Whitepaper

Envalior
Imagine the Future

MASS BALANCE ENABLES *CIRCULARITY AT SCALE*

Circular economy targets can be achieved by chemical recycling and mass–balance, not through mechanical recycling alone.

Circular economy targets are accelerating across industries, driven by regulation, OEM requirements, and pressure to reduce dependence on fossil feedstocks. Mechanical recycling remains an important part of this transition, but it alone cannot deliver the volume, consistency, or virgin–equivalent performance required for many engineering applications.

The challenge extends beyond collecting and recovering plastic waste. Modern polymers are highly engineered materials formulated with specialized additives, reinforcements, fillers, and performance characteristics. As applications become more specialized, demanding and product lifetimes increase, maintaining consistent material quality through mechanical recycling alone becomes increasingly difficult.

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Scaling circularity therefore depends not only on material recovery, but on the ability to integrate recycled feedstocks into industrial production systems operating at global scale. Chemical recycling is a necessary option to obtain virgin quality materials from wasted plastics by producing a naphtha–alike feedstock. Mass balance enables recycled and renewable feedstocks to enter existing chemical manufacturing infrastructure at lowest investment cost and fastest speed while maintaining the performance, processability, and consistency required for demanding applications.

Mass balance enables recycled and renewable feedstocks to be integrated into existing chemical production systems alongside conventional fossil–based feedstocks. These feedstocks are processed together through the same chemical manufacturing system, while certified accounting methods track and allocate the associated circular content to specific outputs.

This approach enables significantly larger volumes of plastic waste to re–enter the value chain through chemical recycling. Material that cannot be effectively recovered through mechanical recycling can instead be converted back to feedstock–level raw materials, helping divert waste from landfill and incineration while producing materials with virgin–equivalent performance, consistency, and processability.

CIRCULARITY TARGETS *ARE SCALING FASTER THAN* CURRENT RECYCLING SYSTEMS

Proposed regulations such as the European End–of–Life Vehicles Regulation (ELVR), together with broader sustainability commitments across automotive, electronics, consumer, and industrial markets, continue to increase demand for recycled and renewable content in finished products.

At the same time, engineering requirements remain largely unchanged. Materials used in demanding applications must still meet strict expectations for mechanical strength, thermal stability, dimensional consistency, durability, processability, and long–term reliability across global manufacturing environments.

This combination creates a significant industrial scaling challenge for the plastics industry:

increasing circular content while maintaining the performance standards required for engineering applications.

MECHANICAL RECYCLING *CANNOT CONSISTENTLY REPRODUCE* VIRGIN–LEVEL MATERIAL PERFORMANCE

Mechanical recycling plays an essential role in reducing waste and supporting circular material flows. However, maintaining consistent material quality through mechanical recycling becomes increasingly difficult as waste streams grow more complex and application requirements remain demanding.

Engineering plastics rarely exist as single, uniform materials. They are highly formulated systems designed for specific performance requirements and often contain glass fibers, flame retardants, impact modifiers, stabilizers, pigments, lubricants, and other additives. Products also enter different recycling streams after very different service lives and environmental exposures, further increasing variability in the recovered material.

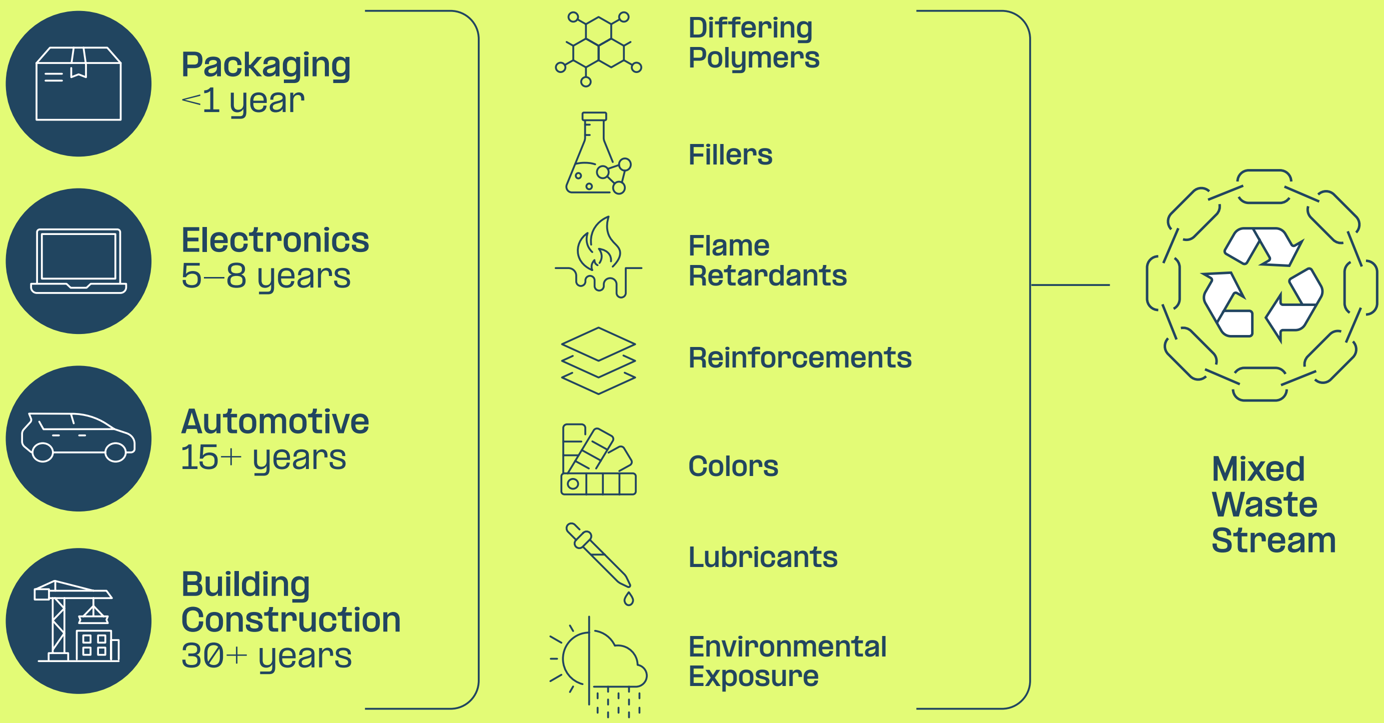
A packaging material used for several months, an electronic component used for eight years, and an automotive component exposed to heat, vibration, chemicals, and mechanical stress over fifteen years may all enter the recycling stream with fundamentally different material histories and performance profiles.

To add to the complexity, some legacy additives in plastics are required to be absent from new products, thus providing an additional hurdle to use mechanical recycling for engineered plastics.

As waste streams become more diverse over time, maintaining consistent feedstock quality and volume through mechanical recycling alone becomes increasingly difficult for demanding engineering applications.

EVERY WASTE STREAM. THOUSANDS OF MATERIAL HISTORIES.

Recovered material quality becomes increasingly difficult to standardize as formulations, additives, application requirements, and product lifetimes diverge across recycling streams.



CIRCULARITY DEPENDS ON *INTEGRATING RECYCLED FEEDSTOCKS* INTO INDUSTRIAL–SCALE PRODUCTION

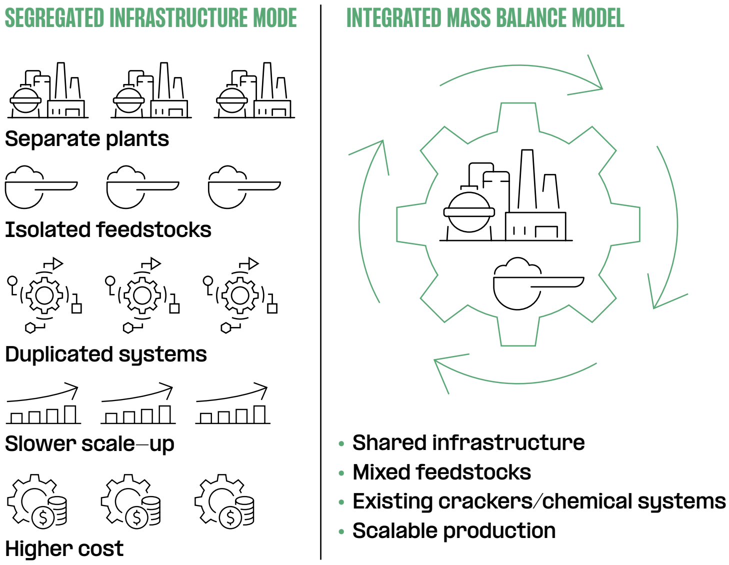
Circular economy discussions often focus on material recovery: collecting, sorting, and reprocessing waste streams back into usable materials. These steps remain essential. However, recovering material alone does not solve the larger industrial challenge of scaling circular feedstocks across global manufacturing systems.

Industrial production depends on stable feedstocks, predictable processing conditions, consistent material quality, and continuous cost–efficient manufacturing at global scale. Existing chemical infrastructure already operates continuously across integrated global supply chains, producing the base chemicals and polymers used in thousands of engineering and consumer applications.

Replacing this infrastructure with fully segregated circular production systems would require substantial new investment, duplicated processing assets, additional logistics complexity, and significantly longer implementation timelines. Maintaining separate production pathways for fossil, recycled, and renewable feedstocks would also reduce the manufacturing efficiencies that integrated chemical systems currently provide, creating a high–cost approach that hampers the implementation of a circular economy.

Scaling circularity therefore depends on integrating larger volumes of recycled and renewable feedstocks into existing industrial production systems while maintaining the quality, consistency, and economics required for large–scale manufacturing.

Integrated Infrastructure Enables Circular Feedstocks to Scale



Integrated chemical infrastructure already operates at the scale required to support global manufacturing systems. The transition to circular feedstocks depends on increasing recycled and renewable inputs within these existing production networks.

MASS BALANCE ENABLES RECYCLED *FEEDSTOCKS TO SCALE THROUGH* EXISTING CHEMICAL INFRASTRUCTURE

Mass balance enables recycled and renewable feedstocks to enter existing chemical production systems alongside conventional fossil–based feedstocks. Through certified accounting methods, circular content is allocated proportionally to specific outputs while the materials themselves move through integrated manufacturing operations.

This approach allows manufacturers to increase circular feedstock use without requiring fully separate production systems for each feedstock type. At the same time, the resulting materials retain the same chemical structure, processability, and performance characteristics expected from conventional virgin–grade materials.

By operating within existing industrial infrastructure, mass balance provides a practical pathway for increasing circular feedstock use across industries that require high material consistency, complex formulations, and global production scale.

MASS BALANCE PRESERVES CIRCULAR CONTENT THROUGH *COMPLEX CHEMICAL PRODUCTION SYSTEMS*

Chemical production systems convert a relatively small number of raw materials into thousands of downstream products through manufacturing operations that are often highly integrated. Within these systems, feedstocks undergo multiple chemical transformations before becoming intermediates, engineering materials, or finished products.

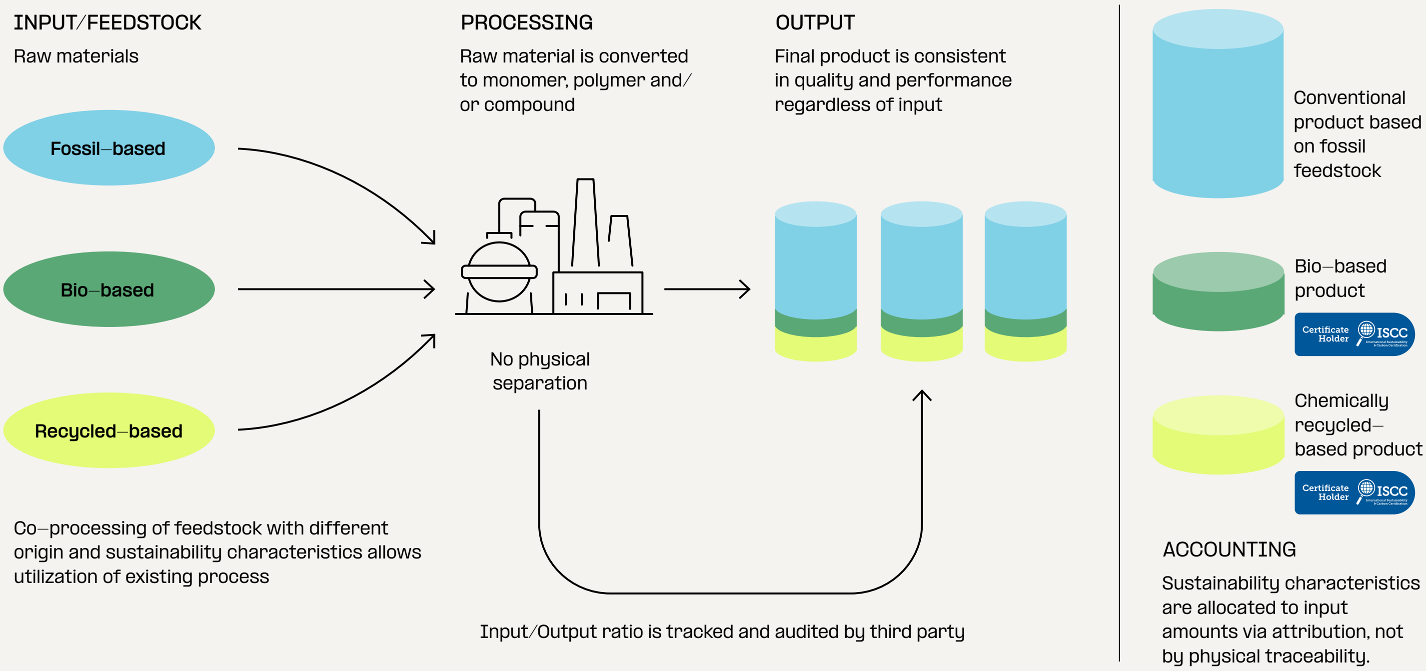
As recycled and renewable feedstocks enter these integrated operations alongside fossil–based feedstocks, physically separating individual molecules throughout production becomes impractical at industrial scale. Mass balance addresses this challenge through a certified chain–of–custody approach that tracks and attributes circular content across the production system.

Under a mass balance approach, recycled or renewable feedstocks enter existing chemical infrastructure and are processed together with conventional feedstocks. The circular content associated with those feedstocks is then attributed to specific products through auditable accounting methods to verify that sufficient quantity of recycled or renewable material has entered at the start of the supply chain.

This allows manufacturers to increase circular feedstock use while maintaining the efficiency, throughput, and product consistency of existing large–scale production systems.

How Mass Balance Works in Chemical Production

Chemical recycling restores waste plastics to feedstock–level raw materials. Mass balance preserves and attributes the associated circular content as those feedstocks move through integrated chemical production systems.



Mass balance enables recycled and renewable feedstocks to move through existing chemical production systems while preserving certified circular content allocation across industrial–scale manufacturing.

CHEMICAL RECYCLING RESTORES *FEEDSTOCK QUALITY FOR DEMANDING APPLICATIONS*

Mechanical recycling retains much of the original material history of the recovered plastic, including degradation from processing, thermal exposure, mechanical stress, contamination, and aging. While this remains highly valuable for many applications, some engineering requirements demand material performance and consistency closer to virgin–grade feedstocks.

Chemical recycling converts plastic waste back into feedstock–level raw materials through processes such as pyrolysis and depolymerization. These feedstocks can then re–enter chemical production systems and be transformed into new polymers with virgin–equivalent chemical structure and performance characteristics.

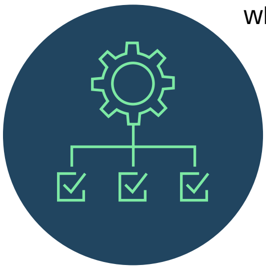
This becomes particularly important for applications requiring:

- High thermal stability
- Tight dimensional tolerances
- Long–term durability
- Complex compounded formulations
- Stringent qualification requirements
- Global production consistency

By combining chemical recycling with mass balance accounting, manufacturers can increase circular feedstock use while continuing to meet the performance and reliability standards required for demanding engineering applications.

MASS BALANCE BUILDS ON CERTIFIED ALLOCATION SYSTEMS *ALREADY OPERATING AT INDUSTRIAL SCALE*

Allocation–based chain–of–custody systems already operate across multiple large–scale industries. Renewable electricity systems track renewable energy credits across shared electrical grids. Forestry and paper systems certify sustainably sourced fiber through integrated production networks. Similar allocation frameworks also support biofuels and agricultural supply chains.



These systems follow a common principle: certified inputs move through shared industrial infrastructures where complete physical separation becomes impractical at scale, while auditable accounting preserves transparency and prevents over–allocation.

Mass balance applies the same industrial logic to chemical production systems. Recycled and renewable feedstocks enter integrated chemical infrastructure alongside fossil–based feedstocks, and certified accounting methods allocate circular content proportionally to downstream products.

Manufacturers therefore cannot allocate more circular content than the volume of recycled or renewable feedstock entering the production system.

Certified Allocation Systems Already Operate Across Shared Industrial Infrastructures

	Renewable Electricity	Forestry and Paper	Chemical Production
Inputs	Renewable + conventional power generation	Certified + conventional fiber sources	Recycled + fossil–based feedstocks
Shared Infrastructure	Integrated electrical grid	Integrated paper production systems	Integrated chemical production systems
Certified Allocation	Renewable energy credits	FSC/PEFC chain–of–custody certification	Mass balance accounting
Outcome	**Verified renewable electricity claims**	**Certified sourcing claims**	**Verified circular content (attributed) claims**

Certified allocation systems preserve traceability and transparency across large integrated infrastructures where complete physical separation becomes impractical at industrial scale.

CERTIFICATION AND TRACEABILITY SUPPORT *TRANSPARENCY ACROSS THE VALUE CHAIN*

As circular–content requirements increase across industries, traceability and third–party verification become increasingly important for manufacturers, OEMs, regulators, and downstream customers.

Certification systems such as ISCC provide auditable chain–of–custody frameworks for recycled and renewable feedstocks moving through chemical production systems. These frameworks establish rules for allocation, accounting, traceability, and verification across the value chain.

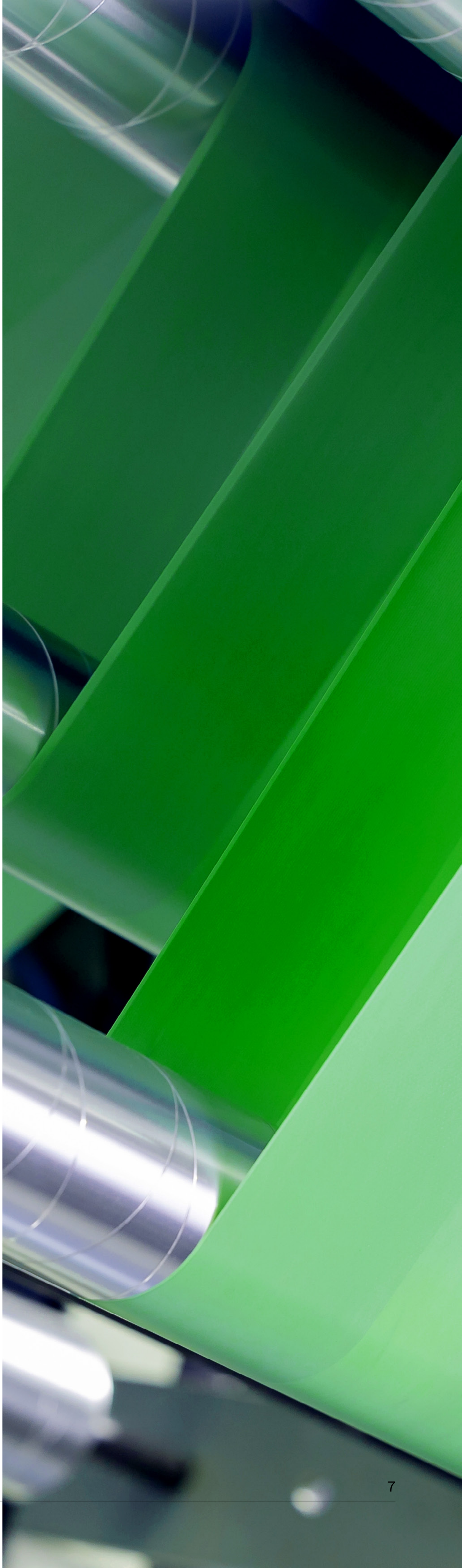
For industries operating under recycled–content targets, sustainability reporting requirements, and procurement standards, certified mass balance systems provide a scalable mechanism for integrating circular feedstocks into industrial production while preserving traceability across manufacturing operations.

MASS BALANCE SUPPORTS CIRCULARITY *WITHOUT COMPROMISING* MATERIAL PERFORMANCE

Many engineering applications operate within narrow processing windows and strict qualification requirements. Materials used in automotive, electrical and electronics, industrial, and consumer applications must consistently meet expectations for mechanical performance, thermal stability, dimensional accuracy, chemical resistance, durability, and long–term reliability across global manufacturing environments.

Introducing circular content into these applications requires more than proving recycled origin. Manufacturers must also maintain material consistency, processing behavior, regulatory compliance, and validated application performance across large production volumes.

By integrating recycled and renewable feedstocks at the chemical feedstock level, mass balance enables the production of materials with virgin–equivalent chemical structure and performance characteristics. This allows manufacturers to increase circular feedstock use while continuing to meet the technical requirements of demanding engineering applications.



VIRGIN–EQUIVALENT MATERIAL PERFORMANCE *ACCELERATES INDUSTRIAL ADOPTION*

Maintaining virgin–equivalent material properties becomes especially important in applications that require:

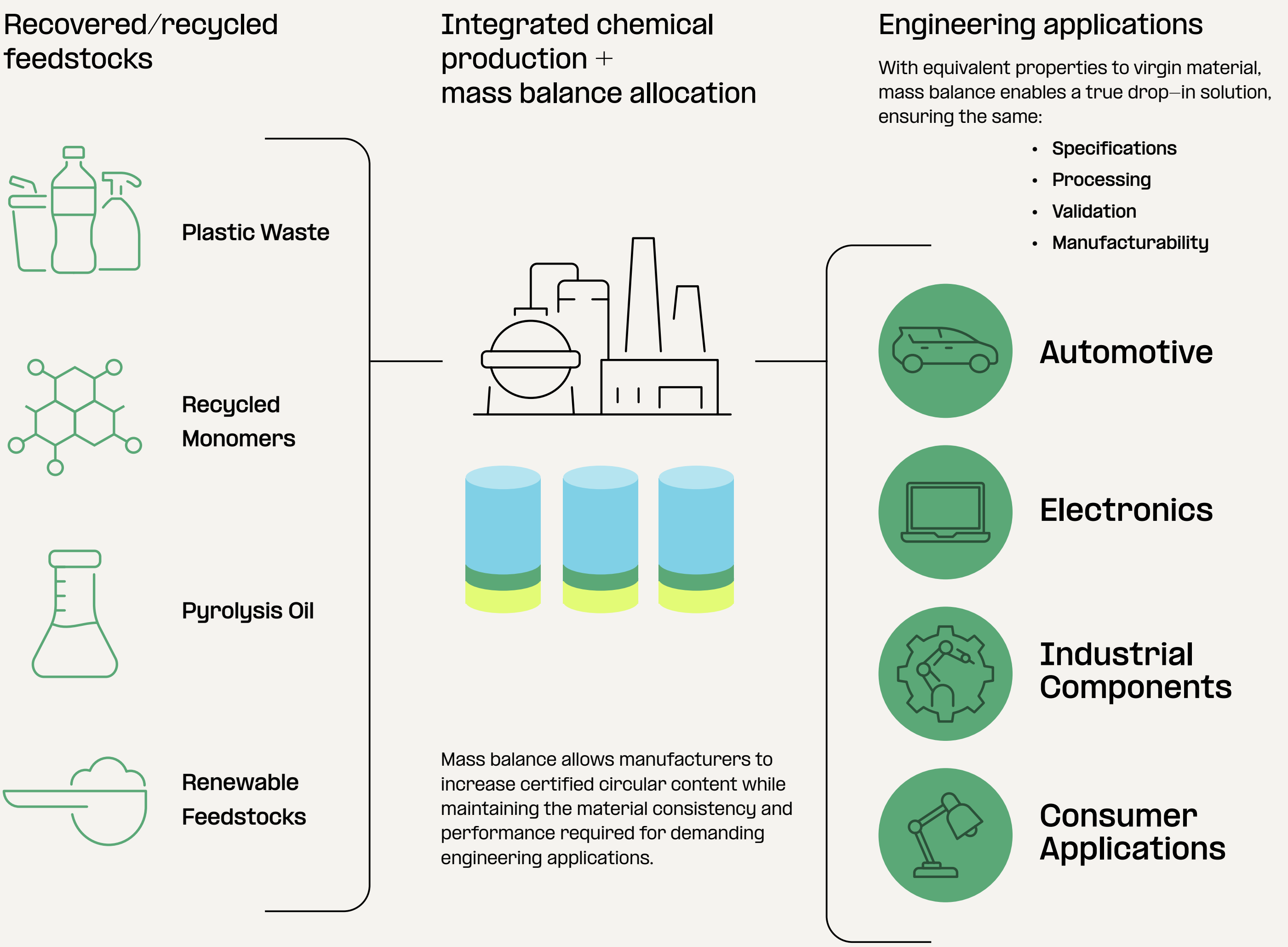
- Validated mechanical performance
- Dimensional consistency
- Recycled content
- Long service life
- Thermal stability
- Complex compounded formulations
- Global production consistency
- Qualification across multiple manufacturing sites

Materials produced through certified mass balance systems retain the same processing behavior and performance characteristics expected from conventional virgin–grade materials because the underlying chemical structure remains unchanged.

This allows manufacturers to integrate circular–content solutions into existing applications more efficiently, often without requiring major redesign, tooling modifications, or extensive requalification programs.

For industries working to increase circular content while maintaining established engineering standards, this compatibility supports faster and broader implementation across existing product platforms and manufacturing operations.

Circular Feedstocks. Virgin–Equivalent Material Performance.



PRACTICAL CIRCULARITY REQUIRES ON *SCALABLE INDUSTRIAL IMPLEMENTATION*

Increasing circular content across global manufacturing systems requires more than recovering larger volumes of plastic waste. It requires industrial processes capable of converting recycled and renewable feedstocks into materials that meet the performance, consistency, and reliability requirements of demanding engineering applications.

Mechanical recycling remains an essential part of the circular economy and will continue to support many material streams and applications. At the same time, scaling circular feedstocks across highly integrated manufacturing systems also requires approaches capable of operating within existing industrial infrastructure while maintaining virgin–equivalent material performance.

Mass balance enables recycled and renewable feedstocks to move through established chemical production systems using certified allocation methods already applied across other large–scale industries. This allows manufacturers to increase circular content while preserving the efficiencies, consistency, and production scale modern supply chains depend on. And using mass balanced materials allows plastic part designers to reduce the quantity of fossil material without the need for requalification of their design.

As circular economy requirements continue to accelerate, integrating circular feedstocks into industrial–scale manufacturing systems will play a central role in reducing dependence on fossil resources and supporting long–term circular material flows.

ENVALIOR SUPPORTS THE TRANSITION WITH *CERTIFIED CIRCULAR MATERIAL SOLUTIONS*

Envalior develops engineering material solutions that help manufacturers increase circular content while maintaining application performance, manufacturability, and long–term reliability across demanding industries.

By combining material science expertise, application development support, and certified mass balance solutions, Envalior supports customers across:

- Material selection
- Application development
- Processing optimization
- Validation and testing
- Manufacturing scale–up
- Credible sustainability claims
- Long–term product performance.

Learn more about Envalior's certified circular material solutions and mass balance approach at Envalior.com.

Envalior is a leading global Engineering Materials company employing around 4,000 people worldwide. With a long track record of customer–focused innovation, Envalior focuses its deep material and application expertise on sustainable and high–performance solutions. The company supplies many of the world's key markets including Automotive, New Mobility, Electronics & Electrical, and Consumer goods.
For more information visit www.envalior.com.

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