



PET THERMOFORM RECYCLING COST & MATERIAL FLOW ANALYSIS

December 2, 2020



PROJECT SCOPE

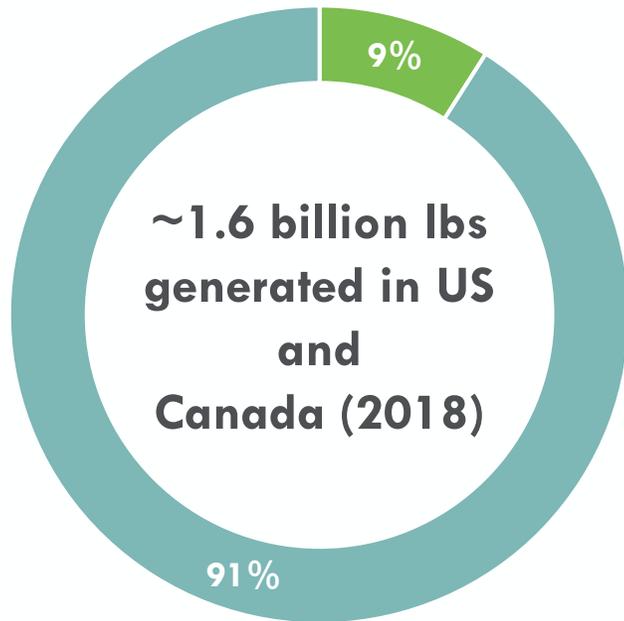
- This multi-partner project set out to:
 - Estimate the total generation and current recovery of PET thermoforms
 - Understand the current PET thermoform sorting and reclamation landscape
 - Determine potential future pathways for PET thermoform recycling
 - Highlight the potential opportunities and challenges associated with each pathway

PROJECT PARTNERS



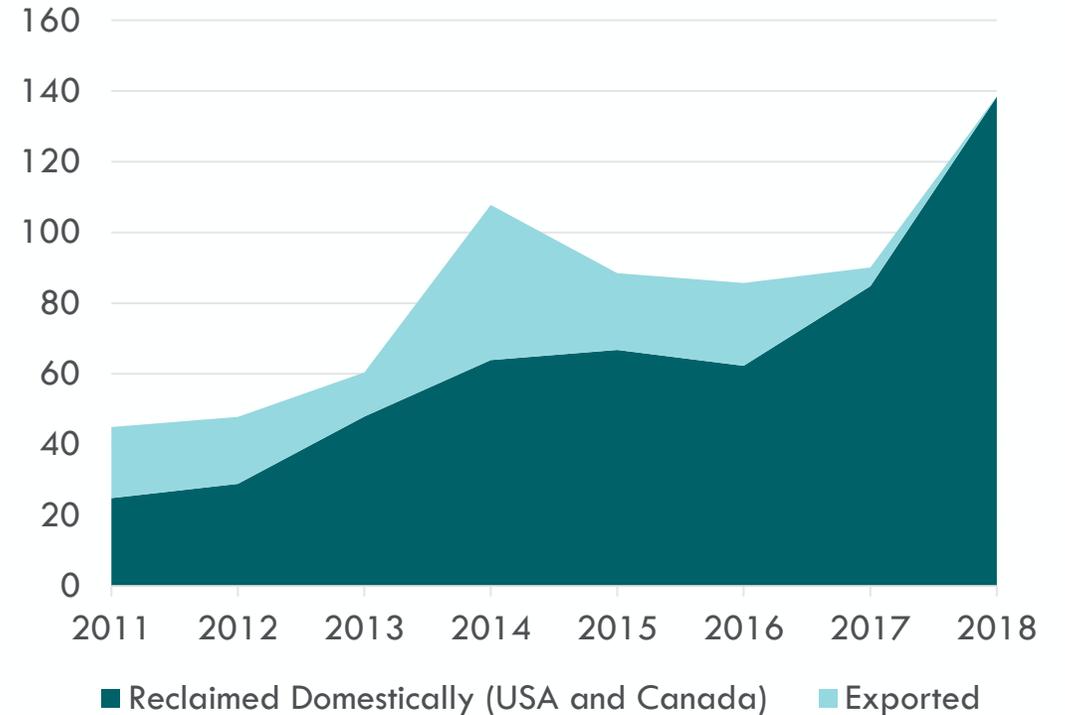
PET THERMOFORM RECOVERY* TRENDS IN THE US AND CANADA

Estimated PET Thermoform Generation and Recovery in the US and Canada in 2018



■ Recovered ■ Unrecovered

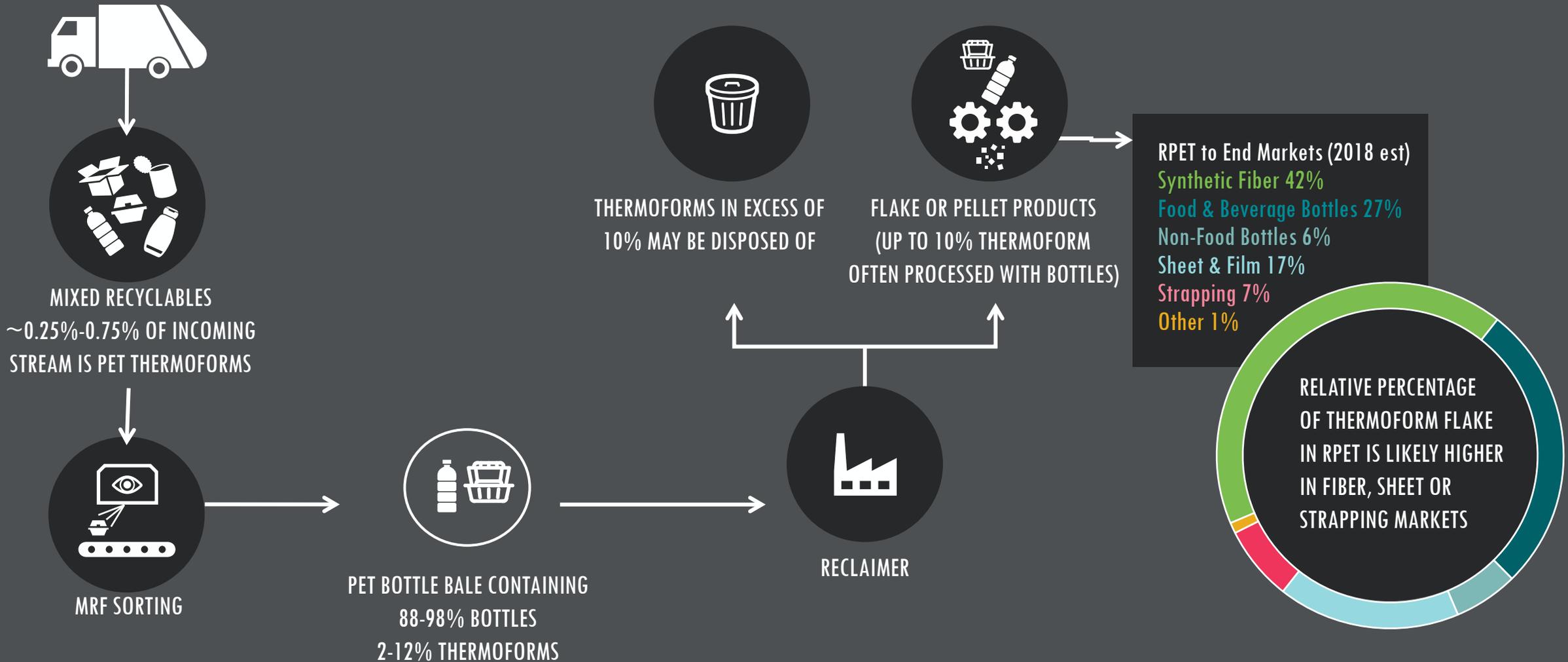
PET Thermoform Recovery in the US and Canada (MM Lbs)



Source: NAPCOR

*PET thermoform recovery, as reported by NAPCOR, represents the amount collected for recycling and sold to reclaimers.

TYPICAL THERMOFORM FLOW / EXISTING SYSTEM





MRF SURVEY FINDINGS

Many MRF respondents are open to sorting a separate PET thermoform stream (segregated from PET bottles), particularly if some or all of the following conditions are met:

- Consistent, stable markets
- Sufficient price
- Reasonable throughput volumes
- Adequate space to convey/bunker

Most respondents report that grants would be helpful to address infrastructure needs—sortation, robotics, conveyers, etc.—assuming consistent, reliable end markets

RECLAIMER SURVEY FINDINGS

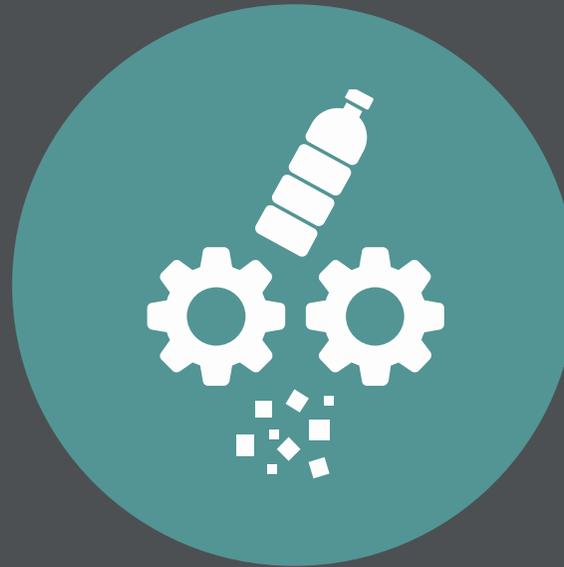
- PET reclaimers seek to utilize all PET purchased (including thermoforms), but are typically operationally constrained to no more than ~10% of bale to meet rPET specs
- PET reclaimers' core business is PET bottle processing to established end markets; they consider it outside their core business to accommodate higher thermoform volumes in bottle stream, or to separate them out to re-market or process separately
- Mixed plastic processors derive value from reclamation of olefins, not from PET thermoforms, but may be open to it with sufficient value and stable end markets (for thermoform flake or for bale resale)



POTENTIAL PET THERMOFORM RECOVERY CHANNELS EVALUATED



MRF



PET RECLAIMERS



PRF



PET THERMOFORM RECYCLING PATHWAY OPTIONS EVALUATED

OPTION 1: Status Quo. The MRF sorts all PET into a mixed PET thermoform/bottle bale. The PET bale is sent to the reclaimer and processed into flake or pellet.

OPTION 2: The MRF sorts all PET into a mixed PET thermoform/bottle bale. The PET bale is sorted at the reclaimer into separate thermoform and bottle streams and thermoforms are separately processed into flake or pellet on-site.

OPTION 3: The MRF sorts all PET into a mixed PET thermoform/bottle bale. The PET bale is sorted at the reclaimer into separate thermoform and bottle streams. The thermoform stream is baled and sent to thermoform-only recycling.

OPTION 4: The MRF sorts and bales PET bottles and PET thermoforms separately. The PET thermoform bales are sent directly to PET thermoform-only recycling markets.

OPTION 5: The MRF sorts PET thermoforms in a mixed plastic bale. The mixed plastics bale is sent to a PRF or mixed plastic recycler. The PRF / mixed plastic recycler sorts and bales a PET thermoform-only stream and sends to reclaimer for further processing or PET thermoform-only recycling markets.

POTENTIAL PET THERMOFORM FLOW IN MRFS



Expand capture of PET thermoforms for recycling, increasing volumes to PET markets



Use optical sort for all PET; manual and/or robotic sort to separate out PET thermoforms, if needed



Produce commodity bales:

1. PET thermoform-only bales for market
2. Mixed PET bottle/ thermoform bale, potentially with higher % of thermoforms, or
3. Mixed Plastic Bale



POTENTIAL MRF ROLES IN PET THERMOFORM RECOVERY

This study evaluated three options for sorting PET thermoforms in MRFs.

1. If PET reclaimers were able to handle greater percentages of thermoforms (higher than 10% or current operational limits), MRFs could operate within the existing flow construct and produce bales of mixed PET bottles and thermoforms, with higher levels of thermoforms than is current practice
2. MRFs with an optically sorted PET stream could manually or robotically sort PET thermoforms from the PET line, and redirect them to a thermoform-only bale
3. MRFs with an optically sorted PET stream could manually or robotically sort PET thermoforms from the PET line, and redirect them to a mixed plastic bale

From a technical perspective, removing thermoforms from the PET stream is a fairly simple change, assuming the market supports the costs, the facility has the space and design to allow for conveyance and storage, and the throughput volumes are adequate for timely shipment of material.

While implementing MRF sorting of PET thermoforms is arguably the most ready-to-implement pathway, achieving scale would require engagement of hundreds of MRFs, rather than tens of reclaimers.

POTENTIAL PET THERMOFORM FLOW IN RECLAIMERS



Broaden bale specs to allow for greater % of thermoforms – communicate back to MRFs and communities to expand access



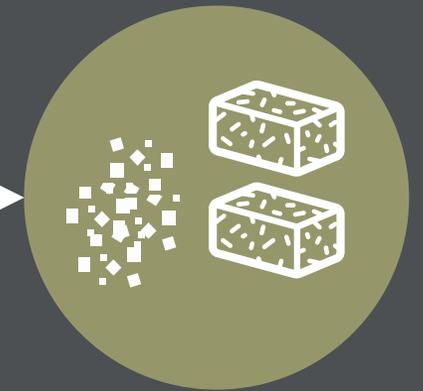
SORT/PROCESS Mixed PET bottle / PET thermoform

Sort & process all PET to rPET end market(s)
(Option 1)



SORT/PROCESS PET thermoform only

Manual/ robotic / optical sort for PET thermoforms. Process or sell PET thermo material (Options 2 & 3)



PRODUCE FOR MARKET

1. Mixed bottle / thermoform rPET flake/pellet,
2. Thermoform rPET flake/pellet, and/or
3. PET thermoform (or mixed PET out-throw) bales



POTENTIAL PET RECLAIMER ROLES IN THERMOFORM RECOVERY

The study evaluated potential reclaimer roles for sorting and / or processing PET thermoforms:

1. PET reclaimers could make process or system changes to allow them to process higher proportions of PET thermoforms in bottle / thermoform mixed feedstock
2. PET reclaimers could sort thermoforms out of the incoming material stream and run them separately from bottles, to produce thermoform rPET flake
3. PET reclaimers could sort thermoforms out of the incoming material stream and rebale / resell them to a thermoform-only market
4. PET thermoform-only recyclers (mechanical reclaimers and/or chemical recyclers) could process thermoform bales produced by MRFs, PRFs or PET bottle reclaimers (that sort and market thermoforms)

Working with PET reclaimers has the advantage of involving fewer points of intervention and most options have low marginal cost (reflecting sorting, handling and transportation only). However, it is potentially more technically and commercially challenging, with no appetite expressed by the PET bottle reclaimers surveyed.

POTENTIAL PET THERMOFORM FLOW IN PRFS / MIXED PLASTIC RECLAIMERS



Purchase mixed plastic bales from MRFs with higher rate of thermoforms



SORT

Manual / robotic / optical sort for PET thermoforms



PRODUCE FOR MARKET

PET thermoform bale



POTENTIAL PRF / MIXED PLASTICS RECLAIMER ROLES IN PET THERMOFORM RECOVERY

The study evaluated the option of having plastics recycling facilities (PRFs) or mixed plastic reclaimers accept PET thermoforms in mixed plastic bales and sort those thermoforms out for resale to a PET thermoform-only market.

This pathway would face the following challenges:

1. PRFs have not proven to be a viable stand-alone business model;
2. Mixed plastics reclaimers typically harvest PP and PE from mixed plastic bales and do not often remarket other materials present in the bales.

Like the PET reclaimer pathway, this approach would require fewer interventions to achieve a scaled impact. However, ongoing marginal costs would likely be higher.



COST ANALYSIS APPROACH

- The project sought to identify the marginal costs of each pathway and option analyzed
 - Includes additional costs to sort, bale and transport a material stream, such as PET thermoforms
 - Reflects ongoing costs that would need to be supported by the marketplace, either through processing fees or end market values
 - Compares the costs for each option to the current (baseline) pathway where PET thermoforms flow with bottles in the MRF to the PET reclaimer
 - Does not include the cost of capital, equipment, overhead, or other fixed or operational costs of MRFs and / or reclaimers

NOTE: marginal costs are not the only factor to determining the most feasible approach. Technical and logistical constraints were also evaluated.



PET THERMOFORM RECYCLING PATHWAY OPTIONS EVALUATED

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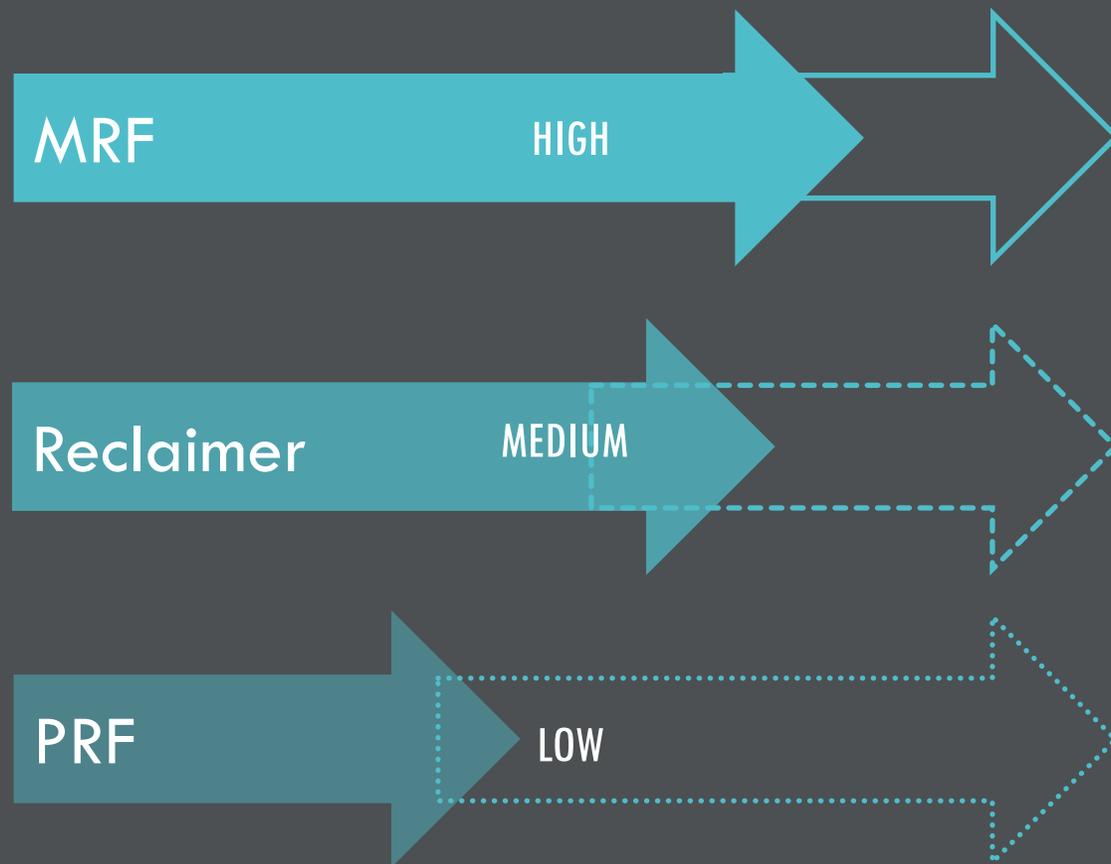
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COMPARATIVE MARGINAL SORTING AND HANDLING COSTS FOR SEPARATE THERMOFORM POTENTIAL PATHWAYS



Note: This chart only represents the marginal costs of sorting, baling / handling and transporting a separate material stream, such as PET thermoforms; it does not reflect capital costs, overhead or other fixed or operational costs of MRFs or reclaimers. Option 1 is not shown as it is the status quo.

PET THERMOFORM CHANNEL IMPLEMENTATION READINESS SCALE



FACTORS IMPACTING READINESS

PET already optically sorted in MRFs representing 70% of capacity. Could separate thermoforms with an additional manual sorter; efficiency gains with advanced sorting. Direct gateway to increased access. Survey indicates willingness to consider with stable market and price.

Current pathway for most recovered thermoforms, though not preferred. Technical limitations constrain using more thermoforms. Separate sort and/or wash line needed to process thermoforms separately. Survey suggests low enthusiasm for sorting.

Historically unsuccessful business model with renewed interest. Highest capital investment and marginal system cost. Can leverage interest in other resins. Can expand access broadly within a region with one large targeted investment.

BARRIERS IN THE PET THERMOFORM RECOVERY SUPPLY CHAIN

Barriers:

Limited MRF sorting capacity for segregated PET thermoform or low value (+ colored bottle) stream

MRFs may not be ready to handle volume increase. Concerns include markets, storage, volumes, price.

Barriers:

Inconsistent messages about sortability/desirability of non-bottle PET are a challenge to increasing recycling collection

Barriers:

Technical and market constraints at PET reclaimer facilities

RECLAMATION



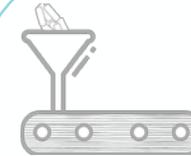
RESIN PRODUCTION



Barriers:

Low virgin resin price creates competitive challenge

DESIGN & CONVERSION



Barriers:

Limited end markets; design challenges (e.g., labels, inks, adhesives, colorants, additives)

CONSUMER



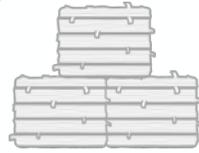
Barriers:

Inconsistent education about non-bottle PET is a challenge to increasing recovery volumes

COLLECTION



SORTATION





PROJECT FINDINGS

- PET thermoform generation is equivalent to natural HDPE bottles, therefore likely sufficient volume to target for increased recovery
- There is potential to increase the recovery of PET thermoforms, but barriers remain
- Key findings:
 - Inconsistent acceptance by PET reclaimer markets limits MRF openness to greater access / education efforts
 - Current acceptance at most reclaimers capped at ~10% of bale weight (combined with bottles) due to process and market constraints
 - Lower reclaimer interest in sorting PET thermoform-only stream compared to MRFs
 - Willingness to sort a new stream is highly dependent on consistent, reliable markets and sufficient market price



PROJECT CONCLUSIONS

- MRF flow has potential to demonstrate near term gains in PET thermoform recovery, assuming end markets or processing fees can support additional costs
- PET reclaimer pathways may have greatest optimization potential, but significant technical and operational questions remain
- PRF / mixed plastic reclaimer pathway has the least clear route to success



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