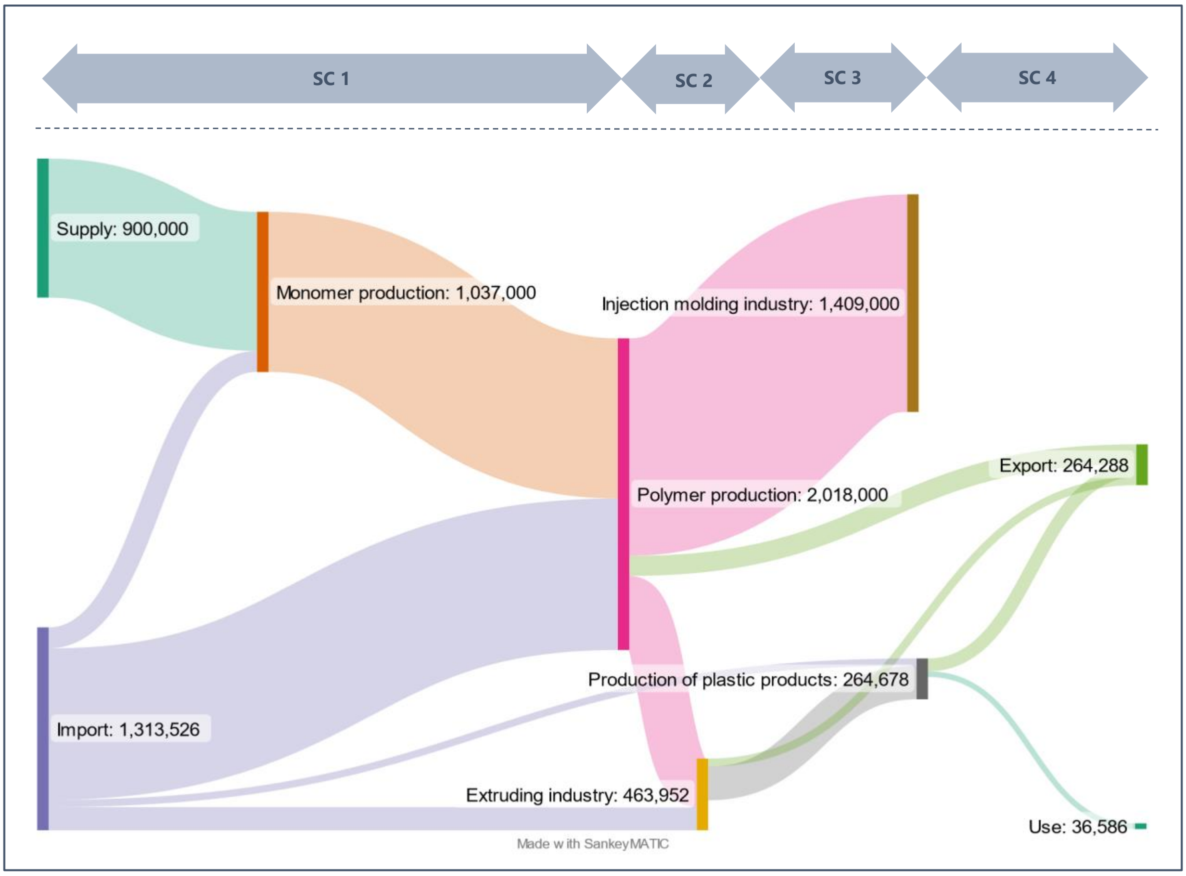


Figure 3.3 Simplified material flow analysis of PP plastic supply chain

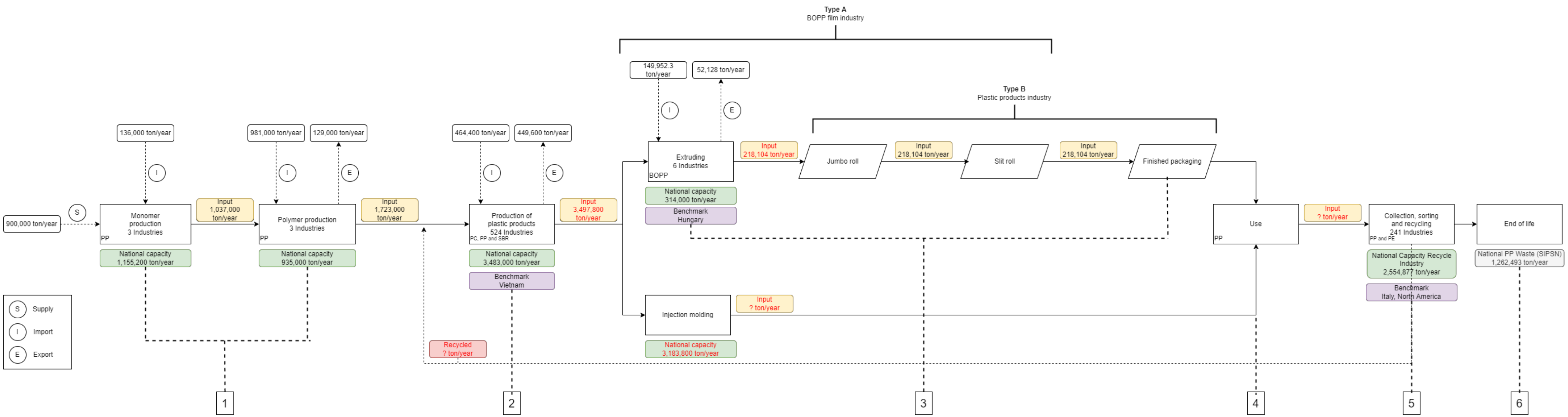


Figure 3.4 Detailed material flow analysis of PP plastic supply chain

3.2.1. Supply chain 1 (SC-1): monomer and polymer production

Monomer manufacturing industries consist of three industries involved in the production of propylene. Monomer manufacturing industries in Indonesia have a national installed production capacity of 1,155,200 ton/year, while the actual production capacity is 900,000 ton/year. Indonesia still relies on imports of 136,000 ton/year to meet actual demand of 1,037,000 ton/year. One of monomer manufacturing industries produces polypropylene (integrated petrochemical industry) while the rest are suppliers for two polypropylene production industries (standalone petrochemical industry).

The three polymer manufacturing industries in Indonesia have a national installed production capacity of 935,000 ton/year, while the actual production capacity is 870,000 ton/year. Indonesia still relies on imports of 981,000 ton/year to meet actual demand of 1,723,000 ton/year. The following figure shows the distribution of polymer manufacturing industries in 2020. Industry C dominates the national production capacity with a 59% share followed by B (34%) and lastly A (7%) as shown in **Figure 3.5**. National production of polypropylene is shown in **Figure 3.6**.

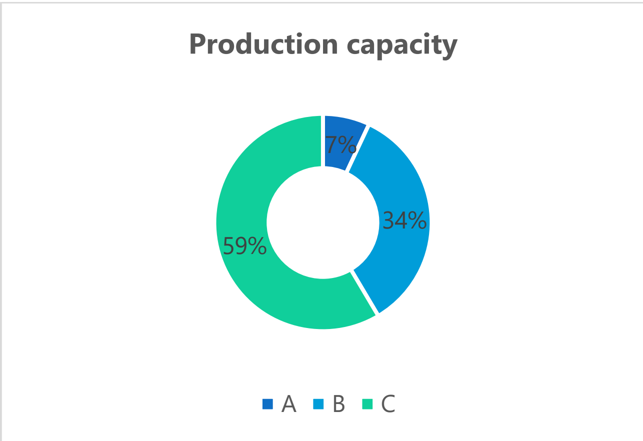


Figure 3.5 Production capacity of three polypropylene industries

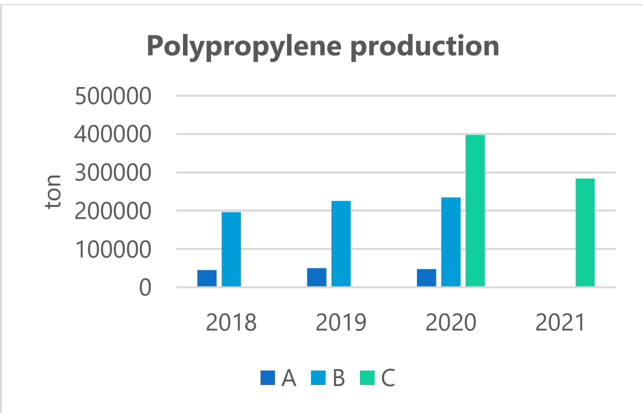


Figure 3.6 Polypropylene production in 2018 – 2021

Figure 3.7 illustrates the proportion of local, local-import and imported raw materials used in the polypropylene production. A comparison was made throughout 2018 – 2021. Examples of imported raw materials include main raw materials (naphtha, propylene) as well as solvents, catalysts and additives (hexene, C3, raffinate, extractor and hydrogen). It can be seen that polypropylene manufacturing industries still import a significant portion of their material source.

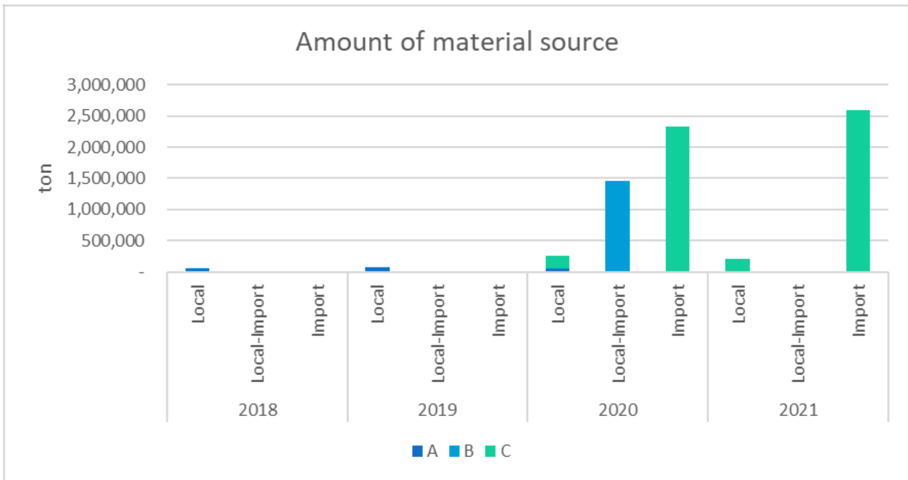


Figure 3.7 Amount of material source for polypropylene production

Energy productivity and CO_2e emission intensity (SC-1)

In terms of energy use, it can be seen on **Figure 3.8 (a)** that all industries possess different values of energy productivity across the year 2018 – 2020. Industry C has a lower energy productivity than A and B which leads to a decreased average value in 2020. Energy productivity trend is coherent with CO_2e emission intensity findings. Industries with a high energy productivity have a lower CO_2e emission intensity. A carbon intensity calculation on three industries has shown a performance of 0.785 - 0.820 ton CO_2e/ton product **Figure 3.8 (b)**. All industries have a higher value of carbon intensity if compared to a benchmark in Europe. According to a study conducted by [18] for Plastics Europe, the production process of polypropylene would emit a total of 0.403 ton CO_2e/ton product which excludes fuel production, use and transport.

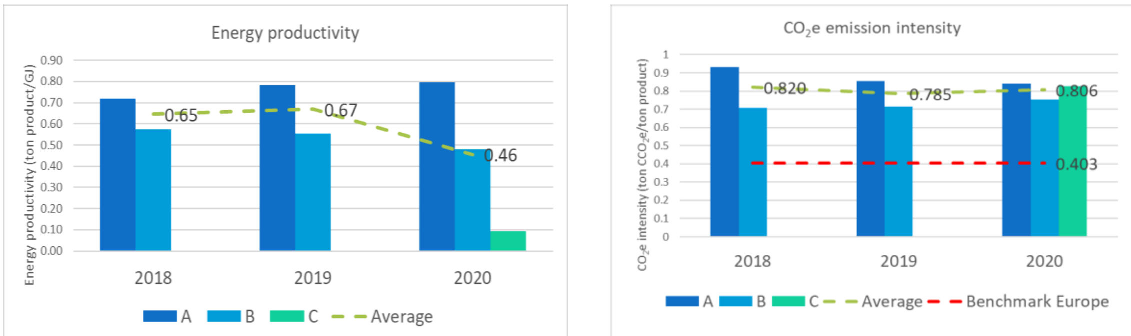


Figure 3.8 (a) Energy productivity and (b) CO_2e emission intensity of polypropylene industries

Greenhouse gas calculation method in the form of CO_2e is adapted from the Greenhouse Gas Protocol (**Annex 4**). Emissions are divided into three categories, namely scope 1, 2 and 3. Emission calculation based on scope of activity is given in **Table 3.1**. Scope 1 was calculated from internal electricity generation and liquid fuel use by industries. Scope 2 was calculated from purchased electricity from PLN.

Table 3.1 Emission category based on scope of activity

Emission category	2018 (CO_2e)	2019 (CO_2e)	2020 (CO_2e)	2021 (CO_2e)	Total emission (CO_2e)	Percentage* (%)
Scope 1	48874.35	52989.04	328057.89	-	429921.29	46%
Scope 2	138867.78	150845.33	216114.31	-	505827.42	54%
Scope 3	-	-	-	-	-	**

*Percentage only considers emission from scope 1 and 2

**Scope 3 is not calculated and considered in analysis

It is assumed that PLN uses coal as their source of energy in Jawa-Madura-Bali (Jamali) grid. It can be observed that emission comes from both scope 1 and 2 activity which can be linked to direct combustion and electricity use by industries (**Table 3.1**).

Material productivity and solid waste intensity (SC-1)

Material productivity could not be compared between three industries due to unreliable data of propylene quantity as main raw material. Moreover, different type of finished products (granules and pellets), applied technology and PP quality, require different type of chemicals and materials. Only one industry possesses reliable data as shown on **Figure 3.9 (a)**. One industry has stated the use of outdated technology which leads to the difficulty to optimize their production and use of green material.

In terms of waste intensity, both industry A and B show fluctuations across the year 2018 – 2020 (**Figure 3.9 (b)**). On the contrary, industry C shows an increasing trend of waste produced in the manufacturing process. The calculation of waste intensity comprises both non-hazardous and hazardous waste. For one industry, non-hazardous waste from domestic sources (garden waste, food waste, paper, plastics, glass, fabric, etc.) takes up a significant proportion of the total amount of waste. Percentages of non-hazardous waste compared to hazardous waste through 2018 – 2020 are 40.15%, 63.38% and 27.71% in respective order. This study does not compare solid waste intensity to a benchmark due to the difference of produced waste.

If compared to the sustainability report in 2020, non-hazardous waste has a lower proportion compared to hazardous waste. This result difference may be caused by the assumption of polypropylene production with respect to the total production of one industry.

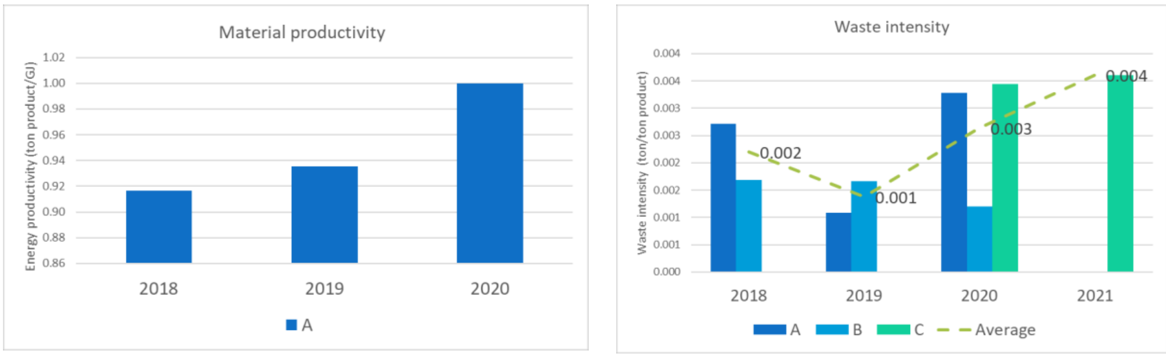


Figure 3.9 (a) Material productivity and (b) waste intensity of polypropylene industries

Water productivity and wastewater intensity (SC-2)

An interesting trend in water productivity can be observed in **Figure 3.10 (a)**. Industry B consumes a very small amount of water. Water productivity trend is coherent with wastewater intensity findings given in **Figure 3.10 (b)**. Despite having a lower productivity, industry A claims to use water for utilities and cooling tower purposes, and performs water recycling in the process, Thus, no wastewater is produced in the manufacturing process.

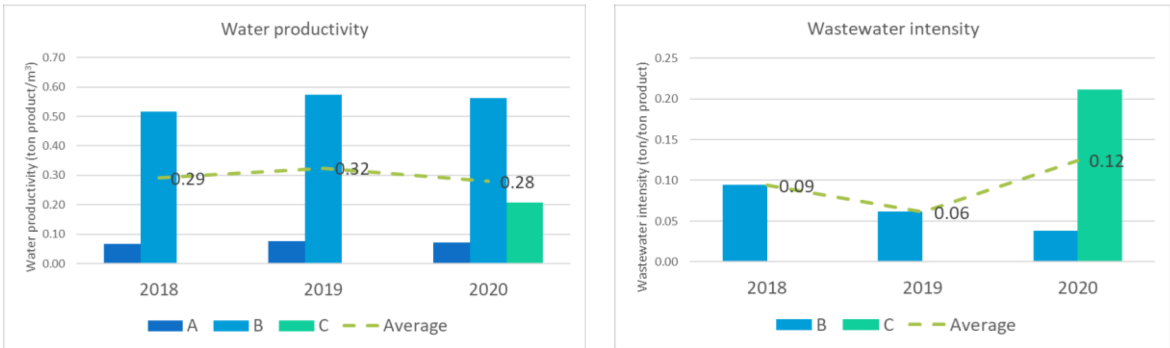


Figure 3.10 (a) Water productivity and (b) wastewater intensity of polypropylene industries

National benchmarking (SC-1)

Additional benchmarking for SC-1 was performed by comparing calculated values with benchmark from Ministry of Environment and Forestry (MoEF) for PROPER which classified polypropylene industries as part of oil and gas refineries (MoEF regulation number P.14/PPKL/SET/KIM.1/10/2019). Due to the differences in units, a conversion has been made for resource productivity indicators as it is given in ton product/GJ and ton product/m^3.

Data summary of resource efficiency from SC-1 is shown in **Table 3.2** while data conversion based on MoEF guideline is shown in **Table 3.3**. Benchmark values as stated in MoEF regulation show each indicator divided by the total oil equivalent (TOE). From the calculation, it can be seen that only solid waste has exceeded the 25% highest benchmark from oil and gas refinery industries. A more detailed analysis is needed to find the cause of higher value if compared to benchmark, considering polypropylene is only a part of oil and gas refineries activity. Wastewater intensity data has been omitted from analysis due to the large discrepancy in value across industries. It must be noted that TOE is an expression of total oil equivalent, meaning that the whole industrial process is considered in calculation. For this study, only polypropylene has been considered as a final product, which ultimately leads to a seemingly better value if compared to this benchmark.

Table 3.2 Resource efficiency indicators calculation

Indicator	Units	Value
Resource productivity		
Energy	ton product/GJ	0.456
Water	ton product/m^3	0.280
Pollution intensity		
Air emission	ton CO_2e/ton product	0.803
Wastewater	m^3/ton product	0.125
Solid waste	ton/ton product	0.001
Hazardous waste	ton/ton product	0.001

Table 3.3 Resource efficiency indicators compared to benchmark of Ministry of Environment and Forestry (P.14/PPKL/SET/KIM.1/10/2019)

Indicator	Units	Value	Benchmark		
			25% lowest	Average	25% highest
Energy	GJ/TOE	0.101	2.45	2.29	1.49
Air emission	ton CO_2e/TOE	0.017	0.195	0.165	0.116
Water	m^3/TOE	0.147	0.698	0.642	0.458
Wastewater	m^3/TOE	0.125	0.498	0.459	0.186
Solid waste	ton/TOE	0.000027	0.000098	0.00006	0.000026
Hazardous waste	ton/TOE	0.000030	0.00052	0.00044	0.000145

Best practices (SC-1)

Energy productivity and $CO2_e$ emission intensity

Based on sustainability report (2020) of industry A, B, and C, each industry has already implemented energy efficiency programs. Industries are in the process of shifting energy sources such as gas and diesel oil to renewable energy, such as installation of solar panels. Industries are trying to minimize the dependency of electricity provided by PLN, moreover, one of the industries is fully independent in energy source. Several programs such as substituting boiler fuel with off-gas, shifting to less carbon intensive fuel (from gas oil to natural gas), heat utilization, implementation of ISO50001 energy management system and good housekeeping have been implemented. Good housekeeping practices include auto-switch control in utilities, sustain reduce pressure steam in utilities, use of LED lamps and energy saving campaigns, and etc.

Material productivity and waste intensity

Based on sustainability report (2020) of industry A, B, and C, each industry has already applied various programs to reduce waste intensity. For non-hazardous waste, industries have already used waste management hierarchy. For hazardous waste, industries partly send their waste to third party or implement internal management such as sludge oil recovery and reuse of used wooden pallet in product packaging as well as used lubricants.

Water productivity and wastewater intensity

Based on sustainability report (2020) of industry A, B, and C, each industry has already implemented water saving programs. Some of the programs include the reuse and recycle of steam condensate from PP processes and good housekeeping practices such as the simplification and reparation of line steam, improve efficiency of steam production, improve demin plant process, pressure control at utilities, and use of continuous blow down for domestic use (bathrooms & toilets).

3.2.2. Supply chain 2 (SC-2): plastic conversion

Starting from supply chain 2, resource efficiency indicators will mainly focus on polypropylene (PP) flexible film plastic packaging. Based on data from the Ministry of Industry (MoI), there are 6 industries engaged in the plastic conversion chain. For flexible film plastic packaging itself, raw polypropylene has been converted into a variety of types including biaxially-oriented polypropylene (BOPP), cast-polypropylene (CPP), and oriented-polypropylene (OPP). In 2009, it shows that BOPP film is the second most consumed in market share globally with 26.5%, as depicted in **Figure 3.11** [19].

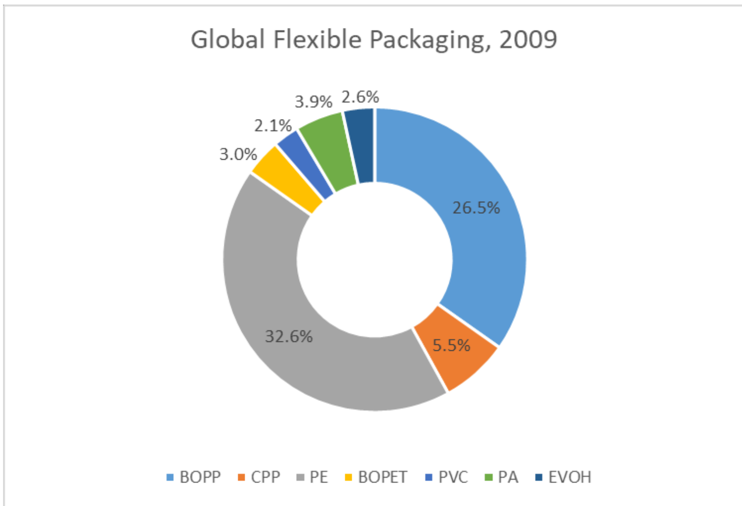


Figure 3.11 Global plastic packaging in 2009 [19]

Data in the plastic conversion chain have been collected from the Ministry of Industry (MoI). The source of raw materials for the production of BOPP film mostly comes from local and imported virgin plastic (**Figure 3.12 (a)**), even though there's also an industry that uses local scrap plastic (6% from total material use) as additional material for their production. Based on data, industries still rely on imported virgin plastic and increased through the year compared to using local virgin plastic. For their production itself, **Figure 3.12 (b)** shows the percentage of BOPP film production represented by 6 industries throughout Indonesia with an average production of 124,538 – 222,296 tons in 2018 - 2021.

Figure 3.12 (a) Raw material source for BOPP production (b) BOPP plastic film production percentage (2020)

Figure 3.13 shows the process of BOPP film production [20]. Polypropylene resin and master batch are firstly combined. The mixture is then added in an extruding machine (extrusion) to be melted with a temperature of 225 – 285℃. After passing a filter, melted resin is pressed in a die to be shaped to thick film (casting process). Hot thick film is then cooled in a chill roll with a temperature of 20 – 50℃ and is re-heated and stretched vertically with a 5-time ratio. Film is further stretched horizontally with a 10-time ratio until forming 6 – 8 meters of thin film (stretching). Thin film is then cooled and passed through a corona station to increase surface tension (dyne level) before casting (pull roll & treatments). After that, thin film is rolled and aged for a few days before being cut to meet customer demand (ageing and slitting).

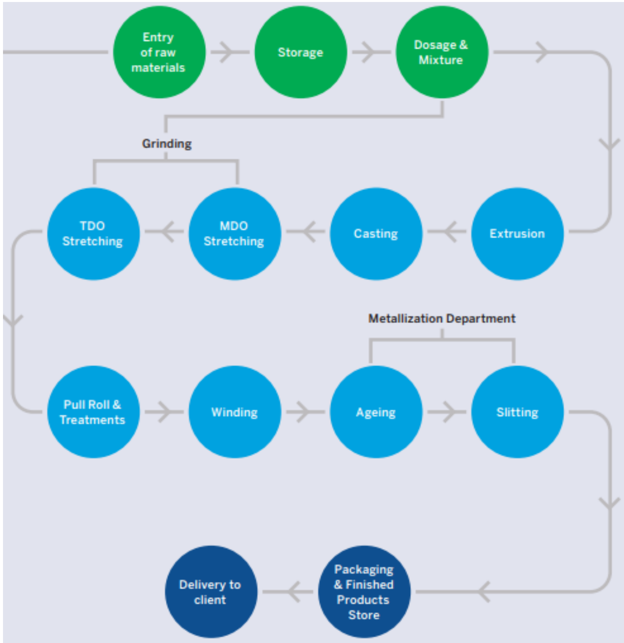


Figure 3.13 BOPP film production process [20]

Energy productivity and CO_2e emission intensity (SC-2)

The energy source of most facilities is electricity provided by PLN while some industries use additional fossil fuel as their energy source as well. In **Figure 3.14 (a),** on average, the energy productivity for BOPP production around 0.001 ton product/kWh. However, without the presence of process flow diagram (PFD), a more detailed study is needed to determine energy productivity differences. Based on data and literatures, there are two reasons which could cause differences of value such as product variety (BOPP films, BOPP metallized, OPP films, etc.) and technology used for their extrusion process.

Based on the calculation, CO_2e emission intensity fluctuated and its average increased around 1.09 – 1.28 ton CO_2e/ton product as shown in **Figure 3.14 (b).** Industry D itself produces the largest amount of CO_2e emission intensity in 2019, which leads to an increase in the average CO_2e emission intensity. Compared to other industries, fluctuation of CO_2e emission intensity of industry D is caused by fossil fuel consumption.

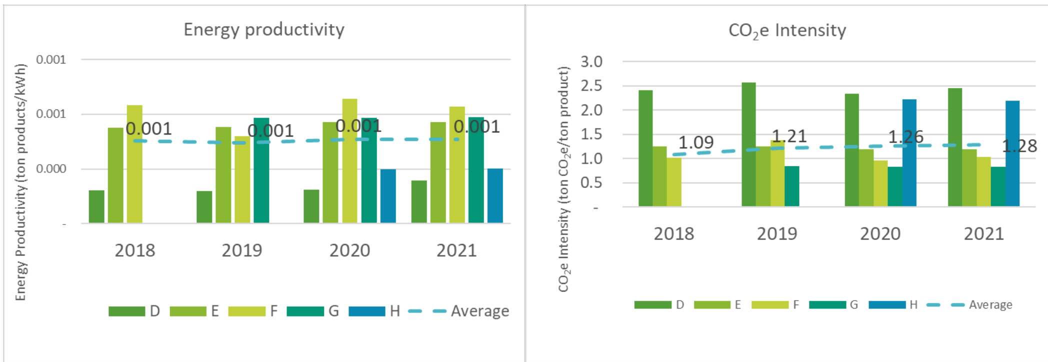


Figure 3.14 (a) Energy productivity and (b) CO_2e emission intensity of BOPP film industries

Greenhouse gases calculation method in the form of CO_2e is adapted from the Greenhouse Gas Protocol (**Annex 4**). Emissions are divided into three categories, namely scope 1, 2 and 3. For SC-2, an industry has already started calculating emissions from scope 3. Emission calculation based on scope of activity is given in **Table 3.4**. Scope 1 was calculated from internal electricity generation and liquid fuel use (LNG, LPG, solar and diesel) by industries. Scope 2 was calculated from purchased electricity from PLN. Scope 3 was calculated from product transportation and employee business trips, retrieved from only one industry.

Literatures from Hungary and India have been reviewed to complete data analysis. Some industries abroad (e.g., Hungary, India) have implemented several programs to increase energy productivity such as upgrading their extrusion technology, applied automation, reduce electricity by using thermal energy (e.g., methane), and other renewable energy (e.g., wind power, solar panel). An Indian industry has also invested in innovation to reduce GHG emissions such as downgauging monitoring, and management of plant environment parameters such as noise, illumination, ventilation, air quality, and etc., did directly and indirectly result in a reduction of emissions produced intensity [21].

Table 3.4 Emission category based on scope of activity in plastic conversion chain

Emission category	2018 (CO_2e)	2019 (CO_2e)	2020 (CO_2e)	2021 (CO_2e)	Total emission (CO_2e)	Percentage (%)
Scope 1	9,590.25	11,564.47	14,362.29	7,207.19	42,724.2	5.6
Scope 2	117,157.54	147,631.8	259,042.51	198,783.48	722,615.33	94.2
Scope 3*	-	616.16	628.57	610.3	1,855.03	0.2

*Scope 3 calculated from only 1 industry

Material productivity and waste intensity (SC-2)

Material productivity to produce plastic film is depicted in **Figure 3.15 (a),** with an average range between 0.79 - 0.84 ton/ton product in 2018 - 2021. A fluctuating trend can be observed throughout 2018 – 2021 with industry G having the highest material productivity.

Compared to generated waste, it can be seen in **Figure 3.15 (b)** that waste generated by 6 industries fluctuates between 2018 - 2021. Waste is mostly generated from the processing stage, which produces BOPP film waste and also produces hazardous waste such as oil sludge and oil lubricant. In 2020, the 6 industries generated the largest amount of waste, thus increasing waste intensity to 0.014 ton/ton product on average.

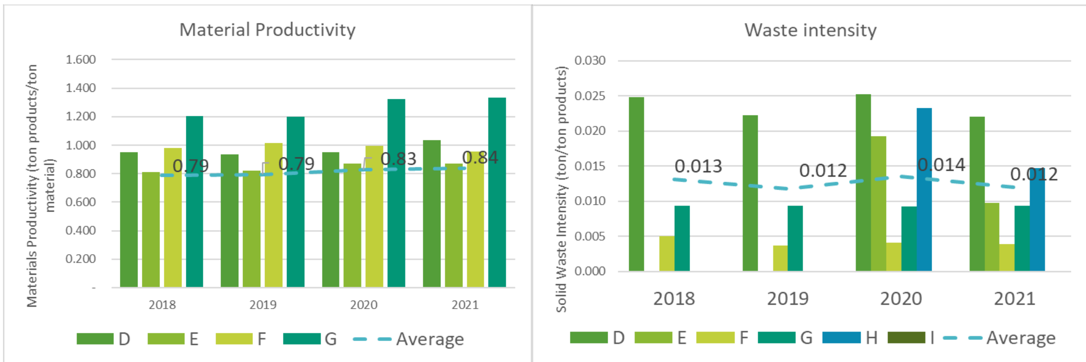


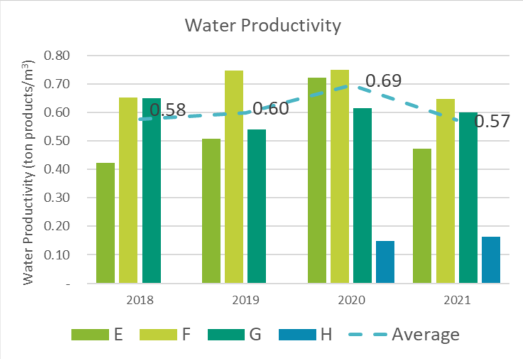
Figure 3.15 (a) Material productivity and (b) solid waste intensity of BOPP film industries

Water productivity and wastewater intensity (SC-2)

In plastic conversion industries, the source of water consumption mostly comes from freshwater (surface water/groundwater/PDAM water). For water productivity, it can be seen in **Figure 3.16 (a)** that industry F had the largest water productivity in 2018 - 2019 compared to other industries, which leads to an increased average value of overall water productivity around 0.57 – 0.69 ton product/m^3. However, water productivity fluctuates across the years.

In general, industries in Indonesia only uses water for the chill roll, if compared to multi-national company, which has an additional re-granulation step. Based on this industry, water consumption highly varies depending on the volume of film produced. Regeneration process requires a significant use of water for material cooling, which affects the performance of water productivity indicator.

Different from the water use, the data of wastewater produced from the BOPP process only consists of two industries whilst other industries possibly send their wastewater to off-site treatment facilities. The wastewater is most likely produced from the chill roll process of the BOPP film production process, which fluctuates across the years as indicated in **Figure 3.16 (b)**.



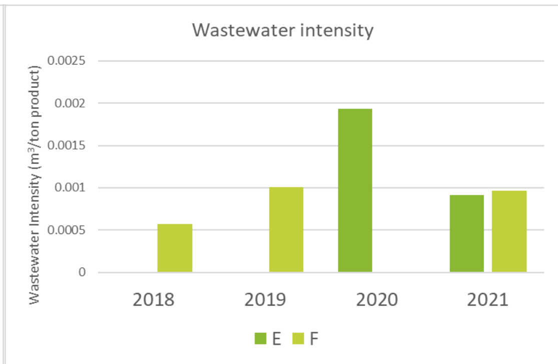


Figure 3.16 (a) Water productivity and (b) wastewater intensity of BOPP film industries

Best practices (SC-2)

Energy productivity and CO2e emission intensity

Based on sustainability reports (2021), it was stated that In Indonesia, some industries have applied some programs to save their energy and reduce GHGs emissions. Industry D is currently in the process of using solar panels for efficiency in electricity use. Besides, industry G has also carried out inverter installation, and heat recovery since 2018, with the use of solar panel as renewable energy source. In addition, industry G has also installed a smart building lighting system and implemented an air conditioning wireless control. It has converted its energy sources through programs such as flame operational conversion by using LNG in production activities and switching from LPG fuel to electricity in their forklift operation.

Material productivity and waste intensity

Based on sustainability reports (2021), it was stated that some industries perform internal recycling of produced waste such as reuse plastic scrap and reclaiming reject product as added material. Scrap reprocessing procedure is known as regranulation. The scraps are derived from film break-offs (during either stretching or the start-up of extrusion lines), slitter scraps, grinding of jumbo rolls or byproducts not matching standards. To minimize chemical adhesives use in lamination process, thermal lamination films which allow the film to be laminated on paper have been developed. Industries have started to focus its production in innovative green packaging (mono material concept and biodegradable PP).

In terms of waste management, industries store reusable non-hazardous and toxic wastes (non-hazardous wastes) as pallets, wood, sacks, scrap, and others in their respective storages. Non-reusable non-hazardous solid wastes are periodically collected and processed. Lastly, hazardous waste wastes are held in temporary storage containers to be sent to a third party without polluting the environment. Industries also optimize the use of iron pallets to preserve the natural ecosystem by reducing wooden pallets usage in production activities.

3.2.3. Supply chain 3 (SC-3): production of plastic product

Production of plastic products is categorized into two main processes, which are extrude and molding. A molding process immediately shapes plastic raw material to the desired plastic packaging form. Examples include plastic bottles, caps and several other rigid polypropylene packaging. Indonesian PP consumption is at 1,800,000 ton/year with food (923,000 ton) and beverage (971,000 ton) as dominantly used household packaging. Five major players are involved in the rigid plastic packaging market and a 5.2% compound annual growth rate (CAGR) is expected in 2020 - 2025 [22].

In an extrude process, the plastic is firstly formed to a jumbo roll or sheet before being reshaped to the desired form. Extruding process is done for flexible polypropylene packaging such as sachets and plastic bottle labels. This study will cover a more detailed analysis in production of plastic products through the extruding process.

Production of plastic products through extruding can further be classified into two main types of industries which will be referred to as A and B which can be seen in **Figure 3.4**. Type A industries produce plastic products from plastic pellets through the extruding process until a jumbo roll is formed. Type B industries start their manufacturing process by further converting a jumbo roll to slit roll (smaller sized plastic film rolls) with ready-to-use plastic packaging as a finished product. Industries involved in this supply chain therefore belong to Type B. A process flow diagram from North Coast Plastics [23] illustrates the typical manufacturing process of flexible packaging through extrusion **Figure 3.17**. Bags are made from resin which then enters an extruder to form plastic films. As the production of plastic products usually cover labeling and finishing of packaging (ready to use by the next industry in the supply chain), bag machines then convert the film to high quality bags and other types of packaging. Lastly, finished packaging enters storage before being sent for shipping. Manufacturing process of flexible packaging in Indonesia is also shown in **Figure 3.18**.

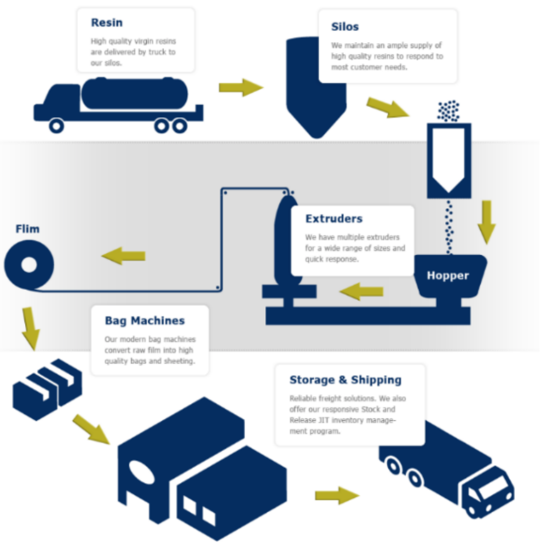


Figure 3.17 Schematic diagram of flexible packaging production process [24]

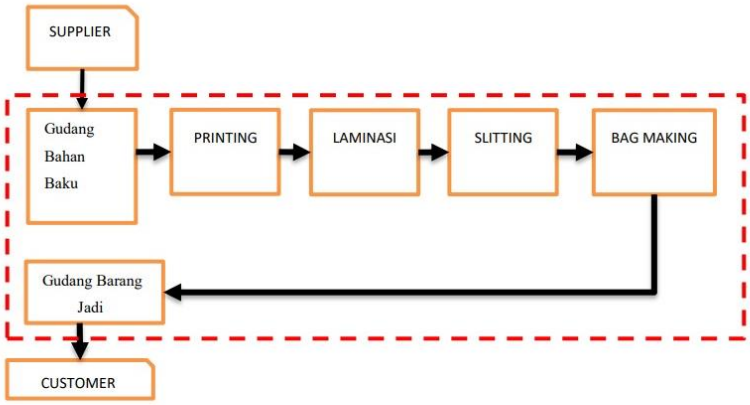


Figure 3.18 Flexible packaging production process in Indonesia [25]

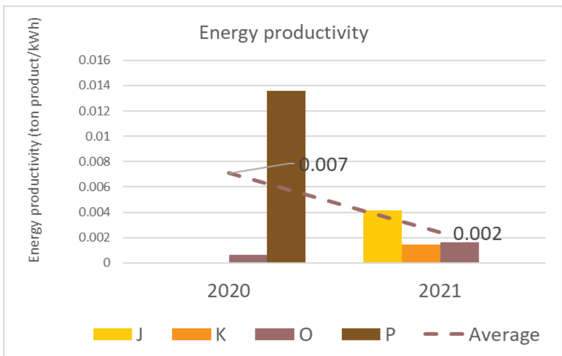
The national production capacity of all plastic types including polycarbonate (PC), PP and styrene-butadiene rubber (SBR) is at 3,483,000 ton/year. The said production capacity meets a 65.7% of utilization from the installed capacity of 5,301,370 ton/year. Indonesia imports 464,600 ton/year raw material and exports 449,600 ton/year of finished plastic products.

Energy productivity and CO_2e emission intensity (SC-3)

Data for the production of plastic products chain had been collected from 8 out of 12 industries involved in the production of plastic products in Indonesia. In terms of energy productivity, industry P leads with a calculated value above 0.01 ton product/kWh, increasing the overall average (**Figure 3.19 (a)**).

If compared to the resulting air emission, a coherent trend can be observed where a higher value of energy productivity would lead to a lower CO_2e emission intensity. CO_2e emission has been calculated by taking used fuel into consideration. Coal has been assumed as fuel for industries who rely on PLN as their electricity source. A CO_2e emission intensity calculation has shown a value of 0.455 - 0.746 ton CO_2e/ton product (**Figure 3.19 (b)**).

Greenhouse gases calculation method in the form of CO_2e is adapted from the Greenhouse Gas Protocol (**Annex 4**). Emissions are divided into three categories, namely scope 1, 2 and 3. In addition, almost all emission comes from scope 2 activity which can be linked to electricity use by industries (**Table 3.5**). Only 0.49% of emission comes from direct combustion sources (scope 1).



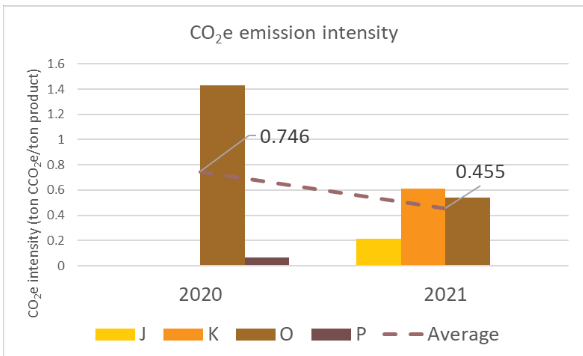


Figure 3.19 (a) Energy productivity and (b) CO_2e emission intensity of plastic producing industries

Table 3.5 Emission category based on scope of activity of plastic production chain

Emission category	2018 (CO_2e)	2019 (CO_2e)	2020 (CO_2e)	2021 (CO_2e)	Total emission (CO_2e)	Percentage (%)*
Scope 1	-	56.20	5,421.57	9.04	5,486.82	0.49%
Scope 2	972,106.04	123,022.24	1,148.56	12,760.68	1,109,037.52	99.51%
Scope 3	-	-	-	-	-	**

*Percentage only considers emission from scope 1 and 2

**Scope 3 is not calculated and considered in analysis

Material productivity and waste intensity (SC-3)

Material productivity has been excluded from analysis due to the unavailability of data. In terms of waste, industry Q produces the highest amount of non-hazardous waste (waste intensity) which leads to an increased average value of 8.03 ton/ton product in 2018 (**Figure 3.20**). As for hazardous waste, industry Q produces the highest amount of waste which is then followed by industry L and O (**Figure 3.21**). A fluctuating trend of generated waste intensity and hazardous waste intensity up to 2021 can also be observed due to the data availability (data were mostly provided from 2020).

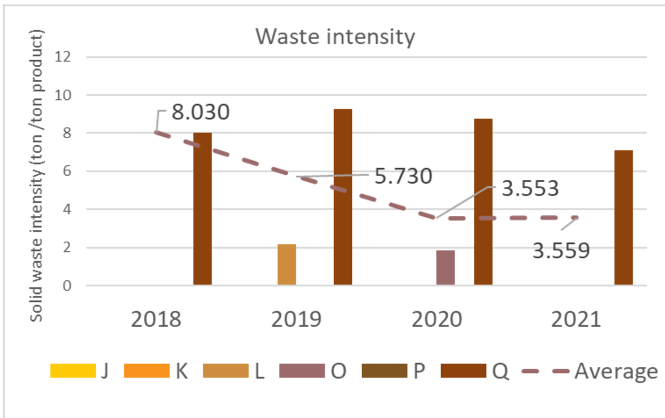


Figure 3.20 Non-hazardous waste intensity of plastic producing industries

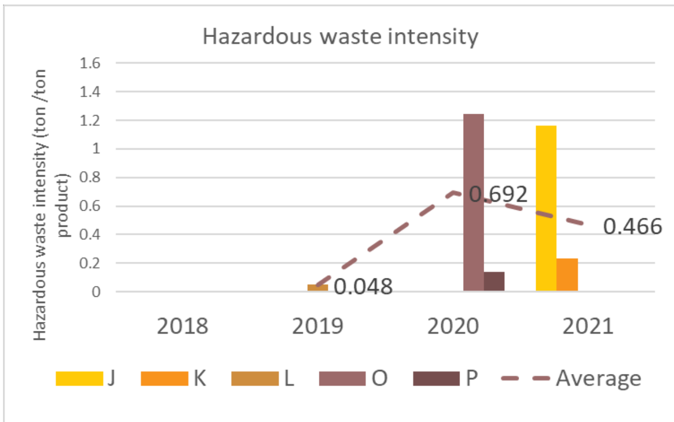


Figure 3.21 Hazardous waste intensity of plastic producing industries

Calculation of non-hazardous and hazardous waste intensity has been done separately referencing some industries in Vietnam [26]. Solid waste intensity is calculated from exclusively non-recyclable solid waste produced in the manufacturing process of plastic products. This study also stated the possibility of reintroducing plastic to production process to be used as material. No data is given regarding the generated hazardous waste. This study includes other types of plastics and is not limited to polypropylene.

Water productivity and wastewater intensity (SC-3)

Figure 3.22 shows the water productivity from two industries. Significant increase of water productivity of industry O in 2021 is due to the decrease of consumed water coupled by an increase of manufactured products. Industries predominantly use groundwater (90 – 99%) for their production process. A small fraction of water also comes from municipal sources and rivers. Wastewater intensity has been excluded from analysis due to the unavailability of data.

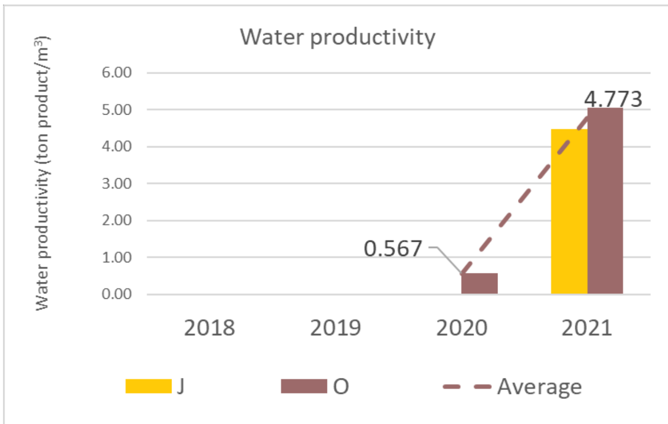


Figure 3.22 Water productivity of plastic producing industries

Best practices (SC-3)

Energy productivity and $CO2_e$ emission intensity

Some industries have already implemented energy management system in their production process. This is done through steam and electrical system optimization in various electrical motors (to improve efficiency) and provide field training for energy management. An industry has also stated the use of renewable energy sources from oil palm shell to reduce CO2e emission.

Material productivity and waste intensity

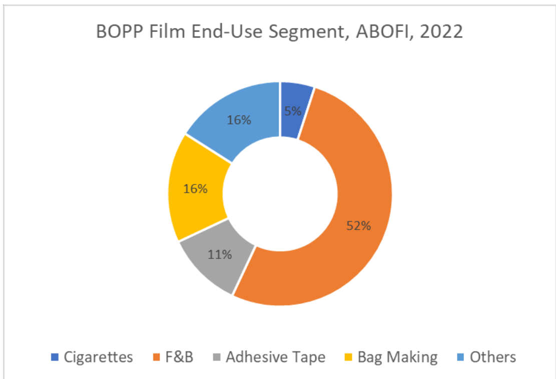
Based on an industry sustainability report, several action plans have been implemented to reduce waste intensity. This industry has already applied waste separation (organic, carton and plastic waste) and recycles 24% (equivalent to 2,800 ton) of post-production plastic waste internally while the rest are sent to external recycling facilities with help of a third party.

Water productivity and wastewater intensity

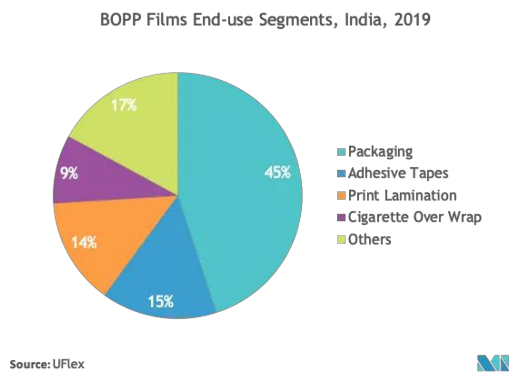
To reduce water usage, an industry has stated the implementation of water saving campaigns in their sustainability report. Moreover, another industry also does periodic monitoring of water usage to avoid a high water intensity. Other initiatives such as condensate recovery for boiler water, leakage audits, digitalization control for deep well discharge, closing the loop for water used in utilities and cooling systems, recovery from production for clean in place and rainwater harvesting have also been done to minimize water use.

3.2.4. Supply chain 4 (SC-4): use

Supply chain 4 (SC-4) is defined as the use of BOPP film in F&B industry. In reality, BOPP film use in industry cannot be precisely identified by their sector (F&B, cigarettes, bag making, adhesive tape, etc.). The food packaging industry (including BOPP film) itself remains the largest plastics end-user in Indonesia (**Figure 3.23 (a)**). Based on Indonesia's BOPP Association, the total national consumption of BOPP film is used by F&B sectors (52%), bag making (16%), others (16%), adhesive tape (11%) and cigarettes (5%) in order. In comparison, in India, BOPP film is mostly used for packaging (45%) followed by others (17%), adhesive tape (15%), print lamination (14%) and cigarettes (9%) as shown in **Figure 3.23 (b)**.



(a)



(b)

Figure 3.23 (a) BOPP film end-use segments in Indonesia and (b) India [22]

In the food sector and packaging industry itself, the demand for BOPP plastic films in Indonesia continues to increase. The main applications for BOPP films are in flexible packaging where the major use is in snack food packaging. BOPP film provides resistance to moisture vapor to keep snacks crisp and fresh tasting and provides a heat-sealable layer. Also, BOPP films are used in bakery products and many adhesive tapes packaging. An opaque film is a special kind of BOPP that is used in packaging products such as candy, chocolate bars, labeling, and lamination.

Industries involved in the plastic use chain in Indonesia uses BOPP plastic film as a paper cup, drink carrier, lunch box, and tray mat layer. Resource efficiency indicators calculation for plastic use chain is shown in **Table 3.7**. In this supply chain, only one industry is exclusively involved in the use of BOPP film, while several industries are involved in multiple supply chains (SC-2 through SC-4) which are excluded from analysis.

The industry itself uses electricity from PLN and has an energy productivity around 0.24 ton product/kWh. The value of CO_2e emission intensity has a value of 0.0036 ton CO_2e/ton product, which is estimated from greenhouse gases calculation method in the form of CO_2e based on the Greenhouse Gas Protocol (**Annex 4**). For SC-4, only scope 2 emissions are considered, which is comprised of electricity use provided by PLN. This industry has a waste intensity of 0.03 ton/ton product, which consists of domestic waste including paper and aluminum waste and also hazardous waste such as ink waste.

Table 3.6 Resource efficiency indicators calculation for plastic use chain

No.	Indicator	Value	Resource efficiency indicator	Value
1	Product (ton)	480		
2	Energy Use (kWh)	1,980	Energy Productivity (ton product/kWh)	0.24
3	Total CO_2e (ton)	1.75	CO_2e Emission Intensity (ton CO_2e/ton product)	0.0036
4	Total Waste (ton)	15	Waste Intensity (ton/ton product)	0.03

Indonesia Packaging Federation (IPF) mentioned about the use of single packaging in F&B. The fraction cost of plastic packaging for F&B is relatively low compared to the product, hence, industries are generally not aware of the used content in plastic packaging (multi-material, recyclability, etc.) as long as it complies with the food grade standard. Thus, plastic packaging development mainly focuses on how to attract potential consumers. Multi-layered packaging also has many components (types of plastics), both from the process, color, and also materials. As a result, the recycling process of multi-layered packaging itself is cumbersome because the plastic has to be separated based on its plastic type.

Therefore, one of the approaches is to improve the recyclability of plastic products is by using eco-design approach. Eco-design is the integration of environmental aspects into the product development process, by balancing ecological and economic requirements [27]. Eco-design considers environmental aspects at all stages of the product development process, striving for products that make the lowest possible environmental impact throughout the product life cycle. All stages of a product’s life cycle have potential environmental impacts, and different packaging materials create different types of environmental profiles. Thus, environmental improvement through eco-design can only be achieved on the basis of deep insight into packaging materials and the life cycle of packaged products [28].

3.2.5. Supply chain 5 (SC-5): collection, sorting and recycling

Collection, sorting, and recycling activities are classified into three different categories by the Indonesian Standard Industrial Classification (*Klasifikasi Baku Lapangan Usaha Indonesia*-KBLI) in 2020.

- Waste Collection classification (no. 381) is the collection of waste such as municipal waste, used batteries, used oils using trash cans, wheeled bins, garbage containers, and other kinds of transportation.
    - Non-Hazardous Waste Collection (no. 3811) is a subclassification that includes recoverable materials, recyclable materials, used oil, and public waste.
- Waste disposal and treatment (no. 382) are activities that treat and dispose various waste according to waste types, including waste-to-energy.
- Material Recovery (no. 383) are activities that produce secondary material from the recycling process, either mechanically or chemically. Its subclassification for recycling plastic aspect includes separation, sorting, and treatment (cleaning, melting, grinding) into flakes or pellets.
- Plastic processing industry (no. 222) includes the processing of virgin and/or recycled material into final or intermediate products, through various processes and molding.
    - Plastic packaging manufacturing (no. 2222) includes industries that generate plastic bags, sacks, containers, bottles, boxes, shelves, etc.

To approach the collection, sorting, and recycling supply chain, a questionnaire has been used to collect data for the collection & sorting activities, while data from SIINAS is used to analyze the recycling industry.

Collection and Sorting

For collection and sorting, the target of respondents includes waste management facilities, such as transfer depo, 3R transfer depo, waste bank, aggregator, and waste collectors. In Indonesia, these facilities often (but are not limited to) collect waste either directly from households, scavengers, or other collector facilities. The questionnaire is included in **Annex 1** and **Annex 2**. Commonly used plastic terms in these value chains are not classified by their chemical structure (such as PET, PP, etc.), but by the shape of the plastic, such as bottles, cups, sachets, and so on. As a result, the questionnaire options follow their common terms, which are defined in **Annex 1** and **Annex 2**. The lack of respondents is due to the COVID-19 situation and the limited time study period.

Based on the questionnaire result, scope activity of all the waste management facilities consists of collecting and sorting the waste. The source of waste varies, such as directly from households, transfer depo, and waste banks. Most of them sort waste manually. The 3R transfer depo usually compact plastic waste with a plastic waste press machine. The additional treatment in most 3R transfer depo includes cleaning labels or caps of the plastic bottle and packaging waste. The final product is mostly sorted plastic waste with economic value, such as bottles, plastic cups, etc. (not limited to PP). Both 3R transfer depo and waste bank distribute their final product to collectors or advanced recycle industries locally. PP plastic composition is around 22 to 56% of plastic waste which is equivalent to 1 to 25 kg/day. Meanwhile, study of waste data from *Badan Perencanaan Pembangunan Nasional* (Bappenas) and *Deutsche Gesellschaft für Internationale Zusammenarbeit* (GIZ) in 2022 in six cities/regencies has shown that collected PP plastic waste in transfer depo is around 5.86 to 26.05% of plastic waste. Difference in PP composition of plastic waste is caused by various preferences of waste collectors.

The six cities/regencies consist of Bukittinggi, Jambi, Bogor Regency, Cirebon, Malang, and Denpasar. Each of cities/regencies has their distinctive characteristics of waste and waste management flow. In Cirebon and Malang, PP plastic waste is dominant in commercial area and public facilities in form of food containers and transparent/colored cups. According to a study conducted in Java Island, the percentage of collected PP plastic are 25% PP rigid and 9% PP film [29].

In terms of resource productivity, waste management facilities vary in energy productivity with a range from 0.001 to 0.017 ton product/kWh. This value may not represent actual plastic energy productivity since electricity is also used for other waste processing activities besides plastic waste processing machines, lighting and air conditioning. Energy sources are comprised of purchased electricity from PLN and additional fuel such as solar and diesel.

The value of material productivity ranges from 0.750 to 1.000 ton product/ton material (received plastic waste material), while solid waste intensity has a range of 0 to 0.231 ton plastic waste/ton material. These material productivity and solid waste intensity performance show that the facilities mostly receive plastic waste that have economic value. According to a FGD with *Asosiasi Pengusaha Sampah Indonesia* (APSI), intermediates (3R transfer depo, waste bank, and informal collector) prefer to collect waste that have economic value (profitable, heavy weight). In addition, 3R transfer depo and waste banks only act as intermediary facilities before distributing their collected and sorted high-value plastic waste to end collectors or the advanced recycling industry, while low-value plastic waste is sent to landfills.

In some waste management facilities, most of the water source comes from PDAM and groundwater (difficult to measure the water consumption). The water consumption is primarily used for domestic purposes, not specifically for the plastic waste cleaning process which requires a relatively high amount of water. However, most of the facilities do not consider the water consumption and wastewater generation as important aspects.

Recycling

The data for the plastic recycling supply chain has been collected from formal recycling industries, which is not limited to PP plastic. **Figure 3.24** shows the percentage of plastic recycling industry with a total of 213,753 ton of products in 2019 to 2021. Industries that recycle plastic waste into only plastic pellets are industries R, S, T, and Y. Meanwhile, industries that recycle into plastic pellets and new plastic products are industries U, V, W, and X. Industry

U contributes the highest production with 58% of total recycled plastic production from 2019 to 2021 by 124,000 ton.

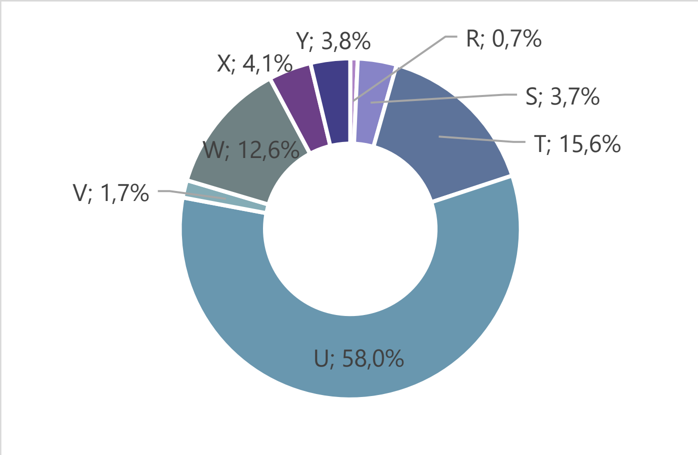


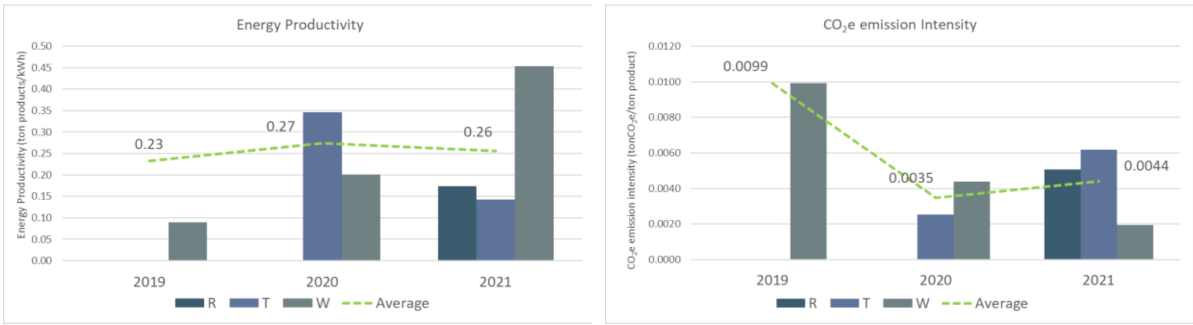
Figure 3.24 Plastic recycling industries product output

The product output of plastic recycling industries varies from plastic flakes, plastic pellets, plastic packaging, plastic bag, and other forms of plastic products. The outline of the recycling process consists of sorting, crushing, cleaning, and pelletizing to become plastic pellets. Some industries proceed to the next process (to produce new products) by extruding (to form plastic rolls) or molding (to form plastic packaging). Some industries are excluded from RE analysis due to unavailable data or due to outlier values.

Energy productivity and CO_2e emission intensity (SC-5)

According to SIINAS data, energy productivity average in recycling industry ranges from 0.23 to 0.27 ton products/kWh from 2019 to 2021 (**Figure 3.25(a)**). Recycling industries mainly use PLN as their source of energy, but an Industry uses its own generator to support its PLN electricity consumption. Even though most of the industries use PLN, but the value of energy productivity still varies. This indicates the different efficiency in energy use. Industries with energy productivity less than 0.2 ton products/kWh should use less energy intensive technology.

None industries reported CO_2e emissions from their operations, hence greenhouse gases are calculated in the form of CO_2e, which is adapted from the Greenhouse Gas Protocol (**Annex 4**), as shown in **Figure 3.23 (b)**. Emission category based on scope of activity is given in **Table 3.7**. The average of CO_2e emission intensity in recycling industry ranges from 0.0035 to 0.0099 ton CO_2e/ton product. Most CO_2e emission generated from fossil fuel combustion utilized by PLN (scope 2).



(a) (b)

Figure 3.25 (a) Energy productivity and (b) CO_2e emission intensity of plastic recycling industries

Table 3.7 Emission category based on scope of activity of collection, sorting and recycling chain

Emission category	2019	2020	2021	Total emission (ton CO_2e)	Percentage (%)*
Scope 1	-	-	-	-	**
Scope 2	89.05	79.32	104.43	272.79	100%
Scope 3	-	-	-	-	**

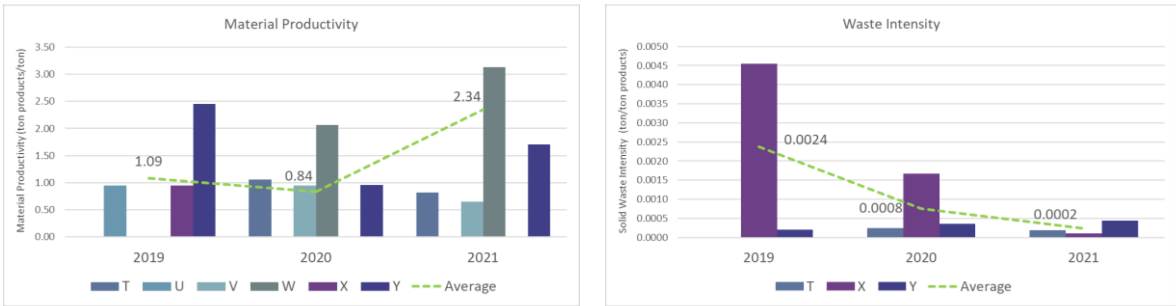
*Percentage only considers emission from scope 2

**Scope 1 and 3 is not calculated and considered in analysis

Material productivity and solid waste intensity (SC-5)

According to SIINAS data, material productivity average in recycling industry ranges from 0.84 to 2.34 ton products/ton from 2019 to 2021 (**Figure 3.26 (a**)). The difference between the amount of product output and the material could be due to unlisted material and different scopes of activity (recycle process to plastic pellet product or recycle process to new plastic product). From SIINAS data, materials are not only plastic scraps but there are industries that use additional virgin plastic.

Most industries generate hazardous waste, such as lubricant. Hazardous materials are mostly used for machine maintenance and operation. Waste intensity average in recycling industry ranges from 0.0002 to 0.0024 ton/ton products from 2019 to 2021 (**Figure 3.26 (b)**). Even though waste intensity average varies, but the value relatively low. This may be due to prior manual and selective sorting process before distribution to the recycling industry.



(a) (b)

Figure 3.26 (a) Material productivity and (b) solid waste intensity of plastic recycling industries

Water productivity and wastewater intensity (SC-5)

Mostly, the source of water consumption is freshwater (surface water/groundwater/PDAM water). Only one industry has reported the reuse or recycle of its water usage. According to SIINAS data, water productivity average in recycling industry ranges from 0.09 to 1.44 ton products/m^3 from 2019 to 2021 (**Figure 3.27 (a)**). APSI states that most recycling industries only retrieve clean plastic waste, hence need less water usage and water productivity will be high, while low water productivity may occur in industries that clean their incoming plastic waste. Water is also used for domestic purposes, which is influenced by the number of the labor.

Wastewater intensity average in recycling industry ranges from 0.64 to 1.20 m^3/ton products from 2019 to 2021 (**Figure 3.27 (b)**). This variation may be caused by different quality of product, different number of labor, and different scopes of activity (recycle process to plastic pellet product or recycle process to new plastic product). Besides that, some industry has already used wastewater treatment plant and used the treated water for the process.

(a) (b)

Figure 3.27 (a) Water productivity and (b) wastewater intensity of plastic recycling industries

The rate of plastic waste collection must be addressed in parallel with optimizing plastic waste recycling. The system of waste management with many actors in the value chain is common in Indonesia. Based on World Economic Forum's NPAP report [4], the informal sector, which involved scavengers or waste pickers, intermediates, and waste collectors, plays the main role in plastic waste collection. This sector collects around 7% of total plastic waste directly from residential areas and 8% of total plastic waste from collected waste that is in transit to landfills and from landfills themselves. Nearly all waste collected by the informal sector ends up at a recycling facility, therefore collection is conducted from the source up to the landfill sites. Informal sector workers are most active in and around large cities, as this is where recycling plants are concentrated, and population density is highest. In contrast, in remote areas of Indonesia, they play a very limited role in waste management. Most of the recycling industries are concentrated in Java Island (between 80% to 90%) with a much smaller concentration in Northern Sumatra. Furthermore, according to FGD with several associations, including APSI and ADUPI, the majority of recycling centers are centralized on Java Island. This is supported by SIPSN data, which shows that 40 out of 70 recycling centers are located on Java Island, with Central Java having 19 recycling centers, East Java having 17 recycling centers, and West Java having 4 recycling centers [30]. It should be determined whether recycling plastic can result in more efficient resources in the plastic supply chain or the contrary, considering the logistic costs of regions outside Java Island. Strategic measures need to be developed to shift plastic waste into a resource.

Possible Intervention (SC-5)

- In general, the gap in resource productivity and pollution intensity value between industries may be due to differences in industrial classifications in the plastic recycling industry (Waste Collection, Material Recovery for recycling into flakes or pellets, and Plastic Processing Industry for industry that produces new products from recycled material). It is necessary to determine the boundary during the collection of CE and RE data in the plastic industry and related stakeholders.
- To improve resource productivity, it is necessary to produce more recyclable plastics with low waste intensity by utilizing resource-efficient technologies for achieving better material efficiency.
- To reduce the CO_2e emission intensity, industries need to implementing cleaner production to make their operation more efficient.
- Increasing the plastic waste collection rate while advancing plastic waste recycling.

3.2.6. Supply chain 6 (SC-6): end of life

The disposal of plastic from municipal waste is shown in this study as an end-of-life phase from the supply chain. **Figure 3.28** shows the material flow analysis of PP plastic waste in Indonesia. Plastic waste is divided into high and low economic value. High economic value plastic is usually recycled into raw materials, such as flake or pellet (blue box in **Figure 3.28**), while low economic value plastic ends up in the landfill or leaks to the environment (orange box in **Figure 3.28**). Data used in the diagram is comprised of

- SIPSN data accessed on August 4, 2022, for national waste generation, recovered waste from landfills, and plastic waste composition [30].
- A study conducted by Widyarsana for material flow analysis and the number of waste facilities in Bali [31] [32].

- Studies conducted by Darus et al. for PP plastic waste percentage in the urban areas of Java Island and Hidayat et al. for PP plastic packaging percentage in Indonesia [29] [33].

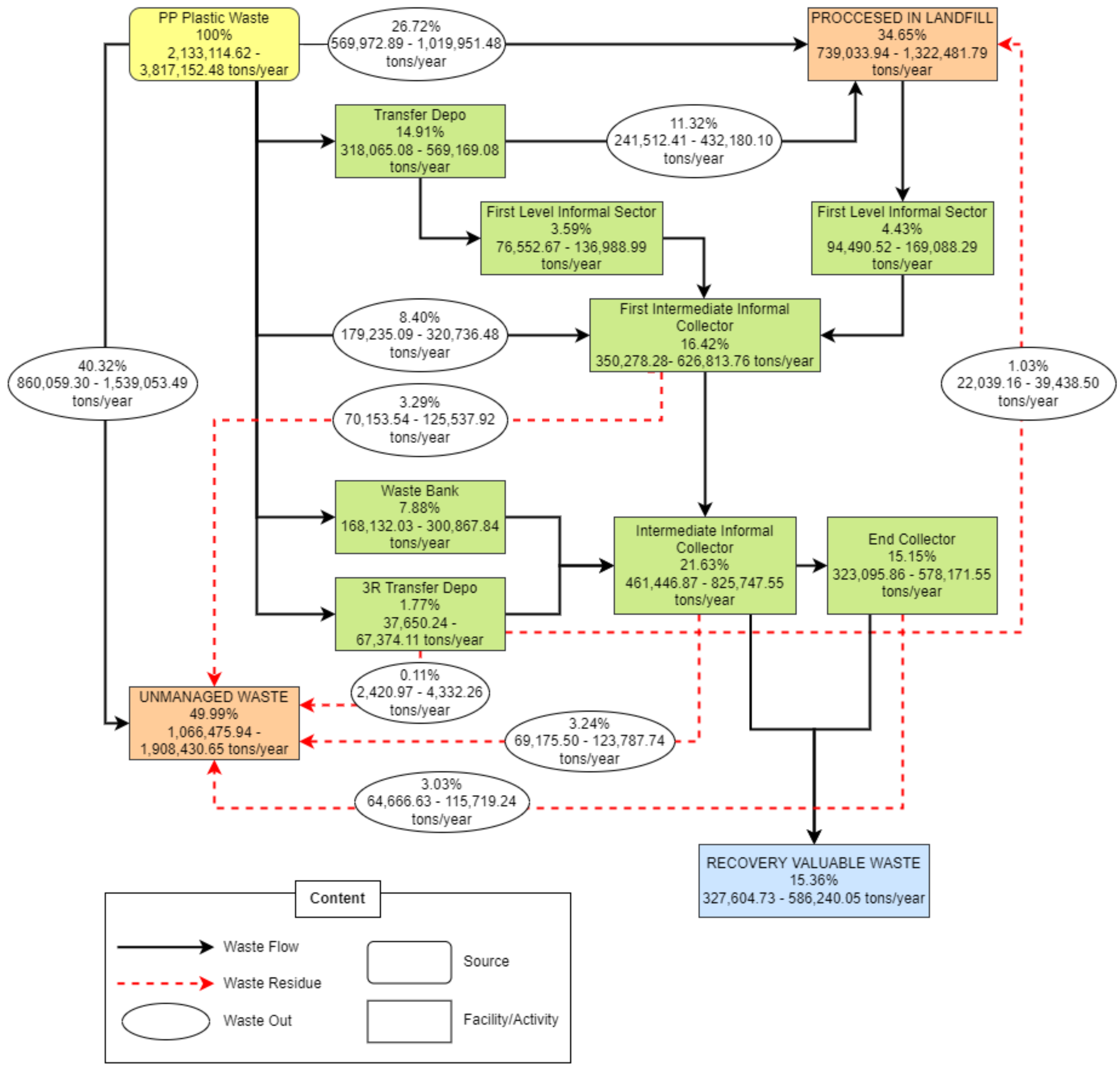


Figure 3.28 Material flow analysis of PP plastic waste in Indonesia

According to SIPSN, national waste generation in 2021 is **28,871,946.24 tons/year (230/541 City/Regency)**. With a plastic composition of **17.40%**, the extrapolated national plastic waste generation is approximately **11,226,919.06 tons/year.** The assumed **PP plastic waste composition ranges from 19%** [33] **to 34%** [29]**, with a tonnage range of 2,133,114.62 to 3,817,152.48 tons/year.** Calculation of extrapolation is attached in **Annex 3**. It has to be noted that the domestic demand of PP is only 1,800,000 tons/year, but the waste generation might be more than 2,000,000 tons/year. This difference is caused by unaccounted waste from imported product as well as domestic PP production.

The national plastic recycling percentage is estimated using three approaches. The first approach compares material input (plastic waste scrap of the plastic recycling industry, SC-5) to national PP plastic production capacity (3,483,000 tons/year), resulting in 5 to 6% of PP plastic being recycled. Meanwhile, the second approach compares material input to PP plastic waste generated (**Figure 3.28 – yellow box**), resulting in 4 to 9% of PP plastic being recycled. The last approach is based on MFA on **Figure 3.28 – blue box**, about 15.36% of valuable PP plastic waste is recovered and sold to a third party to be recycled. Assuming this fraction is supplied to industries in supply chains 2 and 3 in the form of polypropylene pellets, 327,604 to 586,240 tons/year of recycled material can be expected to substitute imported recycled material. As a result, the percentage of PP plastic recycling in this study ranges from 4 to 15%.

Plastic waste recycling will reduce the amount of plastic waste that ends up in landfills. Plastic waste recycling can be classified as

- Mechanical recycling, a process that is represented by a physical method and does not involve polymer modification. Plastic waste will be reprocessed by cutting, shredding, or washing into granulates, flakes or pellets for manufacturing. Then the flakes or pellets are melted and extruded to make new plastic product.
- Chemical recycling, a process of chemically converting polymers to monomers or partially depolymerizing polymers to oligomers. The resulting monomers can be used to create new polymerizations to reproduce the original or a related polymeric product, such as liquefication (plastic to oil).
- Thermal recycling (energy recovery), a process of incinerating waste that produces heat and exhaust gas which can be used to generate new energy sources. Energy recovery techniques include incineration with heat utilization or power generation, cement fuel, and refuse-derived fuel (RDF) [34] [3].

The vast majority of resources and products are still involved in a linear economy, despite the advantages of shifting toward a circular economy. The level of circular material use by society ranges from 6 to 37% globally, implying that 63 to 94% of all materials and products we currently consume are managed linearly [35]. According to a FGD with *Gabungan Pengusaha Makanan dan Minuman Seluruh Indonesia* (GAPMMI), many F&B industries tend to not prioritize the environmental impacts of plastic packaging they utilize because they believe plastic reduces food loss and waste. Moreover, according to several plastic associations including INAPLAS and ADUPI, plastic waste collection needs to be improved in order to make management at the end-of-life easier. The current state of insufficient PP plastic waste management at end of life is indicated by MFA in **Figure 3.28** that predicted 34.65% of PP plastic waste end up in landfills and 49.99% of PP plastic waste leaks into the environment.

Possible Intervention (SC-6)

Different practical approaches to promoting circularity and reducing waste production in the value chain can be applied. These interventions might be reactive, dealing with waste after it has been generated, or proactive, attempting to avoid waste generation. Proactive approaches are implemented during the product design stage when the majority of the environmental impacts of a product are determined. The approach of eco-design and sustainable design strategies varies from those focused on supporting decision making, such as design for recycling, design for material avoidance, and design for life extension, to those focused on supporting analysis, such as the material input per unit of service [35].

3.3. Summary of resource efficiency indicator evaluation

Figure 3.30,

Figure 3.31, and **Figure 3.32** show fishbones of resource productivity and pollution intensity indicators. Each aspect is further divided into 2 categories which correspond to internal (bones located on the left side of each branch) and external source (bones located on the right side of each branch). This fishbone diagram is a visualization tool for categorizing the potential causes of a problem. Using this diagram, the problem's root causes for low material productivity/high waste intensity, low energy productivity/high CO_2e emission, low water productivity/high wastewater intensity can be identified.

Energy productivity and CO_2e emission intensity

Plastic producing industry still rely on fossil fuels for their energy sources. Fossil fuel usage results in a high CO_2e emission. Calculation of CO_2e emission intensity of each supply chain has found that SC-1 emits the highest amount of CO_2e emission. This finding is consistent with several literatures which have reported a high amount of emission in the upstream industry. Emission intensity (in decreasing order) is then followed by SC-2, SC-3, SC-5 and lastly SC-4 (**Figure 3.29**).

The scope of CO_2e emissions vary within supply chains. For example, industries in SC-1 have an almost equal proportion (if compared to other SC) of scope 1 and 2 emissions due to high energy requirement. High energy use requires industries to partly provide their own energy source. SC-1 industries are closely related to upstream oil and gas companies which enables them to produce and utilize less carbon intensive fuels such as LNG. On the other hand, industries in SC-2 through SC-5 mainly release emissions from scope 2 activity, which indicates electricity dependency to PLN (**Table 3.8**). According to INAPLAS, electricity dependency to PLN is also driven by economic factor (relatively low price). Not many industries have started calculating scope 3 emissions, since it is comprised of other indirect emissions (besides scope 1 and 2) from upstream and downstream activities (currently reported by only 1 industry in SC-2).

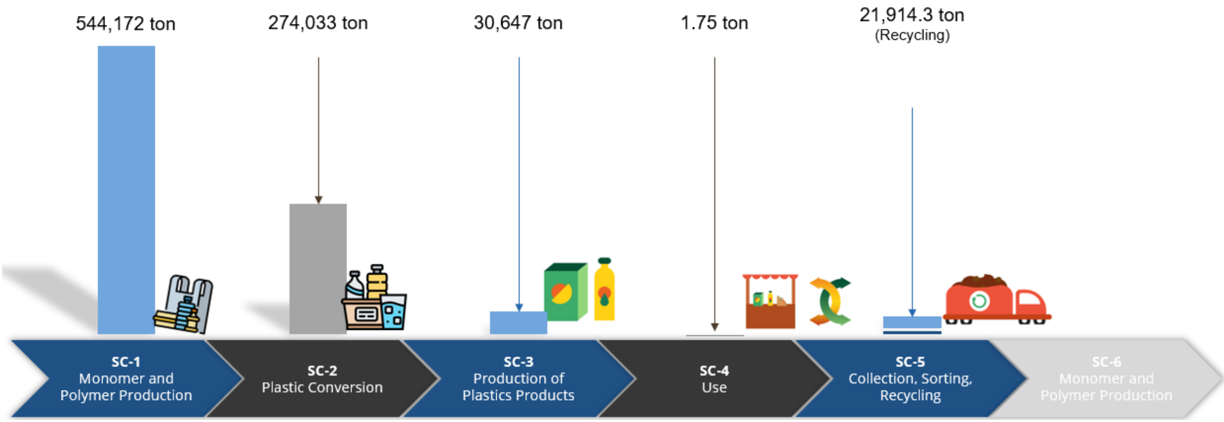


Figure 3.29 Total CO_2e emission intensity

Table 3.8 Emission source of supply chains based on scope of activity

Scope of activity	SC-1	SC-2	SC-3	SC-4	SC-5
Scope 1	46%	5.6%	0.49%	-	-
Scope 2	54%	94.2%	99.51%	100%	100%
Scope 3	*	0.2%	*	*	*

*Scope 3 emissions are not calculated for SC 1, SC 3-5

If 4 to 15% of PP plastic from the waste can be recycled, the range of avoided CO_2e emission in SC-3 will be up from 870 to 3,264 ton CO_2e. Regarding low energy productivity and high CO_2e emission intensity, two main issues have been identified in terms of management and technical aspects (**Figure 3.30**).

Industries do not put renewable energy as their priority since it is not a mandatory. Indonesia has pledged an unconditional 29% CO_2e emission reduction by 2030 (compared to BAU in 2020) based on Nationally Determined Contribution 2020. Manufacturing industries (including plastic producing industries) contribute 21.46% of GHG emissions from energy sector. However, the government has not yet issued a specific mitigation target to contribute towards said CO_2e emission reduction. Several policies have been issued for industries to manage CO_2e emissions although the basis is still voluntary participation, for instance, green industries (PP 29 Year 2018). Green industry is an industry which in its process prioritizes sustainable resource efficiency with respect to the environment to contribute towards society. Several programs in the green industry may contribute towards GHG emission reduction. Despite some ongoing and finished voluntary programs to minimize energy use and CO_2e emission, the increased use of renewables is highly encouraged.

Energy productivity and CO_2e emission intensity are also influenced by implementation and continuous improvement of cleaner production (CP). Limited CP implementation is caused by three main reasons: lack of management and individual awareness, lack of trained staff and limited energy sources choice. Based on collected data, awareness indicators are comprised of continuous evaluation and monitoring reports, which are still limited. Minimum staff training i.e., for energy saving campaign is also another contributor. Lastly, limited energy source in production process increases difficulty in CP implementation which will be further discussed in technical aspect.

In terms of technical problems, besides the use of fossil fuels, the non-competitive renewable energy installment cost, outdated production technology and gas flaring could lead to a high CO_2e emission intensity. The reliance on fossil fuel-based energy provided by PLN also adds to the problem. PLN predominantly uses coal as its source of energy, which produces a high emission intensity. Calculation of CO_2e emission by industries also considers purchased electricity from PLN (scope 2).

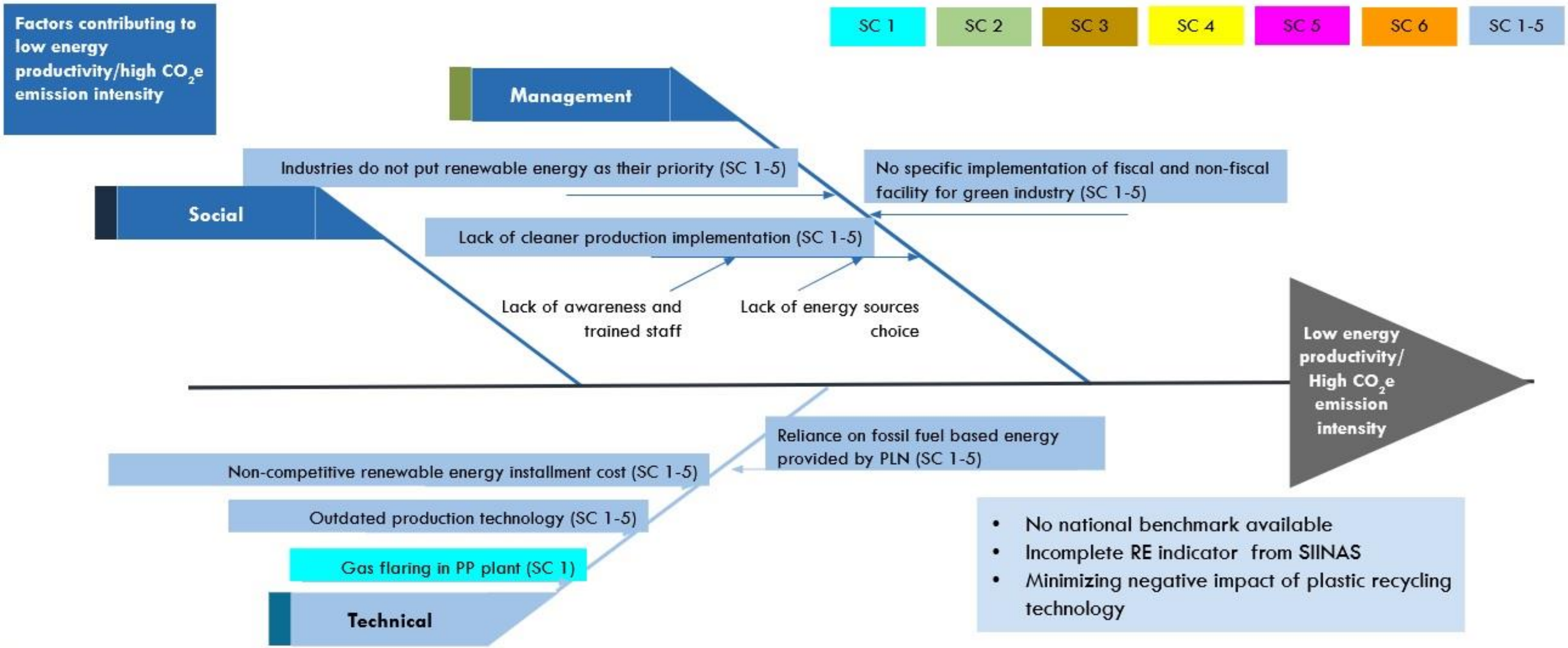


Figure 3.30 Energy productivity fishbone analysis

Material productivity and waste intensity

Regarding low material productivity and high waste intensity, three main issues have been identified in terms of management, technical as well as social aspect (

Figure 3.31). This study has defined material as raw material in form of plastics (virgin and scrap) as well as chemicals and additives used in production.

In terms of management aspect, lack of cleaner production implementation may lead to a high amount of waste produced. This is further caused by irresponsible handling of pellets due to lack of management and individual awareness as well as lack of trained staff. This practice would lead to wastage of valuable plastic material. Researchers have reported that seabirds, turtles and fish have ingested a variety of plastic items which are comprised of used consumer products and resin pellets which enter the waste stream and oceans. The plastics industry should also play a part in managing plastic pellets in order to avoid them in entering waterways. This is done through employee training to handle and dispose plastic pellets [36] [37]. European Union and New Zealand have published guidelines to promote zero pellets loss.

Besides cleaner production, unreliable reported use of materials may also lead to an inaccurate material productivity which is caused by the absence of compulsory environmental report (SIINAS reporting is not mandatory) and lack of trained staff in resource efficiency data identification. For example, several industries have not yet implemented waste sorting, which could lead to loss of valuable material that can be reused/recycled either internally or externally.

Several industries in SC-3 have reported different units of manufactured products (by weight/piece/roll). These industries have been omitted from analysis. As for waste, some industries have still reported accumulated waste in different units (by volume/weight/trucks) which increases the difficulty in data analysis.

Lastly, FGD with APSI have found that recycling facilities are not equally distributed. According to our interview, this is mainly caused by the majority of plastic waste accumulation in Java. In addition, labor cost is also lower than other areas in Indonesia, creating a preferable investment. Waste management actors outside Java have reported difficulty in distributing their plastic scraps due to high cost of logistics.

In terms of technical aspect, several problems have been identified. According to an interview with an industry in SC-1, outdated production technology has led to the inability of using environmentally friendly material in the production process. The use of this outdated production technology has also led to plastic product failure throughout SC-1 to SC-4. Several industries still do not optimize the use of recycled material, on the contrary, some recycling industries have reported using virgin material.

Lastly, most industries are still using multi-material and unnecessary packaging, which adds the level of difficulty in recycle. The use of multi-material and excess packaging by industries throughout SC-3 to SC-5 makes the recycling process difficult. Unused polypropylene usually ends up in landfills for energy production by RDF. According to GAPMMI, this is majorly caused by the low-cost fraction of plastic packaging production if compared to the actual product. Findings have shown that PP still remains an unfavorable material for recycling due to various reasons such as the use of multi-material, adhesives, color and lightweight characteristics. As a consequence, waste management actors would need to collect a high amount of waste to get a reasonable price. Despite present efforts in Indonesia, plastics are mainly recycled through an open-loop mechanism (IPF). Open-loop mechanism recycles food & beverage packaging to non-food-grade products. Striving towards an eco-design of packaging would increase the recyclability and enable close-loop recycling of PP plastics.

The Efficient Consumer Response (ECR) Community in Austria made a guideline for a broader target group in a practice-oriented way and focuses on the packaging system, including giving design recommendations for plastic packaging (**Table 3.9**). The three main criteria summarize the most important design features: material, decoration and other components, and closure system. The recommendations are divided into three categories: for the best case, if necessary, and to be avoided by the industries.

Table 3.9 Design recommendation for PP plastic packaging [38] [39]

Design feature	Best case	If necessary	To be avoided
Material	· Unpigmented as possible (transparent) or white · Consist of PP mono-material without barrier.	· A multi-layer composite material can be used if necessary if this is made up of different PP types (e.g., OPP, BOPP). · Additives can be added if the density of the base material remains < 1 g/cm³.	· A material compound with PS, PVC, PLA, PET, and PET-G should be avoided. · Carbon black-based colors which prevent detectability.
Decoration and other components	· If the packaging is printed directly, the printing inks must at least be European Printing Ink Association (EuPIA)-compliant and non-bleeding. · If labels and sleeves are used, they should be made of the same base material (PP) as the body.	· wet-strength paper labels are preferable to conventional paper labels. · Labels and sleeves made of PE and PET can be used if necessary and should be water-washable.	· Large-area decorations (> 50% of the packaging surface). · · Adhesive materials containing metal or aluminum (with a layer thickness of > 5 µm).
Closure system	· Ideally be made of the same basic material (PP) as the body with the same color, preferably without liners.	· Closures made of other materials such as PET-G, PS, and PLA should be avoided.	· Metals, thermosets, EPS PVC. · Sealing foils that are not completely

Design feature	Best case	If necessary	To be avoided
	· If sealing foils are used, they must be easy to remove without leaving any residue.		removable and contain an aluminum component (layer thickness > 5 µm)

Eco-design incentives could encourage a shift from rigid plastic packaging to transparent (pigment-free) mono-material formats that are more easily recycled into high-value products. Compared to clear or natural-colored packaging, color pigments used in plastic packaging can contaminate the recycling process and lead to lower value output. Then, if barrier requirements exist, a silicon oxide (SiO_x), an aluminum oxide (Al_2O_3) barrier, or a carbon plasma coating (for colored bottles only) can be used, as these do not significantly affect the quality of the recycle [4].

For product labels, these days, many manufacturers offer different shaped pots using IML (in-mold labeling), a labeling solution that is glue-free and therefore has no impact on process waters. This process consists of adding labels to a mold prior to injection or thermoforming and therefore bonding them without using glue or adhesives. Since this solution generally combines a PP label and body, it facilitates the recycling of packaging [40]. However, a high degree of printing can have a negative effect here, as the label is recycled together with the base material.

The implementation of the eco-design for plastic packaging also began to be developed to improve the after-use value of plastic products and packaging by a company. In 2021, this company outlined The Golden Rules – a comprehensive set of rules to guide their sustainable packaging transformation journey [41]. These should be applied to all packaging innovations and renovations, in order to improve design for recycling and overall environmental performance. They use several types of packaging including plastic packaging from polypropylene (PP). For rigid plastic packaging PP, they use mono PP and aim ethylene vinyl alcohol (EVOH) at 6% for their barrier layer, and ensure that material choice, adhesive choice, inks, and size is not problematic for recycling for all labels used. They also consider direct printing labels for the container, tray, lid, and pot but assessment at the local level must be performed and comply with Food safety and Ink standards. For the flexible package, they use mono PP films and use unlaminated film (basic film) for bags, when possible. They also avoid stickers/labels on the film. If required, the same material as the film should be used.

However, although a wide range of tools and methods now exist for assessing the environmental impact of a product, eco-design's contribution to increasing resource efficiency remains hard to evaluate and initiate, especially for one who still lacks awareness of knowledge about the environmental impact of individual stages and the possibility of using environmentally friendly materials. The greatest challenge of this phase is not the product itself, but the selection of the eco-design criteria to be applied, creating the basis for all ecological impacts of the product's life. In addition,

Table 3.10 summarizes the analysis of strength, weakness, opportunities, and threats related application of the eco-design in Poland and Spain.

Through surveys, interviews, and workshops with plastics packaging industry representatives, the report finds out what competency needs and skills shortages regarding the transformation towards the circular economy are recognized by the plastic packaging industry, including the eco-design approach in manufacturing processing throughout SWOT analysis shown on

Table 3.10. Still, eco-design plays a significant role in manufacturing companies 'quest for improved sustainability performance. It is believed that over 80% of all product-related environmental impacts are determined during the production phase [43]. As the most potential sector to apply the circular economy transformation, the development of properly designed packaging by the food & beverages industry is essential to reducing both costs and environmental impacts throughout the packaging's entire life cycle while maintaining food quality and safety. Packaging optimization based on the eco-design concept is becoming an important marketing factor and conveys the benefits of optimized packaging to the customer, which can make products more durable or easier to renew or recycle.

According to GAPMMI, low to middle income earners prefer to buy products in small quantities (in form of sachets). Sachets are composed of multi-material plastics (including PP), which is not preferred for recycle. Hence, low awareness and initiative of consumers in choosing environmentally friendly packaging are of concern in social aspect. According to Puspa [44], level of education and income has not a significant influence in determining preferences towards packaging products.

The GoI has already issued a Ministry of Environment and Forestry Regulation No. 75 of 2019 concerning Roadmap to Waste Reduction by Producers but implementation and detailed action plan are yet to be issued. Associations have expressed their concern towards this action plan.

Table 3.10 Summary of SWOT analysis regarding the eco-design approach in Poland and Spain [42]

Strengths	Weaknesses
· Ability to identify the environmental aspects related to a product and to integrate them into the design process. · Knowledge of the production process and product life cycle, which allows for reducing the material and energy consumption of products along the entire value chain. · Knowledge of consumer preferences and supplier market. · Ability to use new business models based on the circular economy.	· Risk of the real impact of the new materials. · Limitations resulting from the investments made in the field or "wrong choice" from the environmental point of view. · Limitations related to access to funds for investments and company development.
Opportunities	**Threats**
· Support for pro-ecological innovations on the European Union (EU) and national level through legal regulations and increasing social awareness. · Greater availability to obtain preferential financing. · Modern technologies enable the use of the company's potential and gain competitive advantages. · Opportunities to gain knowledge and improve skills in the field of pro-environmental competencies (universities, training companies).	· Growing competition in the market of pro-environmental products and technologies. · Too quick development of new technologies and their costs. · New strategies and guidelines in terms of perception force companies to be environmentally friendly - increasing demands on environmental aspects. · Non-competitive prices compared to traditional plastics.

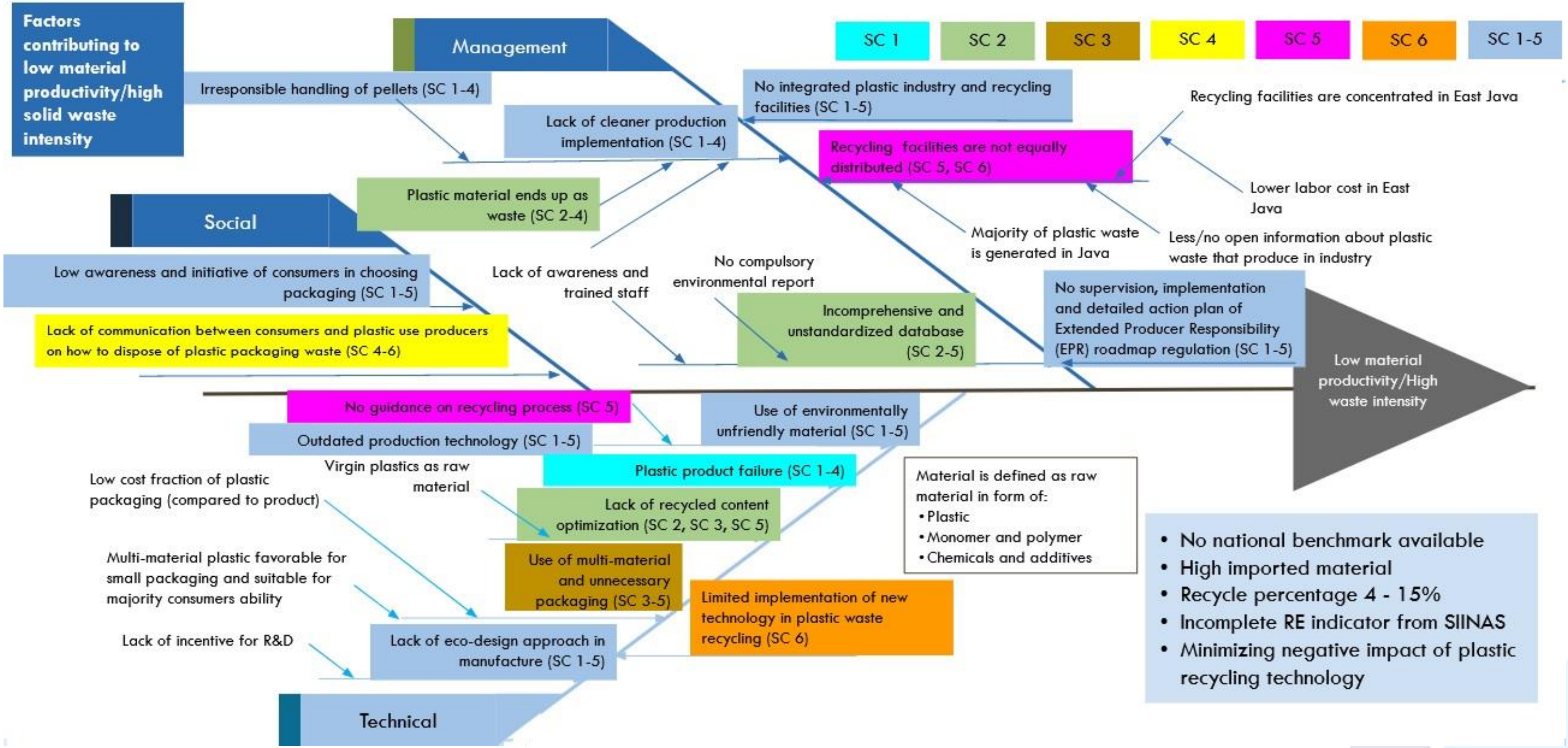


Figure 3.31 Material productivity fishbone analysis

Water productivity and wastewater intensity

Regarding water productivity and wastewater intensity, two problems have been identified in terms of management and technical aspect (**Figure 3.32**). As for technical problems, it has been identified that some industries still use water intensive technology if compared to other industries with similar production process.

In terms of management, the lack of water recycling implementation (SC-1 to SC-5) may lead to a low water productivity. High water use of material recycle purification in SC-5 is caused by the lack of dedicated public waste bins, low awareness of plastic waste sorting and lack of waste management system. This would ultimately lead to the mix of waste, thus needing a high amount of water to clean plastics before recycle. Several industries have already implemented water recycling programs in form of steam condensate recovery.

The lack of cleaner production further adds up to this issue. Lastly, unstandardized reported water use is caused by lack of trained staff and no compulsory environmental report may also lead to an underestimate/overestimate of used water.

Implementation of resource efficient programs and activities

Based on sustainability reports published by industries in SC-1 through SC-3, several programs have been implemented to minimize the use of resources. Programs vary from technical, management as well as social aspects.

Recyclability of PP plastics

The Indonesian government plans to reduce 70% plastic wastes by 2025 [45] by creating regulations which states a 5% recyclability of produced plastic from total production capacity (upstream industry) as well as a 25% recyclability of plastics from total production capacity (downstream industry) [46].

Based on this conducted study, it has been found that most industries still heavily rely on imported raw materials in their production process. By reducing the number of imported materials and increasing local material consumption, the concept of a circular economy may be implemented. Substituting imported recycled material with collected polypropylene waste of recovery value should meet a proportion of imported recycled material demand of industries.

Collected for recycling rate (CFR) of PP in Thailand [15], Philippines [16], and Malaysia [14] is at 10 – 20%, 30% and 25 – 35% consecutively. The finding in Thailand is consistent with our findings of 4 – 15%. Low CFR in Thailand is analyzed by the behavior of consumer products and did not account for collection for recycling rates of industrial PP packaging which tend to be much higher [15].

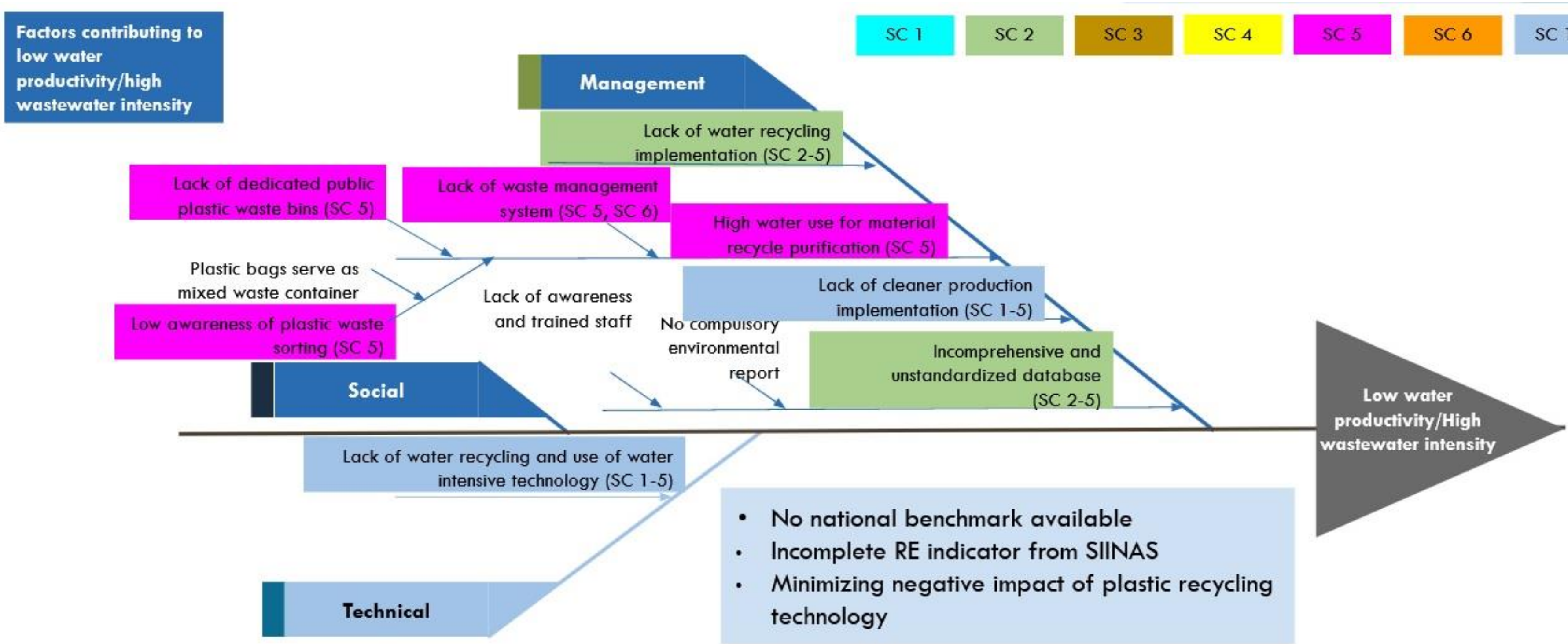


Figure 3.32 Water productivity fishbone analysis

To optimize plastic recycling in Indonesia, collection rate needs to be reinforced. Furthermore, sorting and separation from the waste source must be implemented to successfully meet the recycling rate target. Upgrading sorting and separation technology in waste management facilities can stimulate higher PP sorting rate from 31 to 81% each plant in EU, with the example of technology such as: trommel screen, Near Infrared (NIR), magnet, and etc. For mechanical recycling, recycling rate can be improved up to 53 to 72% each recycling plant in EU, with technological setup that also has additional sorting unit, such as: cascade screen, air classifier, density separator, and etc. For example, one of the recycling plants with 72% recycling rate using these unit operations: Feed hopper, film splitter, trommel, air classifier, NIR (5 times), wind sifter, manual sorting, baler, granulation, density separation (2 times), turbo wash, centrifuge dryer, air filter, and bagging [47]. Currently, available thermal recycling (energy recovery) in Indonesia options are RDF and waste power generation, such as incineration, gasification, and pyrolysis. The waste reduction potential of RDF is up to 75%, incineration is up to 80%, and both gasification and pyrolysis are up to 80 to 90% [48]. . RDF is the best practice to address the limitation of multilayer plastic recycling at the moment. In addition, some of the industry in Indonesia has implemented RDF as part of their waste management efforts.

Data as key strategy towards resource efficiency implementation

To implement a successful resource efficient process, a comprehensive and standardized database is required. Data variability in this study is caused by unavailable and inconsistent data. As the number of reported resource efficiency indicator varies from the analysis period (2018 – 2021), drawn conclusions may not give a completely accurate overview of the respective supply chain. Lastly, incomparable RE indicator data and reporting due to different scope of industry within the same industrial classification (KBLI) leads to the unavailability of national benchmark calculation. Data reported in SIINAS is collected based on KBLI, which is categorized by finished product (general classification). Ideally, data should be classified by type of resin and finished product.

Table 3.11 and **Table 3.12** show the summary of calculated resource productivity indicators and pollution intensity indicators respectively. Due to the absence of benchmarks, only a few indicators for SC-1 could be evaluated. SC-5 can be divided into two types: industries that recycle plastic waste into only plastic pellets (which could enter SC-2) and industries that recycle into plastic pellets and new plastic products (which could enter SC-3).

Values highlighted in red show indicators which are in need of improvement. In terms of pollution intensity, Indonesian industries involved in the production of polypropylene should reduce the amount of generated solid waste and CO_2e emission intensity.

Table 3.11 Productivity matrix of RE indicators

Productivity matrix			SC 1	SC 2	SC 3	SC 4	SC 5*	SC 5**
Material Productivity	ton product/ton material	Calculated	0.95	0.813	-	-	2.55	0.78
		Benchmark	-	-	-	-	-	-
Energy Productivity	ton product/kWh	Calculated	0.46	0.0006	0.005	0.24	0.25	0.30
		Benchmark	-	-	-	-	-	-
Water Productivity	ton product/m^3	Calculated	0.28	0.61	2.67	-	2.68	0.41
		Benchmark	-	-	-	-	-	-

*Recycled into only plastic pellets

**Recycled into plastic pellets and new plastic products

Table 3.12 Intensity matrix of RE indicators

Intensity matrix			SC 1	SC 2	SC 3	SC 4	SC 5*	SC 5**
Solid Waste Intensity	ton solid waste/ton product	Calculated	0.0026	0.013	5.22 (non HW) 0.4 (HW)	0.03	0.0003	0.0021
		Benchmark	0,0013	-	-	-	-	-
CO_2e Intensity	ton CO_2e/ton product	Calculated	0.803	1.21	0.6	0.0036	0.0041	0.0054
		Benchmark	0,403	-	-	-	-	-
Wastewater Intensity	m^3/ton product	Calculated	0.12	0.156	-	-	0.90	0.89
		Benchmark	-	-	-	-	-	-

*Recycled into only plastic pellets

**Recycled into plastic pellets and new plastic products

4. Strategy formulation for resource efficiency implementation

Three strategic categories consisting of technical, management and social aspects have been identified in this study. Period of implementation are divided into short term (1 – 3 years), medium term (5 years) and long term (10 – 25 years). **Table 4.1** shows the proposed strategy for resource efficiency implementation in plastics packaging of each supply chain.

Table 4.1 Proposed strategy for resource efficiency implementation in plastic packaging

	Stage		Order	Aspect	Strategy	Stakeholder	Policy	Period
SC-1	Monomer and polymer production		1	Management	Implementing regular employee training of **good housekeeping** practice **(cleaner production)**	Industry, Association	- Ministry of Industry decree No. P.18/2016 on Green Industry Award - Ministry of Environment and Forestry decree No. P.1/2021 concerning Company Performance Assessment Program in Environment Management	Short term
			2	Management	**Responsible handling** of pellets, e.g., eliminating plastic pellets loss for improving plastic conversion efficiency and technical improvement by installing special pellets retainers and strainer.	Industry, Association		Short term
			3	Technical	Reducing monomer and polymer imports, **increasing local** monomer and polymer **production**	Industry, Kemendag, Kemenperin (PIH, IKHF), Association	Presidential Regulation of Republic of Indonesia No. 74/2022 concerning National Industrial Policy for 2020-2024	Medium term
			4	Technical	Renewing the **technology** for **PP production** with high resource efficiency, low waste and low emission intensity	Industry, Kemenperin (PIH, IKHF), KLHK, Association	Regulation of the Minister of Industry concerning the Third Amendment to the Regulation of the Minister of Industry Number 27/M-IND/PER/7/2017 concerning the Growth and Development of Small and Medium Industries through the Machine and/or Equipment Restructuring Program	Long term
			5	Technical	Improving the use of **environmentally friendly material** for PP production **(cleaner production)**	Industry, Kemenperin (PIH, IKHF), KLHK, Association	Guidelines and Criteria for Recycled Polyethylene Terephthalate (PET) Plastics Safe for Food Packaging (to be developed for PP)	Long term
			6	Technical	Developing of alternative, **substitute materials** for plastics **(eco-design)**	Industry, Kemenperin (PIH, IKHF), Association	Guidelines and Criteria for Recycled Polyethylene Terephthalate (PET) Plastics Safe for Food Packaging (to be developed for PP)	Long term
			7	Technical	Improving the use of **renewable energy** for plastic production	Industry, Kemenperin (PIH, IKHF), KLHK, Association, PLN	- Ministry of Industry decree No. P.18/2016 on Green Industry Award - Ministry of Environment and Forestry decree No. P.1/2021 concerning Company Performance Assessment Program in Environment Management	Long term
SC-2	Plastic conversion		1	Management	Implementing regular employee training of good housekeeping practice **(cleaner production)**	Industry, Association (ABOFI)	- Ministry of Industry decree No. P.18/2016 on Green Industry Award - Ministry of Environment and Forestry decree No. P.1/2021 concerning Company Performance Assessment Program in Environment Management	Short term
			2	Management	**Responsible handling** of pellets, e.g., eliminating plastic pellets loss for improving plastic conversion efficiency and technical improvement by installing special pellets retainers and strainer **(cleaner production)**	Industry, Association (ABOFI)		Short term

	Stage		Order	Aspect	Strategy	Stakeholder	Policy	Period
			3	Technical	Reducing raw material imports, **increasing local material** consumption	Industry, Kemendag, Kemenperin (PIH, IKHF), Association (ABOFI)	Presidential Regulation of Republic of Indonesia No. 74/2022 concerning National Industrial Policy for 2020-2024	Medium term
			4	Technical	Maximizing the **recycled content** in PP plastic conversion	Industry, Kemenperin (PIH, IKHF), Association (ABOFI)	Guidelines and Criteria for Recycled Polyethylene Terephthalate (PET) Plastics Safe for Food Packaging (to be developed for PP)	Long term
			5	Technical	Developing of alternative, **substitute materials** for plastics **(eco-design)**	Industry, Kemenperin (PIH, IKHF), Association	Guidelines and Criteria for Recycled Polyethylene Terephthalate (PET) Plastics Safe for Food Packaging (to be developed for PP)	Long term
			6	Technical	Improving the use of **renewable energy** for plastic conversion	Industry, Kemenperin (PIH, IKHF), KLHK, Association (ABOFI), PLN	- Ministry of Industry decree No. P.18/2016 on Green Industry Award - Ministry of Environment and Forestry decree No. P.1/2021 concerning Company Performance Assessment Program in Environment Management	Long term
SC-3	Production of plastics products		1	Management	Implementing regular employee training of **good housekeeping** practice **(cleaner production)**	Industry, Association	- Ministry of Industry decree No. P.18/2016 on Green Industry Award - Ministry of Environment and Forestry decree No. P.1/2021 concerning Company Performance Assessment Program in Environment Management	Short term
			2	Technical	Maximizing the **recycled content** in production of PP plastic products	Industry, Kemenperin (PIH, IKHF), Association	- Guidelines and Criteria for Recycled Polyethylene Terephthalate (PET) Plastics Safe for Food Packaging (to be developed for PP) - Ministry of Industry decree No. P.18/2016 on Green Industry Award - Ministry of Environment and Forestry decree No. P.1/2021 concerning Company Performance Assessment Program in Environment Management	Long term
			3	Technical	Reducing and **introducing** plastic failure for a **close loop** production of plastic products	Industry, Kemenperin (PIH, IKHF), KLHK, Association (GAPMMI)	- Ministry of Environment and Forestry decree No. P.75/2019 on Roadmap to Waste Reduction by Producers - Ministry of Industry decree No. P.18/2016 on Green Industry Award - Ministry of Environment and Forestry decree No. P.1/2021 concerning Company Performance Assessment Program in Environment Management	Short term
			4	Technical	Encouraging **mono material** for plastic products	Industry, Kemenperin (PIH, IKHF), KLHK, Association (GAPMMI)	Ministry of Environment and Forestry decree No. P.75/2019 on Roadmap to Waste Reduction by Producers	Long term

	Stage		Order	Aspect	Strategy	Stakeholder	Policy	Period
			5	Technical	Developing of alternative, **substitute materials** for plastics **(eco-design)**	Industry, Kemenperin (PIH, IKHF), Association	Guidelines and Criteria for Recycled Polyethylene Terephthalate (PET) Plastics Safe for Food Packaging (to be developed for PP)	Long term
			6	Technical	Improving the use of **renewable energy** for plastic production	Industry, Kemenperin (PIH, IKHF), KLHK, Association, PLN	- Ministry of Environment and Forestry decree No. P.75/2019 on Roadmap to Waste Reduction by Producers - Ministry of Industry decree No. P.18/2016 on Green Industry Award - Ministry of Environment and Forestry decree No. P.1/2021 concerning Company Performance Assessment Program in Environment Management	Long term
SC-4	Use		1	Technical	Reducing plastic imports consumption, **increasing** plastic **local** consumption	Industry, Kemendag, Kemenperin (PIH, IKHF), Association	Presidential Regulation of Republic of Indonesia No. 74/2022 concerning National Industrial Policy for 2020-2024	Medium term
			2	Technical	Selecting **good quality** of PP plastic **material** to avoid failure of plastic packaging	Industry, Kemenperin (PIH, IKHF), Association	- National Agency of Drug and Food Control (BPOM) regulation No. 20/2019 on Food Packaging - National Standardization Board (BSN) regulation No. 11/2019 on Plastic Packaging	Short term
			3	Technical	Use **mono material** structure for plastic packaging to enable recyclability	Industry, Kemenperin (PIH, IKHF), KLHK, Association (GAPMMI)	Ministry of Environment and Forestry decree No. P.75/2019 on Roadmap to Waste Reduction by Producers	Long term
			4	Technical	Eliminating problematic or **unnecessary packaging** to avoid waste in end user	Industry, Kemenperin (PIH, IKHF), BPOM, Association	- National Agency of Drug and Food Control (BPOM) regulation No. 20/2019 on Food Packaging - National Standardization Board (BSN) regulation No. 11/2019 on Plastic Packaging	Long term
			5	Technical	Improving of the **sustainability performance** of the packed product **(eco-design)**	Industry, Kemenperin (PIH, IKHF), KLHK, BPOM, Association	- National Agency of Drug and Food Control (BPOM) regulation No. 20/2019 on Food Packaging - National Standardization Board (BSN) regulation No. 11/2019 on Plastic Packaging	Long term
			6	Technical	Developing of alternative, **substitute materials** for plastics **(eco-design)**	Industry, Kemenperin (PIH, IKHF), Association	Guidelines and Criteria for Recycled Polyethylene Terephthalate (PET) Plastics Safe for Food Packaging (to be developed for PP)	Long term
			7	Technical	Improving the use of **renewable energy** for plastic conversion	Industry, Kemenperin (PIH, IKHF), KLHK, Association, PLN	- Ministry of Industry decree No. P.18/2016 on Green Industry Award - Ministry of Environment and Forestry decree No. P.1/2021 concerning Company Performance Assessment Program in Environment Management	Long term

	Stage		Order	Aspect	Strategy	Stakeholder	Policy	Period
SC-5	Collection, sorting, recycling		1	Management	Developing **safety guidance and standard** for PP plastic collection, sorting, and recycling	KLHK, Kemenperin (PIH, IKHF), Association (GAPMMI, APSI, ADUPI, INAPLAS, APHINDO)	Guidelines and Criteria for Recycled Polyethylene Terephthalate (PET) Plastics Safe for Food Packaging (to be developed for PP)	Short term
			2	Management	Improving collecting and sorting of **plastic waste management** system to reduce water use for material recycle purification	KLHK, Kemenperin (PIH, IKHF), Industry, Association	Ministry of Environment and Forestry decree No. P.75/2019 on Roadmap to Waste Reduction by Producers	Long term
			3	Technical	Increasing **recycling capacity** to process PP plastic waste	Industry, KLHK, Kemenperin (PIH, IKHF), PUPR, Association (GAPMMI, APSI, ADUPI, INAPLAS, APHINDO)	Ministry of Environment and Forestry of Republic Indonesia No. P.7/Menlhk/Setjen/Kum.1/1/2020 Concerning The Use of Special Physical Allocation Funds For Environment And Forestry Assignment For The 2020 Fiscal Year	Long term
			4	Technical	Increasing the **pellets production** from PP plastics waste	Industry, Kemenperin (PIH, IKHF), KLHK, Association (GAPMMI, APSI, ADUPI, INAPLAS, APHINDO)	Ministry of Environment and Forestry decree No. P.75/2019 on Roadmap to Waste Reduction by Producers (to be developed for PP)	Long term
			5	Technical	Improving of the **sustainability performance** of the packed product **(eco-design)**	Industry, Kemenperin (PIH, IKHF), KLHK, BPOM, Association	- National Agency of Drug and Food Control (BPOM) regulation No. 20/2019 on Food Packaging - National Standardization Board (BSN) regulation No. 11/2019 on Plastic Packaging	Long term
			6	Technical	Developing of alternative, **substitute materials** for plastics **(eco-design)**	Industry, Kemenperin (PIH, IKHF), Association	Guidelines and Criteria for Recycled Polyethylene Terephthalate (PET) Plastics Safe for Food Packaging (to be developed for PP)	Long term
			7	Technical	Improving the use of **renewable energy** for collection, sorting and recycling	Industry, Kemenperin (PIH, IKHF), KLHK, Association (GAPMMI, APSI, ADUPI, INAPLAS, APHINDO), PLN	- Ministry of Industry decree No. P.18/2016 on Green Industry Award - Ministry of Environment and Forestry decree No. P.1/2021 concerning Company Performance Assessment Program in Environment Management	Long term
			8	Technical	Identifying and **quantifying of chemical inputs** (e.g. sodium hydroxices, washing agents, defoamants) as well as reducing water use in PP reclamation	Industry, Kemenperin (PIH, IKHF), KLHK, Association (GAPMMI, APSI, ADUPI, INAPLAS, APHINDO)	National Industrial Information System	Medium term
			9	Technical	**Chemical recycling** of plastic waste **as feedstock** for petroleum refineries or other chemical treatment facilities	Industry, Kemenperin (PIH, IKHF), KLHK, Association (GAPMMI, APSI, ADUPI, INAPLAS, APHINDO)	Ministry of Environment and Forestry decree No. P.75/2019 on Roadmap to Waste Reduction by Producers (to be developed for PP)	Medium term
SC-6	End of life		1	Technical	Considering the plastic waste management not only by the conventional technology (mechanical	KLHK, Kemenperin (PIH, IKHF), Association	Ministry of Environment and Forestry decree No. P.75/2019 on Roadmap to Waste Reduction by Producers	Long term

	Stage		Order	Aspect	Strategy	Stakeholder	Policy	Period
					recycling or landfilling), but also considering **new technology** such as pyrolysis technology, polymer blended-bitumen road, and co-processing of plastic waste), RDF (thermal recycling)	(GAPMMI, APSI, ADUPI, INAPLAS, APHINDO)		
			2	Technical	**Further research** on emission of organic compound from thermal recycling, and developing supporting infrastructure for waste monitoring	KLHK, Kemenperin (PIH, IKHF), Association (GAPMMI, APSI, ADUPI, INAPLAS, APHINDO)		Long term
			3	Technical	Improving of the **sustainability performance** of the packed product **(eco-design)**	Industry, Kemenperin (PIH, IKHF), KLHK, BPOM, Association	- National Agency of Drug and Food Control (BPOM) regulation No. 20/2019 on Food Packaging - National Standardization Board (BSN) regulation No. 11/2019 on Plastic Packaging	Long term
			4	Technical	Developing of alternative, **substitute materials** for plastics **(eco-design)**	Industry, Kemenperin (PIH, IKHF), Association	Guidelines and Criteria for Recycled Polyethylene Terephthalate (PET) Plastics Safe for Food Packaging (to be developed for PP)	Long term
Additional	**Regulation**	SC-5 SC-6	1	Management	Implementation of **regulation** of the plastic waste handling (Ministry of Environment and Forestry Regulation No. 75 of 2019 concerning Roadmap to Waste Reduction by Producers) including Extended Producer Responsibility	KLHK, Kemenperin (PIH, IKHF), Industry, Association	Ministry of Environment and Forestry decree No. P.75/2019 on Roadmap to Waste Reduction by Producers	Long term
		SC-2 SC-3 SC-4 SC-5	2	Management	Supervising the **phase out** of non-recyclable multi-material structures and single use PP packaging	KLHK, Kemenperin (PIH, IKHF), Industry, Association	Ministry of Environment and Forestry decree No. P.75/2019 on Roadmap to Waste Reduction by Producers	Medium term
		SC-1 SC-2 SC-3 SC-4 SC-5	3	Management	Policy related to the **integrated industrial park** enabling the recycle, reuse, and recovery of PP waste as possible resource	KLHK, Kemenperin (PIH, IKHF), Industry, Association (GAPMMI)	Government decree P.145/2015 on Industrial Parks	Short term
		SC-5 SC-6	4	Management	Policy focusing on the collection and management of PP **waste infrastructure**	KLHK, Kemenperin (PIH, IKHF), Industry, Association	Ministry of Environment and Forestry decree No. P.75/2019 on Roadmap to Waste Reduction by Producers	Short term
		SC-2 SC-3 SC-5	5	Management	Policy focusing on the **distribution of recycle infrastructure** close to the source of the plastic waste	KLHK, Kemenperin (PIH, IKHF), Industry, Association		Short term
		SC-1 SC-2	6	Management	Specific implementation of **fiscal** and **non-fiscal facility** for green industry	KLHK, Kemenperin (PIH, IKHF), Industry, Association		Long term

	Stage		Order	Aspect	Strategy	Stakeholder	Policy	Period
		SC-3 SC-4 SC-5						
		SC-2 SC-3 SC-4 SC-5	7	Technical	Redesigning and **standardizing plastic packaging** for easy collection and recycling, whilst keeping material properties and economic value (Redesign plastic packaging for improved recyclability)	KLHK, Kemenperin (PIH, IKHF), Industry, Association		Long term
Additional	**Behavior**	SC-1 SC-2 SC-3 SC-4 SC-5 SC-6	1	Social	Educating and increasing **social awareness** to avoid using single use and non-recycleable plastics	Society, industry, KLHK, Kemenperin (PIH, IKHF), DLH, Association	Ministry of Environment and Forestry decree No. P.75/2019 on Roadmap to Waste Reduction by Producers	Long term
		SC-5 SC-6	2	Social	Engaging and improving **communication responsibly** with consumers on how to dispose of packaging	Society, industry, KLHK, Kemenperin (PIH, IKHF), DLH, Association		Long term
Additional	**Improvement of data collection on CE and RE indicators**	SC-1 SC-2 SC-3 SC-4 SC-5 SC-6	1	Management	Setting up **comprehensive** and **standardized system** for CE and RE indicators data collection	Kemenperin (PIH, IKHF), KLHK	- Ministry of Environment and Forestry decree No. P.1/2021 concerning Company Performance Assessment Program in Environment Management - National Industrial Information System - National Waste Management Information System	Short term
		SC-1 SC-2 SC-3 SC-4 SC-5 SC-6	2	Management	Determination of **boundary** during CE and RE data collection in plastic industry and related stakeholders	Kemenperin (PIH, IKHF), KLHK		Short term
		SC-1 SC-2 SC-3 SC-4 SC-5 SC-6	3	Management	Expanded set of **environmental indicators** such as acidification potential, eutrophication potental, and smog formation potential	Kemenperin (PIH, IKHF), KLHK		Short term
		SC-1 SC-2 SC-3	4	Management	**Monitoring, reporting, and evaluating** CE and RE indicators data periodically	Industry, KLHK, Kemenperin		Long term

	Stage		Order	Aspect	Strategy	Stakeholder	Policy	Period
		SC-4 SC-5 SC-6			and developing **National Scale Benchmark**			
	Stage			Aspect	Strategy	Stakeholder	Policy	Period
Additional	Technology perspective	SC-1 SC-2 SC-3 SC-4 SC-5	1	Technical	Production of **renewable plastics** with low waste intensity (changing to renewable resources and utilizing resource-efficient technologies for achieving better material efficiency and reduction in the use of fossil resources in the value chain of plastics)	Industry, Kemenperin (PIH, IKHF), Kemendikbudristek, BRIN	Ministry of Industry decree No. P.18/2016 on Green Industry Award	Long term
		SC-1 SC-2 SC-3 SC-4 SC-5 SC-6	2	Technical	Design to make the **close loop** of PP for the similar use	Industry, Kemenperin (PIH, IKHF), Kemendikbudristek, BRIN, Association (GAPMMI)	Ministry of Environment and Forestry decree No. P.75/2019 on Roadmap to Waste Reduction by Producers	Long term
		SC-1 SC-2 SC-3	3	Technical	Design to **enable easy sorting** and ensure that packaging is detectable in automated sorting facilities.	Industry, Kemenperin (PIH, IKHF), Kemendikbudristek, BRIN	Regulation of the Minister of Industry concerning the Third Amendment to the Regulation of the Minister of Industry Number 27/M-IND/PER/7/2017 concerning the Growth and Development of Small and Medium Industries through the Machine and/or Equipment Restructuring Program	Long term
		SC-1 SC-2 SC-3	4	Technical	Uncoloured, transparant, stream, or lightly coloured materials are preferred to **maximize value of the recycling** (Removing dyes and additives to minimizes the loss rate of plastics in mechanical recycling)	Industry, Kemenperin (PIH, IKHF), Kemendikbudristek, BRIN		Long term
		SC-1 SC-2 SC-3	5	Technical	**Incentive** for research and development of redesign plastic packaging, green technology (Resource Efficiency and Cleaner Production), and circular economy for polylpropylene (PP) industry.	Industry, Kemenperin (PIH, IKHF), KLHK, Kemendikbudristek, BRIN		Long term

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Annex 1: Questionnaire Question

No.	Question	Option	Unit	Description
A	**Plastic waste management and processing**			
1	Facility location name	text entry		
2	Facility district	text entry		
3	Facility regency/city	text entry		
4	Accepted sources of plastic waste	collector		
		households		
		TPS		
		TPS3R		
		waste bank		
		importer		
		other, please specify		
5	Average weight of plastic waste from each source	text entry	kg/day	
6	Plastic waste management at the facility	collecting only		
		sorting only		
		collecting and sorting		
7	Plastic waste processing at the facility	crushing		
		compacting		
		grinding		
		pelletizing		
		craft-making		
		other, please specify		
8	Resource used in plastic waste processing	manual with labor		
		with machinery		
		mixed between labor and machinery		

No.	Question	Option	Unit	Description
9	Plastic waste processing method explanation	text entry		If there are more than two processing methods, please list them in order.
	If using machinery, which machine does the facility use?			
10	Number of workers by function	text entry		Example: collection officer= 2 people; sorting officer= 5 people; administration = 1 person.
11	Target distribution of the final product produced	collector		
		producer industry		
		further recycling industry		
		retail		
		directly to consumers		
		other, please specify		
12	The location of final product distribution is delivered	text entry		Filled with the format: Place name - Regency/City. Example: Recycling industry - Bandung City
B	**Plastic waste collection**			
1	Collected plastic waste by type	transparent drink bottle		PET
		colored drink bottle		PET
		blowing packaging (shampoo, soap, floor cleaner bottles)		HDPE
		oil bottle		PVC
		bottle cap		PP
		styrofoam		PS
		water gallon		Other
		transparent cup		PP

No.	Question	Option	Unit	Description
		colored cup		PP
		rigid food packaging		PP
		sachet packaging		multilayer
		clear plastic sheet		PP, PE
		other, please specify		
2	Average weight of plastic waste collected	text entry	kg/day	Example: Transparent drink bottle = 3 kg/day
C	**Plastic waste sorting**			
1	Sorting method	manual with labor		
		with machinery		
		mixed between labor and machinery		
2	Plastic waste sorting method explanation	text entry		
	If using machinery, which machine does the facility use?			
D	**Plastic waste final product**			
1	Additional plastic waste processing	label/bottle cap cleaning		
		washing		
		packaging		
		no further processing		
		other, please specify		
2	Other materials used to process plastic waste	text entry	kg/day; liter/day; etc.	Example: boxes/plastics/sacks for packing 3 kg/day, 5 liters of chemicals/day etc.
	Specify with the amount			
3	Byproduct from recycling process	plastic flakes		
		plastic pellets		

No.	Question	Option	Unit	Description
		craft works		
		other, please specify		
4	The capacity of the product produced	text entry	tons/month; kg/day	Example: plastic pellets = 1 kg/day.
5	Average final product sales by product type	text entry	Rp/day; Rp/month	Example: transparent drink bottle = Rp 50.000/day
E	**Energy**			
1	Energi source	public electric company (PLN)		
		diesel/solar		
		generator set		
		other, please specify		
2	Average amount of energy used, by source	text entry	kWh/month; ton/month; MJ; Rp/month	Example: PLN = 2,500 kWh/month; Diesel = 3 tons/month.
3	Energy uses	plastic waste processing equipment		
		lighting, air conditioning, etc.		
		other, please specify		
F	**Water and wastewater**			
1	Water source	public water supply company (PDAM)		
		groundwater		
		other, please specify		
2	Average amount of water used, by source	text entry	Rp/month; m3/month; the amount of buckets/day	Assume 1 bucket = 10 L (bucket of paint). Example: PDAM = Rp 3.000.000/month; Ground water = 4 buckets/day
3	Water use	plastic waste washing		

No.	Question	Option	Unit	Description
		plastic waste processing (cooling, evaporation)		
		domestic use		
		other, please specify		
4	Wastewater treatment	discharged into the environment (via sewers)		
		use septic tank		
		other, please specify		
5	Wastewater treatment costs	text entry	Rp/month	Example: using a third party service to empty a septic tank Rp. 1,000,000/month.
G	**Solid waste**			
1	Solid waste generated, by type	non-recyclable plastics		
		defective products, raw materials packaging, etc. (can be recycled)		
		hazardous and toxic waste		
		other, please specify		
2	Average weight of solid waste, by type	text entry	kg/day	Example: non-recyclable plastics = 4 kg/day; recyclable plastics = 2 kg/day; Hazardous and Toxic Waste = 0.5 kg/day.
3	Solid waste distribution	Third party		
		Landfill (TPA)		
		other, please specify		
4	If using a third party, please specify the third party	text entry		Example: Hazardous and Toxic Waste treatment plant, other industries, etc.
5	Total costs for solid	text entry	Rp/month	Example: landfill (TPA)

No.	Question	Option	Unit	Description
	waste disposal, by parties involved			= Rp 250,000/month; Hazardous and Toxic Waste processing = Rp 800,000/month.

Annex 2: Questionnaire Instrument

The following is an example of the questionnaire distributed to waste management actors using Google Forms in Indonesian.

Tracking dan Tracing Sampah Plastik pada Industri Daur Ulang

Salam sejahtera,

Dalam rangka studi "Efisiensi Sumber Daya pada Kemasan Plastik di Sektor Industri Makanan dan Minuman", Bappenas, UNDP, PT. Kirei, bersama dengan Tim Peneliti ITB, mengadakan kuesioner yang ditujukan untuk melakukan proses tracking dan tracing sampah plastik pada fasilitas daur ulang kecil menengah. Studi ini dilakukan untuk memberikan rekomendasi kebijakan untuk pengurangan penggunaan kemasan plastik dan peningkatan efisiensi sumber daya plastik di sektor makanan dan minuman.

Data yang diperlukan meliputi proses pengelolaan dan pengolahan sampah plastik sesuai jenis yang dikumpulkan, penggunaan energi dan air, limbah padat yang dihasilkan, serta penjualan atau penyaluran sampah plastik yang berhasil dikelola. Jika Anda pengelola TPS3R, pengelola Bank Sampah, Asosiasi Daur Ulang, penggiat pengelolaan sampah, atau UMKM pengelola sampah lainnya, kami mohon kesediaan Bapak/Ibu untuk mengisi kuesioner berikut.

Berikut tautan berisi tinjauan dari pertanyaan kuesioner untuk membantu memberikan gambaran data-data yang perlu diisi: bit.ly/3Hssw6b. Apabila Anda memiliki pertanyaan terkait kuesioner, Anda dapat menghubungi melalui WhatsApp 08112269273 (Mayrina Firdayati) atau 085721171657 (Maya Larasati).

Terima kasih,
Tim Peneliti.

* Required

1. Nama lokasi fasilitas Anda: *
   Contoh: TPS 3R Cibatu

   ____

2. Kecamatan fasilitas Anda: *

   ____

3. Kota/Kabupaten fasilitas Anda: *

   ____

4. Dari mana saja sampah plastik yang diterima oleh fasilitas Anda? *
   Jika tidak terdapat dalam pilihan, pilih "other" dan sebutkan.

   Check all that apply.

   - [ ] pengepul
   - [ ] sukarela dari masyarakat
   - [ ] TPS
   - [ ] TPS3R
   - [ ] bank sampah
   - [ ] importir
   - [ ] Other: ______________________

5. Berapakah rata-rata berat sampah plastik dari pengepul? *
   Satuan: kg/hari. Jika tidak ada dari sumber tersebut, isi dengan "0".

   ____

6. Berapakah rata-rata berat sampah plastik dari masyarakat langsung? *
   Satuan: kg/hari. Jika tidak ada dari sumber tersebut, isi dengan "0".

   ____

7. Berapakah rata-rata berat sampah plastik TPS? *
   Satuan: kg/hari. Jika tidak ada dari sumber tersebut, isi dengan "0".

   ____

8. Berapakah rata-rata berat sampah plastik TPS3R? *
   Satuan: kg/hari. Jika tidak ada dari sumber tersebut, isi dengan "0".

   ____

9. Berapakah rata-rata berat sampah plastik dari bank sampah? *
   Satuan: kg/hari. Jika tidak ada dari sumber tersebut, isi dengan "0".

   ____

10. Berapakah rata-rata berat sampah plastik dari importir? *

Satuan: kg/hari. Jika tidak ada dari sumber tersebut, isi dengan "0".

____

11. Jika ada sumber lain, berapakah rata-rata berat sampah plastiknya? *

Satuan: kg/hari. Jika tidak ada dari sumber tersebut, isi dengan "0".

____

12. Bagaimana pengelolaan sampah plastik di fasilitas Anda? *

Jika tidak terdapat dalam pilihan, pilih "other" dan sebutkan.

Mark only one oval.

- ( ) hanya mengumpulkan
- ( ) hanya memilah *Skip to question 49*
- ( ) mengumpulkan & memilah *Skip to question 19*
- ( ) Other: _______________________________

13. Bagaimana pengolahan sampah plastik yang dilakukan fasilitas Anda? *

Jika tidak terdapat dalam pilihan, pilih "other" dan sebutkan.

Check all that apply.

- [ ] pencacahan
- [ ] pemadatan
- [ ] penggilingan
- [ ] pembuatan pellet
- [ ] pembuatan kerajinan
- [ ] Other: _______________________________

14. Tenaga apa saja yang digunakan dalam pengolahan sampah di fasilitas Anda? *

Mark only one oval.

- ( ) manual dengan tenaga pekerja
- ( ) dengan alat
- ( ) campuran

15. Jelaskan metode pengolahan yang dilakukan. Jika menggunakan alat, sebutkan alat yang digunakan. *

Jika pengolahan lebih dari dua metode, sebutkan secara berurutan.

____
____
____
____
____

16. Berapa jumlah tenaga kerja untuk mengelola sampah plastik di fasilitas Anda? Sebutkan dengan fungsinya. *

Contoh: petugas pengumpulan= 2 orang; petugas pemilahan= 5 orang; administrasi= 1 orang.

____

17. Ke mana saja target distribusi produk akhir yang dihasilkan fasilitas Anda? *

Jika tidak terdapat dalam pilihan, pilih "other" dan sebutkan.

Check all that apply.

- [ ] pengepul
- [ ] industri produsen
- [ ] industri daur ulang lanjutan
- [ ] ritel
- [ ] langsung pada konsumen
- [ ] Other: _______________________

18. Kabupaten/Kota mana lokasi distribusi produk akhir tersebut dikirimkan? *
Diisi dengan format: Nama tempat - Kabupaten/Kota. Contoh: Industri daur ulang - Kota Bandung

____

Pengumpulan dan Pemilahan Sampah Plastik

19. Apa saja jenis sampah plastik yang dikumpulkan? *
Jika tidak terdapat dalam pilihan, pilih "other" dan sebutkan.

Check all that apply.

- [ ] botol minuman transparan (PET)
- [ ] botol minuman berwarna (PET)
- [ ] kemasan blowing (botol shampo, sabun, pembersih lantai) (HDPE)
- [ ] botol minyak (PVC)
- [ ] tutup botol (PP)
- [ ] styrofoam/alat makan (PS)
- [ ] galon (OTHER)
- [ ] cup transparan (PP)
- [ ] cup berwarna (PP)
- [ ] kemasan makanan rigid (PP)
- [ ] kemasan sachet (multilayer)
- [ ] plastik lembaran bening (PP, PE)
- [ ] Other: _______________________________

20. Berapakah rata-rata berat sampah botol minuman transparan (PET) yang dikumpulkan? *
Satuan: kg/hari. Contoh: botol minuman transparan = 3 kg/hari; botol minuman berwarna = 1 kg/hari. Jika tidak mengumpulkan, isi dengan "0".

____

21. Berapakah rata-rata berat sampah botol minuman berwarna (PET) yang dikumpulkan? *
Satuan: kg/hari. Contoh: botol minuman transparan = 3 kg/hari; botol minuman berwarna = 1 kg/hari. Jika tidak mengumpulkan, isi dengan "0".

____

22. Berapakah rata-rata berat sampah kemasan blowing (botol shampo, sabun, pembersih lantai) (HDPE) yang dikumpulkan? *

Satuan: kg/hari. Contoh: Botol minuman transparan = 3 kg/hari. Jika tidak mengumpulkan, isi dengan "0".

23. Berapakah rata-rata berat sampah botol minyak (PVC) yang dikumpulkan? *

Satuan: kg/hari. Contoh: Botol minuman transparan = 3 kg/hari. Jika tidak mengumpulkan, isi dengan "0".

24. Berapakah rata-rata berat sampah tutup botol (PP) yang dikumpulkan? *

Satuan: kg/hari. Contoh: Botol minuman transparan = 3 kg/hari. Jika tidak mengumpulkan, isi dengan "0".

25. Berapakah rata-rata berat sampah styrofoam/alat (PS) makan yang dikumpulkan? *

Satuan: kg/hari. Contoh: Botol minuman transparan = 3 kg/hari. Jika tidak mengumpulkan, isi dengan "0".

26. Berapakah rata-rata berat sampah galon (other) yang dikumpulkan? *

Satuan: kg/hari. Contoh: Botol minuman transparan = 3 kg/hari. Jika tidak mengumpulkan, isi dengan "0".

27. Berapakah rata-rata berat sampah cup transparan (PP) yang dikumpulkan? *

Satuan: kg/hari. Contoh: cup transparan = 3 kg/hari; cup berwarna = 1 kg/hari. Jika tidak mengumpulkan, isi dengan "0".

28. Berapakah rata-rata berat sampah cup berwarna (PP) yang dikumpulkan? *

Satuan: kg/hari. Contoh: cup transparan = 3 kg/hari; cup berwarna = 1 kg/hari. Jika tidak mengumpulkan, isi dengan "0".

29. Berapakah rata-rata berat sampah kemasan makanan rigid (PP) yang dikumpulkan? *

Satuan: kg/hari. Contoh: Botol minuman transparan = 3 kg/hari. Jika tidak mengumpulkan, isi dengan "0".

30. Berapakah rata-rata berat sampah kemasan sachet (multilayer) yang dikumpulkan? *

Satuan: kg/hari. Contoh: Botol minuman transparan = 3 kg/hari. Jika tidak mengumpulkan, isi dengan "0".

31. Berapakah rata-rata berat sampah plastik (PP,PE) lembaran yang dikumpulkan? *

Satuan: kg/hari. Contoh: Botol minuman transparan = 3 kg/hari. Jika tidak mengumpulkan, isi dengan "0".

32. Jika ada jenis sampah lainnya yang dikumpulkan, sebutkan beserta rata-rata jumlah sampah yang dikumpulkan. *

Satuan: kg/hari. Contoh: Botol minuman transparan = 3 kg/hari. Jika tidak mengumpulkan, isi dengan "0".

33. Metode pemilahan apakah yang dilakukan fasilitas Anda? *

Mark only one oval.

- manual dengan tenaga pekerja
- dengan mesin
- campuran

34. Jelaskan metode pemilahan yang dilakukan. Jika menggunakan mesin, sertakan jenis mesin yang digunakan. *

Pengumpulan Sampah Plastik

35. Apa saja jenis sampah plastik yang dikumpulkan? *
Jika tidak terdapat dalam pilihan, pilih "other" dan sebutkan.

Check all that apply.

- [ ] botol minuman transparan (PET)
- [ ] botol minuman berwarna (PET)
- [ ] kemasan blowing (botol shampo, sabun, pembersih lantai) (HDPE)
- [ ] botol minyak (PVC)
- [ ] tutup botol (PP)
- [ ] styrofoam/alat makan (PS)
- [ ] galon (OTHER)
- [ ] cup transparan (PP)
- [ ] cup berwarna (PP)
- [ ] kemasan makanan rigid (PP)
- [ ] kemasan sachet (multilayer)
- [ ] plastik lembaran bening (PP, PE)
- [ ] Other:

36. Berapakah rata-rata berat sampah botol minuman transparan (PET) yang dikumpulkan? *

Satuan: kg/hari. Contoh: botol minuman transparan = 3 kg/hari; botol minuman berwarna = 1 kg/hari. Jika tidak mengumpulkan, isi dengan "0".

37. Berapakah rata-rata berat sampah botol minuman berwarna (PET) yang dikumpulkan? *

Satuan: kg/hari. Contoh: botol minuman transparan = 3 kg/hari; botol minuman berwarna = 1 kg/hari. Jika tidak mengumpulkan, isi dengan "0".

38. Berapakah rata-rata berat sampah kemasan blowing (botol shampo, sabun, pembersih lantai) (HDPE) yang dikumpulkan? *

Satuan: kg/hari. Contoh: Botol minuman transparan = 3 kg/hari. Jika tidak mengumpulkan, isi dengan "0".

39. Berapakah rata-rata berat sampah botol minyak (PVC) yang dikumpulkan? *

Satuan: kg/hari. Contoh: Botol minuman transparan = 3 kg/hari. Jika tidak mengumpulkan, isi dengan "0".

40. Berapakah rata-rata berat sampah tutup botol (PP) yang dikumpulkan? *

Satuan: kg/hari. Contoh: Botol minuman transparan = 3 kg/hari. Jika tidak mengumpulkan, isi dengan "0".

41. Berapakah rata-rata berat sampah styrofoam/alat (PS) makan yang dikumpulkan? *

Satuan: kg/hari. Contoh: Botol minuman transparan = 3 kg/hari. Jika tidak mengumpulkan, isi dengan "0".

42. Berapakah rata-rata berat sampah galon (other) yang dikumpulkan? *

Satuan: kg/hari. Contoh: Botol minuman transparan = 3 kg/hari. Jika tidak mengumpulkan, isi dengan "0".

43. Berapakah rata-rata berat sampah cup transparan (PP) yang dikumpulkan? *

Satuan: kg/hari. Contoh: cup transparan = 3 kg/hari; cup berwarna = 1 kg/hari. Jika tidak mengumpulkan, isi dengan "0".

44. Berapakah rata-rata berat sampah cup berwarna (PP) yang dikumpulkan? *

Satuan: kg/hari. Contoh: cup transparan = 3 kg/hari; cup berwarna = 1 kg/hari. Jika tidak mengumpulkan, isi dengan "0".

45. Berapakah rata-rata berat sampah kemasan makanan rigid (PP) yang dikumpulkan? *

Satuan: kg/hari. Contoh: Botol minuman transparan = 3 kg/hari. Jika tidak mengumpulkan, isi dengan "0".

46. Berapakah rata-rata berat sampah kemasan sachet (multilayer) yang dikumpulkan? *

Satuan: kg/hari. Contoh: Botol minuman transparan = 3 kg/hari. Jika tidak mengumpulkan, isi dengan "0".

47. Berapakah rata-rata berat sampah plastik (PP,PE) lembaran yang dikumpulkan? *

Satuan: kg/hari. Contoh: Botol minuman transparan = 3 kg/hari. Jika tidak mengumpulkan, isi dengan "0".

48. Jika ada jenis sampah lainnya yang dikumpulkan, sebutkan beserta rata-rata jumlah sampah yang dikumpulkan. *

Satuan: kg/hari. Contoh: Botol minuman transparan = 3 kg/hari. Jika tidak mengumpulkan, isi dengan "0".

____

Skip to question 51

Pemilahan Sampah Plastik

49. Metode pemilahan apakah yang dilakukan fasilitas Anda? *

Mark only one oval.

- ⬭ manual dengan tenaga pekerja
- ⬭ dengan mesin
- ⬭ campuran

50. Jelaskan metode pemilahan yang dilakukan. Jika menggunakan mesin, sertakan jenis mesin yang digunakan. *

____

Skip to question 51

Produk Akhir Sampah Plastik

51. Adakah pengolahan sampah plastik lain selain pengumpulan dan pemilahan? *

Jika tidak terdapat dalam pilihan, pilih "other" dan sebutkan.

Check all that apply.

- ☐ pembersihan label/tutup botol dari sampah plastik
- ☐ pencucian
- ☐ pengemasan
- ☐ tidak ada pengolahan lain
- ☐ Other: _______________________________

52. Adakah bahan lain yang digunakan untuk mengolah sampah plastik di fasilitas Anda? Jika ada, sebutkan beserta jumlahnya. *

Contoh: dus/plastik/karung untuk pengemasan 3 kg/hari, bahan kimia 5 liter/hari dsb.

____

53. Apa saja produk lain yang dihasilkan oleh fasilitas Anda dari proses daur ulang sampah plastik? *

Jika tidak terdapat dalam pilihan, pilih "other" dan sebutkan.

Check all that apply.

- [ ] plastik cacah
- [ ] biji plastik
- [ ] karya kerajinan
- [ ] Other: ______________________________

54. Berapakah rata-rata kapasitas produk tersbut yang dihasilkan fasilitas Anda? *

Contoh pilihan satuan: ton/bulan; kg/hari. Sebutkan berdasarkan jenis produk, contoh: biji plastik = 1 kg/hari.

____

55. Berapakah rata-rata penjualan produk tersebut yang berhasil dijual fasilitas Anda? *

Contoh pilihan satuan: Rp/bulan atau Rp/hari. Sebutkan berdasarkan jenis produk, contoh: biji plastik = Rp 500.000/hari.

____

56. Berapakah rata-rata penjualan sampah botol minuman transparan (PET) yang berhasil dijual fasilitas Anda? *

Contoh pilihan satuan: Rp/bulan atau Rp/hari. Contoh: botol minuman transparan = Rp 50.000/hari; botol minuman berwarna = Rp 25.000/hari. Jika tidak mengumpulkan, isi dengan "0".

____

57. Berapakah rata-rata penjualan sampah botol minuman berwarna (PET) yang berhasil dijual fasilitas Anda? *

Contoh pilihan satuan: Rp/bulan atau Rp/hari. Contoh: botol minuman transparan = Rp 50.000/hari; botol minuman berwarna = Rp 25.000/hari. Jika tidak mengumpulkan, isi dengan "0".

58. Berapakah rata-rata penjualan sampah kemasan blowing (botol shampo, sabun, pembersih lantai) (PVC) yang berhasil dijual fasilitas Anda? *

Contoh pilihan satuan: Rp/bulan atau Rp/hari. Contoh: botol minuman transparan = Rp 50.000/hari. Jika tidak mengumpulkan, isi dengan "0".

59. Berapakah rata-rata penjualan sampah botol minyak (PVC) yang berhasil dijual fasilitas Anda? *

Contoh pilihan satuan: Rp/bulan atau Rp/hari. Contoh: botol minuman transparan = Rp 50.000/hari. Jika tidak mengumpulkan, isi dengan "0".

60. Berapakah rata-rata penjualan sampah tutup botol (PP) yang berhasil dijual fasilitas Anda? *

Contoh pilihan satuan: Rp/bulan atau Rp/hari. Contoh: botol minuman transparan = Rp 50.000/hari. Jika tidak mengumpulkan, isi dengan "0".

61. Berapakah rata-rata penjualan sampah styrofoam/alat makan (PS) yang berhasil dijual fasilitas Anda? *

Contoh pilihan satuan: Rp/bulan atau Rp/hari. Contoh: botol minuman transparan = Rp 50.000/hari. Jika tidak mengumpulkan, isi dengan "0".

62. Berapakah rata-rata penjualan sampah galon (other) yang berhasil dijual fasilitas Anda? *

Contoh pilihan satuan: Rp/bulan atau Rp/hari. Contoh: botol minuman transparan = Rp 50.000/hari. Jika tidak mengumpulkan, isi dengan "0".

____

63. Berapakah rata-rata penjualan sampah cup transparan (PP) yang berhasil dijual fasilitas Anda? *

Contoh pilihan satuan: Rp/bulan atau Rp/hari. Contoh: cup transparan = Rp 50.000/hari; cup berwarna = Rp 25.000/hari. Jika tidak mengumpulkan, isi dengan "0".

____

64. Berapakah rata-rata penjualan sampah cup berwarna (PP) yang berhasil dijual fasilitas Anda? *

Contoh pilihan satuan: Rp/bulan atau Rp/hari. Contoh: cup transparan = Rp 50.000/hari; cup berwarna = Rp 25.000/hari. Jika tidak mengumpulkan, isi dengan "0".

____

65. Berapakah rata-rata penjual sampah kemasan makanan rigid (PP) yang berhasil dijual fasilitas Anda? *

Contoh pilihan satuan: Rp/bulan atau Rp/hari. Contoh: botol minuman transparan = Rp 50.000/hari. Jika tidak mengumpulkan, isi dengan "0".

____

66. Berapakah rata-rata penjualan sampah kemasan sachet (multilayer) yang berhasil dijual fasilitas Anda? *

Contoh pilihan satuan: Rp/bulan atau Rp/hari. Contoh: botol minuman transparan = Rp 50.000/hari. Jika tidak mengumpulkan, isi dengan "0".

____

67. Berapakah rata-rata penjualan sampah plastik lembaran (PP, PE) yang berhasil dijual fasilitas Anda? *

Contoh pilihan satuan: Rp/bulan atau Rp/hari. Contoh: botol minuman transparan = Rp 50.000/hari. Jika tidak mengumpulkan, isi dengan "0".

____

68. Adakah jenis sampah lainnya yang dikumpulkan? Sebutkan beserta rata-rata penjualan sampah tersebut yang berhasil dijual fasilitas Anda. *

Contoh pilihan satuan: Rp/bulan atau Rp/hari. Contoh: botol minuman transparan = Rp 50.000/hari. Jika tidak mengumpulkan, isi dengan "0".

____

Penggunaan Energi

69. Dari mana saja sumber energi yang digunakan fasilitas Anda? *

Check all that apply.

- [ ] PLN
- [ ] genset
- [ ] diesel/solar
- [ ] Other: ______________________

70. Berapakah rata-rata jumlah energi yang digunakan untuk operasional dari setiap sumber? *

Contoh pilihan satuan: kWh/bulan; ton/bulan; MJ; Rp/bulan. Sebutkan berdasarkan sumber, contoh: PLN = 2.500 kWh/bulan; Diesel = 3 ton/bulan.

____

71. Untuk apa saja penggunaan energi yang dilakukan fasilitas Anda? *

Check all that apply.

- [ ] alat pengolahan sampah plastik
- [ ] pencahayaan, AC, dll.
- [ ] Other: ______________________

Penggunaan Air dan Limbah Cair

72. Dari mana saja sumber air yang digunakan fasilitas Anda? *
Jika tidak terdapat dalam pilihan, pilih "other" dan sebutkan.

Check all that apply.

- [ ] PDAM
- [ ] air tanah
- [ ] Other: ____________________

73. Berapakah rata-rata jumlah air yang digunakan untuk operasional dari setiap sumber? *
Contoh pilihan satuan: Rp/bulan; m3/bulan; banyak ember/hari. 1 ember diperkirakan = 10L. Sebutkan berdasarkan sumber, contoh: PDAM = Rp 3.000.000/bulan; Air tanah = 4 ember/hari.

____

74. Untuk apa saja penggunaan air yang dilakukan fasilitas Anda? *
Jika tidak terdapat dalam pilihan, pilih "other" dan sebutkan.

Check all that apply.

- [ ] pencucian sampah plastik
- [ ] proses pengolahan sampah plastik (pendinginan, penguapan)
- [ ] domestik (kamar mandi, dapur, dsb.)
- [ ] Other: ____________________

75. Bagaimana pengolahan air limbah yang dihasilkan dari operasional fasilitas Anda? *
Jika tidak terdapat dalam pilihan, pilih "other" dan sebutkan.

Check all that apply.

- [ ] dibuang ke lingkungan (melalui saluran pembuangan)
- [ ] menggunakan septic tank
- [ ] Other: ____________________

76. Adakah biaya tambahan yang dikeluarkan untuk mengolah air limbah fasilitas Anda? Jika ya, sebutkan biayanya per bulan. *

Contoh: menggunakan jasa pihak ke-3 untuk mengosongkan septik tank Rp 1.000.000/bulan.

____

Limbah Padat yang Dihasilkan

77. Apa saja jenis limbah padat yang dihasilkan dari proses operasional fasilitas Anda? *

Jika tidak terdapat dalam pilihan, pilih "other" dan sebutkan.

Check all that apply.

- [ ] plastik tidak layak daur ulang
- [ ] produk cacat, kemasan bahan baku, dsb. (masih dapat di daur ulang)
- [ ] limbah B3
- [ ] Other: ____________________

78. Berapakah rata-rata berat limbah padat yang dihasilkan fasilitas Anda? *

Contoh pilihan satuan: kg/hari. Sebutkan berdasarkan jenis limbah padat, contoh: plastik tidak layak daur ulang = 4 kg/hari; plastik masih layak daur ulang = 2 kg/hari; limbah B3 = 0,5 kg/hari.

____

79. Ke manakah limbah padat tersebut disalurkan? *

Jika tidak terdapat dalam pilihan, pilih "other" dan sebutkan.

Check all that apply.

- [ ] Pihak ke-3
- [ ] TPA
- [ ] Other: ____________________

80. Jika limbah padat disalurkan ke pihak ke-3, sebutkan pihak ke-3 tersebut. *

Contoh: pengolahan LB3, industri lain, dsb. Jika tidak menggunakan pihak ke-3, isi dengan "-"

81. Adakah biaya yang dikeluarkan untuk mengolah/menyalurkan limbah padat fasilitas Anda? Jika ya, sebutkan biayanya per bulan. *

Sebutkan berdasarkan pihak yang terlibat jika lebih dari 1 pihak. Contoh: TPA = Rp 250.000/bulan; Pengolahan LB3 = Rp 800.000/bulan.

Terima Kasih atas Partisipasi Anda.

Annex 3: Material Flow Analysis Calculation Method

To comprehend plastic waste at the end-of-life cycle, it is necessary to identify where the waste is going and where it will end up using Material Flow Analysis (MFA). Figure A depicts how the extrapolation of national polypropylene (PP) plastic waste was estimated and calculated in this study.

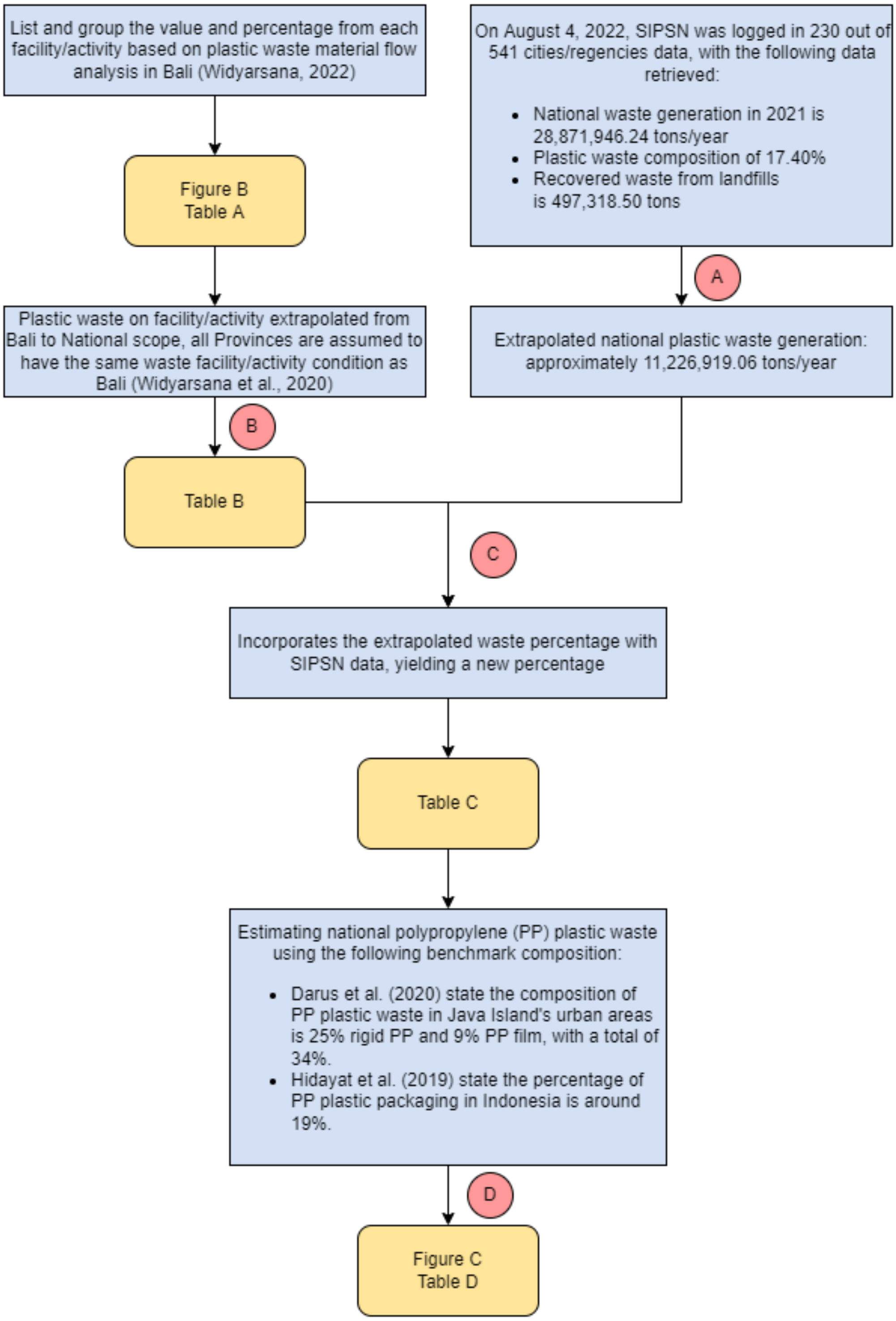

Figure A. Flow diagram of PP plastic waste extrapolation calculation and assumptions

Figure B below depicts the MFA for plastic waste in Bali, which was used as a benchmark.

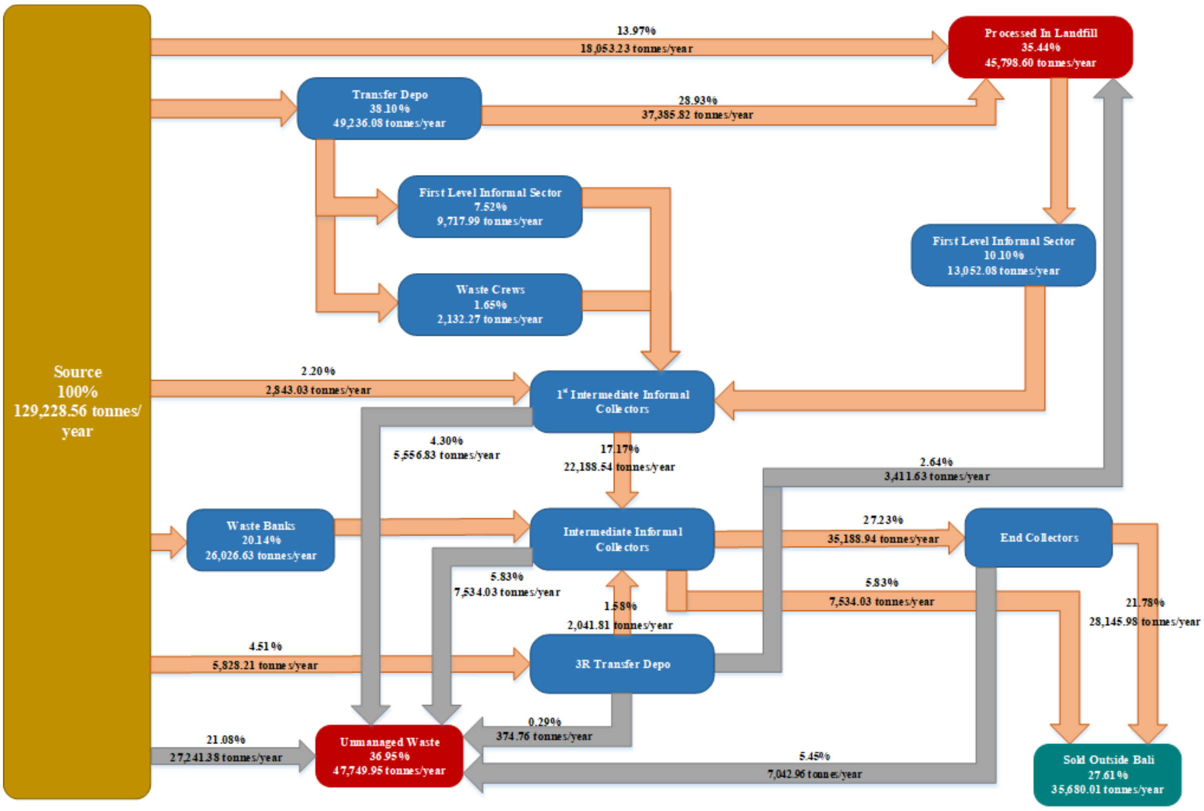

Figure B. Benchmark's Material flow diagram of plastic waste in Bali

Meanwhile, Table A shows the plastic waste MFA value and percentage in detail after listing and grouping each facility/activity.

Table A. The value and percentage of benchmark plastic waste generation

Benchmark				
(From) Facility/activity	**Category**	**(To) Facility/activity**	**Percentage**	**Waste amount (tons/year)**
Source	WASTE FLOW	Processed in landfill	13.97%	18,053.23
	WASTE FLOW	Transfer depo	38.10%	49,236.08
	WASTE FLOW	First intermediate	2.20%	2,843.03
	WASTE FLOW	Waste banks	20.14%	26,026.63
	WASTE FLOW	3R transfer depo	4.51%	5,828.21
	WASTE FLOW	Unmanaged waste	21.08%	27,241.38
Transfer depo	WASTE FLOW	Processed in landfill	28.93%	37,385.82

Benchmark				
(From) Facility/activity	Category	(To) Facility/activity	Percentage	Waste amount (tons/year)
	WASTE FLOW	First intermediate	9.17%	11,850.26
First intermediate informal collector	WASTE FLOW	Intermediate	17.17%	22,188.54
	WASTE RESIDUE	Unmanaged waste	4.30%	5,556.83
Waste bank	WASTE FLOW	Intermediate	20.14%	26,026.63
3R transfer depo	WASTE FLOW	Intermediate	1.58%	2,041.81
	WASTE RESIDUE	Processed in landfill	2.64%	3,411.63
	WASTE RESIDUE	Unmanaged waste	0.29%	374.76
Intermediate informal collector	WASTE FLOW	End collector	27.23%	35,188.94
	WASTE FLOW	Recovery valuable waste	5.83%	7,534.03
	WASTE RESIDUE	Unmanaged waste	5.83%	7,534.03
End collector	WASTE FLOW	Recovery valuable waste	21.78%	28,145.98
	WASTE RESIDUE	Unmanaged waste	5.45%	7,042.96
Processed in landfill	WASTE FLOW	First intermediate	10.10%	13,052.08

Calculation A

The extrapolation of national plastic waste generation is done with the following equation:

$$\begin{aligned}
&National\ plastic\ waste\ generation\\
&\quad = SIPSN\ national\ waste\ generation\\
&\quad \times \frac{number\ of\ cities\ and\ regencies\ in\ Indonesia}{number\ of\ cities\ and\ regencies\ recorded\ in\ SIPSN}\\
&\quad \times plastic\ waste\ composition
\end{aligned}$$

$$= 28{,}871{,}946.24\ tons/year \times 541/230 \times 17.4\%$$

$$= 11{,}226{,}919.06\ tons/year$$

Calculation B

The extrapolation of plastic waste generation on facility/activity from Bali Province to National scope is done with the following equation:

$$Extrapolated\ plastic\ waste\ generation\ on\ waste\ facilities$$
$$= \frac{number\ of\ benchmark's\ waste\ facilities \times\ number\ of\ provinces\ in\ Indonesia}{number\ of\ benchmark's\ waste\ facilities}$$
$$\times\ benchmark's\ amount\ of\ plastic\ waste\ on\ waste\ facilities$$

e.g.,

$$Extrapolated\ plastic\ waste\ generation\ on\ transfer\ depo = \frac{555 \times 34}{555} \times 49{,}236.08\ tons/year$$
$$= \ 1{,}674{,}026.72\ tons/year$$

The calculation result is shown in Table B below.

Table B. The value of extrapolated plastic waste generation

Facility/activity	Benchmark			Extrapolation	
	Percentage	Waste amount (tons/year)	Unit/person amount	Unit/person amount	Waste amount (tons/year)
Transfer depo	38.10%	49,236.08	555	18,870	1,674,026.72
Waste banks	20.14%	26,026.63	468	15,912	884,905.42
3R transfer depo	4.51%	5,828.21	54	1,836	198,159.14
First intermediate informal collector	21.47%	27,745.37	325	11,050	943,342.58
Intermediate informal collector	38.89%	50,256.98	161	5,474	1,708,737.32
End collector	27.23%	35,188.94	10	340	1,196,423.96

Calculation C

The previous calculation estimates waste generation on waste facilities, while for national plastic waste generation is already calculated in Calculation A, and recovered waste from landfill is already known from SIPSN data. Those calculated numbers will yield a different percentage. The following equation is used to calculate the national percentage:

$$Extrapolated\ percentage = \frac{extrapolated\ plastic\ waste\ generation}{national\ plastic\ waste\ generation} \times 100\%$$

e.g.,

$$Extrapolated\ total\ percentage\ of\ transfer\ depo = \frac{1{,}674{,}026.72\ tons/year}{11{,}226{,}919.06\ tons/year} \times 100\%$$

$$= 14.91\%$$

Meanwhile, for the variable with the unknown amount of waste generation that is part of the total waste activity/facility waste generation, the following equation is used:

$$Extrapolated\ variable\ percentage = \frac{benchmark's\ variable\ percentage}{benchmark's\ total\ percentage\ of\ waste\ activity/generation} \times extrapolated\ total\ percentage\ of\ waste\ activity/generation$$

e.g.,

$$Extrapolated\ waste\ processed\ in\ landfill\ from\ transfer\ depo\ percentage = \frac{28.93\%}{38.10\%} \times 14.91\%$$

$$= 11.32\%$$

The new percentages are then adjusted so that the percentages in the national plastic waste MFA is even and the amount of plastic waste generated is known, with the results shown in the table below.

Table C. The value and percentage of extrapolated plastic waste generation

Plastic Waste Extrapolation				
(From) Facility/activity	**Category**	**(To) Facility/activity**	**Waste amount (tons/year)**	**Percentage**
Source	WASTE FLOW	Processed in landfill	2,999,857.30	26.72%
	WASTE FLOW	Transfer depo	1,674,026.72	14.91%
	WASTE FLOW	First intermediate	943,342.58	8.40%
	WASTE FLOW	Waste banks	884,905.42	7.88%
	WASTE FLOW	3R transfer depo	198,159.14	1.77%
	WASTE FLOW	Unmanaged waste	4,526,627.90	40.32%
Transfer depo	WASTE FLOW	Processed in landfill	1,271,117.93	11.32%
	WASTE FLOW	First intermediate	402,908.79	3.59%
First intermediate informal collector	WASTE FLOW	Intermediate	1,474,340.70	13.13%
	WASTE RESIDUE	Unmanaged waste	369,229.18	3.29%
Waste bank	WASTE FLOW	Intermediate	884,905.42	7.88%

Plastic Waste Extrapolation				
(From) Facility/activity	**Category**	**(To) Facility/activity**	**Waste amount (tons/year)**	**Percentage**
3R transfer depo	WASTE FLOW	Intermediate	69,421.61	0.62%
	WASTE RESIDUE	Processed in landfill	115,995.59	1.03%
	WASTE RESIDUE	Unmanaged waste	12,741.94	0.11%
Intermediate informal collector	WASTE FLOW	End collector	1,700,504.55	15.15%
	WASTE FLOW	Recovery valuable waste	364,081.58	3.24%
	WASTE RESIDUE	Unmanaged waste	364,081.58	3.24%
End collector	WASTE FLOW	Recovery valuable waste	1,360,153.84	12.12%
	WASTE RESIDUE	Unmanaged waste	340,350.71	3.03%
Processed in landfill	WASTE FLOW	First intermediate	497,318.50	4.43%

Calculation D

The specific amount of national PP plastic waste generation is then determined by multiplying it by the benchmark, with the following equation:

$$\begin{aligned} &Extrapolated\ PP\ plastic\ waste \\ &\qquad = extrapolated\ plastic\ waste\ generation \times PP\ plastic\ waste\ composition \end{aligned}$$

The results of the calculations are shown in Table D below.

Table D. The value of extrapolated PP plastic waste generation

PP Plastic Waste Extrapolation				
(From) Facility/activity	Category	(To) Facility/activity	Waste amount (tons/year) PP plastic composition:	
			19%	34%
Source	WASTE FLOW	Processed in landfill	569,972.89	1,019,951.48
	WASTE FLOW	Transfer depo	318,065.08	569,169.08
	WASTE FLOW	First intermediate	179,235.09	320,736.48
	WASTE FLOW	Waste banks	168,132.03	300,867.84
	WASTE FLOW	3R transfer depo	37,650.24	67,374.11
	WASTE FLOW	Unmanaged waste	860,059.30	1,539,053.49
Transfer depo	WASTE FLOW	Processed in landfill	241,512.41	432,180.10
	WASTE FLOW	First intermediate	76,552.67	136,988.99
First intermediate informal collector	WASTE FLOW	Intermediate	280,124.73	501,275.84
	WASTE RESIDUE	Unmanaged waste	70,153.54	125,537.92
Waste bank	WASTE FLOW	Intermediate	168,132.03	300,867.84
3R transfer depo	WASTE FLOW	Intermediate	13,190.11	23,603.35
	WASTE RESIDUE	Processed in landfill	22,039.16	39,438.50
	WASTE RESIDUE	Unmanaged waste	2,420.97	4,332.26
Intermediate informal collector	WASTE FLOW	End collector	323,095.86	578,171.55
	WASTE FLOW	Recovery valuable waste	69,175.50	123,787.74
	WASTE RESIDUE	Unmanaged waste	69,175.50	123,787.74
End collector	WASTE FLOW	Recovery valuable waste	258,429.23	462,452.31
	WASTE RESIDUE	Unmanaged waste	64,666.63	115,719.24
Processed in landfill	WASTE FLOW	First intermediate	94,490.52	169,088.29

Furthermore, the result of national PP plastic waste MFA is shown in Figure C.

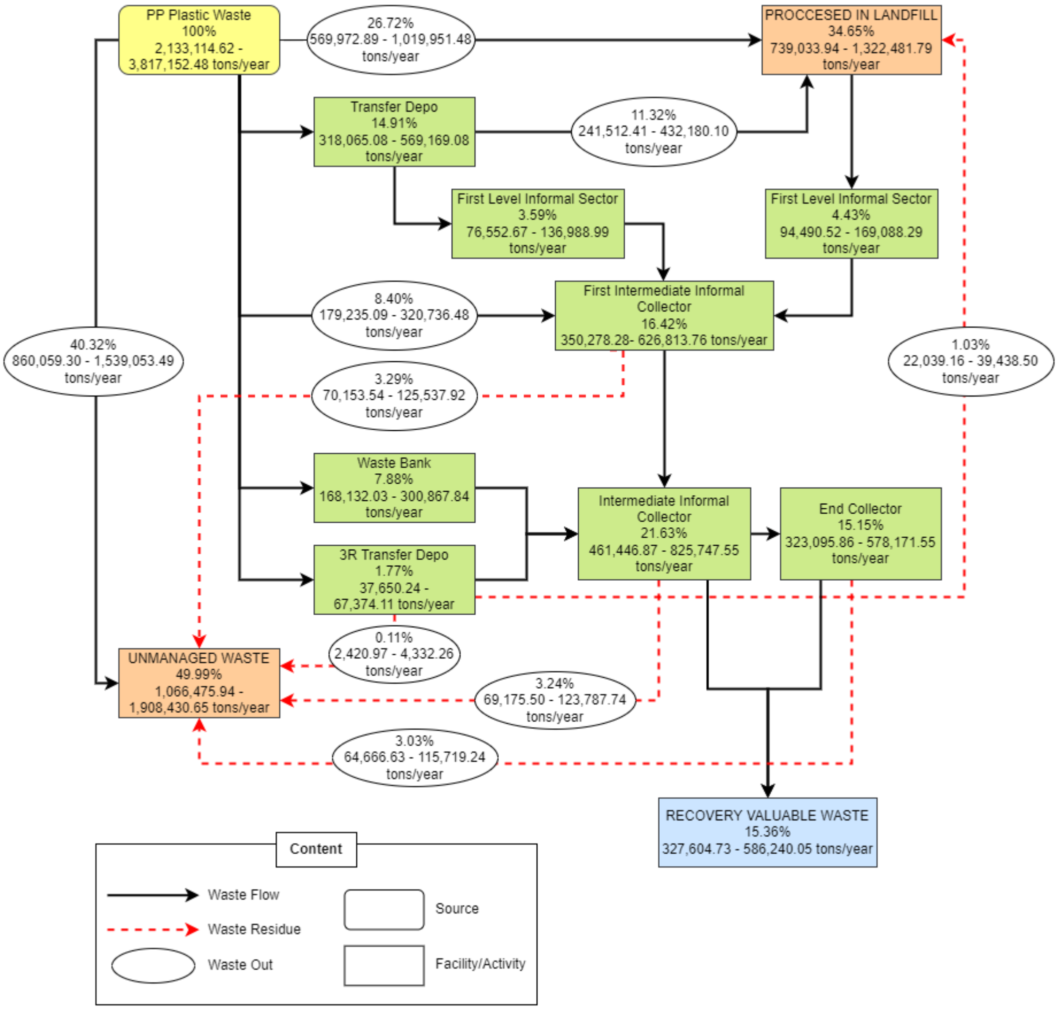

Figure C. Extrapolated material flow diagram of national plastic waste

Annex 4: Greenhouse Gas Calculation

Greenhouse gas calculation method in the form of CO_2e is adapted from the Greenhouse Gas Protocol. Emissions are divided into three categories, namely scope 1, 2 and 3. To better understand the scope of each category, the following scheme is given (Figure A):

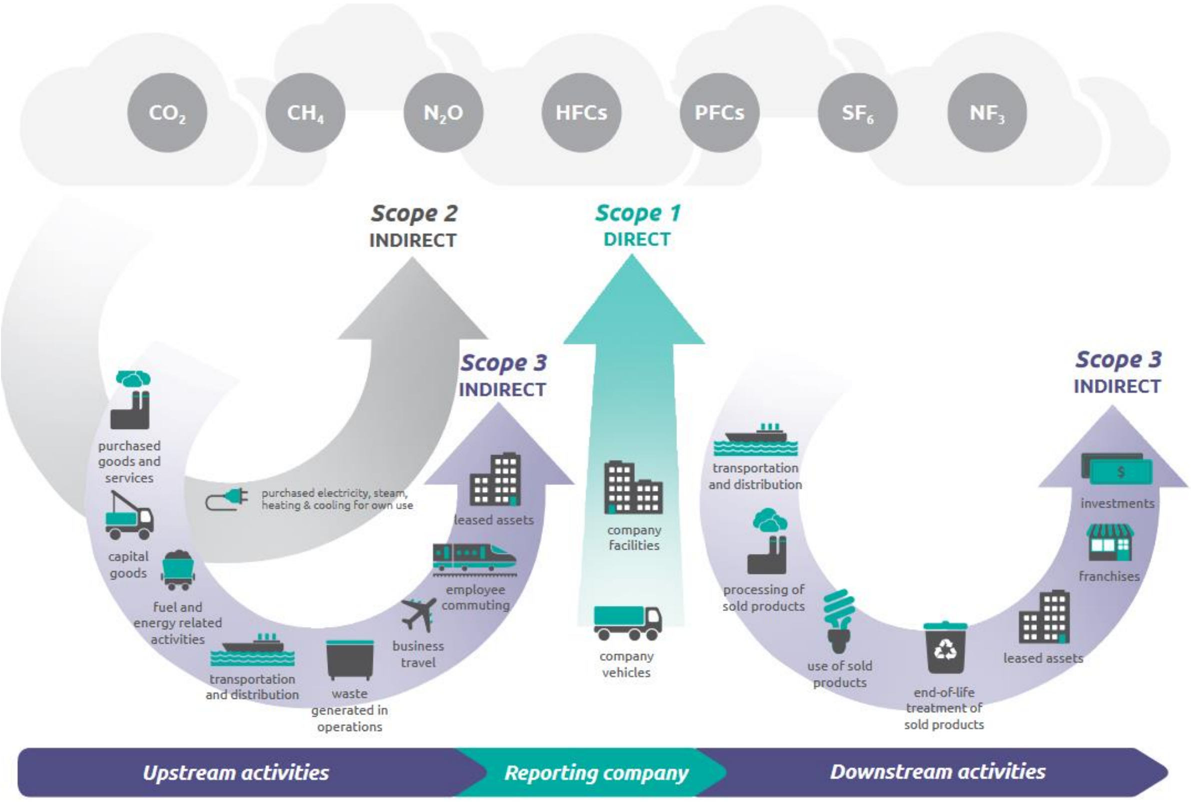

Figure A. Overview of GHG protocol scopes and emissions across value chain [49]

Scope 1 is defined as direct emissions from company facilities and company vehicles. Direct emissions include fuel combustion such as boilers, fleet vehicles and air conditioning leaks. Scope 2 is defined as indirect emissions from electricity purchased and used by the company. Emissions are a result of the electricity generation. Lastly, scope 3 is defined as other indirect emissions from upstream and downstream activities. Source examples include transportation and travel, usage as well as end of life treatment. Emission calculation is only comprised of scope 1 and 2 as we did not send a request for scope 3 emission towards industries.

Scope 1 emissions are calculated based on the NCV and emission factors stated in "Pedoman Penghitungan dan Pelaporan Inventarisasi Gas Rumah Kaca Bidang Energi - Sub Bidang Ketenagalistrikan" issued by Direktorat Jenderal Ketenagalistrikan Kementerian ESDM (2018) in Annex 3. Table 1 shows used emission factors for several types of fuel.

Table 1 NCV and emission factors from IPCC (Tier 1)

Types of fuel	Kg GRK/TJ			Calorific value (NCV)	Carbon content	
	CO_2	CH_4	N_2O	TJ/Gg	Kg/GJ	%
Gas oil	74,100	3	0.6	43.0	20.2	87
Diesel oil	74,100	3	0.6	43.0	20.2	87
Natural gas	56,100	3	0.1	48.0	15.3	73
Sub-bituminous	96,100	1	1.5	18.9	26.2	50

Scope 1 emission calculation is done by fuel analysis method with the following equation:

$$Emissions \; = Fuel\; x\; Emission\; Factor\; (EF) \qquad (1)$$

where:

Emissions : Mass of emitted CO_2, CH_4, or N_2O

Fuel : Mass/volume of fuel combusted

EF : CO_2, CH_4, or N_2O emission factor per mass/volume unit

Calculation of total emission in the form of CO_2e is done by multiplying each resulting emission (CO_2, CH_4, or N_2O) with its corresponding Global Warming Potential (GWP) and then adding up each emission component. Total emission calculation is done with the following equation:

$$Total\; CO_2e\; emission \; = \Sigma(Emissions \; \times \; GWP) \qquad (2)$$

where:

Total emission : Total CO_2e emission

Emissions : Mass of emitted CO_2, CH_4, or N_2O

GWP : Global Warming Potential

A GWP value of 1, 28 and 265 is taken for CO_2, CH_4, or N_2O respectively.

Scope 2 emissions from electricity use are calculated based on the emissions factors stated in "Nilai Faktor Emisi GRK Sistem Ketenagalistrikan" (2018). It has been assumed that all industries use electricity provided by power plants located in the Jawa-Madura-Bali (Jamali) grid. Thus, an emission factor of 0.88 ton CO_2/MWh is used. To convert this value to CO_2e, a calculation of CH_4 and N_2O have also been performed (Equation 1 and 2) by assuming the use of sub-bituminous coal in power plants. CO_2 emission calculation is done with equation:

$$CO_2\ emission = Electricity\ usage \times Emission\ Factor\ (EF) \quad (3)$$

where:

CO_2 emission	: CO_2e emission
Electricity usage	: Used electricity, usually in kWh
EF	: CO_2 emission factor from Jamali grid

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