Exploring the Vital Role of Mass Balance in Plastic Production

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Introduction

Background

To realize the idea of a circular plastic economy, it is imperative to devise methods and processes for circulation of various types of plastic materials and energy. Regulations play a significant role in this, for example, the policies outlined below are creating clear goals and incentives to transition to circular plastics and sustainable material use systems.

- The EU Plastics Strategy, which aims to transform the way plastic products are designed, produced, used and recycled in the EU. It sets a target that all plastic packaging on the EU market must be recyclable by 2030, and the use of microplastics must be restricted.
- The Directive on single-use plastics, which bans certain single-use plastic products and fishing gear that are most often found on European beaches and seas. It also sets recycling targets for plastic bottles and requires a minimum recycled content of 25% for PET bottles by 2025 and 30% for all plastic bottles by 2030.
- The revised Packaging and Packaging Waste Regulation, which proposes that at least 50% of all plastic waste in the EU be recycled by 2025.
- The Renewable Energy Directive, which establishes a common framework for the promotion of energy from renewable sources and sets a binding target of at least 32% share of renewable energy sources in the EU's gross final energy consumption by 2030.

There are several chemical recycling technologies being developed and implemented to address plastic sustainability. The Hydro-PRT plastics recycling technology offered by KBR and Mura is an innovative solution at the core of several plastics recycling projects worldwide, with projects in the UK, Japan, Korea, US and Germany(1). The inaugural implementation of this technology, the Mura owned plant located in Wilton, UK, is scheduled to commence operations this year(2). As these plants and other similar recycling projects start producing products to the market for transforming waste plastic into recycled polymers, mapping the flow of the recycled material into the finished products to recognize, quantify and incentivize the circularity achieved becomes important. A pressing requirement exists for establishing a standardized accounting method for plastics recycling players to monitor and verify recycling yields and efficiencies. This method should also empower operators and investors to confidently report the allocated amount of recycled content in products to meet their circularity and ESG goals as well as scaleup these processes to drive the circular economy.

What is mass balance chain of custody?

In order to establish a protocol to define and measure the recycling, energy recovery, and loss yields in multiple-output recycling processes (producing a mix of energy, fuels, materials, etc.), a chain of custody method is applied. Mass balance accounting is one of several well-known and proven chain of custody approaches (illustrated in Figure 1) which have been designed to trace the flow of materials through a complex value chain. In principle, it allows the inputs, such as feedstock derived from recycled plastic waste, to be allocated to the outputs from a production process. In very simple terms, if 10% of the inputs to a process are recycled feedstock, a mass balance approach can be used to either designate 10% of the outputs as being from 100% sustainable sources, 20% of the outputs as being 50% from sustainable sources, or any other combination as long as the volume of outputs allocated to sustainable inputs do not exceed the total amount of sustainable inputs.

The mass balance concept is not unique to plastics recycling, it has been applied in other industries and sectors, such as renewable energy, biofuels, forestry, cocoa and palm oil. The mass balance concept is also recognized by several international sustainability initiatives and certification schemes, such as the Ellen MacArthur Foundation's Circular Economy 100 (CE100) Network, ISCC Plus, REDcert2 and RSB(3).

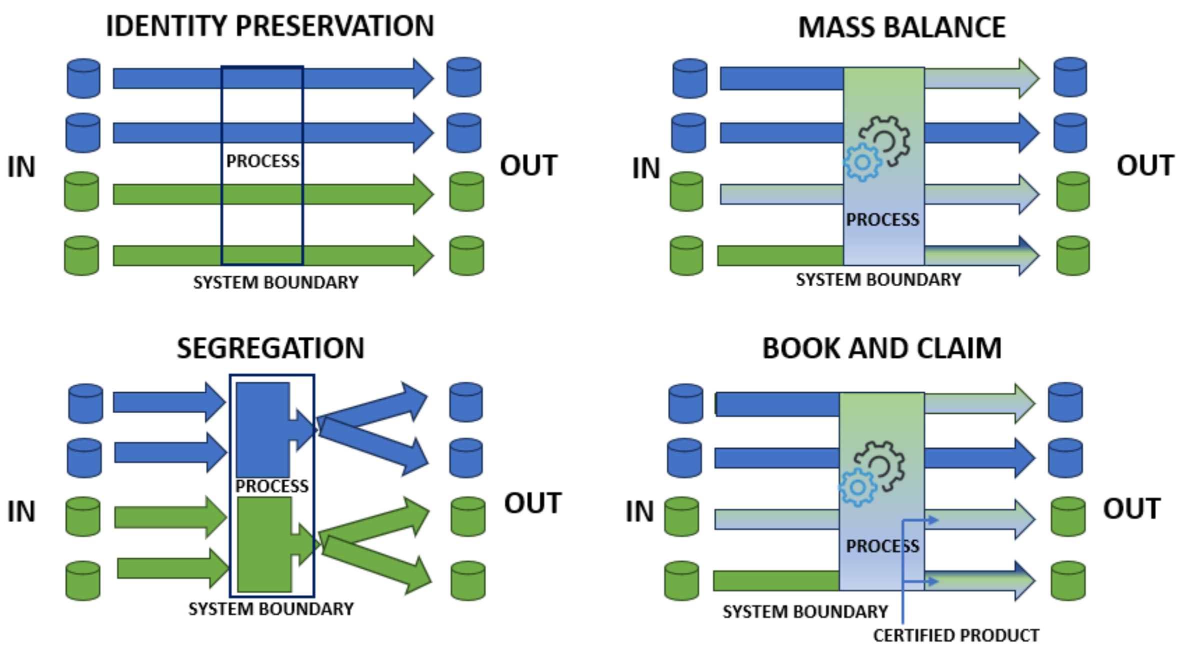

Figure 1: Four types of chain of custody models(4); mass balance is an appropriate chain of custody model for plastics recycling application. While the other models greatly segregate(?) the fossil and recycled

feeds, mass balance chain of custody model offers a pragmatic way to co-feed both recycled and virgin plastic feedstock into the same network of chemical production plants.

Why is mass balance garnering importance in plastics recycling?

Several compelling reasons necessitate the practical adoption of mass balance as the preferred accounting approach for recycling in the plastics industry(5,6):

- The production of plastics from petrochemical feedstocks is a complex, multi-step process involving chemicals and additives and takes place in large manufacturing facilities involving numerous intermediary stages. A complete transition of the production line to incorporate only sustainable systems requires a significant shift in technologies, product design, and supply chain operations. If the industry were to segregate plastics produced from recyclates and renewable-based feedstock from fossil sources, it would require setting up a duplicate production line, using more resources and energy, which is neither economic nor environmentally beneficial.

  The mass balance approach encourages the use of sustainable raw materials based on biomass or waste in the highly efficient plants and infrastructure that already exist in the petrochemical industry. Environmentally and financially wasteful investments in new plants are not necessary. The shift to alternative feedstocks reduces both consumption of fossil resources and greenhouse gas emissions.

- Currently, the industry is in an intermediary period, where there are various types of recycled, bio-based, and virgin (aka fossil) materials co-fed into the system and transformed into products that are indistinguishable from those produced from virgin, fossil feedstock. These production plants operate around the clock and at millions of pounds capacity, hence it is not possible to track each feedstock molecule through to the end product.

  As the mass balance models discussed in this report would demonstrate, the mass balance approach provides a transparent and accountable way to track the use of recycled plastics in various applications and helps verify that recycling targets are met.

In conclusion, the application of the mass balance method in plastics recycling represents a pragmatic and versatile approach for addressing the complexities of tracking and reporting recycled content. Hence, major petrochemical companies, converters, packaging brands and other prominent players in the plastics value chain are lobbying for the adoption of the mass balance method as it can provide greater legal certainty and harmonization for calculating and reporting recycled content in plastic products across the EU.

Mass Balance Models

Mathematical modeling plays a crucial role in applying the principles of mass balance to systems and processes to analyze and predict how mass is distributed and conserved. There isn’t a single universal mathematical model for the mass balance method; mathematical models for the mass balance method can take various forms depending on the specific system and processes being studied.

In this study, we focus on the fundamental elements of the mass balance approach methodology, namely(6):

1. Level of mass balance
2. Allocation
3. Balancing Period

Within each of these components, there exist variations that influence how a company allocates recycled feedstock to its final products. The choice of approach adopted by a business is frequently dictated by the criteria stipulated by the certification scheme it selects for the certification of its products.

1. Level of mass balance

Batch	▪ Actual amount of recycled plastic input into the process is allocated to the output products from that same process. ▪ Strictest level of calculation, ensuring that the inputs used to produce the output products indeed contain recycled material. ▪ Provides the strongest possible level of physical link between the inputs and outputs compared to the other levels of mass balance and potentially reduces both the risk of false claims of relief from the tax and greenwashing. ▪ Level of administrative burden on the business would be higher than under the other levels of mass balance (B**usinesses** would need to complete a calculation after each batch is produced, along with completing the corresponding documentation for its chosen certification scheme)
Site	▪ Only the proportion of recycled feedstock entering a business's individual site is capable of being allocated to the output products produced from the same site. With this calculation, the proportion of recycled feedstock entering and leaving the site is known. However, as sites can run multiple sub-processes, the proportion of recycled material in the output products from individual sub-processes is not known. ▪ A business cannot claim that the output products leaving its site contain more recycled material than the amount of recycled feedstock received at the site during a set timeframe. This timeframe is known as a balancing period. ▪ Provides a stronger physical link between the inputs and outputs compared to the group level calculation, whilst offering a balance between administrative burdens on business, compliance with the requirement of the tax, and reducing risk of greenwashing.
Group (also known as company level)	▪ Applies to businesses operating across multiple sites, which may be geographically dispersed. In this method, the corporate head office consolidates the total quantity of recycled feedstock received for use in its processes, encompassing all sites within the company or group. A portion of this recycled feedstock can then be assigned to the output products generated through the company's or group's various processes. The group level calculation also requires a balancing period. ▪ Provides the weakest physical link between the recycled feedstock inputs and outputs. A site may receive no recycled feedstock, but a proportion of the recycled feedstock the group receives can still be allocated to the output products produced from that site, providing another site has received recycled feedstock that has been accounted for by the group head office.

Table 1: Levels of Mass Balance, both the site level and group level models operate under a set timeframe called the balancing period.

2. Allocation Method

The output products from the cracking process in plastics production can be used for a range of applications such as monomers, chemicals and also fuel. There are currently four allocation methods that can be used to allocate the recycled feedstock input into the cracking process, to the output products. None of these methods account for any deductions for process losses. These 4 methods are(6):

2.1 Free Allocation

2.2 Proportional Balance (also known as technical balance)

2.3 Fuel-exempt

2.4 Polymer only

The free allocation method provides the highest degree of flexibility, permitting businesses to assign all recycled feedstock input into the cracking process to any of the output products. In practical terms, at its discretion, a company can allocate any portion of recycled feedstock to products used in the manufacture of plastic packaging even if some of the feedstock would inherently be destined for products related to fuel production, thereby reducing their PPT (Plastic Packaging Tax) liability. Figure 2 illustrates how the free allocation method facilitates the allocation of recycled feedstock to various output products.

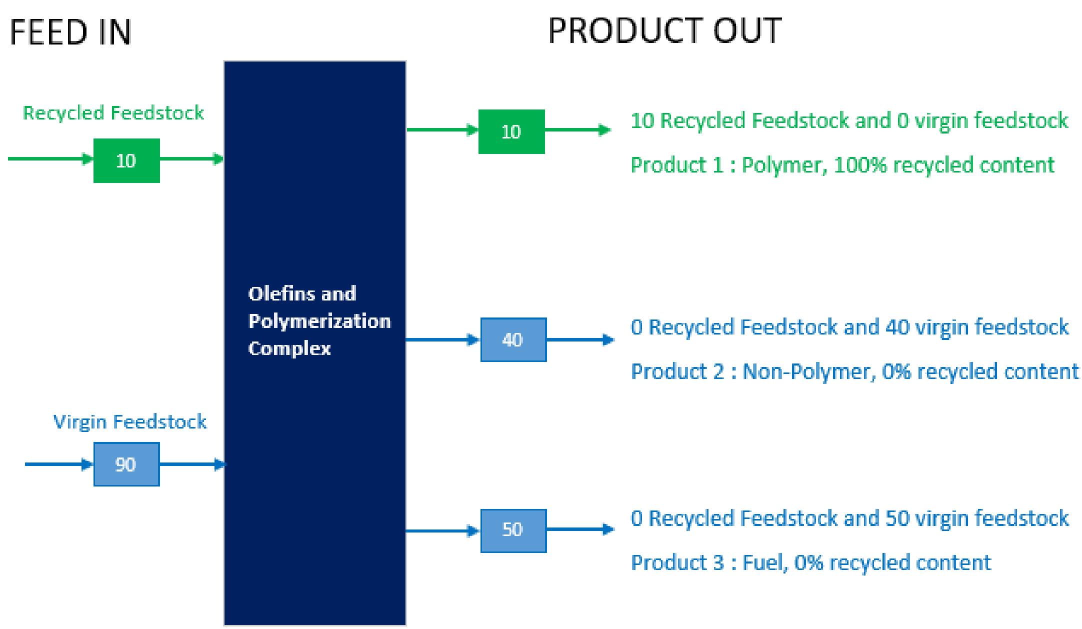

Figure 2: Free Allocation Method

In the proportional balance allocation method, the proportion of recycled feedstock introduced into the cracking process is distributed as per historic yields proportionally among all the output products. Figure 3 illustrates the application of the proportional balance allocation method.

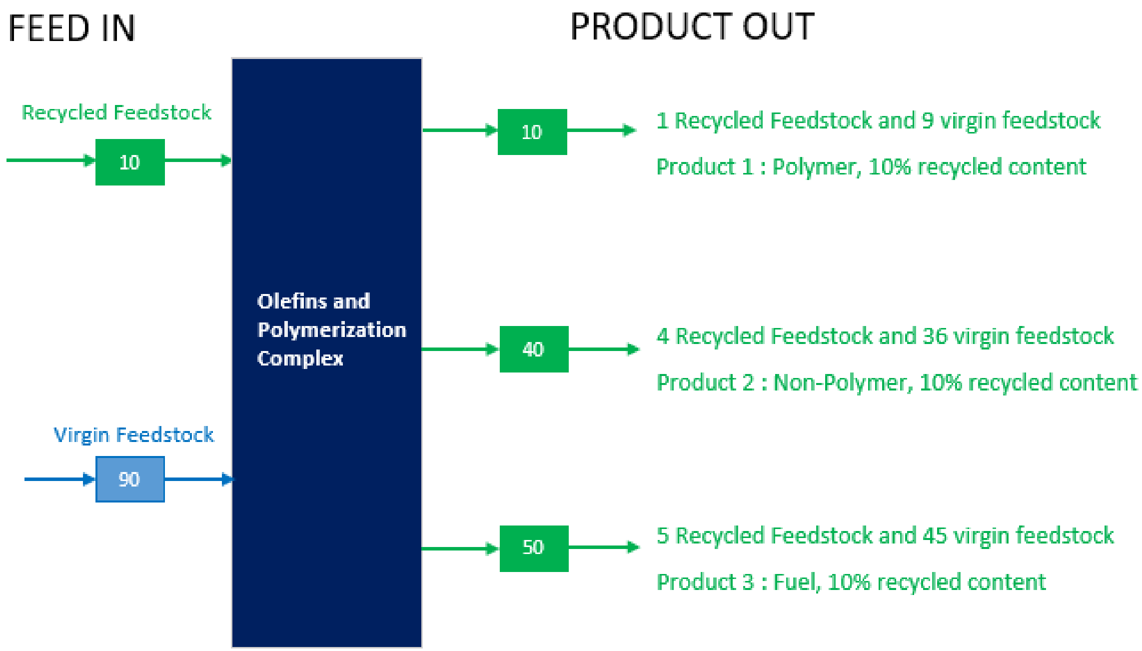

Figure 3: Proportional Balance Method

Under the fuel exempt allocation method, the portion of recycled feedstock directed toward outputs intended for fuel production is excluded from the calculation and cannot be reassigned to other output products. Nonetheless, the business retains the flexibility to freely allocate the remaining proportion of recycled feedstock among the remaining output products. Figure 4 provides an illustration of the fuel exempt method.

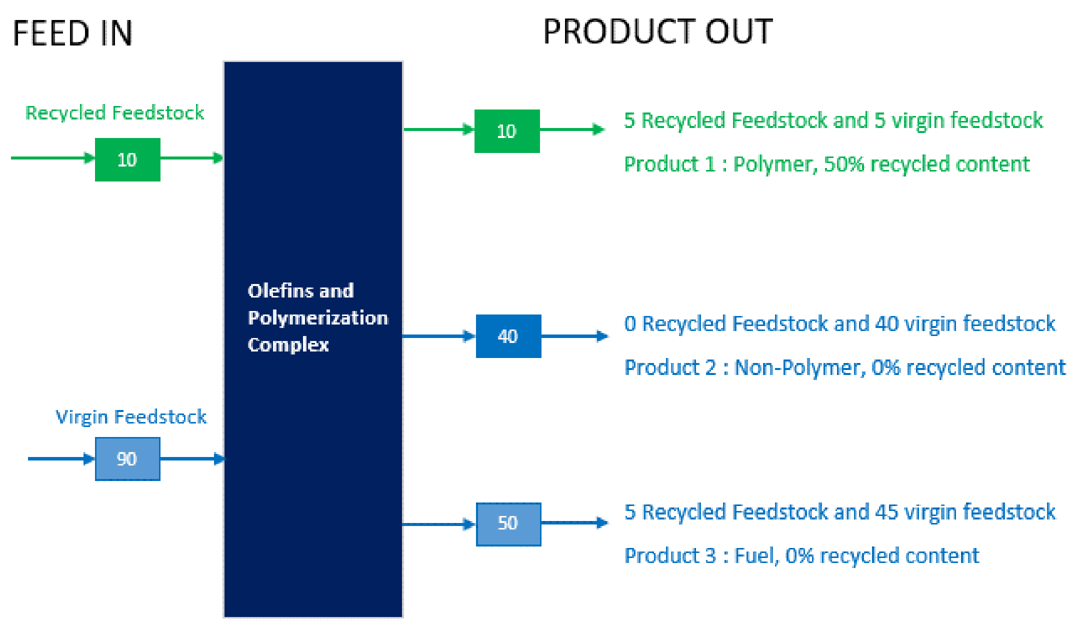

Figure 4: Fuel exempt Method

The polymer-only allocation method aligns most closely with the objectives of the PPT. This is due to the exclusion of the proportion of recycled feedstock dedicated to producing non-polymer output products, such as fuels, base chemicals (as opposed to polymers) pharmaceuticals, from the calculation. This excluded portion cannot be reallocated to polymer-based output products. The remaining proportion of recycled feedstock can then be flexibly allocated among the output products used only in polymer manufacturing. Figure 5 illustrates the application of the polymer-only allocation method.

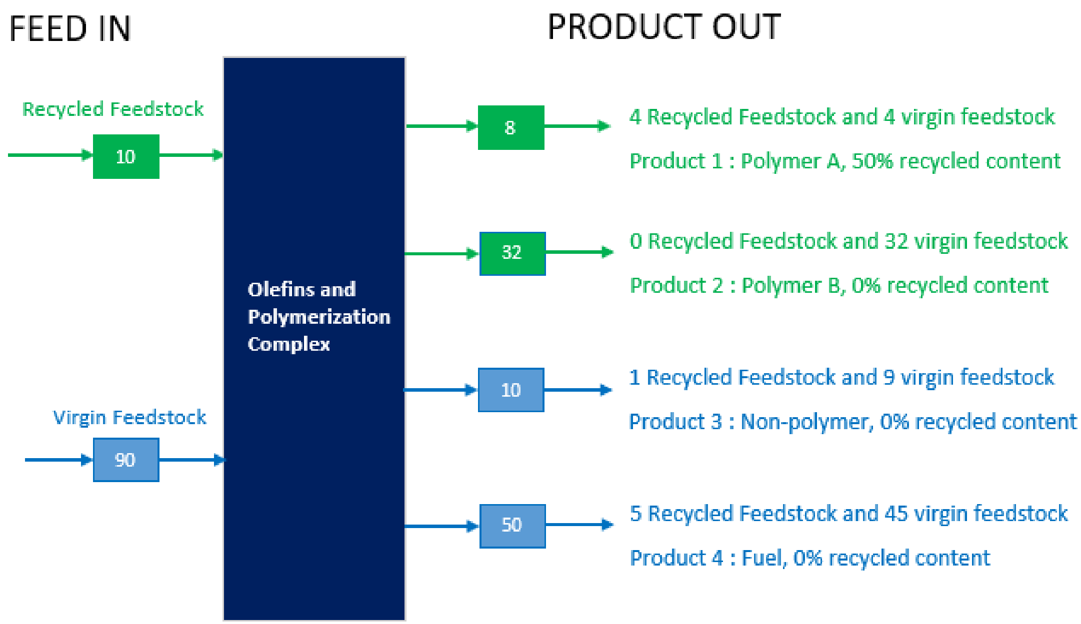

Figure 5: Polymer Only Allocation Method

3. Balancing Period

The balancing period represents the timeframe during which a company is permitted to equate the proportion of recycled feedstock it acquires for input into its cracking process with the claims it asserts regarding the proportion of recycled material in its final output products. Presently, certain certification schemes permit companies to temporarily hold a negative balance within the balancing period, with the condition that this negative balance is rectified by the conclusion of the specified timeframe. A negative balance occurs when a company asserts a higher recycled content in its output products than the actual quantity of recycled feedstock it has received.

Some of the more widely acknowledged certification schemes establish a maximum balancing period of 3 months, with the possibility of extension to a maximum of 12 months granted only under exceptional circumstances. An instance of such an exception might be when a company is relatively new to operating within the plastic value chain and lacks substantial experience in conducting mass balance approach calculations.

Conclusion

In conclusion, plastics recycling is a pivotal component of the modern sustainability landscape. The mass balance approach, with its flexibility and adaptability, offers a practical solution to the complexities of tracking recycled content in the ever-evolving plastics industry. As Hydro-PRT clients strive to establish recycling facilities to align with compliance, ESG, and circularity goals, the credibility and widespread acceptance of the mass balance approach would be an essential driver for the swift execution of global plastics recycling projects. This methodology not only simplifies operations but also paves the way for resource efficiency and transparent environmental impact assessments. Embracing the mass balance approach is a significant step toward a more sustainable and circular future.

References

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