

EPS RECYCLING MATERIAL FLOWS



Pallets of recycled and densified EPS await shipment at the James R. Welch Recycling Center in Rogers, Arkansas

The Guide plays a vital role in framing the current landscape of expanded polystyrene (EPS) recycling and is designed to offer practical insights for enhancing the recyclability of EPS transport packaging. These insights focus on distinctions for different categories within EPS recycling, such as pre-consumer versus post-consumer material and mechanical versus chemical recycling. Additionally, the Guide delves into details on material properties and their effect on the recycling process.

Technologies, classifications and best practices all factor into EPS recycling. Success depends heavily on the specifics of the supply chain, the material flow, and the willingness of partners to participate. EPS transport packaging recycling can be highly effective.

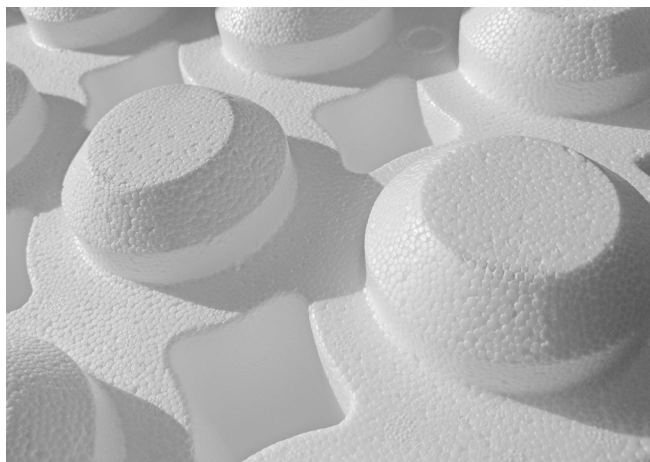
The focus of the Guide is on the recycling opportunities available to the EPS transport packaging sector. Although significant volumes of EPS are used in building and

construction applications as thermal insulation, those applications are intended for lifetime use in the building and are not of immediate concern for recycling. Future editions of this Guide are anticipated to address issues of jobsite waste and recycling following building deconstruction.

Of major significance to recycling in the EPS industry is the recognition and an understanding of the manufacturing value chain for EPS foam products, in this case, transport packaging. The industry has a two-stage value chain comprised of the manufacture of the (unexpanded) EPS resin with the incorporated blowing agent, followed by the conversion of the resin into the foam particles, which are then molded into the desired configuration.

EPS Resin Technology

The production of EPS resin may be accomplished in one of two ways. The most common and traditional method is the polymerization of styrene monomer to polystyrene in a suspension polymerization process during which the blowing agent is incorporated into the expandable resin. A more recent approach has been to feed polystyrene into an extruder with the capability to add the blowing agent during the extrusion process. In this case, the molten polymer is micro-pelletized at the exit of the extruder, yielding an expandable resin. Both approaches can incorporate EPS recyclate, but the extrusion technology provides a more direct solution.



In the case of EPS transport packaging, the conversion is most often accomplished by molding the expanded resin into custom shapes for the desired end-use packaging application. However, it is also possible to make packaging from large blocks of EPS foam by means of hot wire cutting. The Guide will address both approaches to producing packaging parts.

Regrind & Rework as Pre-Consumer Material

Regrind (or rework) does not qualify as pre-consumer material for EPS foam within the molding facility that is out of specification (i.e., scrap) or EPS foam offcuts from final cutting of blocks. Following size reduction, these materials are then reincorporated into EPS foam as a substitute for the original raw material.

Following an extended discussion in a white paper of pre-consumer recycled content claims, UL has published the standard, “Environmental Claim Validation Procedure (ECVP) for Recycled Content: UL ECVP 2809-2: 2023 (ed. 2)” which provides the following:

§ 7.4 Materials excluded from recycled content claims: Material excluded from pre-consumer recycling content claim is a type of waste generated during a manufacturing process which can be reused in the same process without any additional processing. The use of such types of scrap is considered to represent process efficiency and therefore cannot be considered pre-consumer recycled content material.

In contrast, regrind that originates from reclaimed EPS foam materials external to the EPS manufacturing (molding) facility would be counted toward recycled content, as this material would be characterized as post-consumer recycled (PCR) material. Examples of PCR would include EPS foam dropped off in a collection bin at or near the molding plant or EPS offcut or scrap returned to the molder or resin producer from a customer or distribution facility.

Proper accounting for internally generated versus externally received regrind is essential for the proper determination of the recycled content of finished products. An ongoing log should be maintained of the source of the reclaimed material and its disposition. Reclaimed materials that are reprocessed via mechanical or thermal densification and transferred of to a third party for recycling should be logged for tracking purposes but do not count toward the molder.

Classification of EPS Recycling Technologies

EPS Resin with Recycled Content

In broad terms, EPS recyclate can be recycled into EPS resin (i.e., unexpanded EPS beads containing the blowing agent) via mechanical recycling or by various chemical means. For mechanical recycling, densified scrap EPS foam (that is free of contamination) is shredded and added to the feedstock for making new EPS resin. This densified material can be added and remelted with bulk polystyrene in an extruder to make an extruded EPS resin. Alternatively, a limited amount can be dissolved and incorporated into suspension polymerized EPS resin. In either case, the trace additives that are present in the EPS recyclate, such as coating agents and nucleating agents, are incorporated into the recycled content EPS resin.

There are several options for chemical recycling of EPS, depending on the extent to which the polymer is treated. In the simplest approach, the EPS recyclate is dissolved in a solvent, and the trace impurities are removed from the polystyrene. Once separated from the impurities, the solvent is removed from the polystyrene yielding a purified polystyrene resin that can be used in the extrusion or suspension processes to produce virgin EPS resin. This approach addresses any effect of the trace ingredients on the EPS production process.

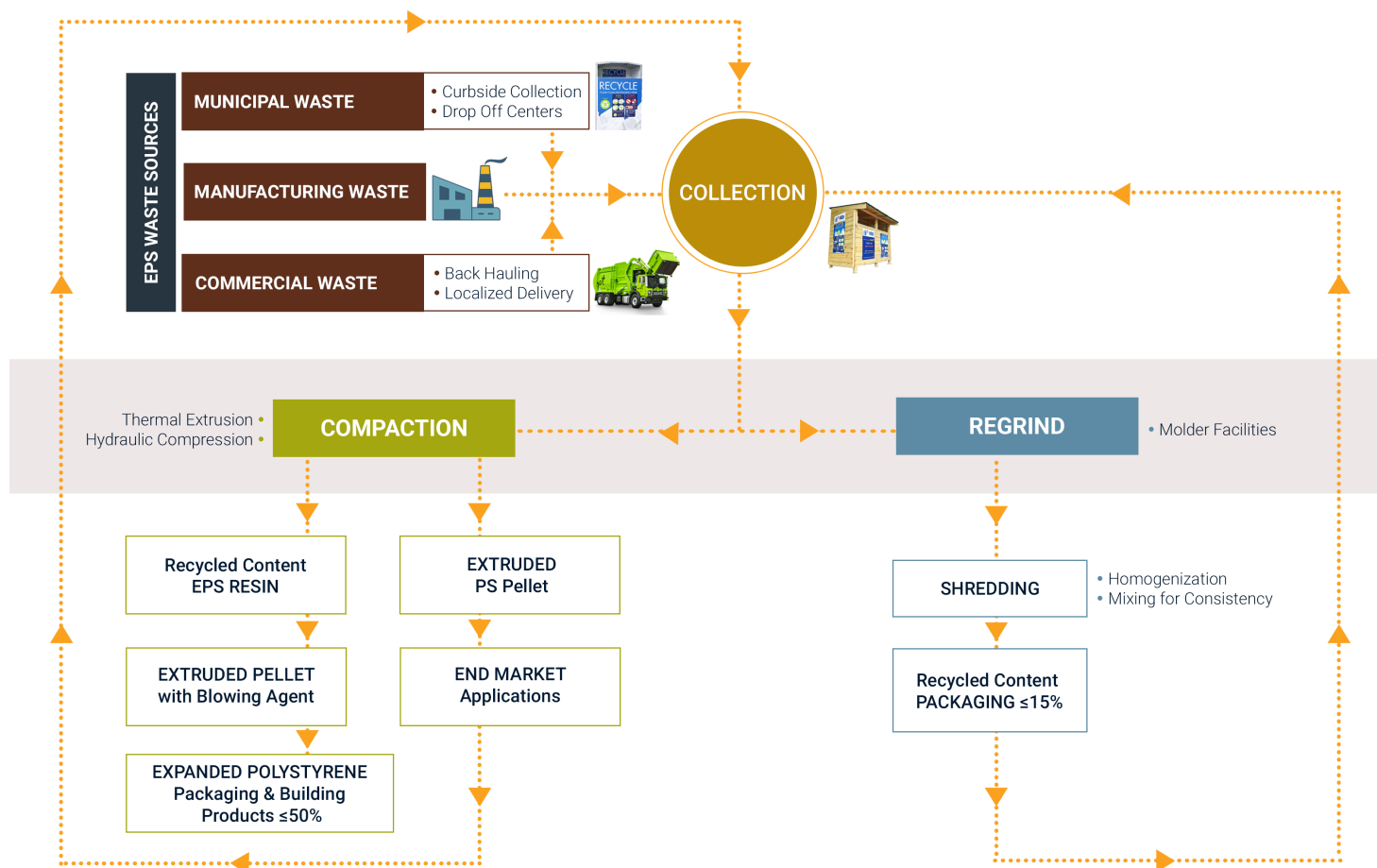
Advanced (chemical) recycling takes a different approach than the polymer purification described above by the application of heat, catalysts, or other means to depolymerize the polystyrene polymer. This material is often referred to as pyrolysis oil. It can be used as a substitute for naphtha in the production of a host of refined hydrocarbon products, not just styrene. If the depolymerization process is engineered to yield styrene by-products, then these can be isolated and reintroduced with virgin styrene monomer in the suspension polymerization of EPS resin or the production of bulk polystyrene resin.

Recycling of EPS Foam by Converters (Molders)

Post-consumer and pre-consumer EPS foam transport packaging can also be recycled directly by EPS foam manufacturers (i.e., converters or molders), though there are limitations to this approach to recycling. First and foremost, the collected EPS foam must be clean and free of dirt and debris. While this packaging may be collected through drop-off or collection bins, the lack of a chain of custody can present challenges.

Molders using this recycling approach are able to incorporate 5-15% (possibly even higher for certain applications) of recycled EPS foam into their EPS transport packaging production. The collected EPS foam packaging is fed into specialized equipment that will reduce the packaging back to nearly its original foam particles. The foam particles can then be mixed with virgin foam particles prior to the molding process and reincorporated into transport packaging.

Additives in the collected packaging, such as flame retardants (typically found in EPS foam used in construction applications), may pose a challenge as some transport packaging applications have strict guidelines about the presence of these additives. For instance, EPS transport packaging that is intended for use in contact with foods, such as fish or grapes, may not be produced with flame retardants.



Determination of Recycled Content

Chain of custody (CoC) is necessary to establish the traceability of recycled content in the final product and validate the recycled content claims. This CoC is straightforward when utilizing controlled blending. In this approach, the relative amounts of recycled material that is blended with virgin feedstock are monitored and recorded. Controlled blending is required for mechanical recycling, either for EPS resin (i.e., extrusion production process) or for EPS foam particle regrind being molded with virgin materials by converters (EPS foam manufacturers).

Establishing CoC when applying chemical recycling generally requires the mass balance approach and the allocation of the recycled content among the various end products. This is especially true the further up the value chain the chemical recycling occurs.

While the way in which the EPS recycle is incorporated into the final product influences the CoC demands and the complexity of traceability, in other respects, the recycling of EPS transport packaging is straightforward compared to other plastic packaging materials. With the exception of minor additives in the EPS resin formulation, EPS is essentially a “mono-material.” In other words, it is predominantly composed of polystyrene without other polymers or significant impurities. As such, this makes EPS transport packaging more readily recyclable.

Best Practices to Facilitate EPS Resin Recycling

Additives in EPS Resin

As already noted, EPS for transport packaging is essentially a “mono-material” composed largely of polystyrene. However, small amounts of additives are present to optimize the processing of the EPS resin and the function of the resulting EPS foam.

Non-essential (for transport packaging) additives should be avoided in the EPS resins used for these applications wherever possible. For instance, flame retardant additives are incorporated into EPS resins used for building and construction applications. While these additives impart necessary fire resistance properties to improve the life safety performance of EPS insulation products, they are generally not necessary in transport applications.

Under some circumstances, however, flame retardants are used in transport packaging by manufacturers to satisfy the requirements of their insurance providers. While flame retardants in EPS transport packaging are not preferred, they can be tolerated if their presence is known and provisions are made for handling them in the recycling infrastructure.

Other “optional” additives, such as colorants or thermal absorbers, also increase the difficulty of recycling reclaimed EPS packaging materials. While these do not prevent recycling, their presence requires special attention to the technology applied for recycling. For instance, the dissolution/purification approach can remove many of these additives from the polystyrene mixture, yielding a clean polystyrene resin for reprocessing into EPS resin.

Densification Technologies

Because of the low density of EPS transport packaging and its high volume-to-weight ratio, EPS packaging is typically densified by mechanical or thermal means to facilitate the reclamation of EPS packaging by minimizing shipping costs.

Thermal densification is the melting of the product to yield plastic patties upon cooling of the molten material.



Best Practices to Facilitate EPS Foam Recycling

Recycling in EPS foam manufacturing requires an understanding of the source of the reclaimed EPS packaging and largely uncontaminated EPS foam. Molders rely on pre-breakers and regrind equipment to reduce the packaging to particles that are approximately the size of the virgin expanded EPS resin. This process results in a small amount of polystyrene dust that is collected, densified and sold in the secondary recycling market.

To effectively recycle in the molding plant, the molder generally segregates the reground (and de-dusted) recyclate in storage bags to be metered into the molding machines with the virgin EPS foam particles. As much as is feasible, the density of the reground material is matched to the virgin material to avoid segregation during molding and any impact on the functionality of the packaging part.

Apart from avoiding reclaimed packaging with gross (and visible) contamination such as dirt, labels, and tapes, the most successful recycling in the molding plant avoids cross-contamination with flame-retarded EPS foam materials so that the recyclate (regrind) may be added to the widest range of EPS transport packaging.

Labeling & Marking

The presence of labels, often paper-based or tapes, as is often the case with fish boxes, grape boxes, and frozen food/pharma cold chain shipping boxes, poses special challenges. These “contaminants” are generally not recyclable and are cost-prohibitive to remove from the reclaimed EPS transport packaging.

Collection Scenarios & Infrastructure

Collection systems in the EPS transport packaging sector take many forms in part because of the unique characteristics of EPS foam. As a “mono-material” and one that is lightweight and bulky, EPS transport packaging recycling does not lend itself to municipal curbside recycling despite efforts to promote and encourage this approach.

After (generally) unsuccessful efforts to replace EPS foam with alternative materials for transport packaging, OEMs and brand owners have, in many cases, resorted to establishing “take-back” programs or partnering with their distribution partners to facilitate the collection and, ultimately, the recycling of their EPS packaging. For instance, distributors, big box retailers, and grocery chains often implement collection programs alongside their corrugated paper collection and recycling initiatives.

In addition to these “closed loop” collection approaches, municipal materials recovery facilities (MRFs) may provide an outlet for recycling their post-consumer EPS transport packaging. These MRFs often have a mechanical densification system in place to process the EPS prior to shipment to recyclers.

Consumers in North America may also locate local drop-off locations or recyclers via the EPS Recycling Map maintained and hosted by the EPS Industry Alliance. This map further provides locations that accept post-consumer EPS foam via mail for those for which a drop-off location is not readily available.

While most of the above collection scenarios are based on local and regional supply chain scenarios, it is important to appreciate the limitations of these approaches, as EPS transport packaging is widely used in global supply chains for mechanical and thermal protection. With exports from North America, there is no opportunity within the region to collect the packaging, and the destination country must have its own infrastructure in place to collect and recycle the EPS. With goods imported into North America, the consumer or the distributor has a critical role to play in effectively collecting the EPS packaging.

Taken in total, EPS transport packaging and infrastructure is highly dependent on the specifics of the goods being packaged and the nature of the supply chains. Motivated channel partners, whether brand owners, distributors, retailers, MRFs, or even the ultimate consumer, are critical and essential to EPS collection efforts being effective and economically viable.



References

¹UL, “Interpreting pre-consumer recycled content claims: Updated guidance of environmental claims for pre-consumer recycled materials.” 2020, <https://www.ul.com/insights/interpreting-pre-consumer-recycled-content-claims>.

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Definitions & Terminology

allocation: the assignment of raw materials, either virgin materials or recyclate, to the finished product(s)

free allocation: in this case, the raw materials (i.e., recyclate) may be assigned non-proportionally to the finished products.

chain of custody models: models to trace inputs to outputs with the necessary related information as the inputs are transferred and monitored through the supply chain as per the requirements of ISO 22095. For EPS recycling, two chain of custody models are most relevant: controlled blending and mass balance.

controlled blending model: chain of custody model in which virgin raw materials are mixed with recyclate in a fixed proportion throughout the ongoing production of the recycled content finished product(s).

mass balance model: chain of custody model in which virgin raw materials are combined with recyclate according to defined criteria, that is not necessarily according to a fixed proportion among all finished products. There are two types of mass balance models.

Mass balance model with rolling average percentage: A rolling average of up to 12 months for recyclate incorporated into recycled content finished products is used to establish the recycled content claim. Under certain conditions, it may be applied across multiple sites.

Mass balance model with credit method (single site only): Using a reconciliation period of no more than 3 months, the reclaimed materials (or chemicals, if the chemical linkage is maintained in the transformation process from the reclaimed chemical to the recycled content finished product) are allocated, proportionally or according to free allocation, to the recycled content finished product(s).

book and claim model: chain of custody model where the linkage between the physical recyclate is disconnected from the source of this material relying on the trading of certificates. This model is outside the scope of this Guide.

modified and unmodified (or non-modified) material: this label is commonly used within the EPS industry to distinguish flame-retarded (modified) EPS materials from those that do not contain any flame retardants.

pre-consumer material (PRE) (post-industrial material): plastic material that has been discarded as unusable prior to reaching the end user and serving its intended purpose but that has been (i) diverted from the waste stream and (ii) not reprocessed via the same process as a substitute for the original raw material. See below for further explanation of regrind and rework for EPS transport packaging.

post-consumer material (PCR): plastic material generated by consumers, industry, or distribution facilities that have served their intended purpose and can no longer fulfill that purpose.

reconciliation period: a defined time period for balancing the inventory of recyclate with that of recycled content finished product(s).

reclaimed material: plastic materials (in the case of this Guide, EPS transport packaging) that have been collected at the end of their intended use and are available to be recycled.

recyclate: polymeric (not monomeric or oligomeric) material that has been reprocessed to be used and incorporated into recycled content finished product(s).

recycled content: proportion of material in the finished product(s) that is derived from recyclate.

supply chain: a series of steps in the physical distribution and transformation of raw materials into finished product(s).