Pathways towards circularity for HDPE packaging

Institute for Sustainable Futures

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About the authors

The **Institute for Sustainable Futures (ISF)** is a transdisciplinary research and policy institute at the University of Technology Sydney with over 100 research staff and students. Since 1997, ISF has been working collaboratively with governments, businesses, organisations and communities to create change towards sustainable futures. Our work in Australia and around the world aims to protect and enhance the environment, human wellbeing and social equity. We do this by developing transformative ideas into strategies that deliver impact and have a strong record of achievement in advancing circular economy and resource stewardship initiatives.

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About the Project (CRC-P, Round 8)

This research was carried out as part of a Cooperative Research Centre Project (CRC-P), a collaborative partnership led by the industry partner, PEGRAS, a technical consulting company solving industrial challenges by introducing new technological solutions to local manufacturers. The 18-months project focussed on HDPE recycling worth $1.5 million dollars, including a $650k Australian Government grant. A consortium of technology, recycling and manufacturing businesses worked with university experts in sensors, polymers, system engineering and environmental policy to overcome the label contamination in HDPE recycling.

PEGRAS consultancy operates across various industries from renewable energy and recycling technologies to automatization and print manufacturing, with consultants based in Australia, Europe and Asia. PEGRAS helps the SMEs that lack the resources to generate innovation and technologies required to compete with global competitors by providing connections, resources and technologies. www.pegras.com

UTS acknowledges the Gadigal People of the Eora Nation, the Boorooberongal people of the Dharug Nation, the Bidiagal people and the Gamaygal people upon whose ancestral lands our university stands. We would also like to pay respect to the Elders both past and present, acknowledging them as the traditional custodians of knowledge for these lands.

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Glossary

APCO	Australian Packaging Covenant Organisation
CDS	Container Deposit Scheme
C&I	Commercial and Industrial Waste
COAG	The Council of Australian Governments
CRC-P	Cooperative Research Centre Project
HDPE	High Density Poly Ethylene
FZANZ	Food Standards Australia New Zealand
ISF	Institute for Sustainable Futures
MFA	Material Flow Analysis
MRF	Material Recovery Facility
MSW	Municipal Solid Waste
PET	Polyethylene terephthalate
rHDPE	Recycled High Density Polyethylene
rPET	Recycled Polyethylene terephthalate
PVC	Polyvinyl chloride
PP	Polypropylene
UK	United Kingdom
UV	Ultraviolet

Introduction

Excessive consumption of plastics, low plastic recycling rates, and the devastating impact plastics have on the environment are critical challenges for governments, industry and the community. For countries like Australia, greater emphasis on addressing these challenges was catalysed with China's introduction of restrictions on imports on recycled waste from foreign countries in 2018, via the 'National Sword' policy.

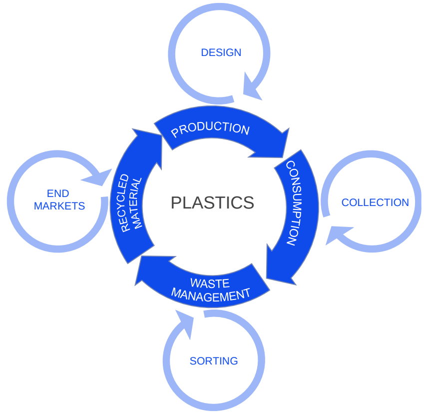
China's policy shift impacted Australia's recycling exports and stimulated a reconsideration of the waste management and processing systems that relied on the export of low quality, poorly sorted recyclable plastics. It prompted the Commonwealth Government's commitment to reduce waste generation and advance recycling industries. The Council of Australian Governments (COAG) established a timeline to ban the export of waste plastic, paper, glass, and tyres, while building capacity to generate higher value recycled commodities and demand[1]. The phased export ban impacts 32% of the total exported recycled material, of which 13% are plastics[2]. In the first phase (July 2021) mixed unsorted plastics were banned. In the second phase (July 2022) unprocessed single resin/polymer plastics (including HDPE milk bottles) will be banned, allowing only processed recycled material to be exported.

The Commonwealth and all State and Territory governments also supported the establishment of the 2025 National Packaging Targets[3]: 100% reusable, recyclable, or compostable packaging; 70% of plastic packaging being recycled or composted; 50% average recycled content included in packaging; and the phase out of problematic and unnecessary single-use plastic packaging. APCO (Australian Packaging Covenant Organisation) is championing the delivery of the Targets and the transition to a circular economy for packaging. While the latest data (2018/19)[4] on the progress towards the 100% reusable, recyclable, or compostable target is within reach at 89%, the other targets remain more challenging. Current recycling rate (including composting) for plastic packaging at 18% is long away from the 70% target. Similarly, the average recycled content for packaging (at 38%) falls short of the 50% target. For HDPE, the recycled content target is 20%, and with the current recycled content only 3%[4], major system changes are required to achieve the 2025 Targets.

This CRC-P aims to increase recycling rates and recycled content for food-grade HDPE packaging with the focus on HDPE milk bottles. The project is directly aligned with efforts to meet the 2025 Target of 70% of plastic packaging being recycled. Significantly, by targeting HDPE packaging, one of the most widely used packaging resins and with the largest market share in Australia, this project supports transition to a circular packaging economy.

The approach taken in this project is to develop a technical solution by sensing and treating the label contamination with particular focus on glue and label removal. A novel delamination process and method for measuring glue removal efficiency has been demonstrated in the lab and verified at pilot-plant scale in readiness for industrial application.

UTS ISF researchers have contributed to this project by providing a whole supply chain analysis from production, consumption, waste management and recycling to identify changes required for the transition to a circular economy. The importance of design, collection, sorting, and end markets for enabling circularity are evaluated, and specific opportunities and barriers for HDPE milk bottle system are explored. We have used material flow analysis (MFA) and scenario modelling to quantify the impact of system changes, including the technical solution developed by the project team.



The HDPE milk bottle baseline (Figure 1) has been established using data from Dairy Australia[5] on total milk consumption, Labelmakers on types/size of bottles placed on market, APCO packaging collection and reprocessing data[4], and life cycle analysis data on material recovery facility (MRF) performance[6]. The MFA identified significant losses at the collection (59%), constraining the downstream recovery, low circularity rate (10%) and significant downcycling rate (41%).

HDPE milk bottle baseline for 2019/20

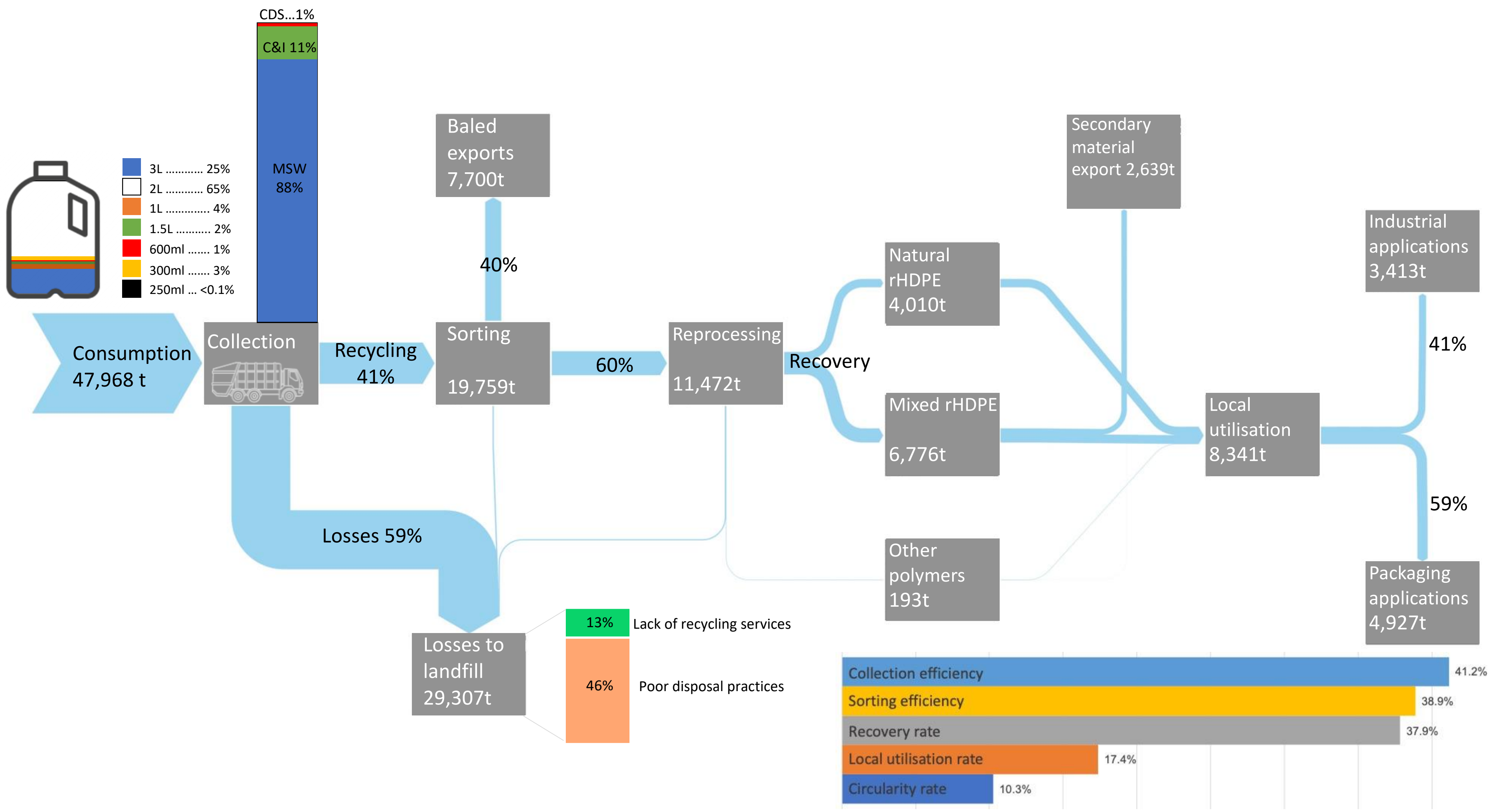


Figure 1: Material flow diagram for HDPE milk bottle, including the distribution of milk bottles by size, collection by collection stream (CDS, C&I, MSW), breakdown of losses to landfill and the system efficiency rates (collection, sorting, recovery, local utilisation and circularity).

Drivers for change, improving collection and growing end markets

Scenario modelling has been informed by literature review and consultation with the industry experts. A workshop was held with the industry experts on the 22nd of June 2021 with the aim to:

- identify key strategies to increase HDPE recycling needed to achive 2025 National Packaging Targets[3];
- obtain expert insight to identify barriers and enablers for key strategies and identify any strategies that have not been considered
- sense check and refine assumptions used to evaluate strategies (based on MFA modelling)

Modelled scenarios consider the system and policy changes coming into effect by 2024-25 (such as export bans), improved collection systems (particularly Container Deposit Scheme – CDS – expansion) and improved HDPE downstream recovery. Scenario assumptions are characterised as *conservative*, where assumptions are based on known packaging consumption projections, projected increases in reprocessing capacity and other relevant insight from the June workshop; vs. *heroic*, with optimistic packaging system changes that may be needed to achieve the 2025 Targets and support a circular economy.

Drivers for change

This section discusses key modelling assumptions that were informed and/or validated by workshop participants and industry experts. Milk bottle consumption is assumed to remain static per capita and will increase proportionally with population growth. Industry experts expect that the larger (>2L) bottles will still be made from HDPE, while smaller formats (<2L) will shift to PET. While there appears to be growth in consumption of alternative milks such as almond milk, this trend is not expected to impact the packaging volumes.

Export bans coming into effect are assumed to cause redirection of the restricted baled exports from MRFs to local reprocessing. Based on publicly announced plans to expand reprocessing capacity it is anticipated that the local reprocessing capacity will increase to a level that will be sufficient to manage the increased volumes. Specifically, current capacity (5,000-10,000t/y) is expected to grow to 12,000-30,000 by 2022 for rPET and rHDPE (food grade) based on the recent announcements, e.g., by PACT/Cleanaway, Visy and Martogg[7]. Other planned expansions from ACP[8] and Recycle Plastics Australia[9] have reported up to 90,000 t/y future capacity. However, it is not clear what percentage will be for food grade. While the projected capacity should be sufficient, there does remain some uncertainty as far as whether this capacity will be available for managing used milk bottles, and whether it will be focused on rHDPE production.

Also reflected in the *conservative* model assumptions is an increase in collections via CDS from the current rates (300t/y) with implementation of CDS Victoria[10] and Tasmania by 2022[11].

Industry experts have identified a range of drivers that will impact recycling. They projected that recycling will be improved through changes to label design (label material and adhesive), use of recyclable plastics, elimination of problematic plastics (PVC), and harmonisation of the recycling system in terms of collection, separation, and processing capacity. Pressure from consumers and retail businesses expecting packaging with recycled content is also anticipated to drive the change in plastic packaging and recycling system performance. Collection and separation are expected to improve through better sorting at household level enabled by an increased number of bins (e.g., in Victoria[12]), and/or drop off points, and through technological advances, such as the use of digital barcodes, UV markers, artificial intelligence, and machine learning. These advances are thought to be specifically relevant in supporting the recycling of food grade packaging for new food grade applications owing to improved traceability, quality assurance and contaminant removal. Food grade packaging will also be impacted by evolving regulatory food safety approvals.

The workshop participants projected that domestic and international markets will grow, specifically driven by demand in jurisdictions where recycled content is mandated or incentivised such as in the UK[13]; and thus, reprocessed material prices are expected to drive demand for the recycled HDPE.

Export bans are re-directing baled exports from MRFs to local reprocessing

In 2019-20, the national average used milk bottle generation rate per-capita was 1.87kg/person. Figure 2 shows the milk bottle supply by state and the CDS system status by jurisdiction.

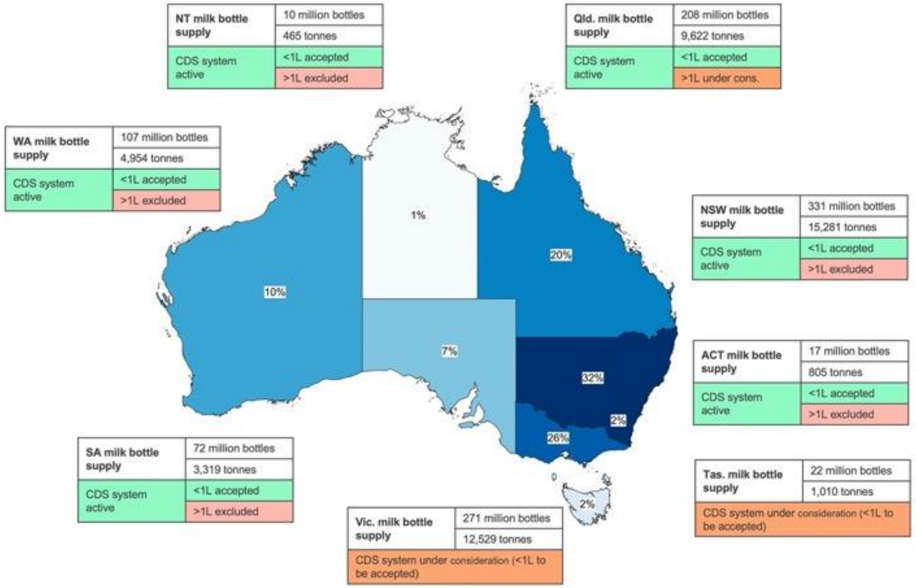


Figure 2: Milk supply distribution by state and CDS system review by state.

While it was assumed that the consumption per capita remains static, the total volume is expected to increase from 47,968t in 2019-20 to 52,241t by 2024-25 owing to the population increase. As noted above, we assumed that HDPE milk products < 2L will shift towards PET bottles. In the *conservative* scenario 25% of <2L products placed on the market are assumed to be PET bottles, while in the *heroic* scenario, all products <2L are assumed to be made of PET. Figure 3 shows the expected changes in material composition for bottles placed on the market. In the *heroic* scenario the PP labels are replaced with HDPE.

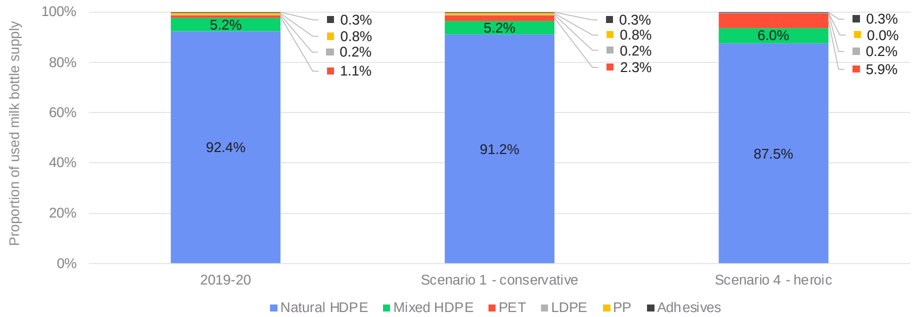


Figure 3: Changes in the used milk bottle supply distribution by material type in conservative and heroic scenario compared to the baseline.

In the *conservative* scenario a slight increase in overall collection rate can be observed (Figure 4), which is attributed to the overall increase in CDS collections owing to the expansion of the CDS scheme to Victoria and Tasmania. Here we assumed the same CDS collection efficiency as the national average (28% based on placed on market). In the *heroic* scenario, all milk bottle products eligible for CDS collection are assumed to be collected via CDS at the same efficiency rate as in *conservative* scenario. All eligible CDS packaging collected via C&I are diverted to the CDS redemption.

With the export ban restricting export of low-quality recycled plastic in effect, packaging and the material collected for export is reprocessed locally. In the *conservative* scenario this results in approximately double the quantity material reprocessed compared to 2019-20. In the *heroic* scenario, the advanced glue removal technology is also implemented and the adhesive contamination rate in recyclate is reduced. Coupled with improved collections (discussed in detail below), this results in triple the quantity of material reprocessed (considering natural and mixed HDPE) compared to the 2019-20 quantities.

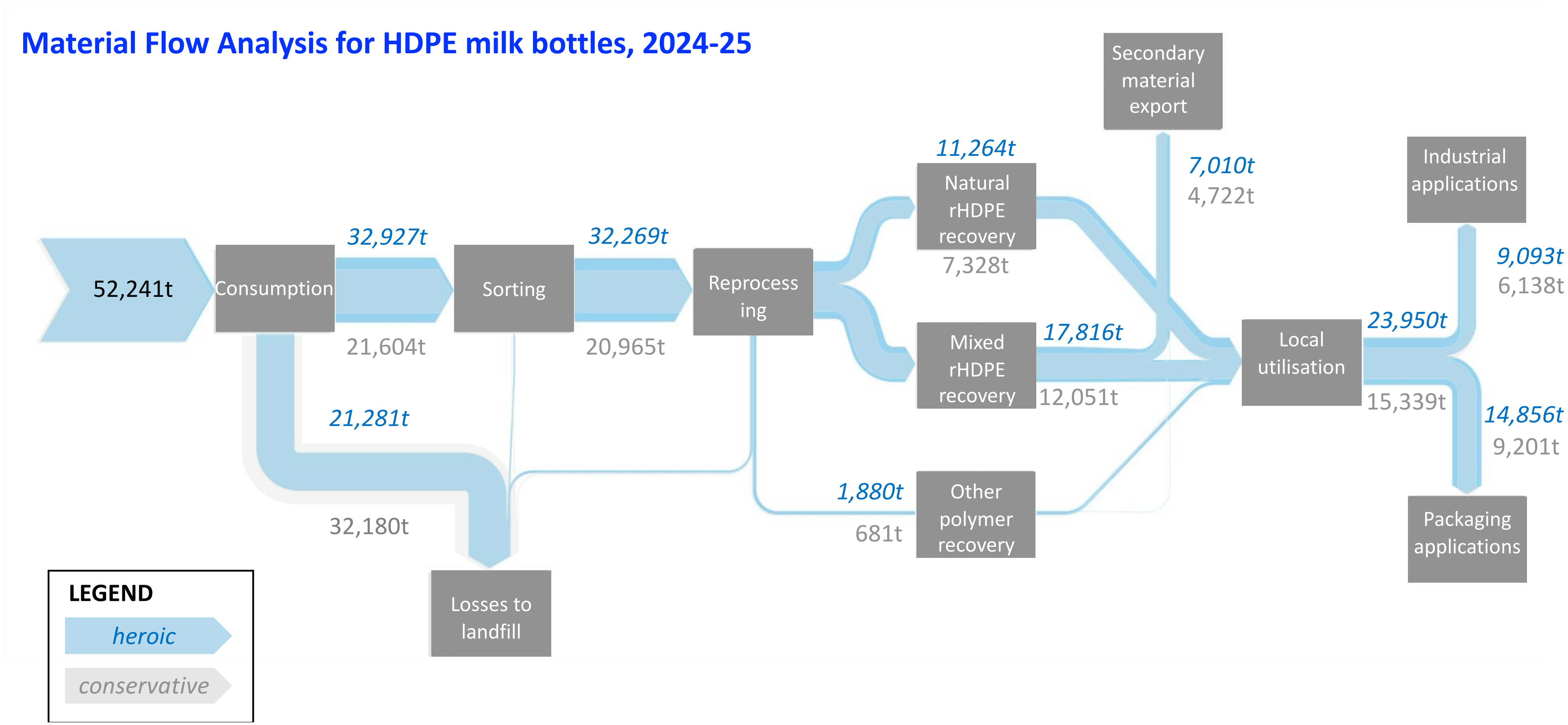


Figure 4: Material flow analysis for the conservative and heroic scenarios in 2024-25.

Tackling collection losses that are >50% will be essential for achieving the HDPE recycling targets

The major constraint on the downstream recovery is the poor collection efficiency (Figure 1). This section explores pathways to reduce the collection losses through expansion of CDS collection and improved C&I and MSW collections.

Collection through CDS provides a cleaner and more efficiently sorted plastic stream compared to the comingled kerbside MSW and C&I collection. However, in the workshop, there was a disagreement among the industry experts whether CDS is an appropriate mechanism to increase the collection of HDPE milk bottles, particularly for the larger formats (>1L). The main concern was around additional costs e.g., associated with participation in the stewardship scheme and how these costs may be shared by supply chain actors. The potential to introduce separate single stream (HDPE milk bottle) collections for C&I was also discussed.

When CDS collection expansion is considered in the scenario modelling (Figure 4), the collection losses are reduced to 41% under *heroic* assumptions that highlights the potential of this strategy for improving recovery.

In Figure 5, a slight shift from MSW collection (kerbside) to CDS can be seen when comparing the *conservative* scenario to the baseline and this corresponds to a small decrease in the collection losses. In the *heroic* scenario, C&I material flow is collected via CDS at the national average efficiency rate (28%). This shifts the collection distribution from kerbside to CDS, reduces overall losses, and reduces the percentage that collection losses contribute to overall losses (by 34% compared to the *conservative* scenario). The significant increase in the share of CDS collection and reduction in losses is owing to the expanded CDS eligibility and the diversion from C&I to separate collections.

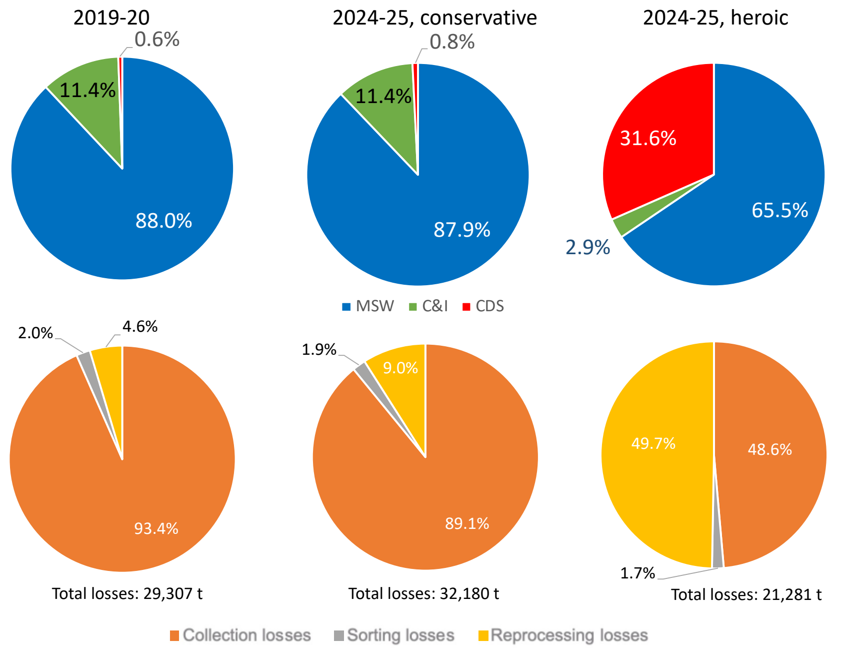


Figure 5: Collection pathways for HDPE milk bottles (MSW [kerbside], C&I, CDS); and collection, sorting and reprocessing losses for the conservative and heroic scenarios in 2024-25 compared to the baseline in 2019-20.

Addressing food grade barriers is critical for achieving HDPE recycled content in milk bottles

Current baseline circularity rate (recovery volume at packaging grade for local utilisation relative to the volume placed on the market) for HDPE is low (~10%). To transition towards a circular economy for HDPE milk bottles, one of the important steps is establishing high value end markets. Industry experts assert that there may be insufficient economic drivers to stimulate the shift to a more circular economy and cost is highlighted as a major barrier. Additional interventions, or incentives, may be necessary to drive local demand for the secondary material for food grade and other packaging applications. Further, it was suggested that without clear guidance from Food Standards Australia New Zealand (FSANZ), manufacturers may be reluctant to increase the recycled content for food grade applications.

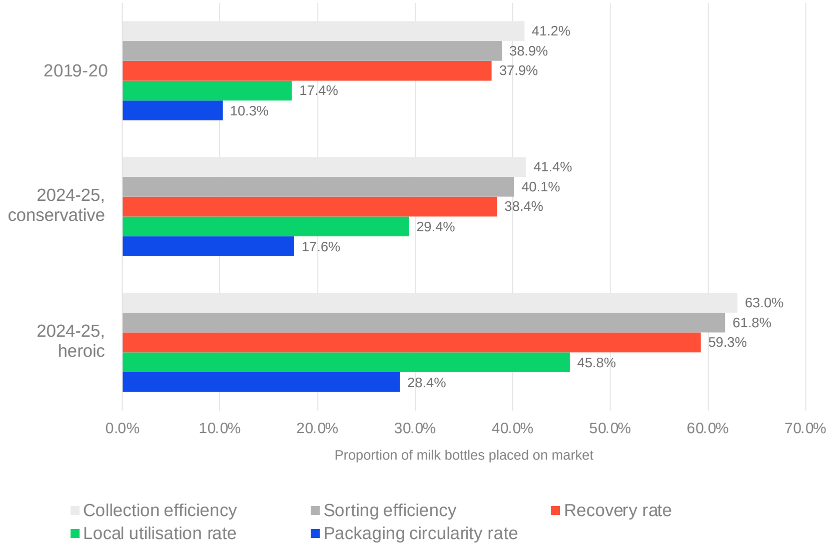


Figure 6: Collection efficiency, sorting efficiency, recovery rate, local utilisation rate and packaging circularity rate of the milk bottles placed on the market.

Workshop participants also flagged that the lack of clear demand may also be a barrier for recyclers in terms of justifying investment in the new capacity for food grade reprocessing and downcycling remains economically viable. In other markets, e.g. the UK[13], where recycled content targets are incentivised through taxation measures are making greater progress towards a circular economy for HDPE.

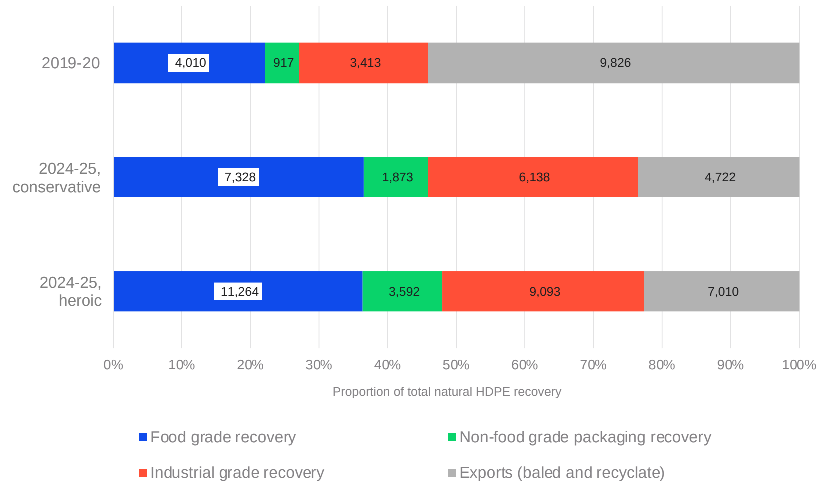
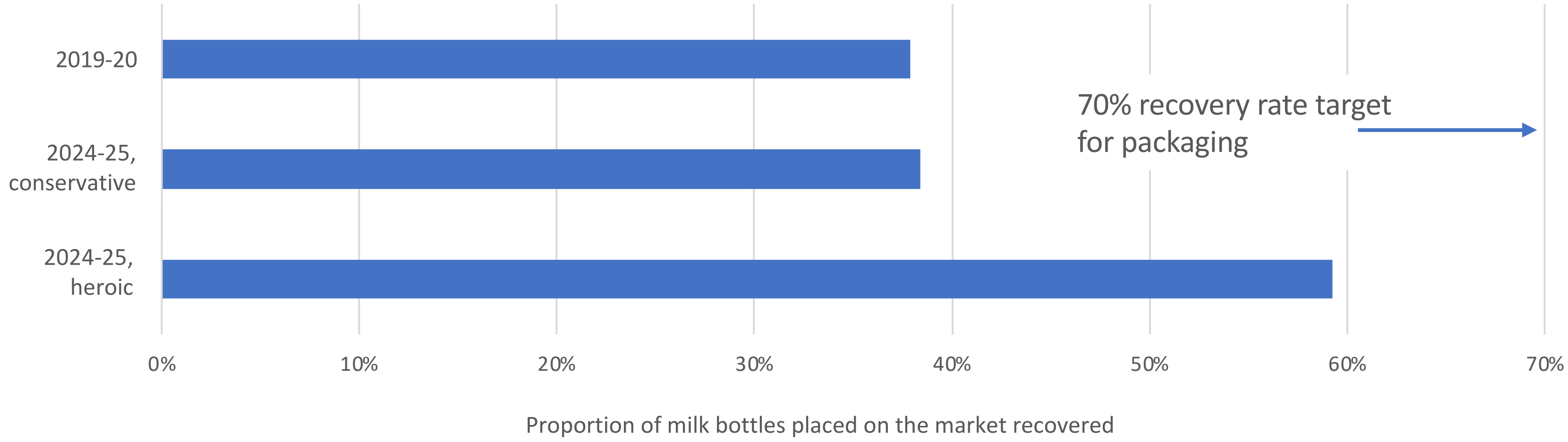
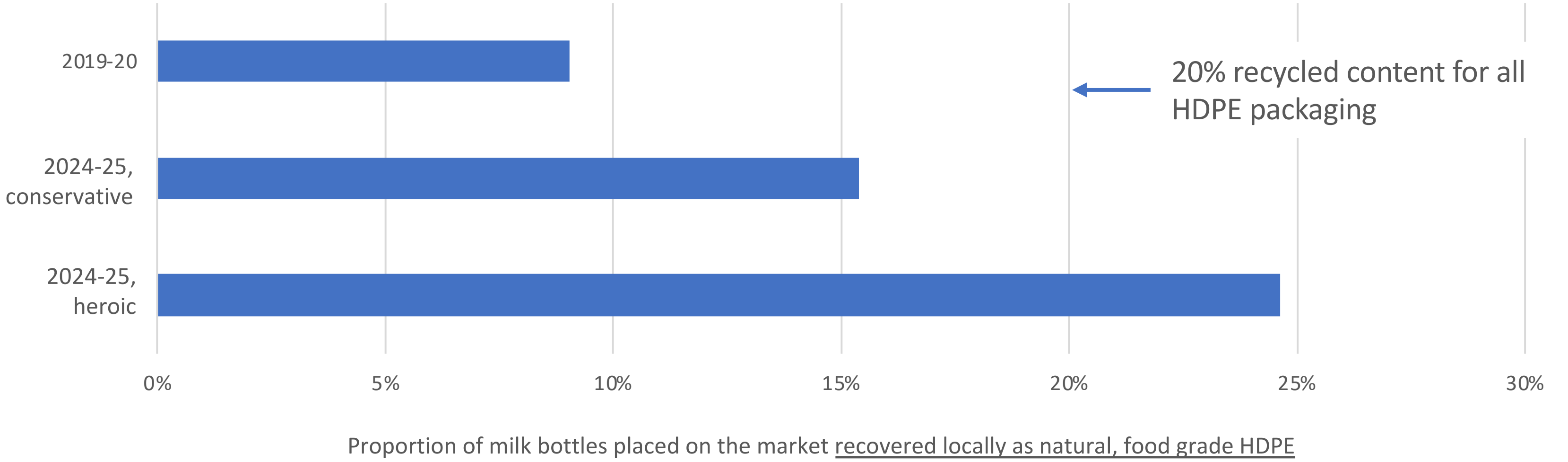


Figure 7: Comparison of natural HDPE recovery.

Scenario assumptions that impact the potential end markets and circular economy include improving label and adhesive design, recovery technology and reprocessing capacity. Specifically, we assumed that PET and PP labels are replaced with HDPE alternatives. In the *conservative* scenario only labels on 2L products and above are replaced, while in the *heroic* scenario all PET and PP labels are replaced with HDPE labels. When considering the whole supply chain, labels might appear to have a small impact on the recycling outcomes. However, when the focus shifts to bottle-to-bottle recycling, the importance of this technical innovation in minimising contamination is important. Improved label and adhesive technology compatible with food grade recovery should be considered alongside chemical recycling as a viable strategy in supporting higher food grade recoveries. Moreover, this recovery pathway is possible with existing mechanical recycling technology.

Local recovery volumes under the heroic scenario are sufficient to meet the recycled content target of 20% with recovery rates of about 60% that fall short of the 70% recycling target





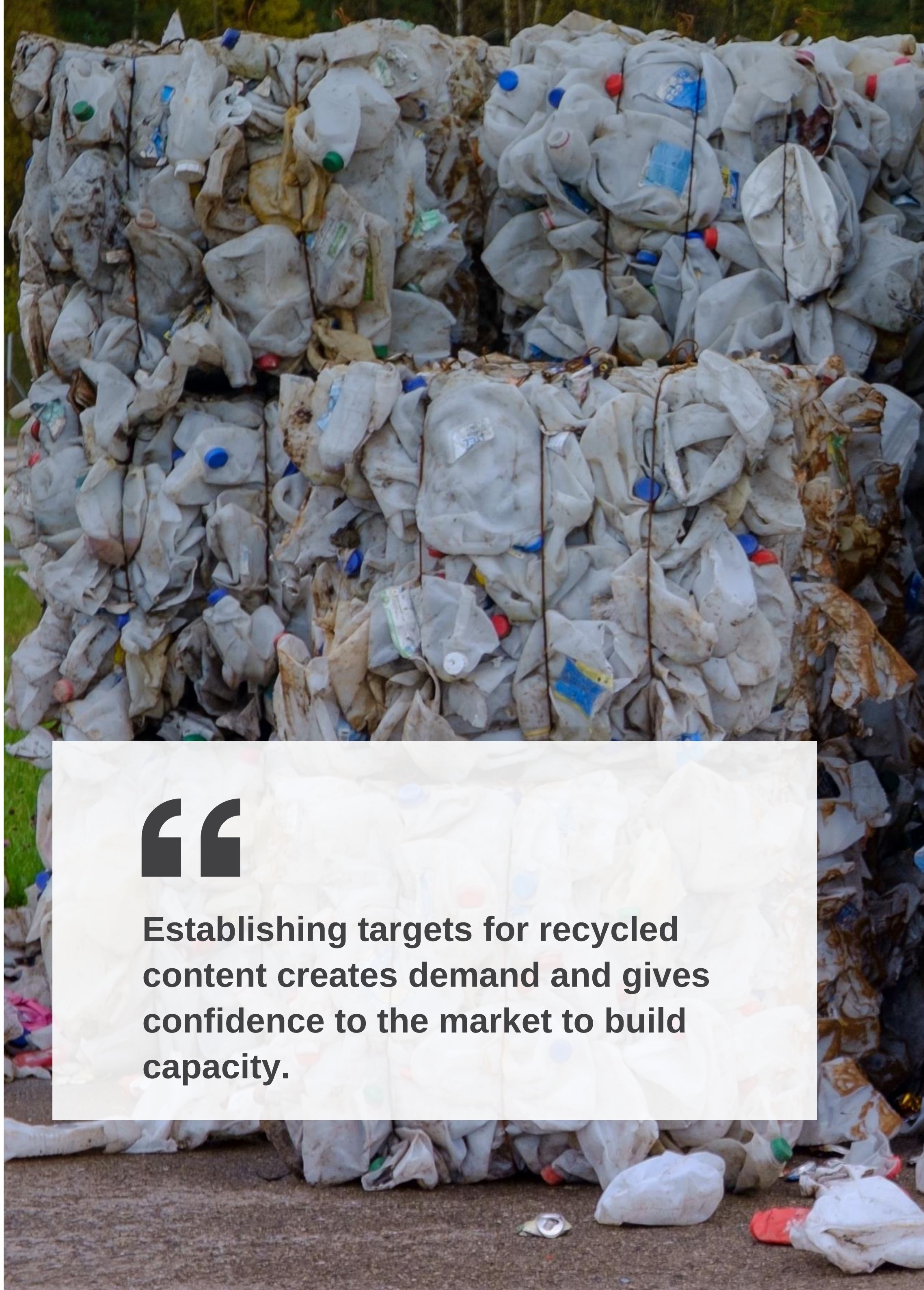
HDPE milk bottle recycling pathways towards circularity

Improving end of life milk bottle management

- Used milk bottle recovery rate is below the 70% recycling rate target for packaging, which has significant implications achieving the recycling rate target as natural HDPE should be doing heavy lifting for the Targets.
- High collection losses are the greatest barrier to improved recovery rates, with more than half of the used milk bottles currently destined for landfill. Even under the *heroic* scenario, 41% of the material placed on market is lost to landfill before it becomes available for recovery
- Reducing collection losses can be addressed by:
  - Diversion of used milk bottles out of mixed recycling for MSW and C&I streams (i.e. via CDS);
  - Increasing CDS product eligibility and redemption rates;
  - Better at-home consumer awarenes and disposal practices;
  - Expansion of kerbside recycling services to all jurisdictions.

Design for circularity of milk bottle packaging

- Local recovery volumes of natural HDPE are sufficient to achieve the recycled content target of 20% for HDPE packaging under the *heroic* scenario, however sufficient local demand must exist.
- A major barrier to increasing demand is concern about contaminants in recovered HDPE for food-grade applications.
- Using existing mechanical recycling systems, with advanced label and glue removal technology developed in this project, there is an opportunity to shift recoveries from industrial-grade (non-food-grade) recyclate to food-grade by addressing contamination.
- Clear guidelines on food-safety standards as well as incentives to increase demand for recycled content will likely accelerate the system changes to support the circular transition.
- Findings from this study are relevant to other packaging material streams and widespread adoption of the range of interventions considered will be needed to transition to a circular packaging economy



> **"Establishing targets for recycled content creates demand and gives confidence to the market to build capacity.**

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