# Plastic Recycling

## A peek at the mechanical and chemical recycling process for post-consumer plastics

Plastic is a popular material that we encounter on a regular basis. While some plastic objects are intended to be used only once, others are designed to last a very long time. Whatever the plastic object is, there will usually come a time when the consumer no longer needs or wants that item. Maybe it's empty, or broken, or no longer useful. If the item can't be reused, then at this point we're usually encouraged to drop it off in a recycling bin.

Not all plastic makes it into a recycling bin. According to the Government of Canada (2023), "only 9% is recycled while the rest ends up in our landfills, waste-to-energy facilities or the environment". Additionally, the plastic that does get "recycled" might not actually make it to the appropriate facilities (CBC, 2019).

However, for the plastic that actually does get to a recycling facility, what happens to it? Read on to learn about two different ways that old plastic objects become ready to be made into new plastic items!

### What is plastic?

Plastics are a group of materials that can be formed into a shape while heated and soft, and then maintain their shape once cooled and hardened. There are different types of plastics, but they're all **polymers** (molecules made of repeating smaller units called monomers - think about making one big lego structure with a bunch of the same smaller blocks). Plastics have characteristics such as high strength and durability, chemical and water resistance, low cost, lightweight, and they're relatively easy to process. Therefore, they have been widely used as packaging, consumer, transport, and construction materials. Unfortunately, the improper disposal and management of plastic waste can lead to pollution and environmental damage (Environment and Climate Change Canada, 2020).

The **circular economy** is a system that aims to minimize waste and maximize resource efficiency by keeping materials in use for as long as possible. It is an alternative to the traditional **linear economy**, in which resources are extracted, used, and disposed of as waste.

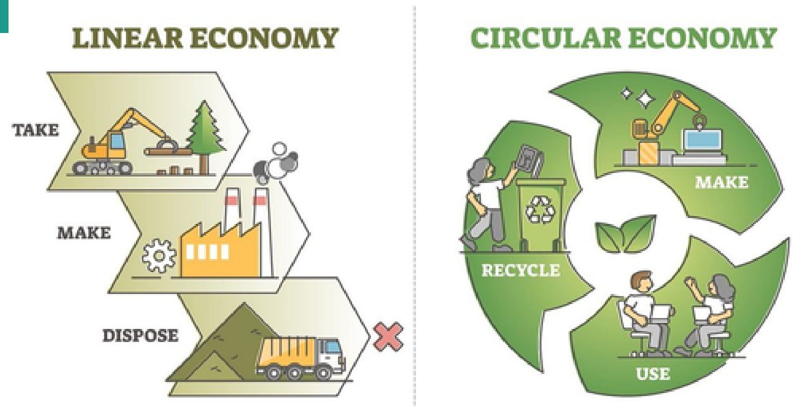
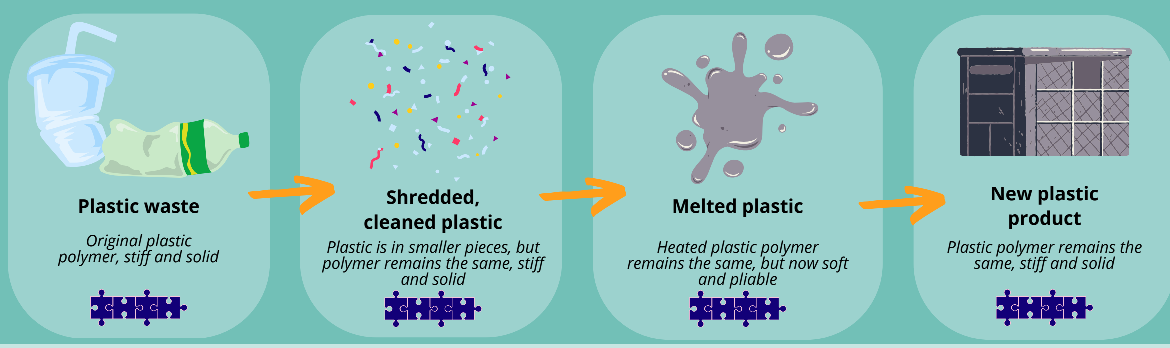



*Figure 1. Linear vs. Circular Economy (University of Aukland, 2021)*

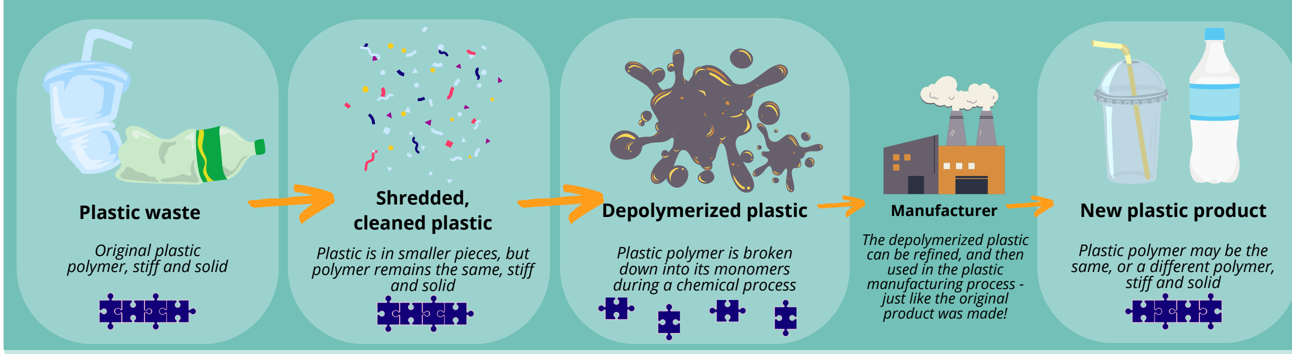
Plastic recycling is an important strategy to achieve circular economy because it helps reduce the amount of plastic waste that ends up in landfills or in our environment. Moreover, plastics are made from valuable natural resources like crude oil or natural gas. By recycling plastic, we can reuse those resources instead of extracting more from the earth. In this backgrounder, we will show you two processes used for plastic recycling, namely mechanical recycling and chemical recycling.

## A quick overview of the two types of plastic recycling:

**Mechanical Recycling** - The process of recycling plastic waste by **physically** transforming it into new products. This usually involves cleaning, shredding, melting, and reforming the plastic.



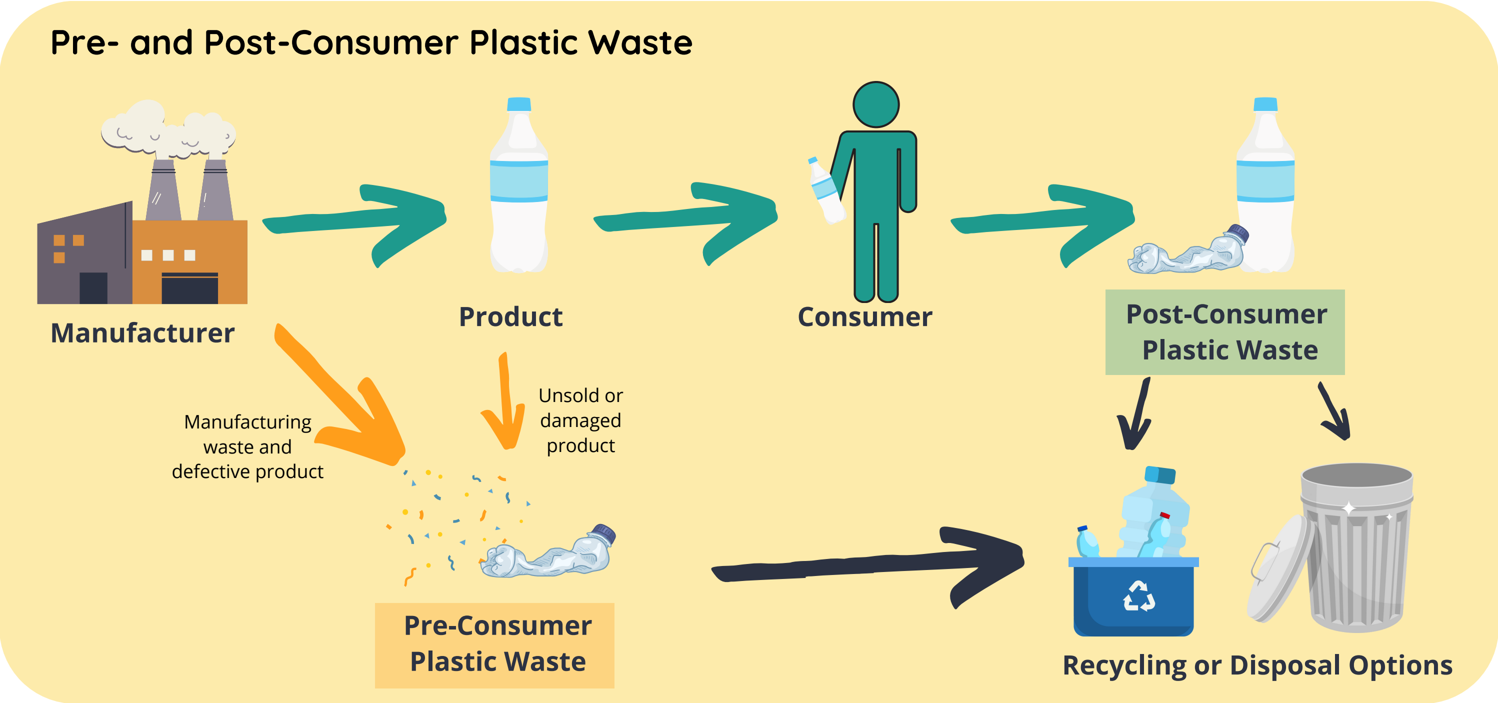

**Chemical Recycling** - The process of recycling plastic waste by **chemically** transforming it into new products. This usually involves cleaning, and shredding the plastic. Then, it goes a step further and **depolymerizes** the plastic (a process where the plastic polymer is chemically broken down into its smaller monomers). The product is very similar to crude oil or natural gas, and can be refined and used to make new plastics or produce energy.



## Mechanical Recycling:

Mechanical recycling refers to the process of recycling plastic waste by physically transforming it into new products. It is the most common way of recycling plastic in the world and there are many mechanical recycling plants across Canada (ENF Recycling, 2024). The process of mechanical recycling involves several steps (Figure 2).

The first step is to collect plastic waste for recycling. Depending on the source, the plastic waste stream can be separated into two categories, **pre-consumer** (post-industrial) and **post-consumer** plastic waste.




**Pre-consumer plastic waste**, as suggested by its name, is plastic that becomes waste before reaching a consumer. This could be rejected product like defective plastic containers or leftover materials during the manufacturing process (such as leftover fabrics and unsold clothes in the textile industries). Due to very limited exposure to customers, this category of plastic waste stream has high purity. It may be reused in the manufacturing process or sold to a third-party buyer and used directly for different purposes.

The other plastic waste stream, which is the plastic waste we commonly refer to, is **post-consumer plastic waste** generated in our everyday life. Compared with the pre-consumer plastic waste steam, this stream is usually highly contaminated and with low purity. For example, a used hand cream bottle usually has a little bit of residual cream inside. The exterior surface of that container also has a product label which is usually made of paper and other kinds of plastic. The glue that is used to attach labels is also extremely difficult to remove. All these contaminants and impurities present a great challenge for domestic plastic waste recovery. The collection of post-consumer plastic waste is usually done through recycling programs in our neighborhood where people separate their plastic waste, put it in recycling bags or send it to recycle stations.

Once the plastic waste is collected, it needs to be sorted based on chemical identities to make sure the recycled plastic can reach desired purity. Plastics can be sorted either through a manual or automated process. The manual process can be seen in our bottle depot centers where workers separate plastic waste based on their recycling symbols, sizes, and personal experiences. In the state-of-the-art recycling facilities, various technologies like near infrared and x-ray are used to quickly detect the chemical identity of each piece of plastic waste which substantially improves the accuracy and efficiency of the sorting process (Habib & Parres, 2020; Thomasnet, 2021).

After sorting, plastic waste is roughly cleaned with soap water and shredded into small pieces. The small pieces will then be thoroughly cleaned with several detergents to minimize the presence of non-plastic components and impurities such residuals, glue, and labeling. In the last step, the shredded plastic pieces will be melted down, passing through extruders, and shaped into small pellets. The pellets can be sold in the market or molded into different plastic products.

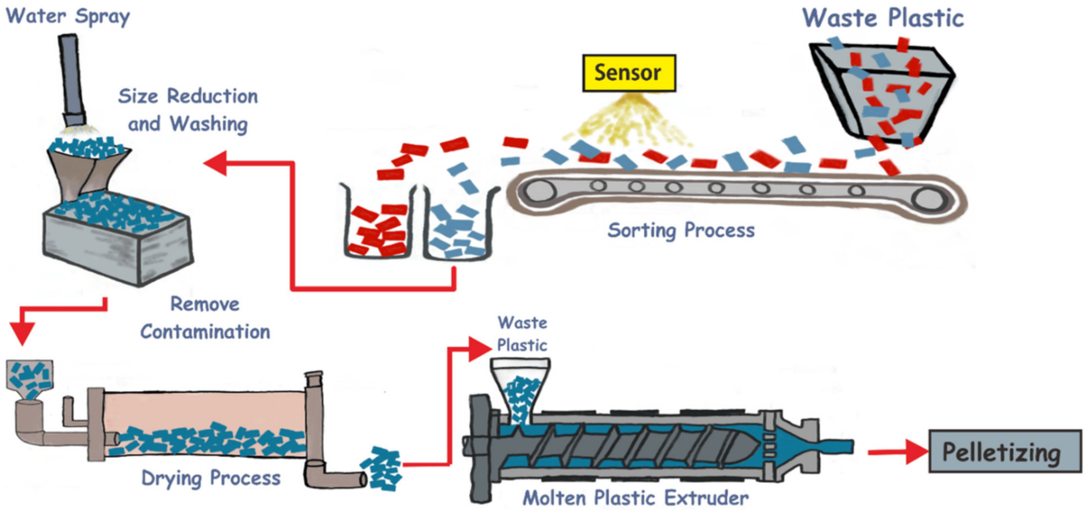



*Figure 2. A typical mechanical recycling process (Damayanti, Saputri, Marpaung, Yusupandi, Sanjaya, Simbolon, Asmarani, Ulfa, & Wu, 2022)*

Although mechanical recycling allows us to reuse plastic and significantly reduce the quantity of waste that ends up in landfills, it has several limitations. Firstly, not all plastic waste can be mechanically recycled. Mechanical recycling only applies to **thermoplastic**, which refers to a category of plastics that can be melted and recast, like polyethylene, polypropylene, etc. The **thermoset** plastic like polyurethane and silicone resin cannot be turned into liquid phase by heating, therefore is not suitable for this process.

Recycled plastics usually have lower impurity and quality than virgin plastics. Many of the recycled plastics in the market only have purities around 90%, therefore, they are mainly used in lower grade applications like construction, agriculture, or piping. This is because certain components like glues and plastic additives that were applied to plastics during the manufacturing process cannot be fully removed by conventional detergents. The sorting process, either done by human or machine, cannot reach 100% accuracy. Moreover, a significant portion of plastic used in our everyday life are composite materials. For example, a potato chip bag is made of three different types of plastics which cannot be easily separated into their original form during the mechanical recycling process.

These impurities and contaminants lead to changes of the physical properties of recycled plastics and stop them from being used in more demanding applications. For example, mechanically recycled polyethylene pellets usually have grey color due to the presence of impurities and contaminants. As a result, their application in food packing is limited because the grey color makes the product less attractive to consumers. In addition, the recycled polyethylene cannot be used to make food contact material or medical devices because many chemical substances, like additives, from the previous life of the plastic materials can contaminate the food or medications, leading to various health issues (Horodytska, Cabanes, & Fullana, 2020).

Repeated melting and reforming of plastic during mechanical recycling process can also deteriorate the mechanical quality of recycled plastics. The same plastic may only be recycled 2 to 3 times before its quality decreases to the point where it can no longer be used.

## Chemical Recyling

From a chemistry standpoint, the plastic is a polymer that is made of thousands of repeated building blocks. Chemical recycling, also known as advanced recycling or feedstock recycling, is a relatively new process that breaks down plastic waste into smaller chemical building blocks and uses them as raw materials to produce virgin plastics. Therefore, the quality of plastics generated from the chemical recycling process is superior to that from mechanical recycling process and in theory the same plastic can be chemically recycled for unlimited times. Moreover, chemical recycling is more versatile as it could be used to recycle both thermoplastics and thermoset plastics like polyurethane (Zahedifar, Pazdur, Vande Velde, & Billen, 2021).

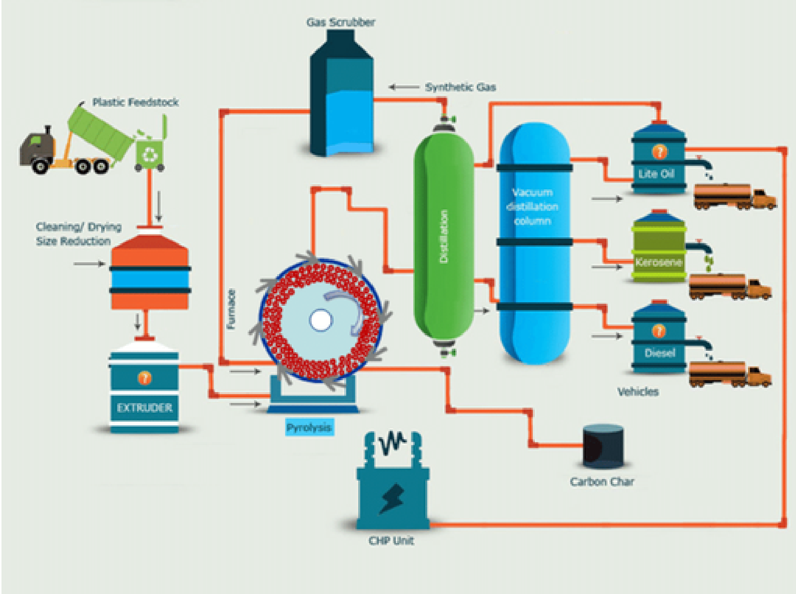



*Figure 3. A classical chemical recycling process that converts plastic waste into various raw materials (Ragaert, Delva, & Van Geem, 2017).*

Like mechanical recycling, the chemical recycling process also includes collecting, sorting, cleaning and shredding plastic waste. Sometimes the cleaning step in the chemical recycling process has much higher requirements. Organic solvent may be used to dissolve plastic waste in this step which facilitate the removal of impurities and contaminants. After that, the plastic waste will go through a totally different process which includes depolymerization and new plastic production.

In the depolymerization process (Figure 3), different combinations of chemistry, solvents, and heat are used to break down plastic polymers into degradation products, which are smaller molecules with chemical structures similar to crude oil or natural gas. These degradation products will go through a refinery process which allows to separate different components from each other. Many of the separated components can be sent to existing plastic manufacturing plants and directly used as feedstocks to produce energy and make new plastics.

Different from mechanical recycling technologies where the same process can be applied to all thermoplastics and the process is relatively mature, chemical recycling technologies are still under development and there is no single chemical recycling process can be used to recycle multiple types of plastics. Although many pilot plants for chemical recycling have been built worldwide, it is still facing challenges when it comes to scaling up chemical recycling operations to handle large volumes of plastic waste. The cost of chemical recycling is also higher than mechanical recycling due to the technologies and energy required for the process. Certain chemical recycling processes may involve the use of hazardous chemicals or generate emissions. It is crucial to carefully manage and control these processes to minimize environmental impacts and ensure the safety of workers and surrounding communities.

## Conclusion

Overall, both mechanical recycling and chemical recycling contribute to plastic waste management and resource conservation. Mechanical recycling is a more established and widely implemented process, while chemical recycling offers the potential for high-quality recycled plastics and advanced materials.

These two methods are complementary and can be used to make recycled plastics to meet different demands. The advance in plastic recycling, in combination with other strategies like reduction and reuse can help us create a more comprehensive and sustainable waste management system.

### Reflection Questions:

- What makes chemical recycling different from mechanical recycling?
- What are the advantages and disadvantages of these two recycling technologies?
- What you can do to improve the purity/quality of mechanically recycled plastics.
- Where is the nearest plastic recycling plant (not bottle depot) in your area?

# References


Damayanti, D., Saputri, D. R., Marpaung, D. S. S., Yusupandi, F., Sanjaya, A., Simbolon, Y. M., Asmarani, W., Ulfa, M., & Wu, H-S. (2022). *Current prospects for plastic waste treatment. Polymers, 14*(15), 3133. https://doi.org/10.3390/polym14153133

Environment and Climate Change Canada & Health Canada. (2020). *Science assessment of plastic pollution* (Cat. No.: En14-424/2020E-PDF). Ottawa, ON: Author. ISBN 978-0-660-35897-0.

ENF Recycling. (2024). *Plastic Recycling Plants In Canada*. Retrieved from https://www.enfplastic.com/directory/plant/Canada

Habib, M. A., & Parres, F. (2020). *Mechanical recycling of packaging plastics: A review. Macromolecular Rapid Communications, 41*(19), e2000415. https://doi.org/10.1002/marc.202000415

Horodytska, O., Cabanes, A., & Fullana, A. (2020). *Non-intentionally added substances (NIAS) in recycled plastics. Chemosphere, 251,* 126373. https://doi.org/10.1016/j.chemosphere.2020.126373

Ragaert, K., Delva, L., & Van Geem, K. (2017). *Mechanical and chemical recycling of solid plastic waste. Waste Management, 69,* 24-58. https://doi.org/10.1016/j.wasman.2017.07.044

Thomasnet. (2024). *Plastic recycling equipment: A comprehensive guide.* Retrieved from https://www.thomasnet.com/articles/plastics-rubber/plastic-recycling-equipment/

University of Auckland. (2021, December 2). *Benefits of NZ Adopting Circular Economy.* Retrieved from https://www.auckland.ac.nz/en/news/2021/12/02/benefits-of-nz-adopting-circular-economy.html

Zahedifar, P., Pazdur, L., Vande Velde, C. M. L., & Billen, P. (2021). Multistage chemical recycling of polyurethanes and dicarbamates: A glycolysis–hydrolysis demonstration. *Sustainability, 13*(6), 3583. https://doi.org/10.3390/su13063583