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TEI THAILAND ENVIRONMENT INSTITUTE

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ANALYSIS OF MARKETS AND TECHNOLOGIES FOR PLASTIC MATERIAL CIRCULARITY IN THE PACKAGING SECTOR IN THAILAND

Final Report

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Global Project
"Support of the Export Initiative Environmental Protection" (BMUV)
Köthener Str. 2
10963 Berlin / Germany
T +49 30 338 424 646
E markus.luecke@giz.de

Collaborative Action for Single-Use Plastic Prevention in Southeast Asia
(CAP-SEA)
193/63 Lake Rajada Office Complex, 16th Fl.
New Ratchadapisek Road, Klongtoey
Bangkok 10110 / Thailand
T +66 65 2400266
E christoffer.brick@giz.de

More information

https://www.giz.de/en/worldwide/78869.html

www.exportinitiative-umweltschutz.de

Authors:
Manit Nithitanakul
Jitima Preechawong
Jirasuta Chungprempree

Layout:
The-ist Design Company Limited
Sirivemon Eiampoklarp

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Bangkok, February 2023

On behalf of:

Federal Ministry
for the Environment, Nature Conservation
and Nuclear Safety

of the Federal Republic of Germany

This report has been prepared for the Collaborative Action for Single-Use Plastic Prevention in Southeast Asia (CAP-SEA) project module and is implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) in order to support the "Export Initiative Environmental Protection".

The GIZ global project "Support of the Export Initiative Environmental Protection" contributes to solving key environmental problems on behalf of the German Federal Ministry for the Environment and Consumer Protection (BMUV). The initiative aims to export know-how available in Germany and support sustainable development worldwide. It includes topics such as poor waste management, air and water pollution or supporting infrastructures for sustainable urban development. Partner countries are Jordan, India, Thailand, Malaysia, Indonesia, Egypt and Ukraine. Project measures focus on building up technical and institutional know-how as well as laying the groundwork for the introduction and use of environmental and climate protection technologies "Made in Germany".

The project component CAP-SEA focusses on the prevention of single-use plastic (SUP) and reusable packaging systems in Thailand, Malaysia, and Indonesia. For more information on CAP SEA project activities, please download the project brochure here.

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Introduction

TEI provides the secretariat for the project CAP-SEA, which stands for "Collaborative Actions on Single-Use Plastic Prevention in South-East Asia". The project is financed by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and Consumer Protection (BMUV) and implemented by GIZ. CAP-SEA key objective is to reduce single-use plastic (SUP) by introducing innovative business models and by developing stakeholders' capacities, explicitly on upstream measures, not downstream waste management. In Thailand CAP-SEA contributes to the Thai Government's priority of the Bio, Circular and Green (BCG) economy model implementation for sustainable development.

Additionally, CAP-SEA is aligned with the Government's Road Map on Plastic Waste Management (2018-2030) and respective Action Plan phase I, II. The Road Map aims at phasing-out SUP products such as plastic cups and foam containers. CAP-SEA supports local governments and corporates to achieve these objectives. It supports SMEs and start-ups to provide alternative and environmentally friendlier solutions, and business models that encourage plastic recycling or reuse. Also, the project supports public-private partnership development to develop solutions jointly.

The report contained the followings;

1. Methodology and Scope
2. Plastics in the Packaging Sector
3. Recycled Plastics from the Packaging Sector
4. Recycling Process and Technology in Thailand
5. Ten Selected Recycling-friendly Designs

01
Methodology and scope

1.1 Research methodology

For market estimation and forecasting, authors use a combination of primary and secondary research. For estimation, the secondary research of the study is where we collected the amount of data, referring to verified data sources such as government data and regulatory publications, journals, trade magazines, and paid data sources. The following parameters were considered for forecasting:

- Market drivers and expected impacts
- End-use industry trends and dynamics
- Consumer behavior trends are used to calculate the expected market growth rate

All of our estimates and forecasts were validated by conducting extensive primary research with Key Industry Participants (KIPs), which typically include:

- Interview by research team

The key objectives of primary research are as follows:

- To verify our data in terms of accuracy and acceptability
- To gain overview of the current market and future expectations

1.2 Research scope and system boundary

The system boundary of the study

Task 1: Forecast analysis on recycled plastics in the packaging sector in Thailand

- Forecast analysis on recycled plastics in the packaging sector in Thailand of production, consumption, supply, and demand of recycled polymers.
- The recycled plastics include PET, PP, PS, and PE.
- Analysis of forecasts until 2030

Task 2: Technologies for sorting and preparation for recycling plastics and market overview

- Description of typical technical characteristics of sorting processes and facilities in Thailand
- Overview on 10 research and analysts in the selected recycling-friendly design options for the most relevant packaging types consumed in Thailand
- Mapping of the major manufacturers and distributors of recycling-friendly packaging types, as selected in task 2.2, in Thailand
- Analysis of forecasts until 2030

The scope of study

Task 1: Forecast analysis on recycled plastics in the packaging sector in Thailand

- To conduct the literature review on currently recycled plastics in the packaging sector in Thailand of production, consumption, supply, and demand of recycled polymers.
- To forecast analysis on recycled plastics in the packaging sector in Thailand until 2030 of production, consumption, supply, and demand of recycled polymers.

Task 2: Technologies for sorting and preparation for recycling plastics and market overview

- To descript of typical technical characteristics of sorting processes and facilities in Thailand
- To conduct the overview on 10 research and analysts in the selected recycling-friendly design options for the most relevant packaging types consumed in Thailand
- To conduct the mapping of the major manufacturers and distributors of recycling- friendly packaging types, as selected in task 2.2, in Thailand
- To forecast analysis on the demand of recycling-friendly packaging in Thailand until 2030

1.3 List of data sources

Some of the secondary sources used for this report include, but are not limited to:

- Company investor presentations
- Company annual reports

Table 1.1 Research methodology and source of data

Task	Key data need	Method	Sources of data (Survey + Interview)
Task 1			
1.1 Overview of production, consumption, supply, and demand of recycled plastics in the packaging sector in Thailand: the data of recycled plastics in the packaging sector in Thailand market, the types will at least cover PET, PP, PS, and PE.	• Production by main producers in the market (Thailand) • Consumption by the statistical data (Thailand) • Demand by end user in the market (Thailand) • Supply by collector in the market (Thailand)	• Secondary data • Forecasting	• Online data (Facebook, company profile) • Annual reports

Task	Key data need	Method	Sources of data (Survey + Interview)
1.2 Forecast analysis on recycled plastics in the packaging sector in Thailand on: the supply-demand analysis of recycled plastics in the packaging sector in Thailand market, the types will at least cover PET, PP, PS, and PE.	• End-user market • Economic statistic	• Secondary data • Forecasting	• Annual reports • NSO data • World Bank report
Task 2			
2.1 Description of typical technical characteristics of sorting processes and facilities in Thailand: Technical process, capacity and possible throughput	• Technical process • Capacity • Possible throughput	• Literature review secondary data • In-dept interview	• Annual reports • Key stakeholder interview • Secondary information
2.2 Overview on 10 selected recycling-friendly design options for the most relevant packaging types consumed in Thailand: such as food packaging, beverage containers, cosmetics, hygiene articles etc.	• Possibility recycling-friendly design • Recycling-friendly design for food packaging, beverage containers, cosmetics, hygiene articles	• Literature review secondary data • Literature review secondary data	• Annual reports • Key stakeholder interview • Secondary information
2.3 Mapping the major manufacturers or distributors of recycling-friendly packaging types, as selected in task 2.2, in Thailand: general information	• General information of manufacturers or distributors such as technical process, capacity, possible throughput	• Literature review secondary data • Literature review secondary data	• Annual reports • Key stakeholder interview • Secondary information
2.4 Forecast analysis (until 2030) on demand of recycling-friendly packaging	• End-user market • Economic statistic	• Secondary data • Forecasting	• Annual reports • Secondary information • World Bank report

*We are committed to ensuring the confidentiality and privacy of all personal information it collects during the conduct of the project. We are required or authorized by law to not disclose personal information of some stakeholder.

02
Plastics in the packaging sector

Plastics are widely used in our daily life, especially in the packaging sector. This report focuses on the packaging sector based on their high consumption and after consumption, most of them end up in a landfill. Virgin resin consumption in the packaging sector of Thailand are as follows:

2.1 Virgin resin consumption in the packaging sector in Thailand

The major products in the study are mainly focuses on the packaging sector such as sheet and films, food & beverage containers and bottles, and non-food containers and bottles.

Figure 2.1 depicts the amounts of virgin PET production focused in this study. Thailand's major PET producers are Indorama Ventures, Thai PET Resin (PTTGC group) and Polyplex Thailand (Polyplex Group).

A study by ChemIntel360's, the global market volume of polyethylene terephthalate (PET) amounted to 24.23 million metric tons in 2021. By 2029, the PET market volume is expected to grow at CAGR of 4.2 percent during the forecast period of 2022 to 2029 (Tiseo, Global market volume of PET 2015-2029, 2022). Polyethylene terephthalate's inherent properties such as water and moisture resistance, flexibility, and a high performance to weight ratio, makes it very suitable for packaging applications.

A study by Krungsri Research, the Thai economy is expected to record an average annual growth of 2.5-4.0% through to 2023. This would help to lift demand for plastic products in downstream industries, which should grow at a similar pace (Khanunthong, 2021). Research team expects the output of plastic packaging to expand by 3.0% (see appendix) annually during the forecast period of 2022 to 2030. The growth in the polyethylene terephthalate market is mainly driven by the rise in demand from the food and beverage industry, along with the growing preference for recycled food and beverage bottles. This demand is not only local demand but also demand for export.

FIGURE 2.1 Market volume of virgin polyethylene terephthalate production for the packaging sector in Thailand from 2012 to 2021, with a forecast for 2022 to 2030

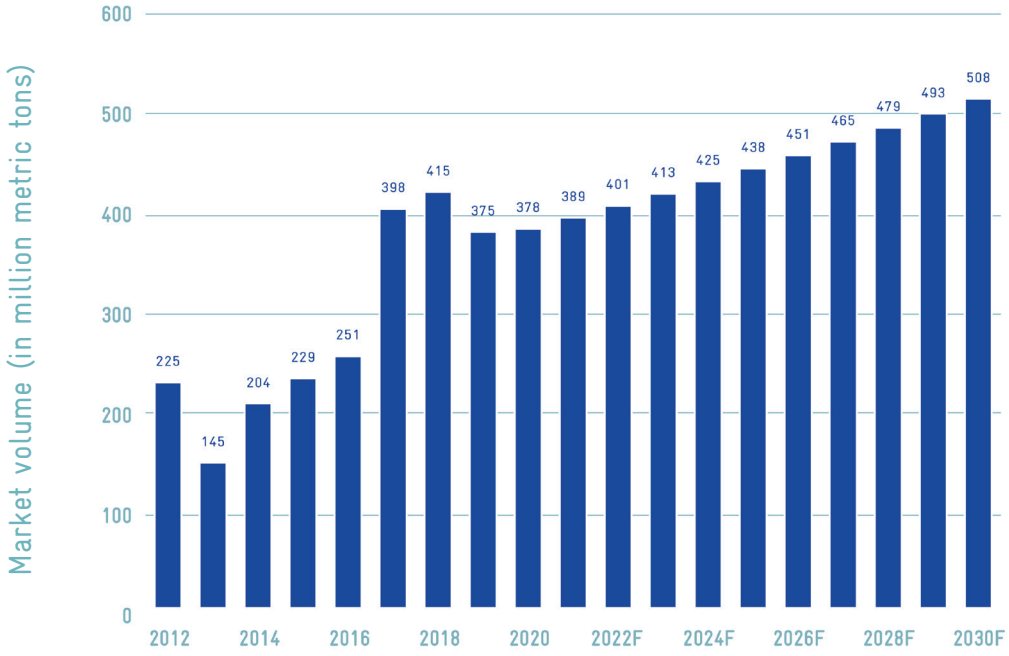


FIGURE 2.2 Products from virgin polyethylene terephthalate in Thailand from 2021

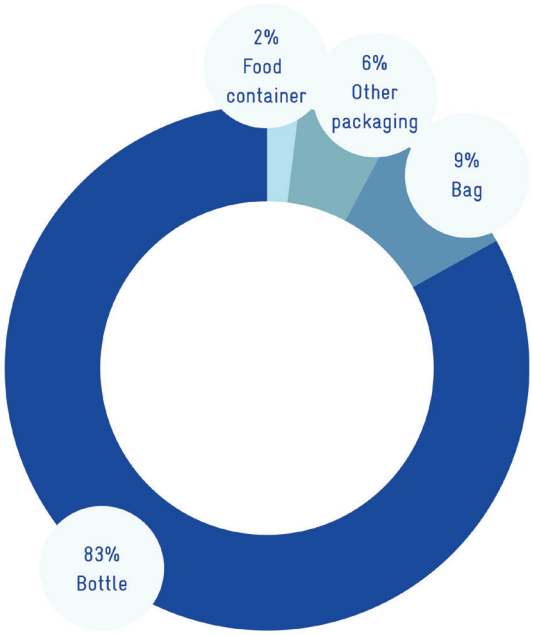


Figure 2.3 depicts the amounts of virgin PE including HDPE, LDPE and LLDPE production focused in this study. Thailand's major PE producers are SCG Chemicals, PTTGC group and IRPC.

A study by Statista, the global market of HDPE is expected to rebound strongly and grow at a CAGR of 4.0 % over 2021-2026 (Tiseo, HDPE market size worldwide 2020-2026, 2021). The main factors driving growth is the chemical's extensive use in packaging industry, the demand for which has witnessed robust growth in light of its eco-friendly properties. High-density polyethylene, often abbreviated as HDPE, refers to a thermoplastic polymer obtained from the monomer ethylene. HDPE is renowned for its high strength-to-density ratio. It has high specific strength, hard, quite opaque, and can resist high temperatures. Also, it can withstand several different solvents. All these properties enable HDPE resin to have applications as a raw material in several industries, some of which are plastic bottles, pipes, ropes, disposable suits, chairs, toys, and others.

A study by Krungsri Research, the Thai economy is expected to record average annual growth of 2.5-4.0% through to 2023 (Khanunthong, 2021). This would help to lift demand for plastic products in downstream industries, which should grow at a similar pace. Research team expects the output of polyethylene to expand by 3.0% annually during the forecast period of 2022 to 2030. The growth in the polyethylene market is driven by the rise in demand from the packaging industry, along with the growing preference for recycled beverage bottles and personal care container. This demand is not only local demand but also demand for export.

FIGURE 2.3 Market volume of virgin polyethylene production for the packaging sector in Thailand from 2012 to 2021, with a forecast for 2022 to 2030

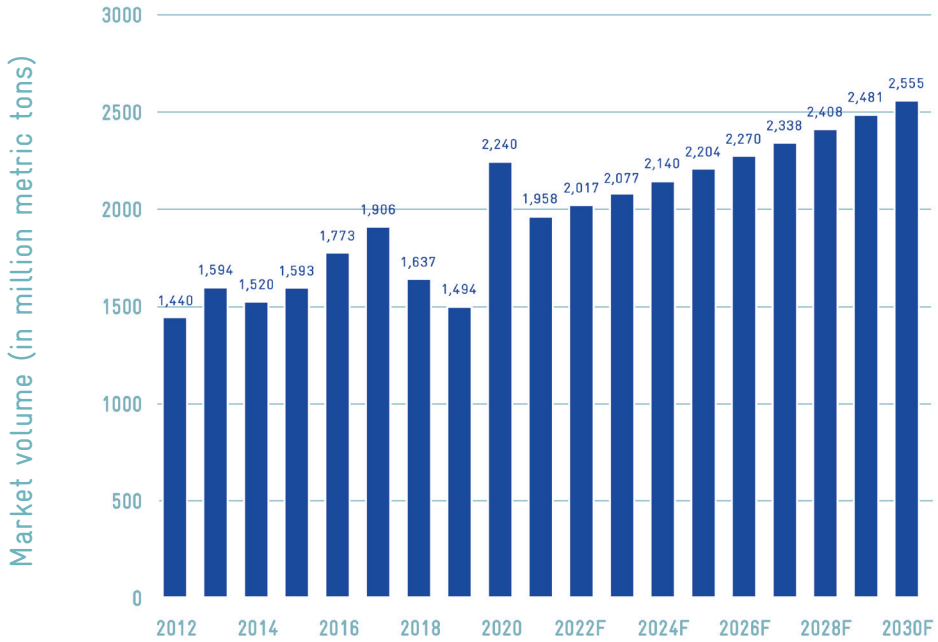


FIGURE 2.4 Products from virgin polyethylene in Thailand from 2021

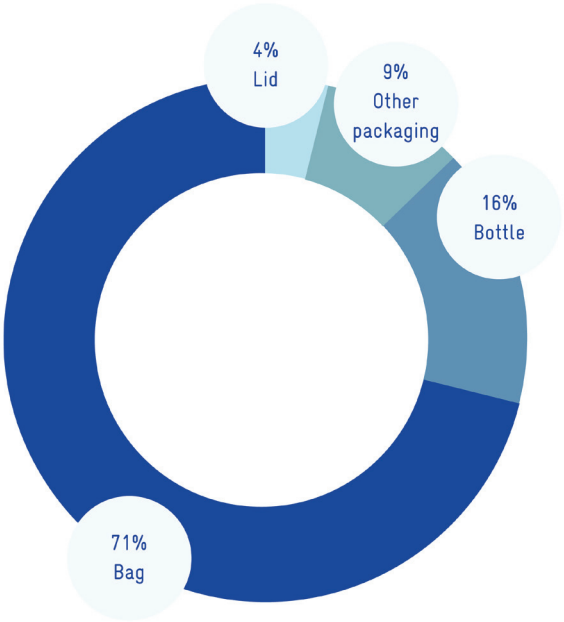


Figure 2.5 depicts the amounts of virgin PP production examined in this study. Thailand's major PP producers are PTTGC group, IRPC and SCG Chemicals.

According to a study by Statista, in 2021, the global market volume of polypropylene is approximately 75.6 million metric tons – an increase of roughly 2.2 percent compared with the previous year. The market volume is expected to grow at a CAGR of 3.6 percent by 2029 (Tiseo, Global polypropylene market volume 2015-2029, 2022). The global polypropylene market growth is primarily driven due to the growing demand for polypropylene in end-use industries perspective.

A study by Krungsri Research, the Thai economy is expected to record an average annual growth of 2.5-4.0% through to 2023. This would help to lift demand for plastic products in downstream industries, which should grow at a similar pace. Research team expects the output of polypropylene to expand by 1.0% annually during the forecast period of 2022 to 2030. The growth in the polypropylene market is driven by the rise in demand from the packaging industry. Packaging was the largest end-use industry for polypropylene market and accounted for 32.6% in 2021. The growing demand for efficient packaging products is driving the polypropylene industry globally. Product properties such as increased clarity, aesthetics, lightweight, high-temperature resistance, moisture barrier, and flexibility make it an ideal material for packaging in the food and beverage industry. Further, polypropylene is also used in the packaging of electrical and electronics products due to its transparency, optical clarity, and non-conductivity properties. Additionally, the demand for polypropylene is expected to rise significantly over the forecast period due to the increasing usage of polymers in the production of electronic products such as computers, laptops, tablets, and mobile phones. Health and pharmaceuticals companies use polypropylene based plastics for manufacturing surgical equipment and other medical products due to their chemical resistance and non-corrosive properties which enhance the shelf life of drugs.

FIGURE 2.5 Market volume of virgin polypropylene production for the packaging sector in Thailand from 2012 to 2021, with a forecast for 2022 to 2030

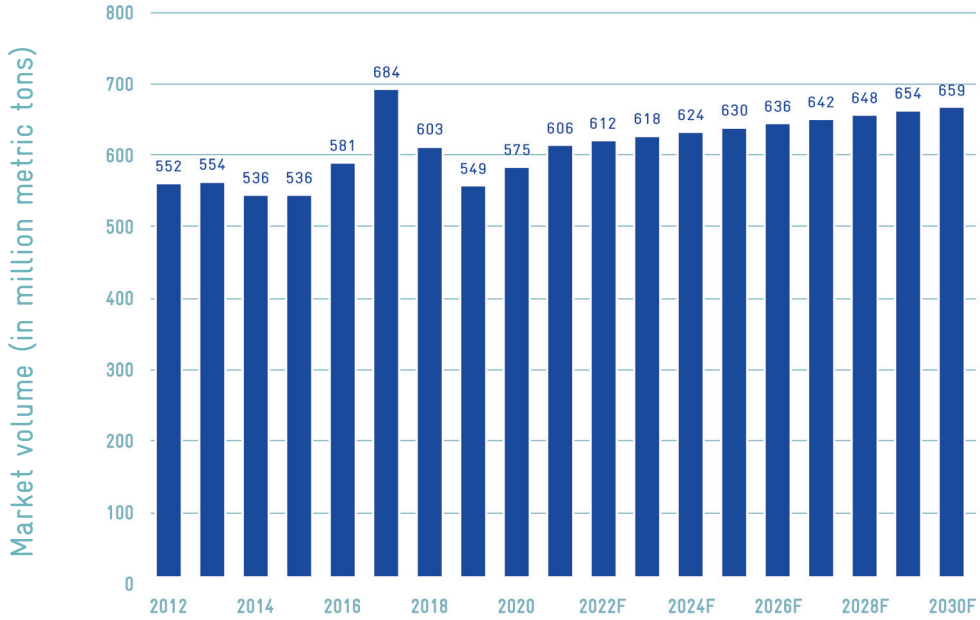


FIGURE 2.6 Products from virgin polypropylene in Thailand from 2021

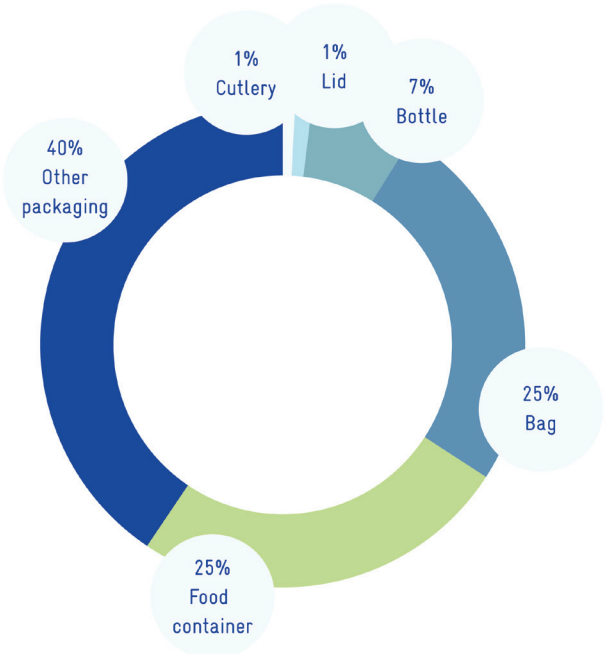


Figure 2.7 depicts the amounts of virgin PS production examined in this study. Thailand's major PS producers are IRPC, Siam Polystyrene (DOW), GC STYRENICS and Ming Dih Chemical.

According to a new market report published by Transparency Market Research, the global polystyrene (PS) foam trays market in terms of revenue was valued at US$2 bn in 2009 and is expected to reach US$3 bn by 2021, growing at a CAGR of 3.2% from 2009 to 2021. In terms of volume, global foam trays market was valued at 31.7 bn units in 2009 and is expected to reach 52.8 bn units by 2021, expanding at a CAGR of 4.4% from 2009 to 2021 (Danny, 2015). The global foam trays market, by application types, can be divided into four segments: pharmaceutical, food packaging, industrial packaging and others. Food packaging was the largest contributor in global foam trays market in 2014, accounting for a market share of more than 80% in terms of both revenue and volume. The growth can be attributed to wide application of foam trays in different packaging industry. Also, the expansion of multi-national food chains into the emerging markets is also raising the demand for foam trays. Considering these factors, food packaging is anticipated to remain the largest segment in foam trays market during the forecast period.

A study by Krungsri Research, the Thai economy is expected to record average annual growth of 2.5-4.0% through to 2023 (Khanunthong, 2021). This would help to lift demand for plastic products in downstream industries, which should grow at a similar pace. Research team expects the output of polystyrene to expand by 1.0% annually during the forecast period of 2022 to 2030. The growth in the polystyrene market is driven by the rise in demand from the packaging industry. Increasing demand for expanded polystyrene (EPS) foam trays is the major factor behind the growth of polystyrene segment, in terms of both revenue and volume. With rising penetration of food service and take away food services, this is expected to increase the growth of the foam trays market during the forecast period from 2022 to 2030. The growth of PS is relatively small due to the reducing or banning the use of EPS foam trays policy from Pollution Control Department of Thailand (PCD) since 2018.

FIGURE 2.7 Market volume of virgin polystyrene production for the packaging sector in Thailand from 2012 to 2021, with a forecast for 2022 to 2030

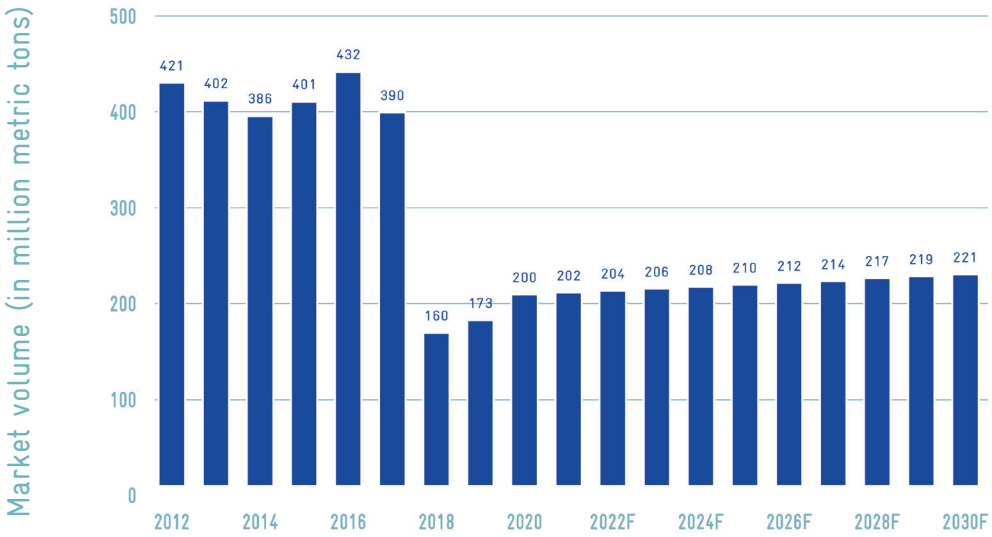
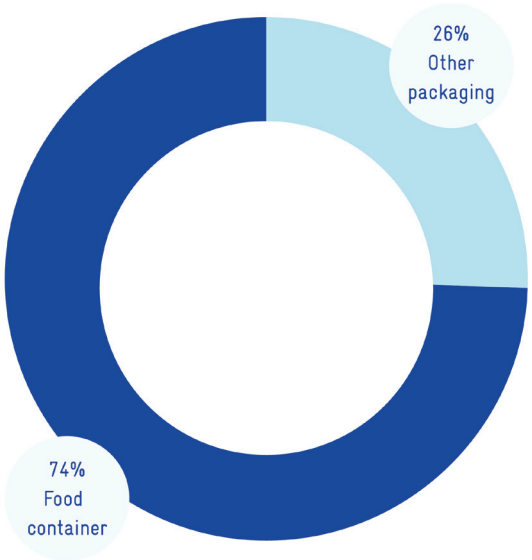


FIGURE 2.8 Products from the virgin polystyrene in Thailand from 2021



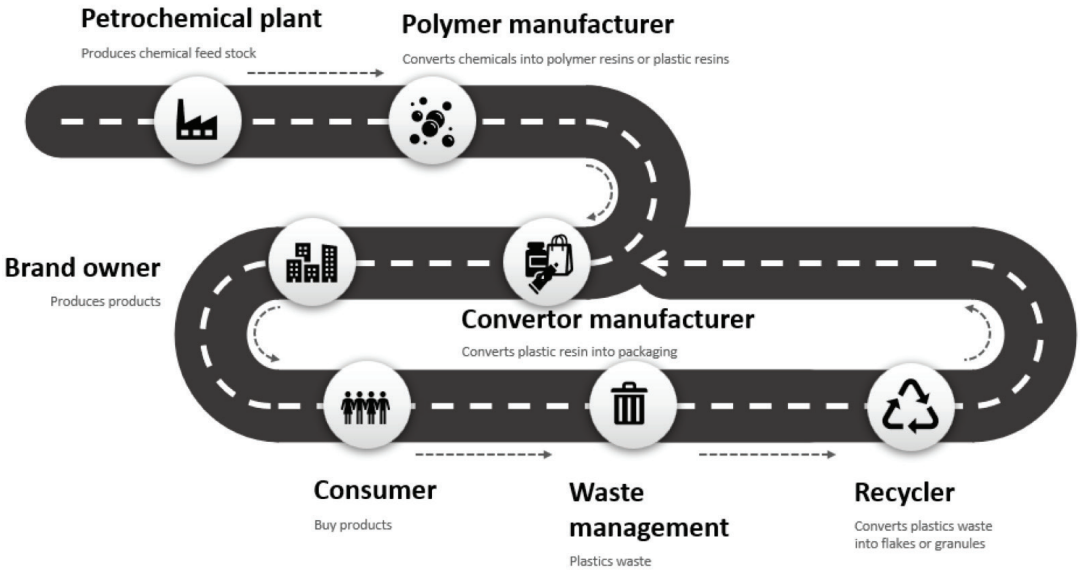
03
Recycled plastics from the packaging sector

3.1 Recycled plastic market analysis

Statista displays the global average recycling rate of plastic packaging and PET bottles as of 2013. During this year, an average of 14 percent of plastic packaging was recycled. The vast majority of this plastic packaging material was sent to landfills and some are leaked into the environment.

The important data in this section are the data from the recycle shops representing the supply for recycled market and the recyclers/convertors representing the amount of recycling production in the market. The data on post-consumer PET products were gathered from recycle shops (small, medium, and large scale) that collected post-consumer PET products in the local area and packed them in the form of bales before sending them to the recycling factory.

FIGURE 3.1 The supply chain of packaging plastic in Thailand.



3.1.1 Recycled polyethylene terephthalate (PET) market analysis

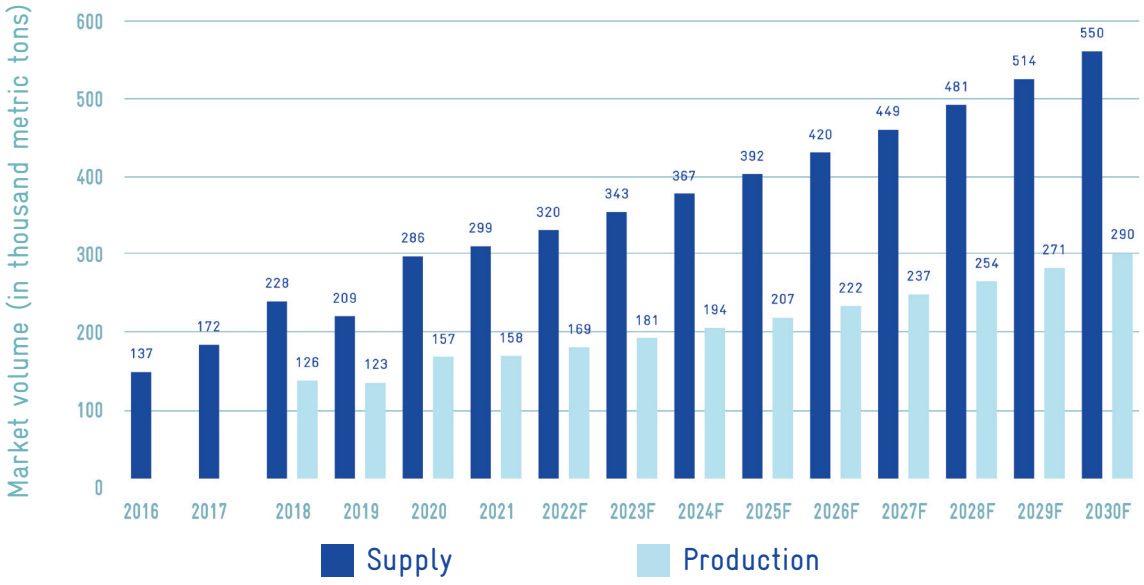
rPET or recycled PET is a resin compound made from post-consumer PET products that are used in a wide variety of end-user industries. The most common source of rPET is

post-consumer PET bottles. First, PET bottles are collected and then sent to a recycling factory. The cleaning, drying, flaking and melting processes are also common processes to obtain rPET pellets.

The estimation of post-consumer PET products from the recycle shops collected were 137 kton in 2016 and noticeably increased to 286 kton in 2020 as shown in Figure 3.2. The estimation of recycling production in the form of rPET fiber is also increased from 126 kton in 2018 to 158 kton in 2021. The recycled PET is classified into the following product types based on the local end-user's market;

- **Fiber:** Fiber is flexible and has a high tensile strength, which allows it to be spun into yarn, which will be used to make clothes, garments, carpets and home furniture.
- **Sheets and films:** Sheets and films are the most common materials used for making packaging products.
- **Strapping:** Straps made of rPET are durable, and are primarily used for packaging purposes, such as securing a package.
- **Non-food/Food and beverage containers and bottles:** The containers and bottles prepared from rPET are used in packaging of food and beverage and non-food products. The rPET bottles are used for packaging of soft drink, juice, water, other beverages, detergents, personal care, and cosmetics.

FIGURE 3.2 Market volume of supply and production of rPET in Thailand from 2016 to 2021, with a forecast for 2022 to 2030



A study by Transparency Market Research, in 2019, the global recycled PET bottles market has been growing at a steady CAGR of ~8%, lack of proper infrastructural facilities for the collection and sorting of discarded plastic has been disrupting the speed of PET recycling (Recycled PET Market Analysis 2021-2031, 2021). In addition, colored or contaminated plastic makes the recycling of PET difficult, which drives these materials towards waste streams.

Research team expects the growth of rPET at ~7.0% annually during the forecast period of 2022 to 2030. The growth in the rPET market is driven by the rise in demand from the packaging industry, especially the recycled content in PET beverage bottles from the Global Commitment by 2025. The different between PET bottles supply and rPET production clarified by the demand by the export market. For global market, majority of companies dealing with FMCG goods have decided to commit at least half of the recycled content in plastic packaging by the year 2030. Though food-grade recycled plastic is in short supply as of now, this factor is bound to certainly take the entire recycled PET market by storm in the forecast period, more so as there is no substitute to recycled PET and the demand for it is not expected to cease soon. North America and Europe are at the saturated stage of recycled PET market. The US, UK, France, Spain, and Germany are displaying maturity with respect to recycled PET packaging market. The EU directive is inclusive of target encompassing 25% recycled content in every PET beverage bottles from the year 2025. This percentage is expected to increase to 30% from the year 2030. The leading brands like PepsiCo, Danone, and Coca-Cola are looking forward to 50% use of recycled PET in bottles by the year 2030. However, the Asia-Pacific is expected to display maximum vibrancy herein. The densely populated economies like China and India are the lucrative markets for recycled PET. The applications of rPET are inclusive of sweaters, carpets, clothes, upholstery, and fiber-fill for cushions and sleeping bags, automotive parts, and sheet and film.

Source: https://www.betagen.co.th

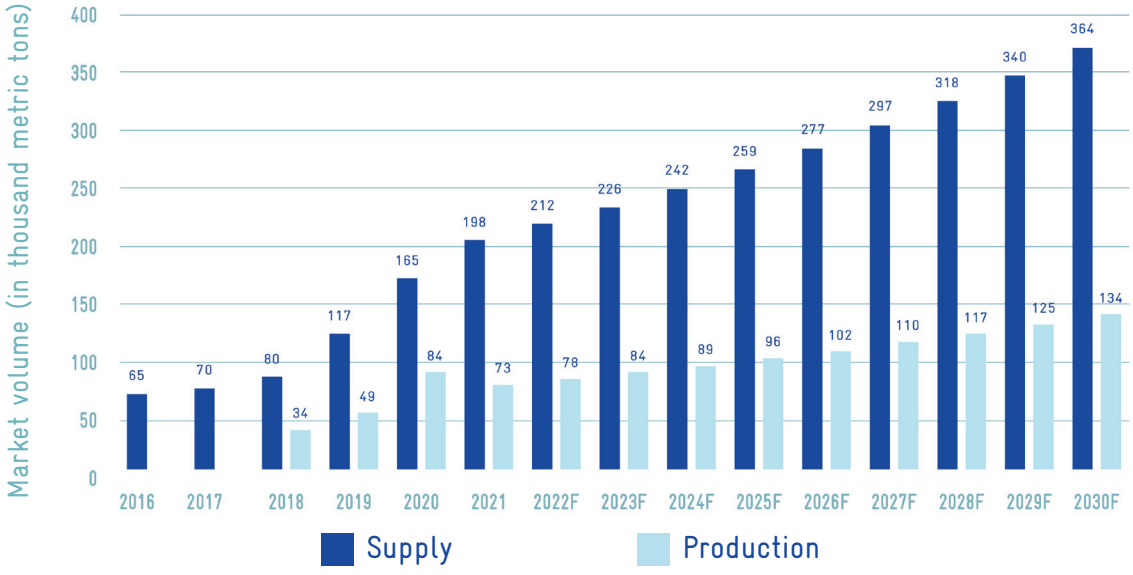
3.1.2 Recycled polyethylene (PE) market analysis

Recycled polyethylene (PE) also known as rPE is a polyethylene compound made from post-consumer PE products. The most common sources of rPE are post-consumer milk bottles, bags, consumer containers, etc. Recycle shops collected post-consumer PE products by types and colors as follows;

- **Natural color PE bottle:** Natural color PE bottle is made from HDPE resin without filler and color. The common products in this category are milk bottles, kitchen ingredient containers and personal care containers.
- **Opaque PE bottle:** Opaque PE bottles are made from HDPE resin compound with filler/s but no added color (or pigment), normally they are white bottles. The common products in this category are also milk bottles, kitchen ingredient containers and personal care containers.
- **Colored PE bottle:** Colored PE bottles are made from HDPE resin compound with filler/s and color (or pigment). Colored PE bottles in this category are usually available in personal care containers and in various colors such as black, green, blue, or yellow color.
- **Natural color PE bag:** Natural color PE bags are made from HDPE, LDPE or LLDPE resin without filler and color.
- **Colored PE bag:** Colored PE bags are made from HDPE, LDPE or LLDPE resin compound with filler and color.

The estimation of post-consumer PE products collected by the recycle shops was 65 kton in 2016 and considerably increased to 165 kton in 2020 as presented in Figure 3.6. The estimation of recycling production in the form of rPE is also increased from 74 kton in 2018 to 114 kton in 2021. Currently, the rPE is used based on the local end-user's market. rPE from bags and films sources are used in blow film process to make shopping bags, garbage bags and agriculture films. For rPE from bottles and containers sources are used for producing plastic rope, durable products such as fruit baskets, plastic furniture or even artificial woods.

FIGURE 3.3 Market volume of supply and production of rPE in Thailand from 2016 to 2021, with a forecast for 2022 to 2030



The global recycled plastics market size was valued at USD 46.09 billion in 2021 and is expected to grow at a compound annual growth rate (CAGR) of 4.8% from 2022 to 2030 (Global Recycled Plastic Market, 2019). Increasing plastic consumption in the production of lightweight components, which are used in various industries including building and construction, automotive, and electrical & electronics, is expected to propel the growth of the market over the forecast period. Amid the global COVID-19 pandemic, the demand for various packaging products was high on account of the rise in online purchases of electrical and electronics, personal care products, and personal protective equipment (PPE) products, such as gloves and face masks.

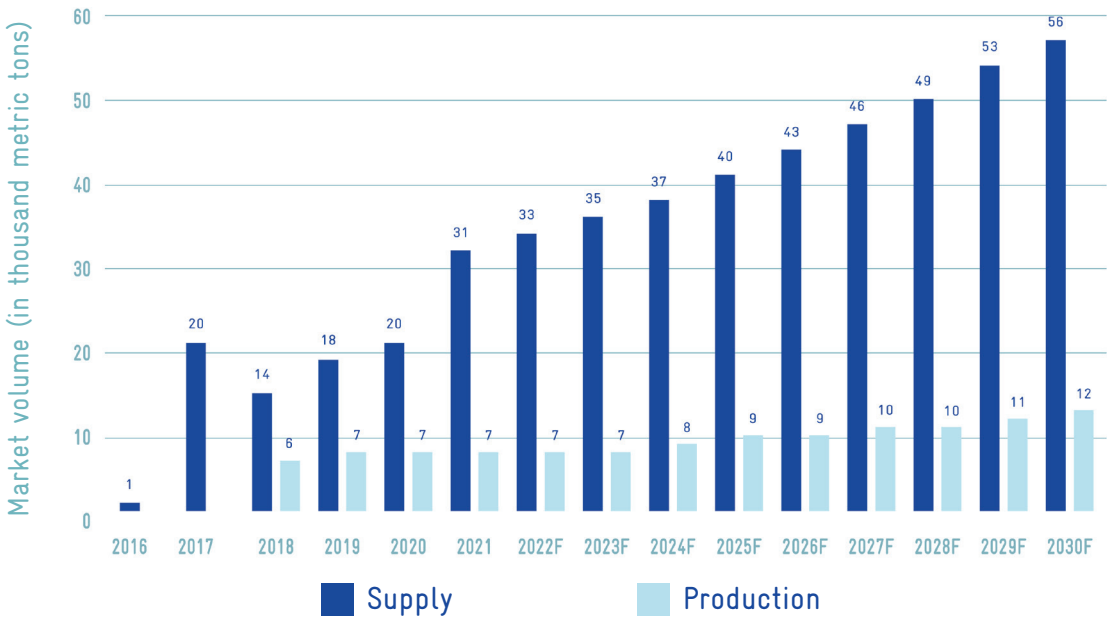
Research team expects the growth of rPE at ~7.0% annually during the forecast period of 2022 to 2030. The supply and production section were expected to grow due to no pandemic. The growth in the rPE market is driven by the rise in demand from the packaging industry driven by the goal of tackling plastic pollution at its source, companies representing 20% of all plastic packaging produced globally have committed to ambitious 2025 targets to help realise that common vision. The polyethylene (PE) product segment led the market and accounted for more than 31% share of the global revenue in 2021. This high share is attributed to the rising demand for packaging material in consumer goods, food and beverage, industrial, and various other industries. In addition, it is commonly used in laundry detergent packaging, milk cartons, cutting boards, and garbage bins, among various other applications.

3.1.3 Recycled polypropylene (PP) market analysis

Recycled polypropylene (PP) also known as rPP is a polypropylene compound made from post-consumer PP products. Plastic food containers are the most common source of rPP. Recycle shops collect post-consumer PP products by type and color, similar to post-consumer PE products. Fewer post-consumer PP products are collected for recycling because of the majority of PP products are used as food carriers and the containers will become dirty after use, making them more difficult to recycle.

The estimation of post-consumer PP products from the recycle shops is shown in Figure 3.4. The amount of collection is mostly the same due to local end-users. rPP was used as a substituted material for producing the low-price products such as baskets, water tanks, plastics chairs, and some plastic furniture.

FIGURE 3.4 Market volume of supply and production of rPP in Thailand from 2016 to 2021, with a forecast for 2022 to 2030



Research team expects the growth of rPP at ~7.0% annually during the forecast period of 2022 to 2030. The supply and production section were expected to grow due to no pandemic. Polypropylene (PP) is extensively used in manufacturing automotive components, packaging and labeling, medical devices, and diverse laboratory equipment owing to its excellent chemical and mechanical properties. It is resistant to several chemical solvents, acids, and bases and has excellent mechanical strength. It is also among the most widely formulated plastics across the globe. In addition, components produced using PP are fatigue resistant, which is beneficial in the building and construction industry for producing plastic hinges, piping systems, consumer-grade daily-use products, manufacturing mats, and carpets and rugs among various other applications. The growth of the automotive, packaging, building and construction industries is expected to drive the demand for recycled PP over the forecast period.

4.1.4 Recycled polystyrene (PS) market analysis

Recycled polystyrene (PS) or known as rPS is a polystyrene compound made from post-consumer PS products such as PS foam which is to prevent any shipping damage to products. PS is commonly used in food containers and protection foam. Due to their contamination and light weight, most recycle shops do not collect post-consumer PS foam products. The lightness of PS wastes is also another important factor that deter collectors from gathering them. Some recycle shop convert PS foam into PS ingot before sending them to recycle factories to convert recycled PS foam into picture frames.

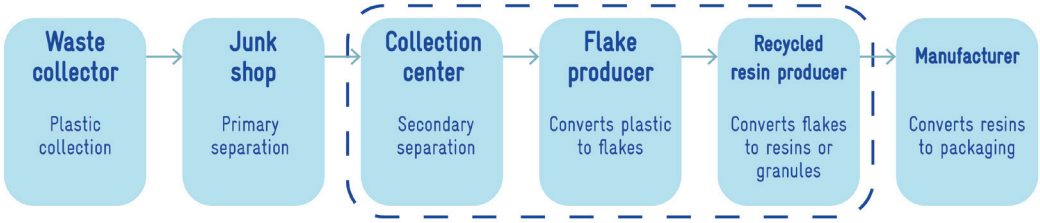
04
Recycling process and technology in Thailand

Thailand is currently recycling plastic wastes from single used plastic products with an average total recycling rate of more than 20%, especially PET, which has a recycling rate of more than 80%. Recycling process started from household or waste pickers collected plastic wastes and selling them to recycle shops in the local area. These recycle shops are the first-tier player in the recycled plastic value chain who collected local wastes and transfer them to the second-tier player i.e. a bigger recycle shop/collector or directly to the recycle factory i.e. third-tier player.

The scale of recycling factory is depended on the type of plastic source, sorting process, cleaning process, flaking, and melting process.

The activities in recycle shop or small collectors are collecting waste from households or waste pickers and separating them into PET bottles, clear-translucent HDPE bottles, white HDPE bottles, color HDPE bottles, clear-translucent PP bottles, white PP bottles, color PP bottles, and all kind of plastics (hard to separate or high filler content). After sorting, these post-consumer plastic wastes may be sold to a larger recycle shop/collector to be packed into bales to make it easier for transportation. Different types of plastic wastes will be sent to different recycling factories such as PET will be sent to PET recycling factory, but PE and PP may be recycled in the same factory.

FIGURE 4.1 Supply chain of plastic recycle in Thailand



Noted: these 3 suppliers may combined 2 or 3 activities in one factory

4.1 Technical characteristics of sorting processes and facilities in Thailand

4.1.1 Technology for rPET production

The production of recylced PET or rPET is made up of a number of different processes with different purposes. Figure 4.1 outlines the process for production of rPET flake and rPET resin. Typically, rPET flakes and rPET resins have slightly more processes when compared

with rPE resin production. In the rPET production process, a hot washing process is introduced to remove any oilly contamination. The main processes for rPET production are as follows;

1) De-baling and label separation process
2) Sorting process (manually)
3) Metal removal
4) Pre-washing process
5) Grinding process
6) Float washing process
7) Special washing process (by surfactant or alkaline solution)
8) Rinsing process
9) Drying process
10) Color sorting process (blue, yellow, natural)
11) Pelletizer process
12) Spinning process (for fiber making process)
13) Packing process

The additional information on each process provides in **Table 4.1.**

FIGURE 4.2 Main production processes for rPET production

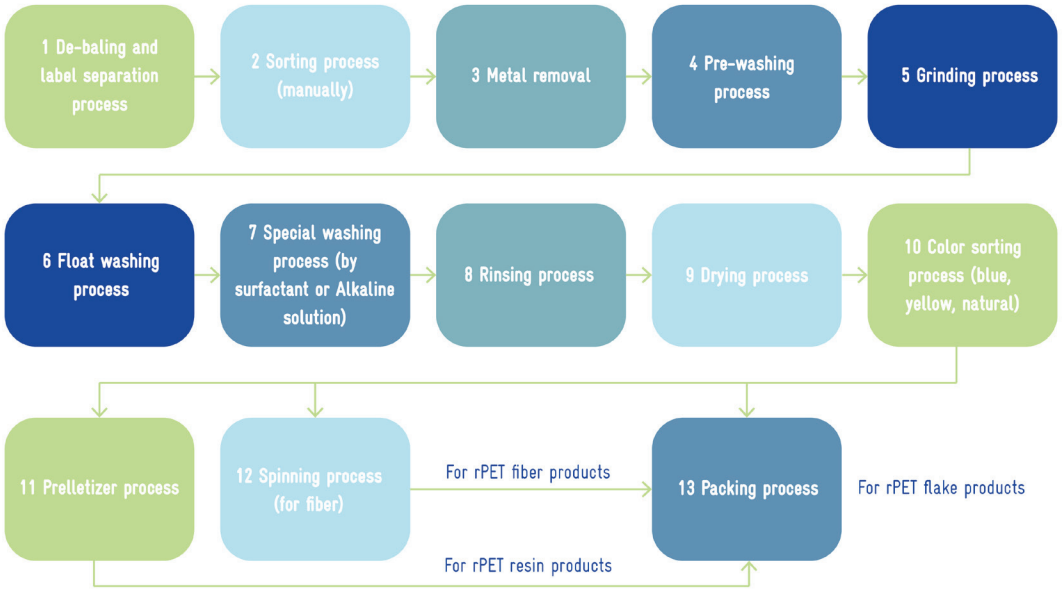


Table 4.1 Technical characteristics of the main processes for rPET production

Process	Objective	Operation
1) De-baling and label separation process	• De-baling: Opening the plastic bottle bales and separating the bottles • Label separation: To separate the labels from the waste PET bottles	• Bottle packs or straps are untied and transported via a conveyor belt system which is both efficient and effective. • All bottles are then go through label separation process, where labels from the bottles are removed by rubbing, vibrating and blowing air. The labels are easy to remove because they are light and thin.
2) Sorting process (manually)	• To separate label that is hard to remove. • To separate colored bottles and the transparent non-PET products out of the process as much as possible	• The remaining labels are collected during this process and returned to the removal process or removed by the operator. • The operator will also be responsible for collecting colored bottles and non-PET bottles at the end of the process.
3) Metal removal	• To remove any metallic objects from the process	• Use an electrostatic separator to separate non-ferrous metal • Use a magnetic separator to separate ferrous metal
4) Pre-washing process	• To pre-wash the bottles and remove some of the dirt	• The pre-washing machine is also used to add chemicals and heat in this procedure. This process separates and removes more than 90% of impurities.
5) Grinding process	• To crush PET bottles and lids to the appropriate size (flake), allowing the bottle (PET) and lid to be easily separated (PE). This procedure can be wet or dry.	• The crushing machine reduces the size of PET bottles and caps, using water as a cooling lubricant. This section is designed specifically for crushing bottles. • The product from this section is called flakes.
6) Float washing process	• To separate the PET flakes from the PP/PE caps, rings, and dirt	• This process used hot water, and different specific gravity of the materials, is used to separate the PET flakes from PP/PE caps and rings.

Process	Objective	Operation
7) Special washing process (by surfactant or alkaline solution)	• To clean PET flakes	• The PET flakes are washed with surfactant or alkaline solution (optional).
8) Rinsing process	• To remove the remaining surfactant or alkaline solution	• This process, clean water is used to rinse PET flakes in a tank with a low-speed agitator.
9) Drying process	• To remove the water from the flakes	• Dust separation: Dust must be removed as much as possible in this section because it can cause yellow and black spots in the pellets in the following phase due to dust contamination. Using a cyclone system, small particles and light materials are separated from the flake, which falls to the bottom due to gravity. • The dryer removes moisture from PET flake by lowering the humidity as much as possible. This is required to ensure that the material output has a low humidity.
10) Color sorting process (blue, yellow, natural)	• To separate non-PET flake as much as possible • To separate the different color flakes	• FTIR detector used to separate non-PET flakes • Image processing detector is used to separate PET flake colors
11) Pelletizer process	• To melt PET flake and cut to rPET pellet	• Extruder is the machine uses to melt and compound PET flakes. • PET flakes are loaded into the hopper, which is then fed into the extruder. Moisture and gas from melt rPET in the extruder are removed from the material using a strong vacuum system. Melted rPET is cut into pellets, which are then fed into a silo and packed.
12) Spinning process (for fiber making process)	• To make polyester staple fiber, polyester filament, monofilament yarn	• The process of conversion of rPET flakes into textile fibers or filaments and yarns.

Process	Objective	Operation
13) Packing process	• To pack a finished product	• This process includes filling and labelling, that a bulk product has to undergo in order to become a finished product.

4.1.2 Technology for rPE and rPP production

The recycling technologies for post-consumer PE and PP from packaging are interchangeable. Gridding, cleaning, and melting are the primary steps. Some recycling factories do not separate PE and PP sources. The followings are the rPE and rPP production processes:

1) De-baling process
2) Sorting process (manually)
3) Metal removal
4) Pre-washing process
5) Rinsing process
6) Grinding process
7) Flake washing process
8) Drying process
9) Flake sorting process (color separation)
10) Pelletizer process
11) Packing process

The additional information on each process is provided in **Table 4.2**.

FIGURE 4.3 Main processes for rPE and rPP production

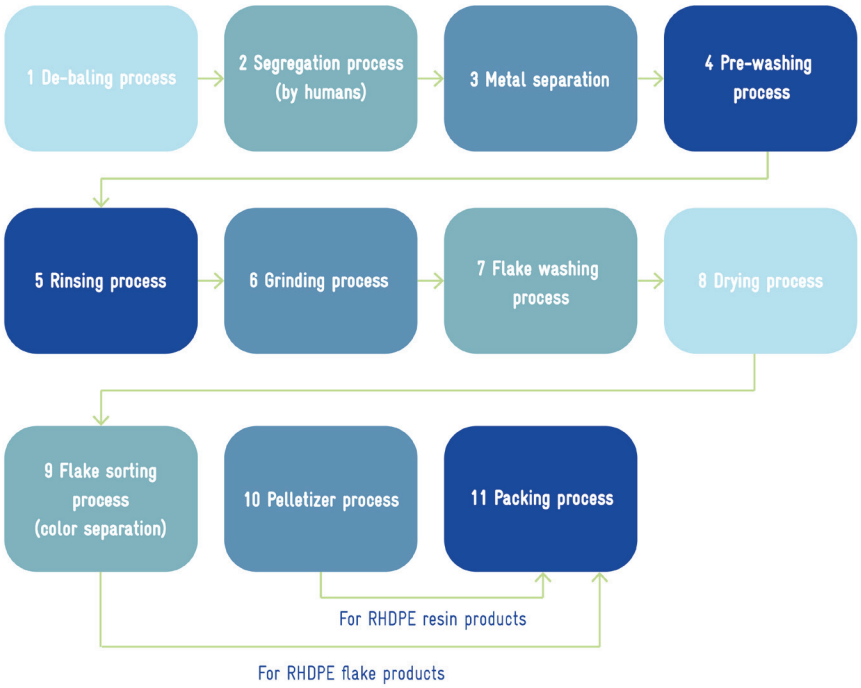


Table 4.2 Technical characteristics of the main processes for rPE and rPP production

Process	Objective	Operation
1) De-baling process	• De-baling: Opening the plastic bottle bales and scatter the bottles	• Bottle packs or straps are untied and transported via a conveyor belt system which is both efficient and effective.
2) Sorting process (manually)	• To separate colored PE or PP out of the process as much as possible • To separate other types of plastic	• The operator is also responsible for collecting colored PE or PP plastics
3) Metal removal	• To remove any metallic object from the process	• Use an electrostatic separator to separate any non-ferrous metal • Use a magnetic separator to separate any ferrous metal
4) Pre-washing process	• To pre-wash the bottles and remove the dirt	• The machine is also used to add chemicals and heat in this procedure. This process separates and removes more than 90% of impurities.

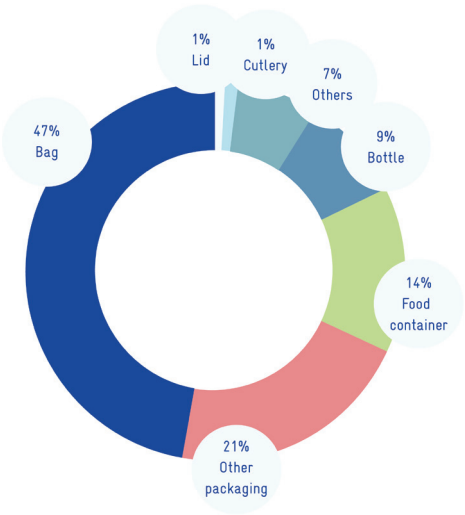
Process	Objective	Operation
5) Rinsing process	• To remove the remaining surfactant or alkaline solution	• This process, clean water is used to rinse flakes in a tank with a low-speed agitator.
6) Grinding process	• To crush PE or PP to the appropriate size (flake)	• The crushing machine reduces the size of PE or PP • The product obtained from this section called flakes.
7) Flake washing process	• To clean flakes	• Clean flakes • This process uses different specific gravity of the materials to separate low- and high-density plastics
8) Drying process	• To remove the water from the flakes	• Dust Separation: Dust must be removed as much as possible in this section because it can cause yellow and black spots in the final pellets in the following phase due to dust contamination. Using a cyclone system, small particles and light materials are separated from the flakes, which will fall to the bottom due to gravity. • The dryer removes moisture from flakes by lowering the humidity as much as possible. This is required to ensure that the material output has low humidity.
9) Flake sorting process (color separation)	• To separate type of plastic flake as much as possible • To separate the different color of flakes	• FTIR detector is used to separate flakes of different polymer type (optional) • Image processing detector is used to separate flake colors (optional)
10) Pelletizer process	• To melt flake and cut to rPE or rPP	• Extruder is the machine used for melting and compounding of flakes. • Flakes is loaded into a hopper, which is then fed the material into the extruder. Melted plastic is cut into resin pellets, which are then fed into a silo and packed. (a twin-screw extruder or a two-step single screw extruder is used)

Process	Objective	Operation
11) Packing process	• To pack a finished product	• This process includes filing and labelling which a bulk product has to undergo in order to become a finished product.

05
Ten selected recycling-friendly designs

The total amount of post-consumer waste generated during 2020 is about 2.1 MMT. Figure 5.1 showed percentage type of plastics waste generated. Plastic bags account for 47% of the common products found in landfills, followed by other packaging (most of which are films, accounting for 21%), food containers (14%), lids (1%), cutlery (1%), and others (7%). The reason that these bags, film, and food container wastes are still being discharged in landfills is that they are contaminated with food and difficult to collect and clean. Furthermore, the cost of collecting, processing, and recycling plastics is currently prohibitively expensive. However, there is still the opportunity to collect more items for recycling if these wastes are to be sorted, separated and cleaned before throwing them away.

FIGURE 5.1 Type of plastic waste generated during 2020



Plastics in packaging sector are used extensively, in order to retain product properties, which covering manufacturing, through products, transportation and delivery. The global movement acknowledges that moving from a single-use or linear economy to a circular is important. Main sectors of packaging are food packaging, beverage packaging, personal care and cosmetics and others. Ten selected recycling-friendly designs for packaging which is mainly needed to be easily separated and recovered and some of these are outlined below;

Food packaging

Packaging, trays, and boxes made from various colors PP should be changed to clear or the original color of plastic, and no further additives should be used. Furthermore, labels should be easily removed.

1. PP color tray and container

While a black container or tray can be recycled but it is low value and limited applications which made them low recycling rate. Packaging, trays, and boxes made of various colors from PP should be changed to clear or the original color of plastic, and no further additives should be used. Furthermore, labels should be easily removed.

2. PS food container

It is not because PS foam cannot be recycled but because of its lightweight made it less collectable. PS container should be changed to clear container, and no further additives should be used. Moreover, labels should be easily removed.

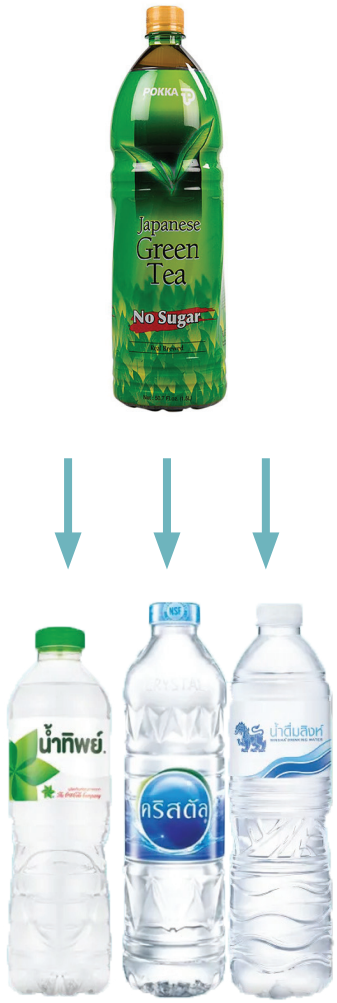
Beverage packaging

Water bottle is one of the packaging that has high recycling rate. All components of a water bottle can be recycled, such as HDPE lids, PET bottles and labels (although, labels are mainly recycled for energy). PET bottles are recycled to polyester fiber and bottle to bottle (B2B). HDPE lids are recycled to many products which uses injection molding process for production.

3. Clear PET bottle

- Some reports suggested that PET bottle in Thailand has recycling rates between 60-80%. One way to further increase recycling rate of PET bottles is to have recycling friendly design, some changes in the design are as follows;
- Color: no blue, no yellow, only clear color
- Cap: clear color or white HDPE
- Filler: no filler
- Label: no label or easily removal label (some products such as carbonated drink or beauty drink products must provide nutritional information for customers)

Note: a suggestion from recyclers on the type of plastic for label is that it would be easier for recycling, if the type of plastic for the label is different to the type of plastic for the bottle, to make it easier to separate for recycling without contamination.



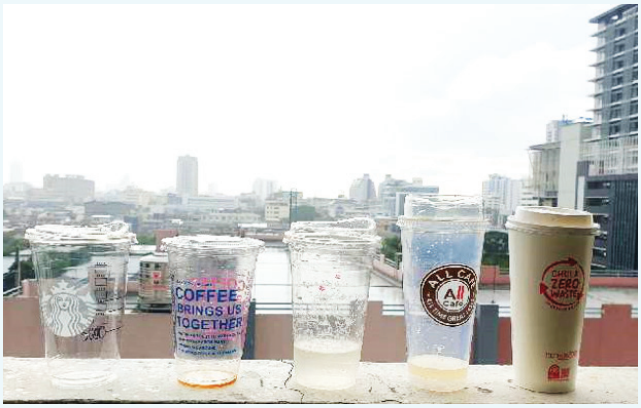
Source: https://www.friendshipmart.com/ (upper photo)
https://marketeeronline.co/ (lower photo)

4. HDPE bottle

- The best quality for HDPE bottles is milk bottles or milk containers. With their clear color and no fillers, make them highly sort after and thus their high recycling rates. They are recycled into high quality products such as yarn, rope, and fishing net.
- To further increase their recycling rates, a more recycling friendly design should be employed, some changes in the design to make it more appealing for recycling, are to use a single material for the bottle and cap with clear color and no printing on the bottles that is difficult to remove.

5. PP drink container

- Different designs and various types of plastic are used for cold drink containers such as PET, PP, PLA, PS, PC and paper coated cup. Some are made using different plastics for lid and cup. This type of packaging is not collected by recyclers because they are lightweight with printing and are made from many types of materials which made them difficult to collect and sorting.
- To make it more attractive for recyclers, it is important to make them from the same material, clear color with no printing or easy remove label.



6. PP bottle

- PP bottles are one of the most desirable packaging for recycling. However, because of the different color caps are utilized and labels are applied to the bottles on a regular basis, recycling is problematic. To make it more appealing for recycling, a single material of bottle and lid should be utilized, clear color, and no difficult-to-remove printing.

Personal care and cosmetics

Packaging for personal care and cosmetics products is dominant worldwide. Especially because of a new lifestyle, hygiene products are important for keeping us healthy and clean.

7. HDPE bottle

- This type of packaging has many designs depending on the applications. Most of them were recycled into black resin and finally produced into nonfood-contact products such as tree pots, tanks, bins, outdoor furniture, etc.
- HDPE bottle will be further collected, if they are designed as follows;
- Color: clear color or white
- Lid: HDPE lid with clear color or white color (or same color with the bottle and can be recycled together with bottle)
- Filler: no filler
- Label: no label or easy remove label.

8. Laminated tube

- The type of plastic used in this type of packaging is based on their specific properties. Packaging for high barrier property is produced with the combination of aluminum barrier or plastic barrier laminated called "laminated tube". This kind of packaging is not popular for recycling due to its many layers and different materials.
- Brand owners should change the packaging from multi-material to mono-material laminated tubes. Throughout the package, all materials should be the same. Moreover, it should not contain aluminum layer making it easily and fully recyclable.
- Filler: no filler
- Label: no label or easily removal label

9. Multilayer bag, sachet and retort pouch

- Brand owners should employ a single material for multilayer packaging. For example, use complete PP Laminate or PE laminate packaging.
- Filler: no filler
- Label: no label or easy removal label.

Others

Other single used packaging that widely used in Asia is plastic bags for carrying food and goods from market, and multilayer packaging for food or pet food.

10. Bag

- Plastic bags must be of an appropriate thickness for recycling, with the Thai government prohibiting bags thinner than 36 microns. To make recycling easier, bag producers should refrain from adding any color or printing to the bag.
- Color: original color

11. Snack bag and others

- Brand owners should employ single martial for this type of packaging. For example, PP Laminate, which is made up of reverse printed BOPP laminated to PP blown film. This type of packaging keeps the bag's original properties, such as excellent load protection and hot-filled product protection, extended shelf life, and high temperature resistance.
- Filler: no filler
- Label: no label or easy removal label

DEFINITION

Household

Person who lives in houses, apartments, homes, etc.

Waste pickers

Person who collects some recyclable waste from households or trashes

Recycled shop

The place where is buying recyclable waste and selling them to the bigger recycle shop or collector or recycle factory

Player

Actors in the market chain in each state

Collector

The player in the market chain who collected and separated each type of recyclable wastes before selling them to the next state

Recycler

The player who buys recyclable waste and processes them into recycled plastic flakes or resin

Sorting process

The process which collecting and separating each type of recyclable waste before passing them to the next state

Cleaning process

The process which washing the dirt from recyclable waste with water or hot water or solution

Flaking

The process which chopping or tearing plastics into a smaller piece which is possible to feed into the extruder

Melting

The process which makes plastic flakes liquefied by heat

LIST OF ACRONYMS

PCR

Post-consumer recycled materials

PCD

Pollution Control Department

PITH

Plastics Institute of Thailand

PPC

The Petroleum and Petrochemical College, Chulalongkorn University

MSW

Municipal solid waste

RDF

Refuse derived fuel

UNEP

United Nations Environment Programme

THB

Thai Baht

HDPE

High density polyethylene

LDPE

Low density polyethylene

LLDPE

Low linear density polyethylene

PP

Polypropylene

PS

Polystyrene

PET

Polyethylene terephthalate

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APPENDIX

Demand forecasting

Demand forecasting helps to understand and predict demand, maintain the right amount of supply to meet that demand, and to manage product lifecycle within an industry. Demand forecasting is the process that enables demand planners and supply chain professionals to estimate customer demand for a product based on prior sales data and other contributing data factors. The demand plan is used to ensure that there will be enough product supply to meet customer demand. This is a key component of the supply chain management process because it also informs the panning aspects of other supply chain process including material procurement, purchasing, logistics and distribution.

The forecast formula multiplies sales data from previous year by a specific factor and then project result over the next year.

These statistical laws govern forecast accuracy:

A long-term forecast is less accurate than a short-term forecast because the further into the future you project the forecast, the more variables can affect the forecast.

A forecast for a product family tends to be more accurate than a forecast for individual members of the product family.

Some errors cancel each other as the forecasts for individual items summarize into the group, thus creating a more accurate forecast

Formulation: Demand forecasting = Data from previous year * (Growth rate * Specific factors)