HOW CIRCULAR IS GLASS?

A report on the circularity of single-use glass packaging, using Germany, France, the UK, and the USA as case studies

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ZERO WASTE EUROPE | eunomia

Executive Summary

Introduction

Glass production, especially from primary sources, is a high energy consuming process. One way to effectively reduce energy consumption and greenhouse gas (GHG) emissions from the repeated production of single-use glass is to retain material in a circular system – e.g. by utilising the cullet from container glass to produce new container glass, i.e. closed-loop recycling, and thereby removing the need to use glass from primary sources.

To understand the current circularity of single-use container glass in different geographical scopes, this study examines the mass flows of single-use glass packaging in four countries: Germany, France, the United Kingdom (UK) and the United States (US). For each case study, the key limitations to circularity are discussed and the potential to improving glass circularity are explored. The study also reviews other limitations and opportunities the single-use container glass industry is facing, and future developments being considered to overcome these challenges.

Current Circularity and Limitations

Current Circularity of Single-Use Glass Packaging

Collection systems vary across countries and even within certain countries. The study uses four key performance indicators to assess circularity in each of the country case studies, as shown in Figure 1. Each of the four indicators is calculated based on glass material only and does not consider caps, labels and other foreign materials that might be classed as contamination. The four indicators used in this study are:

1 Collection rate

The amount of glass packaging collected (excluding any contaminants) vs the amount of glass packaging placed on the market (POM). This indicator shows how much material is collected, thus highlighting how much material is not captured and therefore lost from the system.

2 Overall recycling rate

the amount of glass packaging captured in a sorting and recycling facility, ready for remelt or other recycling end markets vs the amount of glass packaging POM, measured in accordance with EU guidance. This indicator considers all end markets that are considered a recycling route in EU policy. Comparing this indicator to the collection rate highlights any sorting losses that might occur.

3 Closed-loop recycling rate

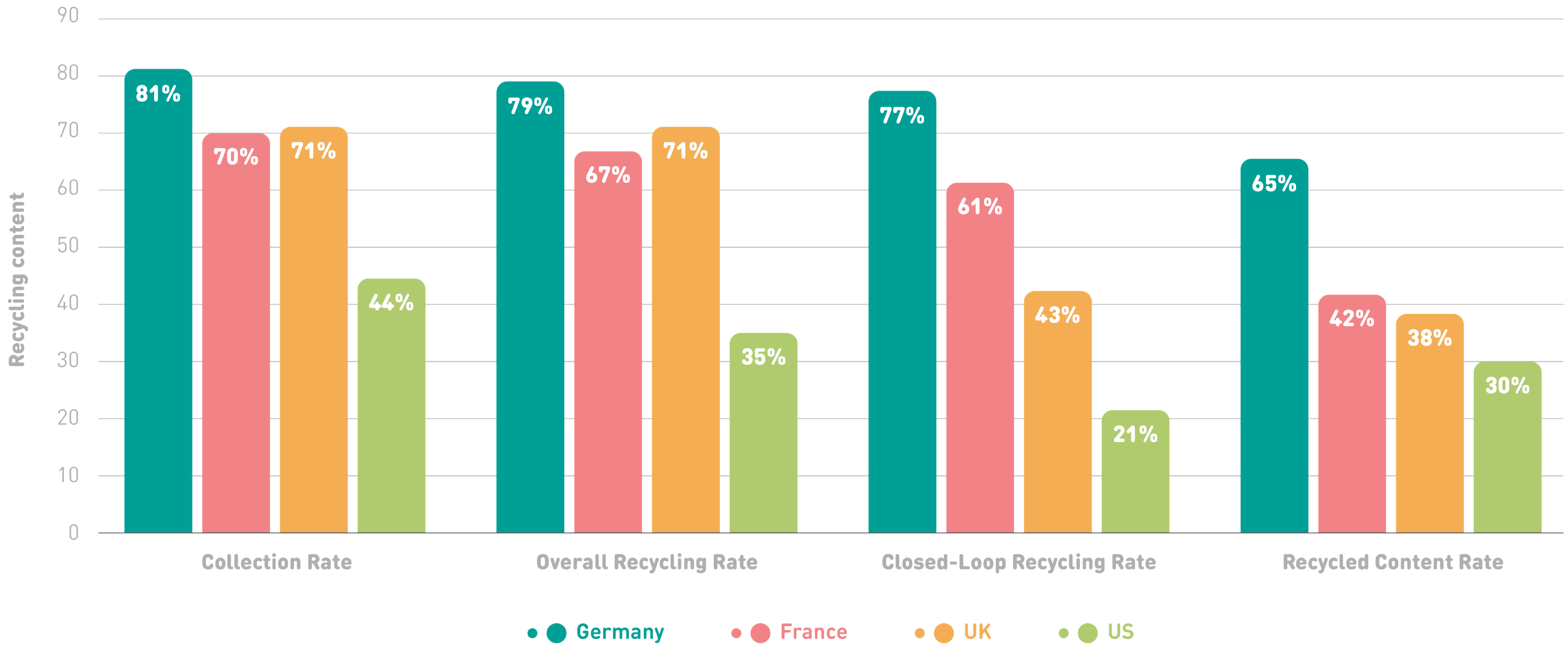
The amount of cullet captured during sorting that is used to manufacture new glass vs glass packaging POM[1]. As opposed to the overall recycling rate measured by the EU, this indicator only considers cullet being used to manufacture new container glass. It is the preferred indicator for the purpose of this study, as this is the only application type that is truly circular. In all other application types, the material is lost from the circular system and from the wider recycling system once its end of life is reached.

4 Recycled content rate

The amount of processed cullet used in the manufacture of new glass packaging vs the production volume of new glass packaging. This indicator shows how much recycled glass is in fact used to make new container glass.

Figure 1:

Collection, Closed-Loop Recycling and Recycled Content Rates for the 4 Case Studies, 2019 Data



Source: Eunomia modelling using available market data[2]

Losses from the circular glass system occur at three stages: in collections, during sorting and at the point at which cullet is distributed to different recycling end markets. The biggest losses of glass material occur at the collection stage. The country with the highest rate of capture is Germany: only 19% of glass packaging placed on the market is not captured in recycling collections. In both France and the UK, about 30% of glass material is lost. The US over half of its glass packaging placed on the market (56%) is not collected for recycling.

While collection methods do not seem to have a significant impact on collection rates, they do affect the potential for circularity, with some collection methods generating higher losses from a closed-loop system. Comparing each country's overall recycling rate to its closed-loop recycling rate shows that those which rely predominantly on a co-mingled collection system[3] (the UK and US with co-mingled collection rates of 55% and 53% respectively) see less cullet returned into glass manufacturing than countries which mainly use a separate collection stream for glass[4] (i.e. Germany and France, where glass collected co-mingled is less than 1% of the total collected tonnages). In Germany and France, only 2% and 9% of the sorted cullet respectively is used for recycling applications other than container glass. In the UK and US, this figure reaches 40% and 39% respectively.

The sorting and recycling process for glass is relatively efficient across all countries. At this stage only 2% to 3% of glass is lost to landfill, mainly due to misidentification as CSP (ceramic, stone and porcelain), a problem discussed further under the Current Limitations to Circularity. In the US, another significant loss of glass (approx. 7%) occurs where collected glass fails to find a viable route to recycling and is instead sent to landfill. In the UK sorting losses are not separately reported in available data sources. It is likely that loss of glass is relatively low due to CSP typically being sorted to aggregate use. The remaining potential for losses will be where glass is sorted with other contaminants or in mixed collections, with other packaging items.

The estimated recycled content rates for all four countries are shown in Figure 1. The recycled content used to manufacture glass containers in Germany makes up 65% of its total production, while on average recycled content makes up 42% of containers made in France. It is noticeable that the recycled content rates in the UK (36%) and the US (30%) are both higher than their closed-loop recycling rates. Both countries are net importers of glass packaging, meaning more glass packaging is placed on the market in these countries than is produced.

Current Limitations to Circularity

When considering the circularity of container glass, we can see key limitations stemming from:

Collection methods

Glass packaging design

Economics of logistics

Collection Methods

The study identified impacts in two aspects of the collection systems:

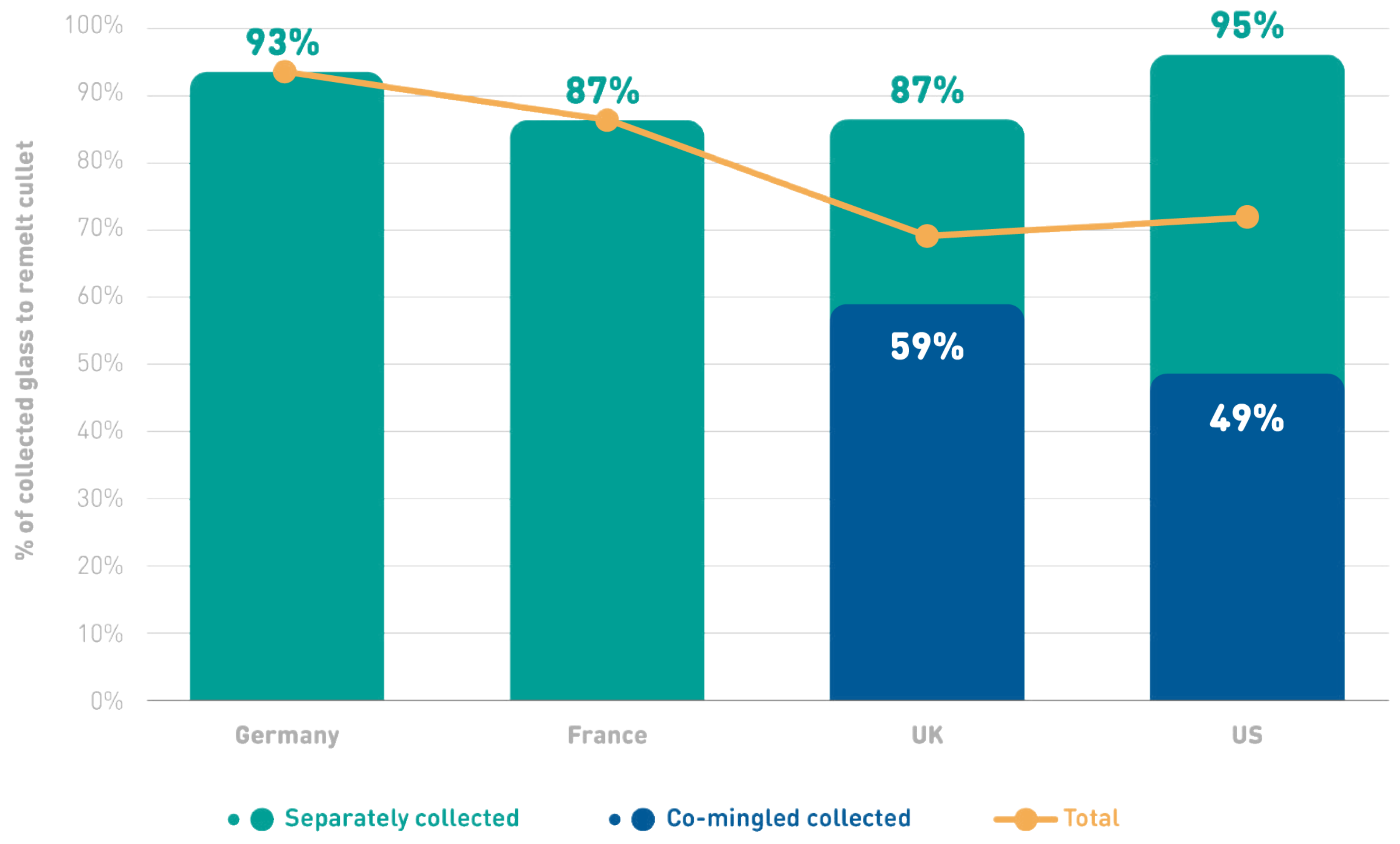
1. Co-mingled collections (glass is collected with other types of packaging) vs separate collections (glass is collected in a separate stream from other packaging); and
2. Colour-separated collections vs mixed colour collections.

Collecting materials in a co-mingled collection system results in a lower yield of cullet suitable for remelt applications than when glass is collected in a separate stream (see Figure 2). It is likely that glass collected in a co-mingled system requires more handling, which reduces particle sizes to an extent that further sorting of colours and contaminants becomes uneconomical. Tight glass manufacturing specifications limit both contaminants and small particle sizes, and so these smaller particle fractions are likely used in other applications than the manufacturing of glass packaging.

Collections of mixed coloured container glass require a positive sort on clear glass to generate a cullet fraction suitable for clear glass production. Usually, this positive sort does not capture all the clear glass and some pieces are left behind in the green and amber cullet, which could lead to an oversupply of amber and green cullet and an undersupply of clear cullet for local manufacturing.

This might become an issue when collection rates increase to a point where demand for green and amber cullet in container glass production is fully met, leaving no circular recycling routes for the surplus.

Figure 2: Estimated Yield to Remelt Cullet by Collection Method



Source: Eunomia modelling

Economics of Logistics

By comparing average disposal fees to average material revenue for material recovery facility (MRF) glass in the US, this study concludes that disposal fees need to be considerably higher than material revenue to ensure it is feasible to transport material to recycling plants – even if these are located some distance away. In the Northeast and Pacific, where disposal tipping fees are relatively high, MRF operators can transport their glass commodities to recyclers over 500 km (310 miles) further than they can transport the glass to disposal facilities. Conversely, in the South-Central region, it is only possible for MRF operators to transport glass to recyclers at a distance of around 116 km (72 miles) more than disposal facilities before it becomes more costly to do so.

This economic limitation might explain why, in the US, some glass that is collected through recycling programs still ends up in landfill (7% of total single-use glass POM). In some cases, the cost of disposing material may be too low to offset the relatively low material value of co-mingled glass sorted at MRFs.

In Europe, net glass packaging exporters such as Germany and France see a considerable discrepancy between their closed-loop recycling rates and their recycled content rates. When glass packaging is exported before it is placed on the market, it will not be captured in the local collection system. The material is essentially lost from the local circular system to an overseas recycling system. In these countries, only small quantities of cullet are imported and exported – either prior or post sorting – reportedly over short land distances (bordering countries) or transported by sea. Thus, it is unlikely to be economically feasible to import large amounts of cullet from far destinations to fill the deficit in local recycled content left by exporting glass packaging.

Design

Cement, stones and porcelain (CSP) is a critical contaminant, and, in the optical sorting process, some perfectly good glass is sorted out to ensure all CSP is removed. In addition, glass that is lacquered or has difficult-to-remove labels fails the optical test and gets ejected together with CSP. The misidentification of fragments at CSP removal stage accounts for the highest loss of glass in Germany. Glass misidentified as CSP represents around 40-50% of the CSP fraction, which is equivalent to approximately 2% of total glass collected.

Future Potential

Each limitation discussed above forms a potential lever to increase circularity of single-use glass in the future. As part of this study, Eunomia investigated this potential in each of the country case studies. The study differentiates between the two regions – Europe (including the UK) vs the US, due to the variances in drivers as shown in Table 1. While in Europe the Commission has set targets in policy, in the US targets are voluntary and agreed within industry, so there is no real incentive to achieve them.

While Germany has already reached the PPWD's recycling target, it sets its own target of 90% for material collected (including contamination) in local packaging law. Currently, this rate is reported at just under 85%. All other case study countries need to increase their collection rates to achieve recycling rate targets, but none of the countries analysed have strategic pathways in place to achieve this. Collection rates could be improved by implementing behaviour change interventions, such as educational measures or expanding the nationwide coverage of bottle bring banks or kerbside collection systems to increase convenience. It is unlikely, however, that even these measures will bridge the large gaps between what is currently being collected and the increase in collections needed to meet future targets.

In the US, improvements to glass sortation at MRFs are underway, but this change would not meet the voluntary recycling targets set by the glass industry.

Other measures such as improving existing deposit return schemes (DRS) is another potential solution, but it is still fairly unlikely that the recycling target could be met without wide-spread change.

A well-designed nationwide DRS program could see significant improvements to the collection and therefore recycling rate for single-use glass packaging. The better performing bottle bill states (states that operate a DRS) in the US achieve collection rates between 75% and 59%. Similarly, existing DRS systems for glass in Europe are currently achieving between 84% and 89%[5] collection rates for glass beverage bottles in 2019 and have since improved in some cases (e.g. Finland reported a 98% glass collection rate in 2021[6]). It is therefore likely that the introduction of a DRS system, which includes single-use glass packaging in its scope, charges a reasonably high deposit and offers a well-developed infrastructure, is a way of improving the overall container glass collection rates, particularly in underperforming countries such as the US and UK.

Increasing collection rates and therefore recycling rates will not necessarily achieve high levels of glass packaging circularity in some countries without a change in the method of glass collection. This would be the case in the UK or US, where much of the cullet is not currently used in a closed-loop. It is unlikely that cullet quality will change without a considerable change to current collection methods. A nationwide, separate collection system, as is the case in France and Germany would likely improve cullet quality and therefore circularity, but it is unlikely that the UK or US will see such large-scale change in the foreseeable future. Alternatively, a DRS system, as described above, would see an increase in separately collected beverage containers, improving the collection quality in countries that currently rely on co-mingled collections.

Table 3: Current Modelled Recycling Rates and Future Recycling Rate Targets

	Germany	France	UK	US
Predominant collection method	By colour separate collection	Mixed colours separate collection	Mixed colours co-mingled collection	Mixed colours co-mingled collection
Current Recycling Rate (overall)	79%	67%	71%	35%
Targets	Target recycling rate (2030): 75%[7]			Voluntary industry target: 50%[8]
	Target rate for material sent for recycling (2022): 90%[9]		Proposed recycling rate target (2030): 83%[10] Current remelt target: 72%; proposed remelt target (2030): 80%[11]	

Source: Recyclingmarkets.net, Environmental Research & Education Foundation (EREF)

Wider Impacts

As well as the circularity of glass packaging, the wider environmental impact of glass must be considered; this is mainly linked to greenhouse gas (GHG) emissions from manufacturing and transport. To identify and evaluate opportunities to reduce the impact of glass packaging on the environment, this study reviewed how single-use glass performs in life cycle assessments (LCAs), the industry's decarbonisation plans, developments in glass design and the potential of refillable glass bottles in this context.

Past LCA studies generally show that single-use glass packaging has the highest associated GHG emissions compared with other single-use beverage packaging materials, such as aluminium cans, PET bottles, HDPE bottles and multi-layer beverage cartons. Minimising the amount of glass from primary sources in the production of container glass is one way to reduce this impact. Other ways include using renewable or other alternative low energy sources or designing lighter-weight products that use less material. The latter might be hindered by consumers' quality expectations – a heavier bottle feels more premium than a lighter bottle – or by technical barriers, such as the need for investment in new production and quality inspection facilities.

Rising energy costs and increased pressure to reduce carbon footprint could encourage this capital investment, as well as lower running costs when set up. There are significant opportunities for decarbonising the manufacture of container glass, as well as reducing associated GHG emissions by lightweighting products. Meanwhile, other beverage packaging material industries are making considerable efforts to reduce GHG emissions. While further LCAs are needed to assess whether decarbonising the glass manufacturing process provides a competitive advantage, a scenario in which single-use glass outperforms its alternatives in single-use applications is unlikely.

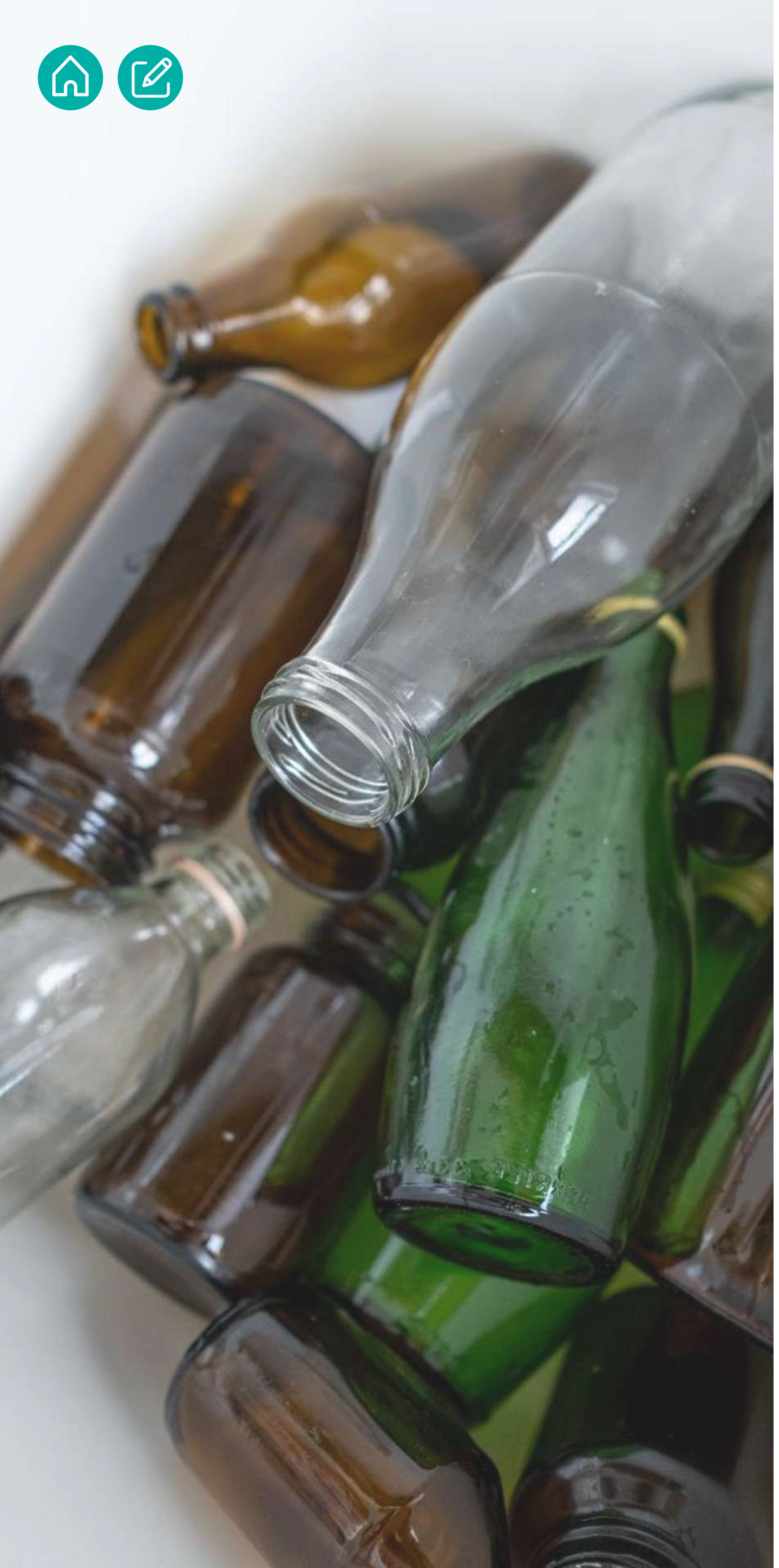
Refillable packaging options offer another important circular material flow opportunity, reducing GHG emissions. Generally, switching to refillable glass packaging cuts down on the environmental impact significantly by avoiding the high GHG emissions associated with new production. This effect is more significant in the early cycles of reuse. While most LCAs conclude that refillable glass has lower overall GHG emissions than its single-use alternative, the results highly depend on a number of factors, such as number of refill cycles, transport distances, packaging weight, recycled content and energy sources for the manufacture and/or cleaning.[12] Particularly transport distances for the take back and redistribution of glass bottles are a key factor in the results of LCAs,[13] which, together with the effects of washing, repeatedly occur at each cycle[14] and become a constant, recurring impact.

Pool systems, in which multiple bottlers use a few standardised bottle designs, allow optimised transport distances. Individually designed bottles, on the other hand, always need to be returned to one specific bottler, generating much further transport distances than a pool system. For glass packaging to provide an effective refillable option that minimises GHG impacts along the entire life cycle, it would be necessary to move towards a pool system with a limited number of design options to optimise logistical flows.

Conclusion

So, to answer the question as to how circular single-use glass packaging is –the study found that circularity, measured by four key performance indicators (the respective rates of collection, recycling, closed-loop recycling and recycled content) varies from country to country. The ability to achieve high circularity depends primarily on the effectiveness and methods of collections. The more glass packaging is collected through a high-quality separate collection system, such as a DRS, the more glass is likely going to flow back into the manufacture of new single-use glass. To retain material in a closed-loop, an efficient refillable system with optimised transport distances and high number of refill cycles could also offer a potential solution as an alternative to single-use glass.

Contents



1.0 Introduction

Single-use container glass (also referred to as glass packaging) is used to package different products, including food and beverages, cosmetics, and pharmaceuticals. In comparison to other packaging materials, glass is often perceived as a durable and food-safe packaging material with unlimited recycling potential. However, glass production, particularly from primary sources, consumes large amounts of energy, which is directly related to its greenhouse gas (GHG) emissions. One source sees a **38% GHG saving in glass production from recycled glass over primary glass sources**[15]. One way to reduce this energy consumption and associated GHG emissions is to use recycled cullet in the production of new glass packaging instead of using only primary sources.

Ideally, material is held in a circular system. For single-use glass, this means using recycled cullet from container glass in the manufacture of new container glass, instead of losing the material to other applications that cannot be recycled again. This approach is often referred to as closed-loop recycling. In addition to closed-loop recycling, there are other approaches to circular material systems, such as a reuse/refillable packaging system, which is often seen as a more favourable alternative to recycling. Refillable glass packaging systems exist in some markets, but this study focuses on the analysis of most of the glass packaging in Europe and the US, which is single-use glass packaging.

To understand the **current circularity of single-use container glass** in different geographical scopes, this study examines the mass flows of single-use glass packaging in four countries: Germany, France, the United Kingdom (UK) and the United States (US). We explore the **key limitations to circularity** and the potential to improve glass circularity for each of the case studies. We also review **other limitations and opportunities** the single-use container glass industry is facing, and any future developments being considered to overcome these challenges.

To model the scenarios, the study used available market data, gathered through desktop research and interviews with industry experts in each of the country case studies. Where data was unavailable, reasonable assumptions have been made; these are highlighted where applicable. Detailed current market overviews for each of the countries are available in the Appendices.

2.0

Current Circularity of Single-Use Glass Packaging and Key Limitations

In this section, we explore the current circularity of glass packaging, using four key performance indicators.

Each of the four indicators is calculated based on glass material only and does not consider caps, labels and other foreign materials that might be classed as contamination. In the recycling process of glass packaging, these other, non-glass materials are removed from the process and either enter another recycling route (e.g. metals from caps), or are sent to landfill (e.g. lead glass).

This section also sheds light on the limitations which hinder or otherwise negatively impact the circularity of container glass.

1 Collection rate

The amount of glass packaging collected (excluding any contaminants) vs the amount of glass packaging placed on the market (POM). This indicator shows how much material is collected, thus highlighting how much material is not captured and therefore lost from the system.

2 Overall recycling rate

The amount of glass packaging captured in a sorting and recycling facility, ready for remelt or other recycling end markets vs the amount of glass packaging POM. This indicator takes into account all end markets that are considered a recycling route in EU policy, including but not limited to container glass, insulation materials, other glass fibre, decorative glass and use in aggregates that are not considered as backfilling or landfilling. Comparing this indicator to the collection rate highlights any sorting losses that might occur.

3 Closed-loop recycling rate

The amount of cullet captured during sorting that is used to manufacture new glass vs glass packaging POM[16]. As opposed to the overall recycling rate measured by the EU, this indicator only considers cullet being used to manufacture new container glass. It is the preferred indicator for the purpose of this study, as this is the only application type that is truly circular. In all other application types, the material is lost from the circular system and from the wider recycling system once its end of life is reached.

4 Recycled content rate

The amount of processed cullet used in the manufacture of new glass packaging vs the production volume of new glass packaging. This indicator shows how much recycled glass is in fact used to make new container glass.

2.1

Current Circularity

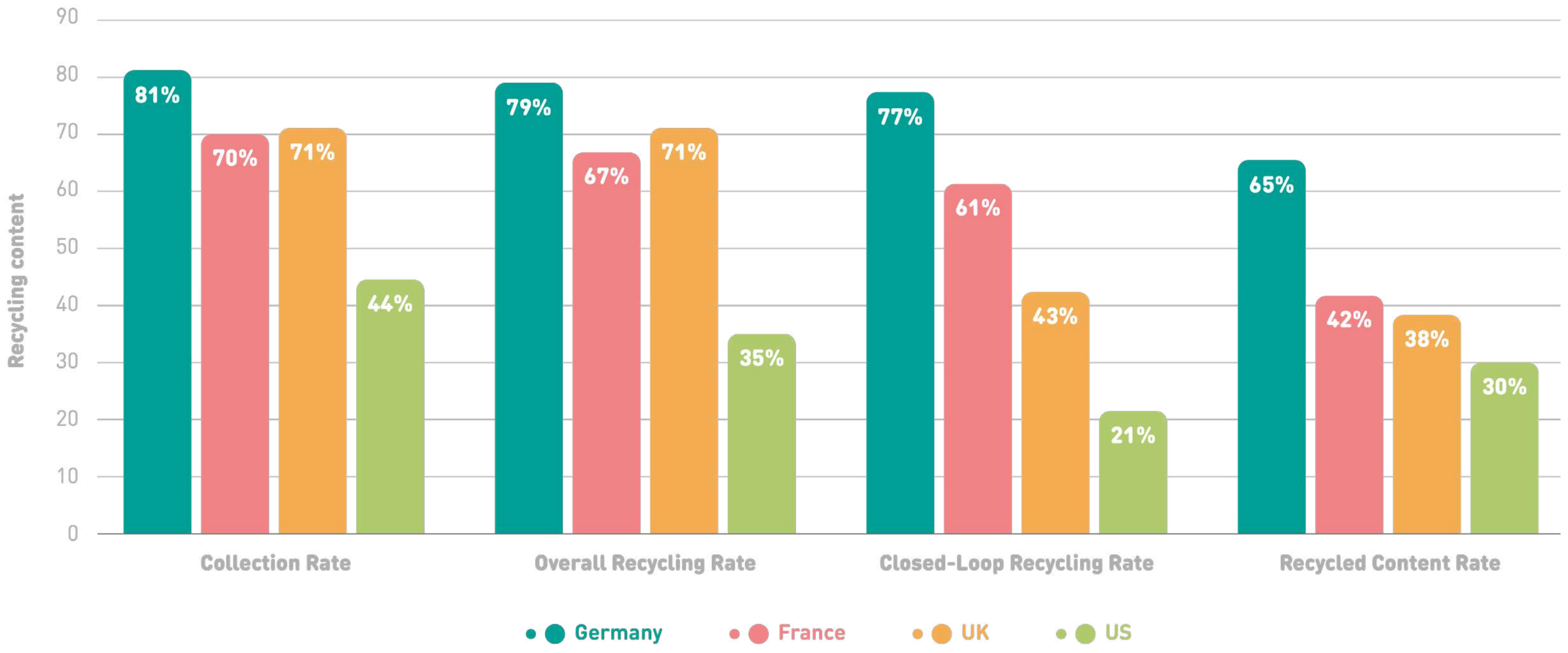
The study's findings demonstrate that whether single-use glass is managed in a circular model greatly depends on the region and its collection methods. Losses from the circular system occur at three key stages of the process:

1. At **collection**;
2. At **sorting**; and
3. At **distribution** to end markets.

Figure 3 compares the collection rate (considering all collection methods of single-use glass packaging), overall recycling rate, closed-loop recycling rate and recycled content rate for the four case studies in the scope of this review.

Figure 3:

Collection, Closed-Loop Recycling and Recycled Content Rates for the 4 Case Studies, 2019 Data



Source: Eunomia modelling using available market data

Collection Rate

The highest losses occur due to lack of capture. Germany has the highest collection rate, achieving 81% in 2019. In the US, on the other hand, the 2019 collection rate was 44%; this means over half of the glass packaging placed on the market was lost from the system because it was not collected. Germany operates a collection system via 250,000 colour-segregated bring banks. The US collection method differs greatly from state to state; some states operate DRS collections, while others use a combination of unincentivised bring depots and kerbside recycling programs. Both the UK and France show a similar collection rate, albeit with very different approaches. Where France mainly operates a network of bring banks similar to Germany, the UK captures glass predominantly via co-mingled[18] kerbside collections (55%) but also uses separate collections[19] from kerbside (32%), bring banks (10%) or recycling centres (3%). It is therefore difficult to identify any material difference between collection rates from kerbside systems and bring systems in these case studies. The differences in collection rate are more likely to be influenced by residual waste restrictions or costs and perhaps also by public education and attitudes.

None of the countries investigated have a comprehensive DRS system which targets all beverage glass bottles. Some US states have "bottle bills", a form of DRS. The better performing bottle bill states have collection rates of 75% to 89%, while the average figure in states without bottle bills is 32%. In the US, this indicates that more widespread, well-designed DRS would increase collection rates. Other DRS systems in Europe, which have glass within the scope of the system, achieve collection rates between 84% and 89% in 2019.[20] More recently, significantly higher collection rates have been reported (e.g., Finland reported 98% for 2021[21]).

While collection methods do not seem to have a significant impact on collection rates, they do affect potential for circularity, with some collection methods generating higher losses from a closed-loop system. These are explored further in Section 2.2.1.

Recycling Rates

Figure 3 depicts the overall recycling rate achieved in each of the case studies. **Germany's robust collection system translates to its high overall recycling rate of 79%**. The system operates with minimum leakage, whereas the US system sees significant losses of viable recyclate, reflected in its overall recycling rate of just 35%. France and the UK both achieved similar overall recycling rates of 67% and 71% respectively.

Each system operates with some sorting losses, where viable glass material is disposed of as landfill, or sent into lower quality recycling applications such as aggregate production. In Germany, non-target glass material is removed along with target material CSP at a rate of 2% (this is described in more detail in Appendix A 1.0). In France, the losses are 3% for similar reasons. In the US, approximately 2% of glass is lost in the sorting process; an additional 7% of cullet that could be recycled also goes to local landfill because this is more cost-effective than sending glass to a recycler hundreds of kilometres away (see Section 2.2.3 for more detail). In the UK, sorting losses were not separately reported in available data sources. It is likely that loss of glass is relatively low due to CSP typically being sorted to aggregate use. The remaining potential for losses will be where glass is sorted with other contaminants or in mixed collections, with other packaging items.

The impacts of different countries' collection methods on recycling performance become more apparent when we examine the **closed-loop recycling rate**. While France and the UK have very similar overall recycling rates, the closed-loop recycling rate for France is 61% and only 43% for the UK. This shows that the UK sends much more of its recycled glass to applications other than container glass. **It is therefore likely that more viable recyclate is lost when glass is collected co-mingled**, as it is in the UK. The root causes for this are discussed further in Section 2.2.1 on collection methods.

Recycled Content

The estimated recycled content rates for all four countries investigated are shown in Figure 3. The amount of recycled content available to use in new glass containers in Germany makes up 65% of its total production. France has a recycled content rate of 42%. It is noticeable that the recycled content rates in the UK (36%) and the US (30%) are both higher than their closed-loop recycling rates. Both countries are net importers of glass packaging, meaning more glass packaging is placed on the market than is produced. Since their own production is lower, the recycled content rate is higher. We will explore the implications of this in Section 2.2.3.

2.2 Limitations to Circularity

When considering the circularity of container glass, we can see key limitations stemming from:

- **Collection methods**
- **Glass packaging design**
- **Economics of logistics**

2.2.1 Collection methods

The largest limitation to achieving a high circularity of container glass is the ability to capture as many used packages as possible. As we discuss in Section 2.1, collection rates vary significantly between the case study countries. While current collection practices vary widely across our case studies, there is no outright correlation between collection method and glass collection rate as such; **however, different collection processes can have a big impact on the amounts of recycled glass used in closed-loop recycling.**

The study reviewed two aspects of collection systems and their respective impacts on the ability to achieve high recycled content:

- Systems where glass is collected with at least two other types of packaging (e.g., paper, plastics, metals) or "co-mingled collections" vs. collecting glass in a separate stream ("separate collection").
- Colour-separated collections vs. mixed colour collections.

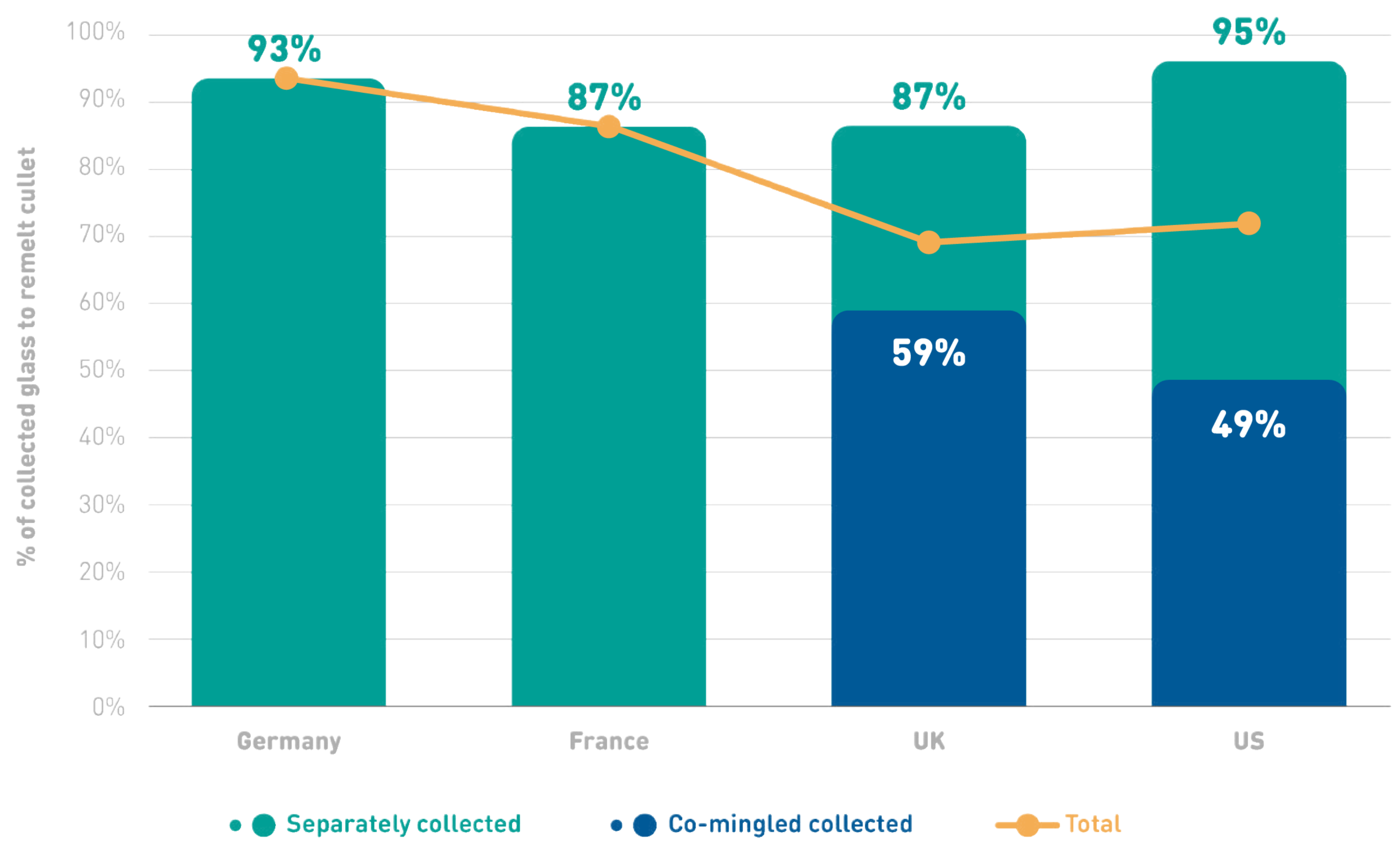
Separate vs co-mingled collections

Only two of the case study countries (UK and USA) collect glass co-mingled with other packaging types to any significant degree. In both cases the data is somewhat unclear but is appears that glass collected co-mingled produces substantially less material suitable for remelt applications than separate collection systems, either in those countries or the other case studies.

Producing large amounts of remelt-quality cullet from collected container glass requires handling that glass appropriately, so that the average particle size does not decrease below the size at which it can be economically sorted with glass sorting machinery. It appears that the practice of co-mingled collecting and sorting glass from other packaging types reduces average particle size and increases the level of contaminants that must be removed for remelt quality, more so than if container glass were collected separately. Thus, **co-mingled collections produce a lower remelt cullet yield**.

Figure 4 shows that separately collected glass has significantly higher proportions of cullet suitable for use in remelt applications than co-mingled collected glass.

Figure 4: Estimated Yield to Remelt Cullet by Collection Method



Source: Eunomia modelling

Mixed colour vs colour separated collections

In the case of Germany, glass is captured separately and mainly by colour streams of clear, amber and green at bring banks. All other markets predominantly operate a mixed colour collection, in which colours are collected together and separated in the sorting process.

All container glass colours have varying restrictions of using recycled cullet from differently coloured glass. For the manufacture of clear glass, only very low levels of coloured cullet are tolerated. **The different collection methods create variations in sorting processes, which in turn lead to differences in yield according to cullet colour**. Typically, in mixed colour collections the clear fraction is positively sorted; this results in some loss of clear material to the coloured fractions and to fines. Source segregated colours typically results in a sorting process that positively sorts unwanted material from the clear fraction. This results in very low amount of clear cullet being diverted to other fractions.

Figure 5 shows theoretical estimates of the possible impact of mixed colours glass collection on the subsequent recycled content in products.

Two scenarios, a 70% collection rate and a 90% collection rate, were modelled, using a colour split of 55% clear glass and 45% amber or green glass, average process losses of 2% and the assumption that all processed cullet is used in new container productions. It was also assumed that a positive sorting on clear glass from a mixed colour collection would result in an average yield of 80%; in other words:

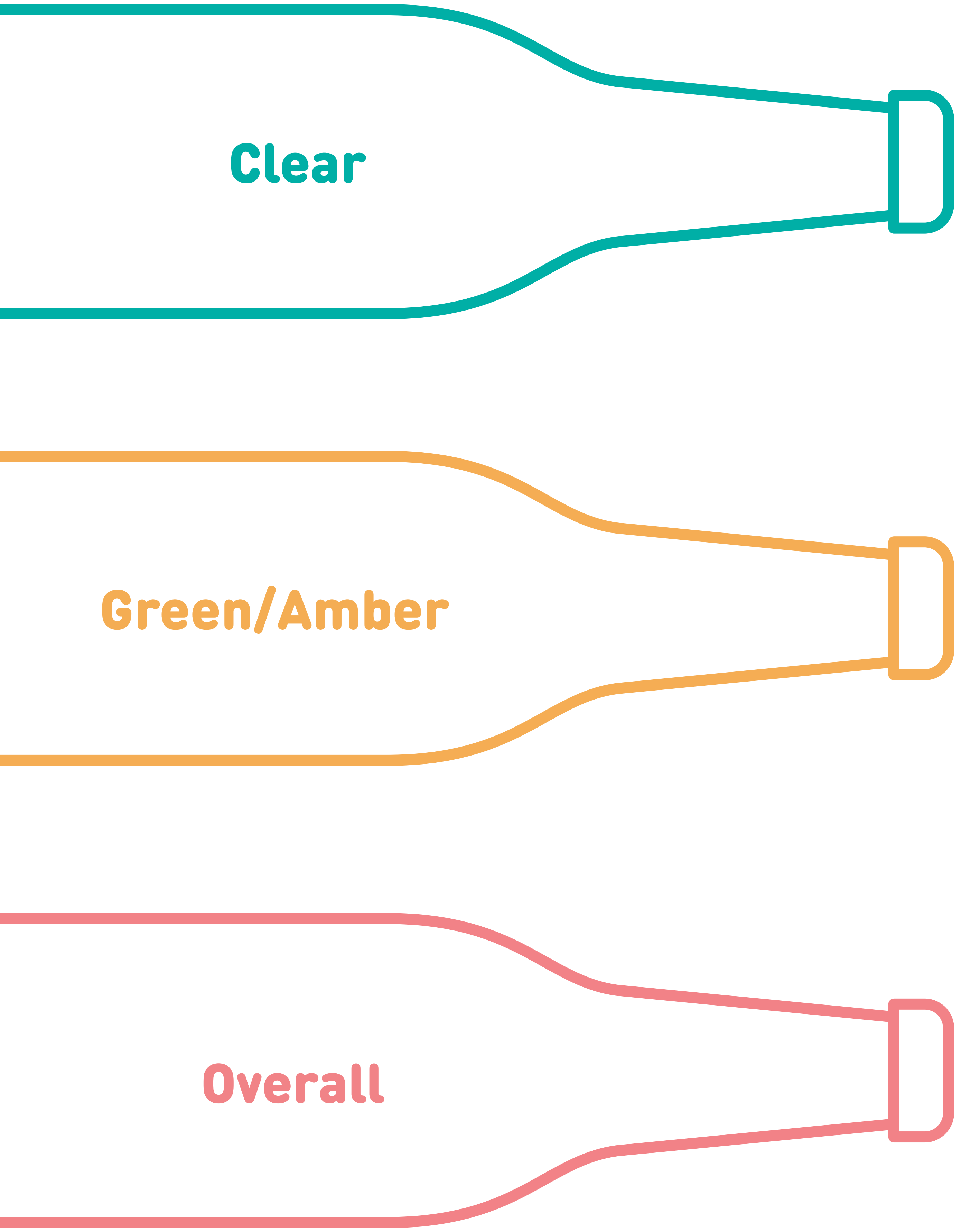
Positive sorting on clear glass from a mixed collection results in 80% of the targeted clear glass being ejected into a clear glass stream, with 20% left in the mixed colour stream

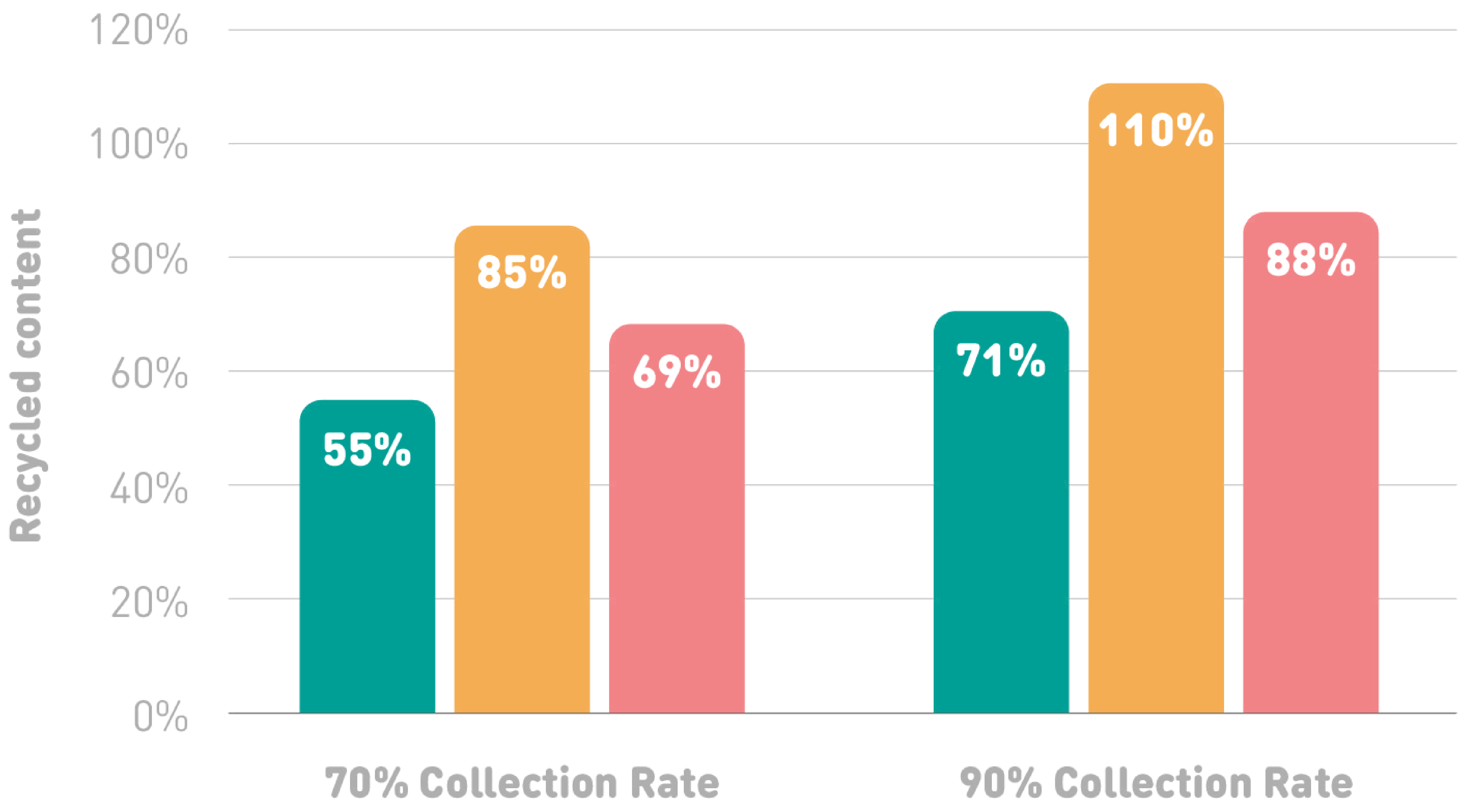
In a scenario with a lower collection rate of 70%, the recycled content in clear glass could reach approximately 55% and in amber/green, approximately 85%. In a scenario in which the collection rate is increased significantly (to 90% in our example), the additional clear cullet left in the amber/green stream leads to an oversupply of cullet in this stream, far exceeding 100% recycled content.

In a market like in the UK which predominantly produces clear and amber container glass, an oversupply of green cullet likely finds use in a non-circular application such as insulation or aggregates, instead of being used in a closed-loop to produce green container glass.

It is unlikely that countries currently collecting glass packaging as mixed colours will change their collection method to source segregation of colours, as in Germany. Separate colour collection is a more costly system due to the need for more bin space and optimised logistics. More effective colour sorting technology could provide a solution, but this is also a costly investment.

Figure 5:
Estimated Impact of Colour Separated Collection on Recycling Rates





Source: Eunomia modelling

2.2.2 Design

Most commonly, collected glass goes through an optical sorting stage; this positively sorts for transparent materials to remove non-transparent contaminants like CSP (ceramic, stone and porcelain). Most paper labels and sleeves are easily removed and do not pose a problem in the optical sorting process. However, if a paper or plastic label is fixed with a strong adhesive, it may be difficult to remove and may remain on the glass throughout the cleaning and sorting process. In such instances, the glass can be misidentified, rejected and not be recycled. Similarly, opaque lacquers used to colour a bottle can also mean that glass is misidentified as CSP at the optical sorting stage.

"If a label is fixed with a strong adhesive, or the glass is coloured with an opaque lacquer, they can be misidentified as CSP. "

In both these cases, glass fragments would be identified as non-transparent. After lack of capture through available collection systems, the misidentification of fragments at CSP removal stage accounts for the highest loss of glass in Germany. Glass misidentified as CSP represents around 40% to 50% of the CSP fraction, which is equivalent to approximately 2% of total glass collected.

Figure 6: Example of a Lacquered Bottle Within the Collected Material in Germany

Source: Eunomia modelling

2.2.3 Economics of logistics

Impacts on recycling

In the United States, disposal fees may influence the final destination of co-mingled glass. Mixed glass has a negative material value after being sorted at an MRF. Disposal fees must therefore be high enough to make sending co-mingled glass after sorting at MRFs (MRF glass) to disposal more expensive than transporting it to a recycling plant. Table 2 below shows the average disposal fee and average material revenue for MRF glass in different regions of the US. Positive values indicate a cost.

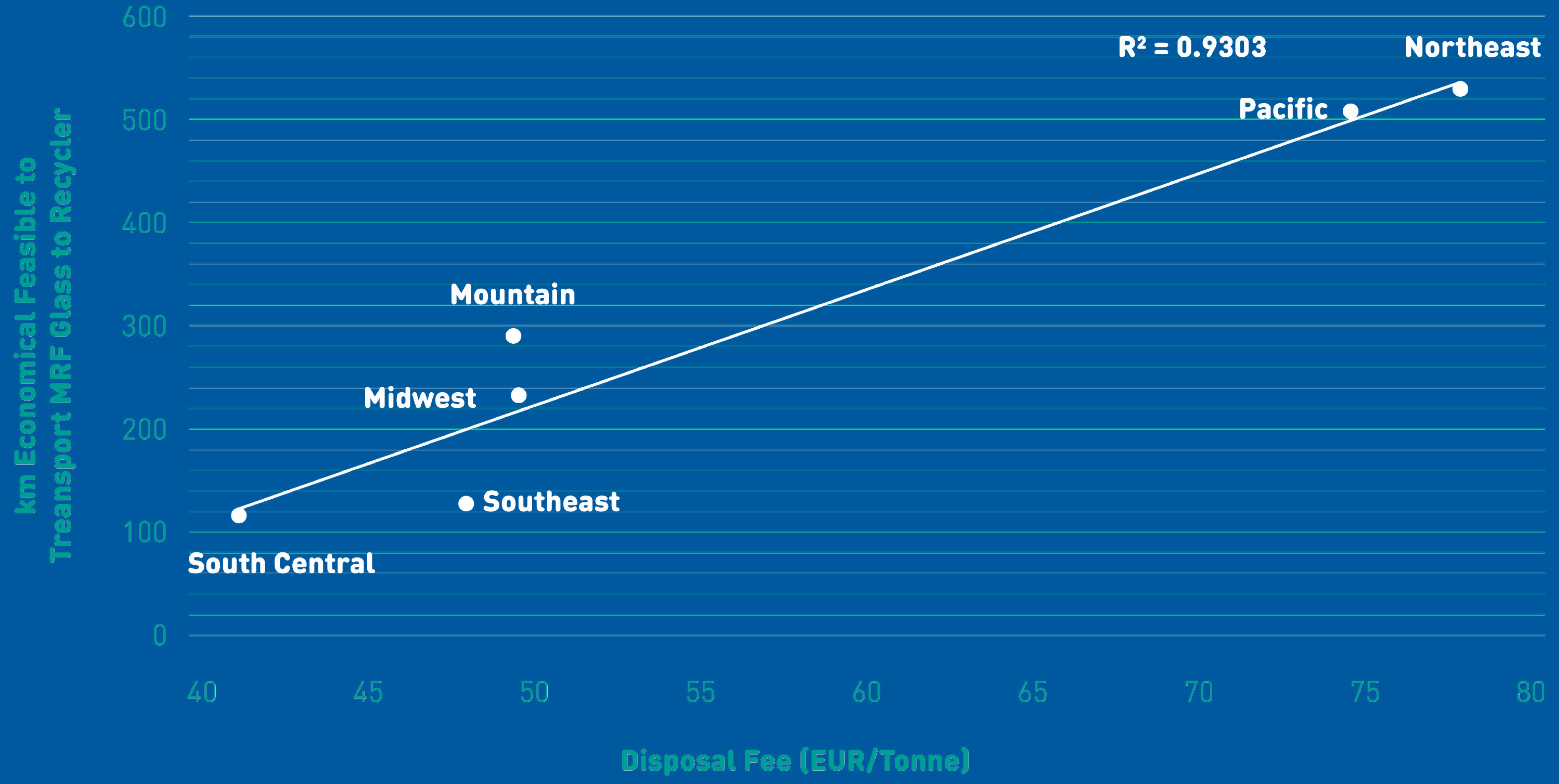
On average across the regions, the difference between the disposal gate fee and the recycling value is 27 EUR/tonne (26 USD/Ton). This difference varies from 49 EUR/tonne (40 USD/Ton) in the Northeast to 10 EUR/tonne (10 USD/Ton) in South Central. When the two costs are close, transporting glass to recycling plants may be more expensive for an MRF operator than sending it to a landfill site, at least one that is closer to the MRF. Figure 7 shows the average maximum distance at which it is cost effective for a MRF operator to send glass to a recycling plant instead of to disposal. The distances in the figure represent how much further a MRF operator could transport MRF glass to a recycling facility over a disposal facility – so if the value is 30 km (~19miles), the MRF operator can transport the MRF glass 30 km (~19 miles) further than the closest landfill, not 30km (~19 miles) in total, and still make a profit.

Table 2: Revenue and Disposal Fees of MRF Glass in US

Region	Pacific	Northeast	Mountain	Midwest	Southeast	South Central
Revenue per ton on delivery (USD/ton)	32.50	27.50	25.00	25.00	35.00	30.00
Disposal Gate Fee (USD/ton)	72.03	75.21	47.83	47.85	46.26	39.66
Revenue per ton on delivery (EUR/tonne)	33.67	28.49	25.90	25.90	36.26	31.08
Disposal Gate Fee (EUR/tonne)	74.61	77.91	49.55	49.57	47.92	41.08

Source: Recyclingmarkets.net, Environmental Research & Education Foundation (EREF)

Figure 7: Estimated Distance Economically Feasible to Transport MRF Glass to Recycler vs Disposal Tip Fee



Source: Eunomia Modelling, DAT Transport Figures

In the Northeast and Pacific where disposal tipping fees are relatively high, MRF operators can cost-effectively transport their glass commodities to recyclers over 500 km (310 miles) further than to disposal facilities. Conversely, in the South Central region, it is only possible for MRF operators to transport glass to recyclers around 116 km (72 miles) farther away than disposal facilities before it becomes more costly to do so. The state of Texas has two glass recycling facilities, about 370 km (230 miles) apart. If a MRF operator is stationed further than 112 km (70 miles) from either one, it may be more cost efficient to send MRF glass to landfill instead of to a recycler.

Disposal fees vary by region more than recycling revenue per tonne does (see Table 2). Disposal tipping fees therefore appear to be more influential than revenue per tonne in determining how far MRF operators are willing to send their glass to recyclers (if the goal is cost effectiveness).

This economic limitation might help explain why some glass collected through recycling programs still goes to landfill. In some cases, the cost of disposing of material may be too low to offset the relatively low material value of MRF glass. This may explain why MRFs responding to recycling coalition surveys in the Northeastern and Southeastern US have stated that they send their glass to landfill 38% and 27% of the time, respectively, rather than to a recycling outlet (although 2/3 of the Northeast glass sent to landfill is used as alternative daily cover (ADC)).[22,23] Eunomia estimates that around 16% of collected glass containers are sent to landfill, either for disposal or ADC. Despite the higher landfill fees in the Northeast, there are very few secondary glass processors which receive MRF glass, resulting in more material being sent to landfill by Northeast MRFs.

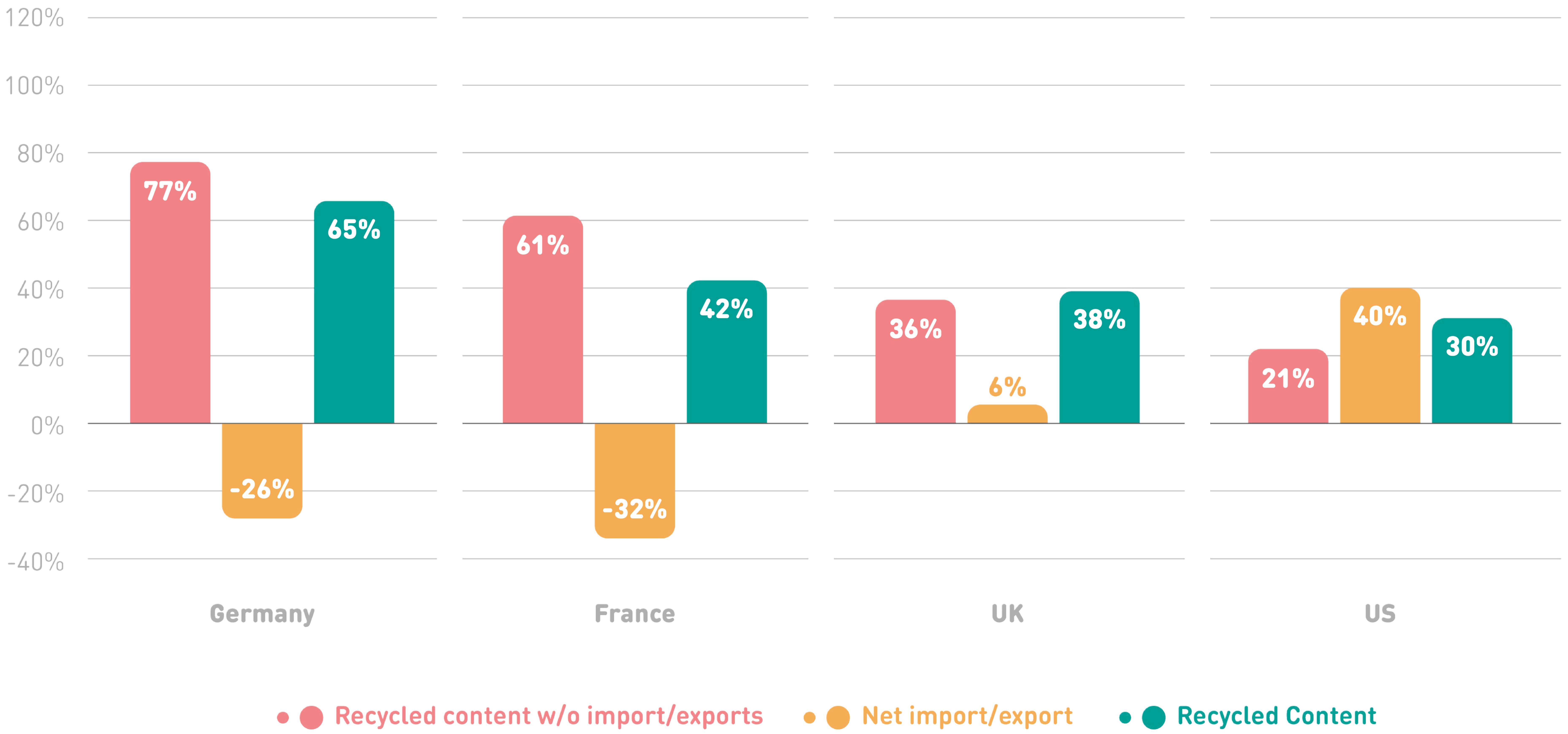
Impacts on recycled content and end products

Examining recycled content in each case study country reveals a further limitation on the economics of logistics. Germany and France are both net exporters of glass packaging, exporting 26% and 32% of their container glass production, respectively (see Figure 8). While the closed-loop recycling rate means that most of the cullet produced through recycling finds use in container glass manufacturing, these higher production quantities mean that the recycled content is much lower than if the material had stayed within country borders. Only small quantities of cullet are imported and exported, either prior or post sorting, reportedly over short land distances (bordering countries) or transported by sea. Because of this, it is unlikely to be economically feasible to import large amounts of cullet from far destinations to make up the deficit left by exported glass packaging in potential local recycled content.

On the other hand, net importers like the UK and the US, who import the equivalent of 6% and 40% of their own production volumes respectively, can achieve higher recycled content rates from the additional glass packaging placed on the market and captured in local collections. As mentioned in Appendix A 3.0, the UK imports high volumes of green glass (e.g. wine) and exports high volumes of clear glass (e.g. whisky and gin). In addition to the impact of colour hierarchies in the sorting process, the import of green glass into a market with little demand for green cullet may lead to an oversupply of green cullet, which is discussed further in Section 2.2.1.

"Southastern US have stated that they send their glass to landfill 38% of the time"

Figure 8: How Recycled Content is Influenced by Imports and Exports



Source: Eunomia modelling

3.0

Future Potential for Circularity of Single-Use Glass Packaging

As part of this study, Eunomia investigated the potential for circularity of single-use glass in each of the country case studies. The study differentiates between the two regions – Europe (including the UK) vs the US, due to the variances in drivers as shown in Table 3. While in Europe the European Commission or local governments have set targets in policy, in the US, targets are only voluntary and agreed within industry; a voluntary target recycling rate of 50% has been in place prior to 2013.[24] There appears to be little real incentive to reach this target in the US.

Table 3: Current Modelled Recycling Rates and Future Recycling Rate Targets

	Germany	France	UK	US
Predominant collection method	By colour separate collection	Mixed colours separate collection	Mixed colours co-mingled collection	Mixed colours co-mingled collection
Current Recycling Rate (overall)	79%	67%	71%	35%
Targets	Target recycling rate (2030): 75%[25]			Voluntary industry target: 50%[26]
	Target rate for material sent for recycling (2022): 90%[27]		Proposed recycling rate target (2030): 83%[28] Current remelt target: 72%; proposed remelt target (2030): 80%[29]	

Source: Recyclingmarkets.net, Environmental Research & Education Foundation (EREF)

3.1

Future in Europe

To understand the potential for reaching the EU target of a 75% recycling rate by 2030 as set in the Packaging and Packaging Waste Directive (PPWD), or alternative agreed targets in local legislation, for each of the case study countries, it is important to recognise the changes needed to enable success and the drivers already in place to support these changes.

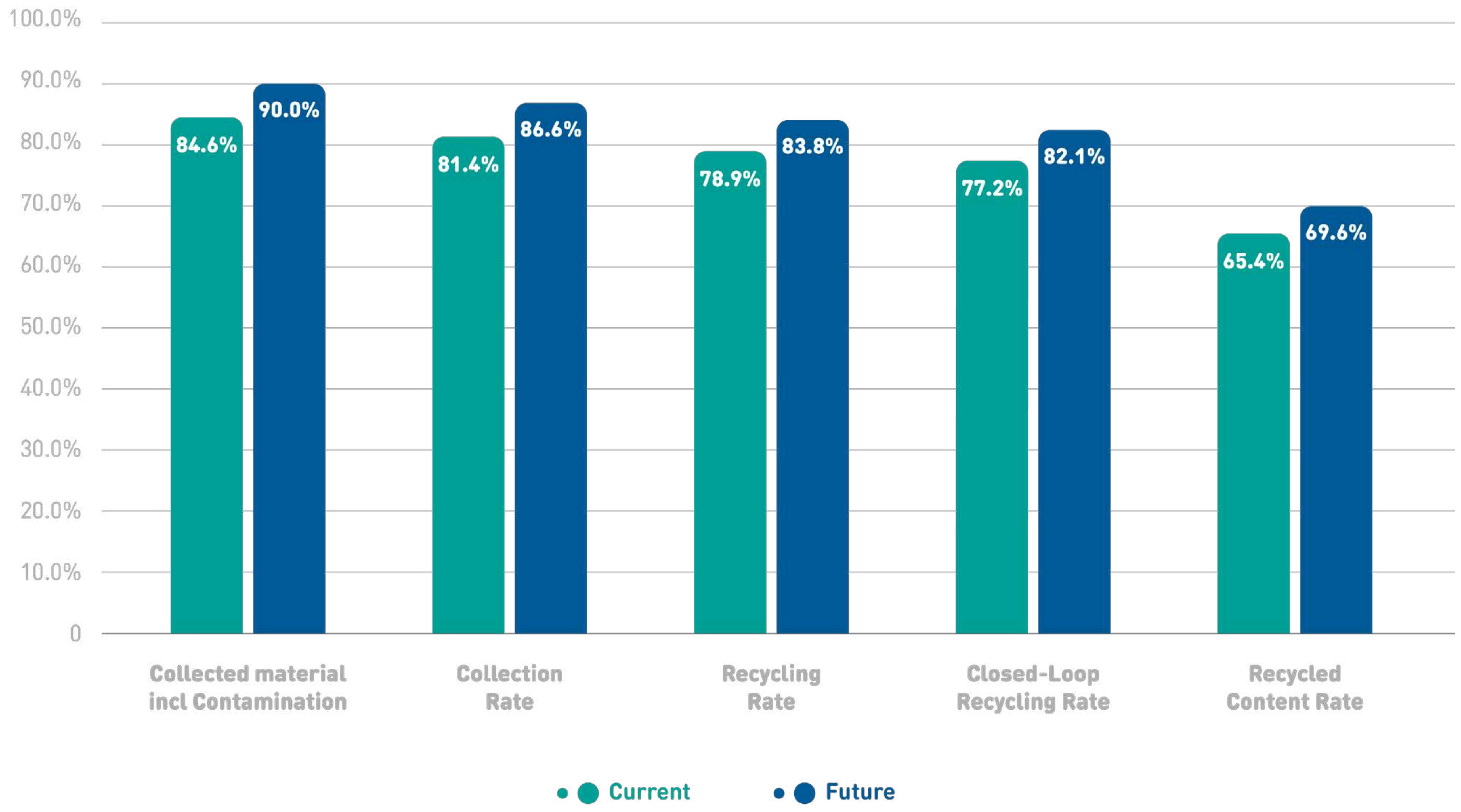
Germany

Table 3 shows that Germany has already reached the PPWD recycling rate target ahead of schedule. German legislation maps a pathway to achieving EU targets by setting a **target rate of 90%** (from January 2022) for material sent for recycling.[30] Unlike the PPWD's recycling rate target, which excludes contamination and is measured after sorting losses have occurred, the calculation method for the German collection target rate measures the material prior to sorting and therefore includes contamination. Currently, this rate is 84.6% in Germany. The study modelled a future scenario by increasing this rate to 90% and illustrates what this would mean for Germany's future recycling and recycled content rates. The results are shown in Figure 9. For easier comparison, the collection rate (excluding contamination) has been added to the graph.

Due to Germany's minimal losses in glass reprocessing and high reuse of cullet in the container glass industry, each percentage point increase in collections means a nearly 1 percentage point increase in the recycling rate and recycled content rate. Therefore, increasing the material collected by 5.4 percentage points to 90% would increase both the closed-loop as well as the overall recycling rate by nearly 5 percentage points. The potential for recycled content in container glass would also increase by 4.2 percentage points in this future scenario.

There are currently no concrete drivers in place to meet the 90% target. One way the target might be achieved is to increase the number of bottle banks to maximise convenience for consumers – for example, placing them near popular destinations such as supermarkets or petrol kiosks. In reality, this requires space and is unlikely to happen, at least in the short term. **It is therefore unclear how Germany will be able to achieve its target.**

Figure 9: Current vs Future Scenario for Single-Use Glass Packaging, Germany



Source: Eunomia modelling using available market data

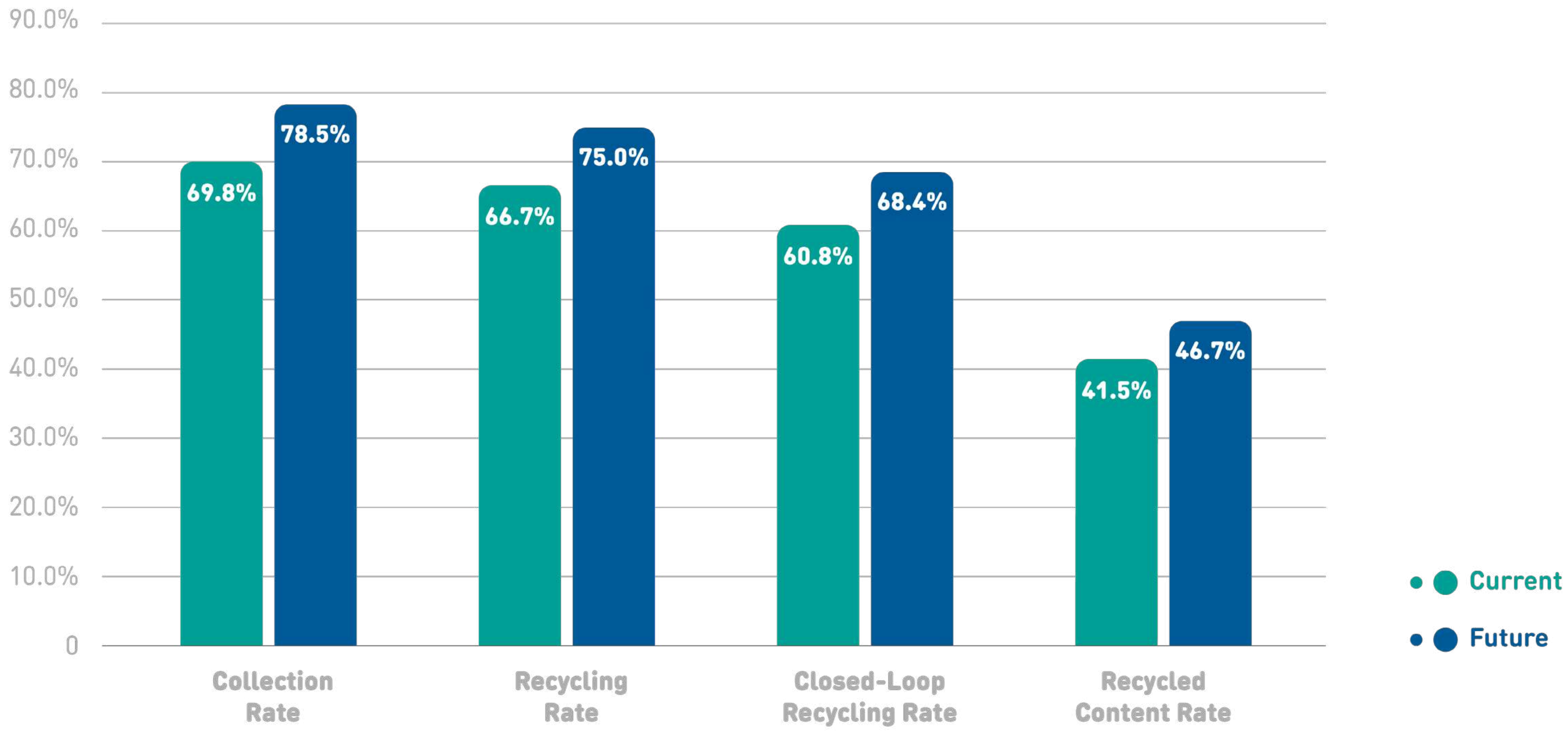
France

For France to achieve a recycling rate of 75% by 2030, the current collection rate must increase from just under 70% to 78.5% – slightly under the current collection rate in Germany, the best-performing case study. This is a plausible target, given that it has been achieved elsewhere. It would, however, mean a considerable, almost 9 percentage point increase from France's current scenario.

There is a substantial difference in the rates of material collected from households in comparison to that collected from non-households, as noted in Appendix A 2.0. Significant changes would therefore be needed to capture more of the materials consumed by non-households.

No known drivers are in place that could boost France's collection rate in the short term. **Discussions on the implementation of a DRS system in France are ongoing**, but from current consultations it is unlikely that single-use glass beverage bottles are covered by such a scheme.

Figure 10: Current vs Future Scenario for Single-Use Glass Packaging, France



Source: Eunomia modelling using available market data

United Kingdom

While the UK has proposed its own recycling rate targets, they have not yet been transposed into law and therefore this study predominantly considers the PPWD existing target set prior to the UK's exit from the EU. To meet the 75% recycling rate target, the study projects the impact of a nationwide DRS on the UK's recycling performance. As a second step, it estimates the collection rate required to reach the recycling target.

While DRS systems will be implemented nationwide, earlier this year it was announced that England and Northern Ireland will not include glass within their schemes. With Wales and Scotland only making up around 13% of the UK's overall population, this means that a relatively small proportion of the total glass beverage bottles POM would fall under the scope of a DRS. Therefore, **the introduction of DRS will probably not significantly improve performance** and may only offer a 2% increase in the UK's overall recycling rate.

To achieve a recycling rate of 75%, collections would need to increase by another 2 percentage points (i.e. 4 percentage points from the current system). While this seems like a small gap to bridge, the **proposed targets calling for an 83% recycling rate by 2030** would require an improvement of 9 percentage points from the current situation. It is unclear what additional drivers the UK will put in place to reach either of these targets.

The use of a DRS system for glass beverage bottles in Wales and Scotland leads to a small but not insignificant jump in the closed-loop recycling rate, which shows that high quality, separate collections improve the circularity of single-use glass packaging. Overall though, the closed-loop recycling and recycled content rates remain considerably lower than in Germany and France. As part of its recycling targets, the UK has agreed a "remelt target" for glass packaging to improve its circularity (currently at 72% but proposed to increase to 81% by 2030).

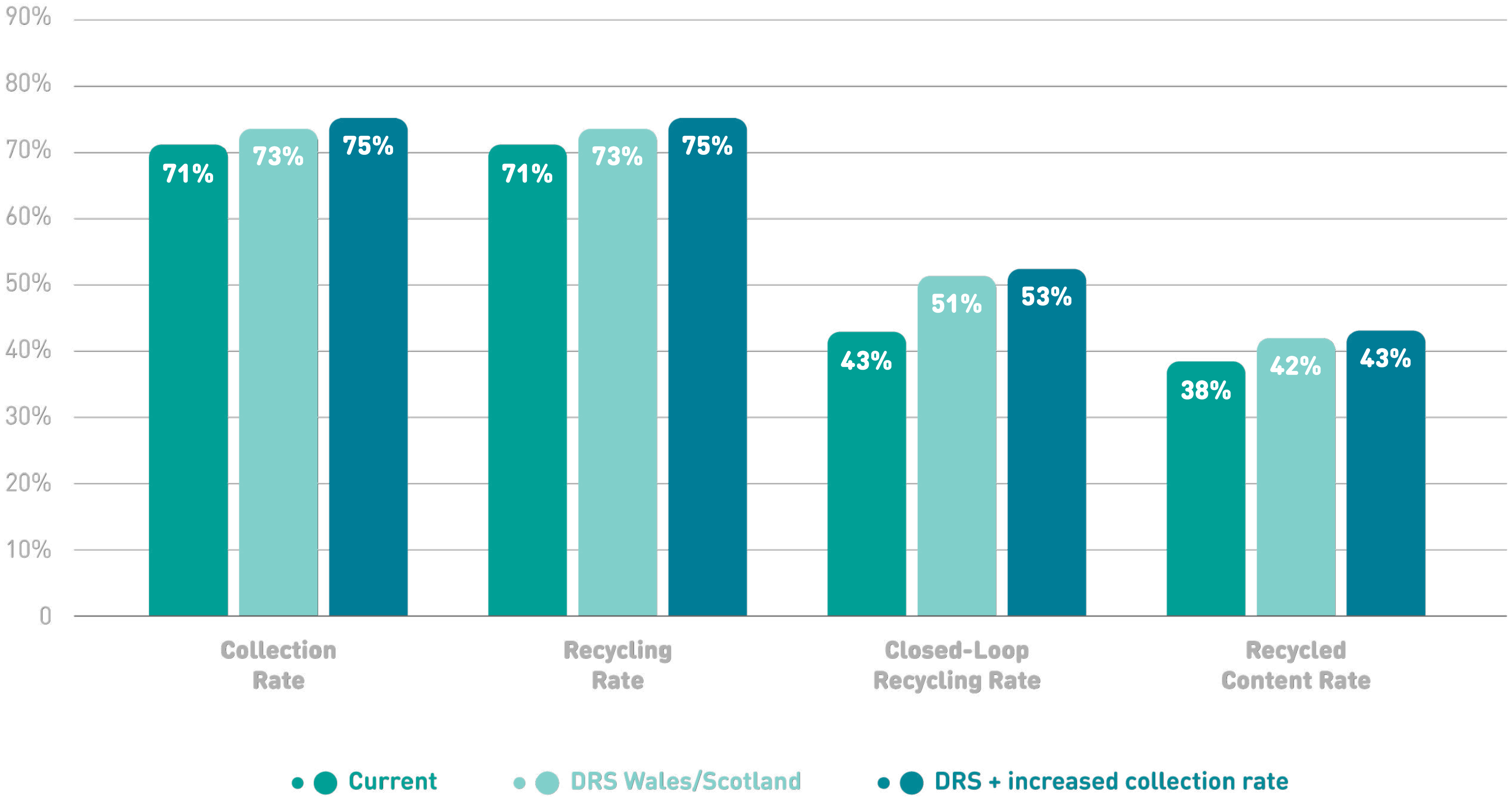
This is not a closed-loop target but prioritises remelt applications such as the use of cullet in container glass and insulation applications over the use of glass in aggregates. **A review of the current collection and recycling system would be needed to ensure out puts of sufficient quality and quantity to be recycled back into container glass** (or other remelt applications). This might be achieved by implementing a nationwide separate collection system (such as through a DRS) as opposed to collecting large quantities of used container glass in a co-mingled system, as is currently the case; however, there are no known plans in place in the UK that would affect such large-scale changes.

In all the countries analysed, no strategic pathways seem to exist for achieving any significant increases in collections to meet the recycling rate targets. Even the highest performing case study, Germany, lacks any solid strategic pathways to achieving an increased performance of collections. Collection rates could be improved by putting in place behaviour change interventions such as educational measures or expanding the nationwide coverage of bottle bring banks or kerbside collection systems to aide convenience. It is unlikely, however, that even these measures will bridge the large gaps between what is currently collected, and the increases needed to meet future targets.

An increase in collection rates and therefore recycling rates would not necessarily achieve high levels of glass packaging circularity in some countries, without a change in the method of glass collection, as is the case in the UK. Improving the quality of collections to ensure cullet for use in remelt applications is key. This would likely result in an increase in closed-loop recycling and recycled content in glass packaging and therefore circularity.

One way of achieving a higher collection rate and a better collection quality, in particular for the lower performing countries, is through the introduction of a DRS system that includes single-use glass packaging in its scope, charges a reasonably high deposit and offers a well-developed infrastructure. As discussed in Section 2.1, existing DRS systems for glass in Europe are reporting collection rates between 84% and 89% in 2019.[31] More recently, significantly higher collection rates have been reported (e.g. Finland reported 98% for 2021[32]). Introducing DRS for glass beverage bottles in any of the case study countries analysed, would therefore likely see significant increases in collections. In addition, as this is a separate collection stream for glass, a DRS collection method would likely improve the collection quality in currently low performing cases such as the UK and the US.

Figure 11: Current vs Future Scenario for Single-Use Glass Packaging, UK



Source: Eunomia modelling using available market data

3.2

Future Circularity in the US

Table 4 gives an overview of the initiatives analysed.

Table 4:
Modelled Initiatives for Improving Glass Recycling in US

Initiative	Likelihood	RAG
Improving glass sorting at MRFs	More likely (currently underway)	
Improving existing DRS programs	Medium likelihood (currently underway)	
Introducing new legislation, including new DRS programs, and the potential for EPR	Less Likely	
Increased recycling in higher performing states	Less Likely	
Average recycling in lower performing states	Less Likely	

Each initiative is described further below. Figure 12 shows the results of the different scenarios.

Improving Glass Sortation at MRFs – More likely (currently underway)

Despite being collected through recycling streams, a percentage of MRF glass still ends up either as landfill cover or being dumped in landfill. Improving glass sortation so this glass finds an end market that includes recycling is therefore an opportunity. Initiatives such as the Glass Recycling Coalition's MRF Glass Certification Program measure the effectiveness of individual MRF's glass recycling programs.[33] The certification awards an MRF the certification if that MRF displays infrastructure, end markets and glass purity measures which meet the Coalition's standards. MRFs investing and meeting these criteria could increase the proportion of collected glass containers that are sent for recycling, rather than to landfills.

Improving Existing DRS Programs – Medium likelihood (currently underway)

There are currently 10 states with deposit programs in the United States. Each DRS program is different, with varying scopes and return rates for containers. Maine is the closest state to having a "complete scope", where all beverage glass containers are included under the program. Additionally, Maine and Oregon have return rates close to 90%, while some other states have return rates in the 50s.[34] Eunomia modelled how to improve existing DRS programs by:

- Expanding each existing DRS scope to include all glass beverage containers.
- Increasing the return rate for each DRS program to 90%.

Less Likely EPR and New DRS Program – Medium likelihood

A few states are currently considering adopting new recycling legislation such as Extended Producer Responsibility (EPR), as well as DRS programs. This scenario models the take-up of EPR legislation in a few states and a new DRS program in the state of New Jersey. Under EPR, collection rates in a state are assumed to meet the regional (as defined by the US Census Bureau) high of collection rates. Eunomia considers this scenario less likely than the previous two scenarios, as EPR laws currently vary in the recycling targets they impose; for example, Maine's EPR program does not establish any recycling targets.

By contrast, there have been multiple DRS expansions in the past few years. Oregon expanded its scope and raised its deposit level in 2019, and Connecticut is set to expand its scope of beverages covered at the beginning of 2023.

Increased Recycling in Overall Higher Performing States – Less Likely

Under this scenario, select states who perform highly when collecting some materials other than glass containers (e.g., cardboard) are assumed to improve their collection systems such that glass containers are also collected at a relatively high rate. This scenario relies on states and haulers within those states improving the capture rate of glass containers, meaning this scenario is less likely the scenarios outlined above.

Average Recycling in Lower Performing States – Less Likely

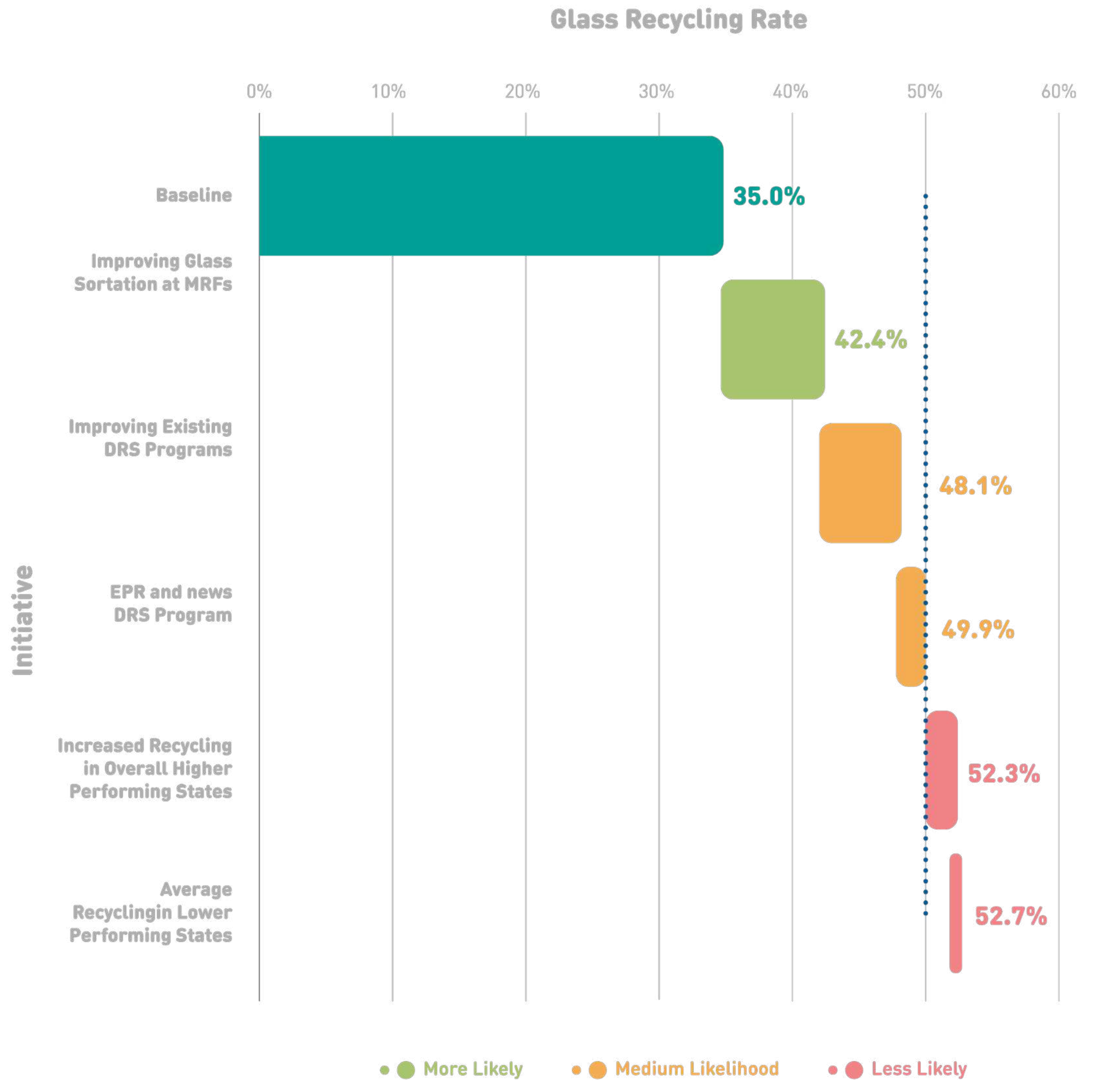
This scenario examines the possibility that select states with lower collection rates will be able to increase collection rates to their respective regional averages. It offers smaller increases (in terms of percentage points) than the Increase Recycling in Overall Higher Performing States scenario, as states with lower capture rates may be in regions with lower average capture rates as a whole.

Similar to the previous scenario, this one relies on these states' current recycling infrastructure to improve independently of EPR or other legislation, meaning this scenario is less likely.

The results of each of the scenarios can be seen in Figure 12. The blue dashed line represents the 50% target for glass recycling. Each scenario is rated red, amber or green based on its perceived likelihood.

Existing legislative upgrades and MRF glass recycling upgrades have the largest marginal impact on overall recycling rates, with effects of 5.7 and 7.4 percentage points, respectively. These two initiatives in combination increase the national recycling rate of glass to 48.1%. Subsequently, introducing EPR in select states and adding one bottle bill state raises the recycling rate to just under the target of 50%. Finally, the scenarios of increasing state collection of glass without legislation brings the total recycling rate to above 50%.

Figure 12: Effect of Different Recycling Scenarios in US



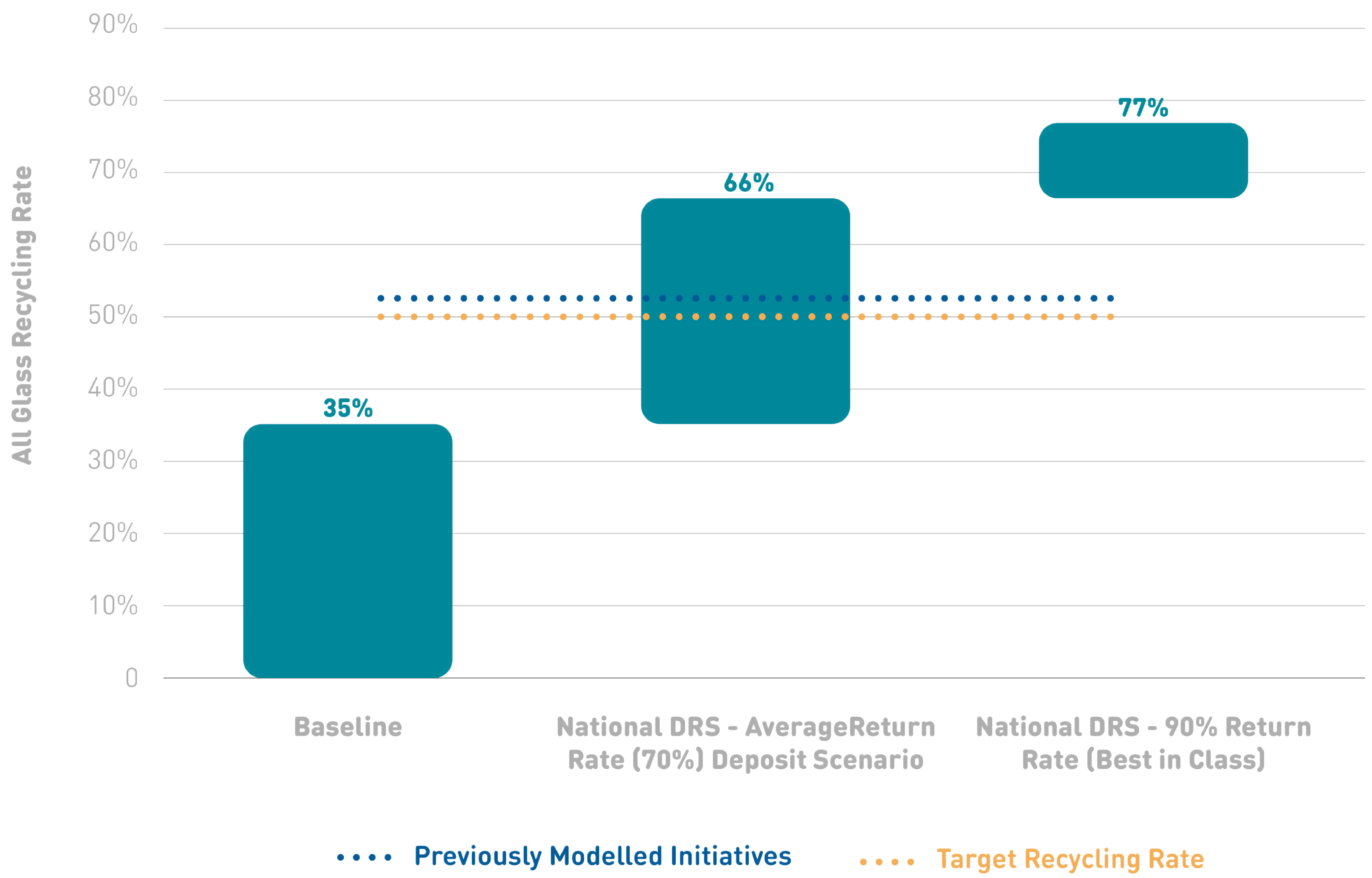
Source: Eunomia modelling

National DRS

In addition to the modelled scenarios laid out above, Eunomia also estimated the potential for nationwide coverage of DRS for all beverage containers to increase glass container recycling rates. The results are shown below for a simulated return rate of 70% (the current average across existing bottle bill states) and 90% (a best in class return rate).

Under each national DRS scenario, the recycling rate for all beverage containers is at least 16 percentage points above the target rate of 50%. In the highest return rate scenario of 90%, the total recycling rate for all glass containers reaches 76%. Each 10 percentage point increase in return rate relates to around a 5 percentage point increase in overall glass container recycling. This is because not every glass container would fall under the scope of the DRS.

Figure 13 :
National Bottle Bill Implications in the US



Source: Eunomia modelling

4.0

Wider Environmental Limitations and Opportunities of Glass Packaging

In addition to considering the circularity of glass packaging, the wider environmental impact of glass needs to be considered; this is mainly linked to greenhouse gas (GHG) emissions from manufacturing and transport. To identify and evaluate opportunities for reducing the impact of glass packaging on the environment, this study reviewed how single-use glass performs in life cycle assessments (LCAs), the industry's decarbonisation plans, developments in glass design and the potential of refillable glass bottles in this context.

4.1 GHG Emissions in Single-Use Glass

The GHG emissions associated with single-use glass packaging can vary widely depending on circumstance. LCAs can be a useful tool for comparing products against each other, but since each analysis accounts for specific circumstances, no one LCA can be used to measure the impact of glass packaging as a whole. Instead, by comparing multiple LCAs, we can get a general picture for how glass performs against other beverage packaging materials.

Such comparison generally shows that single-use glass packaging is the most impactful packaging type with the highest associated GHG emissions when compared with other single-use beverage packaging materials such as aluminium cans, PET bottles, HDPE bottles and multi-layer beverage cartons. A study by the University of Southampton critically evaluated a number of LCAs in different geographical areas, comparing beverage packaging materials for a variety of liquids (pressurised drinks, fruit juice, fresh milk).[35] In all three drinks categories, glass bottles made from virgin materials had the highest associated GHG emissions. For the sake of demonstrating that glass beverage containers can theoretically comprise 100% recycled content, the virgin glass bottle was also compared with a hypothetical bottle made of 100% recycled glass. Unsurprisingly, the 100% recycled bottle had a lower impact, indicating the benefit of recycling on potential GHG emissions. Nevertheless, the 100% recycled glass bottle still ranked with a higher negative impact than any other materials in every drink category, including virgin and recycled PET bottles, HDPE bottles, beverage cartons and aluminium cans. Other LCAs have produced similar results, in that glass bottles generally have the highest associated GHG emissions compared to other common beverage packaging materials.[36]

The use of cullet in the production of new glass packaging can significantly reduce the energy used in the glass making process, since the chemical energy required to melt the raw materials has already been expended. Cullet also requires fewer additives, saving the energy needed to mine such compounds.[37] Furthermore, every 1 tonne of cullet replaces 1.2 tonnes of virgin material in the batch formulation of most soda-lime-silica glasses. Importantly, every 10% increase in the use of cullet results in energy savings of 2.5-3% of the melting process.[38] **Hence, replacing all virgin feedstock with cullet results in 25–30% furnace energy saving.** While a typical furnace consumes between 4–17 GJ/t of energy,[39] the amount of cullet used varies greatly from facility to facility, depending on the quality and consistency of feedstock.

4.1.1
Decarbonisation of Manufacturing Process

Manufacturing container glass is a high-temperature, energy-intensive process. The melting process can require temperatures as high as 1600°C, with energy largely provided by the combustion of fuels such as fuel oil and natural gas with some use of electricity, either separately or in combination. Melting accounts for 75% of the total energy required to make container glass. According to British Glass, the change with the single biggest impact on GHG emissions would be for furnaces to switch from fuel oil or natural gas to electricity, which could reduce GHG emissions by 56% from 2018 levels.

It is challenging to decarbonise energy production. Research and trials are being conducted to investigate the suitability of other fuels, including biomass, hydrogen, synthetic methane and renewable electricity. Wiegand-Glas, for example, have made 'greener' glass bottles using biomethane produced from municipal waste to reduce fossil GHG emissions.[40] In addition, tentative research into hydrogen glass melting has been conducted in Germany with moderate success;[41] hydrogen power can maintain constant furnace temperatures. However, more research and development are needed to tackle issues such as discolouration and glass quality impacts, as well as increasing the available power generation capacity (wind and solar) to sufficient levels for hydrogen production. Europe is likely to see the development of hydrogen infrastructure with potential for integration into the existing natural gas network, making it a more operationally and economically feasible energy source. Aside from fuel substitutions for gas furnaces, renewable electricity can be used to melt glass in electric melting furnaces. These are generally more efficient than gas furnaces, since heat is introduced more efficiently into the glass by the submerged electrodes, rather than by the combustion of natural gas above the glass melt. However, electric furnaces generally have a lower capacity, limited by the melting process; since the price of renewable electricity does not yet compete with natural gas, electric furnaces are infrequently employed as standalone furnaces.[42]

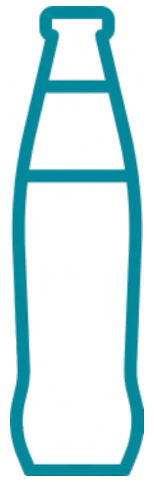
In addition to individual company-led decarbonisation projects, Hybrid Furnaces of the Future have been researched and evaluated via a collaborative sectoral approach, led by the European container glass federation (FEVE), as potential new technologies to complement bottom-up carbon reduction initiatives.[43] Their vision is for their technology to cut direct furnace CO2 emissions by up to 60%.

4.1.2
Lightweighting of Packaging

As well as decarbonising the glass manufacturing process, one major way to reduce the environmental footprint associated with glass containers is to reduce packaging weight. This is a reliable way to lower the costs associated with materials and shipping, along with any associated GHG emissions. At present, packaging weight can vary widely for similar products.
750 ml wine bottles, for example, can range from 300 g to 1000 g or more.

Many major glass manufacturers and drinks brands have successfully designed lightweight glass containers to limit GHG emissions. For example:

Multinational drinks and brewing company AB InBev designed a 150g 330 ml beer bottle in 2021 (17% reduction from previous design).



Packaging producer Ardagh produced a 700 ml spirit bottle and 750 ml wine bottles below 300g.

In 2015, soft drinks company Britvic said they have reached their limit of ability to lightweight glass beverage bottles and so would focus instead on new secondary packaging technologies to improve their sustainability performance.[44]

Other brands have chosen to reduce the weight of their products by changing the packaging material to aluminium,[45,46] plastic,[47] and card.[48]

Quality perception

One limitation for lightweighting is the perception of brands and consumers that heavier bottles are associated with a higher quality product. One expert noted that there are three broad categories for wine bottles that are well understood in the UK wine trade (all 700 ml):[49]

- 290g to 320g for budget/entry-level brands;
- 320g to 360g for mid-range brands;
- 360g plus for high end brands.

OI Glass, a glass bottle manufacturer that operates in all 4 case study countries gives more evidence of this range of bottle weights via their catalogue, which advertises 750 ml still wine bottles weighing as much as 1200g.[50] German packaging supplier Bruni Glass suggested that while gin bottles in France were being lightweighted, cognac brands were sticking to high-end thick-bottomed, heavier bottles.[51]

Despite this perception, a WRAP study found that customers could not detect a weight difference of 3-4% in lab conditions and this level rose to 8-10% when customers picked up bottles in store.

"Heavier bottles are associated with a higher quality product."

Technical barriers

Whilst a number of lightweight bottles have been designed by big brands, and even tested in production scenarios, far fewer brands have translated this into mass production. The newly lightweighted bottles described above use Narrow Neck Press and Blow (NNPB) technology, an update to traditional Press and Blow and Blow and Blow technologies. The NNPB process often requires significant capital investment, including:

- Replacement of production machine-lines;
- Design of new bottles, including strengthening glass coatings;
- Operative training;
- Updates to quality inspection technology; and
- Production trials and process improvements.

Rising energy costs and increased pressure to reduce carbon footprint, along with lower running costs when set up, could encourage this capital investment. There are significant opportunities for decarbonising the manufacture of container glass and decreasing associated GHG emissions by reducing the weight of packaging. Other beverage packaging material industries are making considerable efforts to reduce GHG emissions. For example, the EU single-use plastic directive[52] will require a minimum of 25% recycled content for PET bottles by 2025, meaning their performance will likely improve. Efforts within the aluminium industry are also being made to decarbonise the smelting process, for example with a move towards renewable energy sources. The Aluminium Stewardship Initiative offers a voluntary certification process with the goal to reduce the aluminium sector's emissions in line with climate science's 1.5˚C aligned pathways.[53]

Further LCAs may be needed to assess whether decarbonising the glass manufacturing process provides a competitive advantage for glass packaging, but a scenario in which glass outperforms its alternatives in single-use applications is unlikely. Ultimately, the high levels of investment required are unlikely to be justified by the reductions in emissions they will provide.

4.2

Refillable Glass Packaging

Although the overall use of refillable packaging is currently very low in Europe and the US, the use of refillable glass bottles in the HORECA (hotels, restaurants and catering) segment is relatively widespread and becoming more common in the retail sector. In addition, Germany has a well-established refillable system for beverage bottles and some yoghurt glass jars for home consumption, which is often used as a reference for other markets considering a refillable system. This study uses Germany as an example but draws conclusions to the overall refillable market.

German legislation calls for a 70% market share of the overall beverage market for refillable containers.[54] While this target is far from being reached, the current market share is not insignificant (41.8% in 2019) and slowly rising for the first time since the introduction of single use deposits in 2003.[55] In Germany's refillable beverage packaging market segment, PET and glass bottles are used, with the latter most prominent in the refillable beer and water segments. France also has a law on the reuse of packaging, requiring 10% of packaging placed on the market to be reusable by 2027.[56] France recently introduced a 3R (Reduction, Reuse & Recycling) decree,[57] setting further reduction and reuse targets until 2025.

As mentioned in Section 4.1, most comparative LCAs show single-use glass packaging as the most impactful of all materials. These evaluations highly depend on the system boundaries considered in the analysis, but **in general switching to refillable glass packaging cuts down on the environmental impact significantly by avoiding the high GHG emissions** associated with new production. One study showed a 40% reduction in GHG emissions for the glass bottles analysed after the second cycle.[58] The total GHG emissions for refillable glass packaging are influenced by the total number of refill cycles of the package and therefore the more cycles, the higher the overall benefits compared to single-use.

While most LCAs conclude that refillable glass has lower overall GHG emissions than its single-use alternative, the results highly depend on a number of factors, such as number of cycles, transport distances, packaging weight, recycled content and energy sources for the manufacture and/or cleaning.[59]
In particular, transport distances for the take back and redistribution of glass bottles are key factors in the results of LCAs,[60] which together with the effects of washing, which repeatedly occur at each cycle,[61] will become a constant, repeated impact. This raises an important consideration on refillable packaging – the return logistics and associated transport distances of bottles between filling, retail, use, washing and refilling. One key influencer to ensure efficient refillable packaging systems is the bottle design and linked return system. In Germany, brands have two options: they either use individually designed bottles or join a pool system.

Individually designed bottles are a creative outlet for brands to distinguish their product from other brands by specifying their own design (e.g., shape, embossing, colours or sizes). These types of designs are often preferred by brands, as it makes their bottles easily identifiable and can add a premium feel to the product.

Pool systems, on the other hand, which are formed by two or more producers, use a set of standardised bottles that brands can use and that can move freely amongst pool participants and their stakeholders. Clean and unlabelled bottles are indistinguishable from each other and so the only way for brands to set themselves apart from other brands in the pool system is with the design of the label. Apart from shared ownership of packaging, a well-designed pool system also benefits from a clearly defined governance structure (ideally completely or partially by a neutral party), equal access and fair conditions for all participating parties, agreed internal standards (such as bottle design, filling methods and quality standards), fair distribution of costs and benefits and a transparent reporting structure for all participants.[62]

With several bottlers participating in a pool system, the transport distances from retail to washing and refilling stations can be optimised. Individually designed bottles, on the other hand, are linked to one bottler only and if the bottles are distributed nationwide, transport distances will have a far greater environmental impact than for bottles in a pool system.

The pool system presents some challenges as well. For the water segment, there is a centralised pool system operator in Germany which plans and designs the return systems for an array of standardised bottles. This is not the case for the beer segment, where several bottlers work together but there is no overarching organisation responsible. Also, pool bottles have started to evolve in their design and so there is not only one single design available. This expands the variety of bottles on the market.

One issue stemming from this bottle design variety is the accidental inclusion of bottles in the wrong return crate. If undetected, bottles with the wrong design end up being transported to the wrong bottler. This adds to GHG emissions through the additional transport needed to return the bottles to the correct bottler.

Market research company GVM (Gesellschaft fuer Verpackungsmarktforschung) observes an increase in individually designed glass bottles in the overall beverage market between 2012 and 2017, but particularly in the beer (+27%) and water (+8%) segments in Germany. The company forecasts a further increase in the coming years.[63] This trend towards individually designed bottles has an impact on GHG emissions for the refillable glass bottle market, potentially making the packaging system less environmentally attractive than it currently is.

Globally, two large beverage segments that currently almost exclusively rely on single-use glass bottles are the wine and liquor segments. Particularly **in the wine segment many of these single-use bottles have a similar bottle design which would lend itself to standardised pool bottle designs**. To overcome long transport distances between the production country and the respective countries of consumption, the beverage may be transported in bulk and bottled by a local pool refill system. Otherwise, a refillable system would make more sense in a national refillable system (e.g., French wine in France), utilising a standardised bottle pool system. Further research would be required to assess the practicality, feasibility and likely uptake of such a set-up.

For glass packaging to provide an effective refillable option that minimises GHG impacts along the entire life cycle it would be necessary to move towards a pool system with a limited number of design options to ensure optimised logistical flows of the packaging. In addition, bottle manufacturers should strive for a high recycled content and number of refill cycles to minimise the high GHG impacts of bottle manufacturing. As pointed out above, in terms of overall environmental impact such an optimised refillable system will likely outperform light weight single-use glass packaging with a higher level of recycled content.

A new or optimised refillable glass packaging system requires large-scale changes and investments to the existing infrastructure. Therefore, any policies aimed at increasing refillable packaging need to consider the challenges of specific geographical areas, relating to transport, storage and wash and refill facilities and give sufficient transition time for the implementing bodies.

5.0

Conclusions

Several approaches could be taken to reduce the energy usage and therefore GHG emissions released in the production of single-use glass packaging. One possible way is by using recycled glass instead of glass from primary sources. In a circular system of single-use packaging, recycled container glass is used in the production of new container glass, instead of in other recycling applications to make products that cannot be recycled again at the end of their lifecycle.

This study found that circularity differs from country to country. Material losses from the circular glass system can occur at three stages of the process: collections, sorting, and end market routes.

By far the largest losses occur in the collection phase, where between 19% (in our best performing example) and 56% of glass (in our lowest performing example) is not captured.

It was not possible to find a direct correlation of collection methods to collection rates.

The actual sorting process of glass is reasonably efficient, with only about 2% to 3% of losses happening at this stage. These are mainly due to the stringent sorting process for CSP and to poorly designed bottles which are misidentified by optical sorters. Improved glass design (e.g., easy to remove labels and avoidance of lacquered bottles) may enhance the performance slightly.

Losses from the circular system to other, non-circular recycling applications occur mainly in the UK and US, where 40% and 39% are lost, respectively. Both these countries collect glass predominantly in co-mingled collections instead of in a separate collection stream.

Collection rates have a direct impact on the quantity of material recycled and therefore it is key to improve collections of glass packaging, not just in the four case studies assessed but in the wider, global market. Collection rates might be improved through behaviour change interventions, such as making collections more convenient or educating consumers, but this will likely not yield a high success rate. **A well-designed DRS type of system could improve collections rates significantly,** as evident from well performing bottle bill (DRS) states in the US and European DRS systems which cover glass beverage bottles.

To meet higher policy targets for recycling rates in Europe, collection rates need to be improved. However, this may not lead to significant improvements in the overall circularity of glass in countries where much of the material is currently recycled into other recycling applications (e.g. UK and US). Here, **a shift to a more effective, separate collection method is needed**; this could lead to higher outputs of cullet suitable for closed -oop applications. Other than in the UK, there are no policy targets that could drive circularity in such a way. Overall, it is unclear if and how countries in Europe will meet targets.

The US does not have any policy targets driving glass recycling or circularity. The targets used in this study are voluntary and lack any form of incentive. In fact, the voluntary recycling rate target of 50% was already in place prior to 2013. Some upcoming changes may bring the US closer to this target, but it is unlikely that it will be met without full industry commitment.

Additional consideration needs to be given to the GHG emissions of single-use packaging. As well as keeping materials in a circular system, decarbonising the production process and lightweighting packaging are options to reduce environmental impact. While the industry is working on these, competing packaging industries are also advancing in the field and it is unclear if glass will be able to outshine the competition. Refillable packaging can, due to its repeated use, significantly reduce GHG emissions, as long as transport distances are optimised, for instance through pool systems, with few standardised bottle designs, as they are used in the water segment in Germany. However, a trend is evident towards the use of individually designed glass packaging, which poses the question of whether brands are more concerned about packaging appearance than the environment.

So, to answer the question as to how circular single-use glass packaging is – the study found that circularity, measured by four key performance indicators (the respective rates of collection, recycling, closed-loop recycling and recycled content) varies from country to country. The ability to achieve high circularity depends primarily on the effectiveness and methods of collections. The more glass packaging is collected through a high-quality separate collection system, such as a DRS, the more glass is likely going to flow back into the manufacture of new single-use glass. To retain material in a closed-loop, an efficient refillable system with optimised transport distances and high number of refill cycles could also offer a potential solution as an alternative to single-use glass.

Appendices

While glass sorting and recycling is nearly a fully automated process, glass suffers from contamination during the collection process. Some key contaminants are:

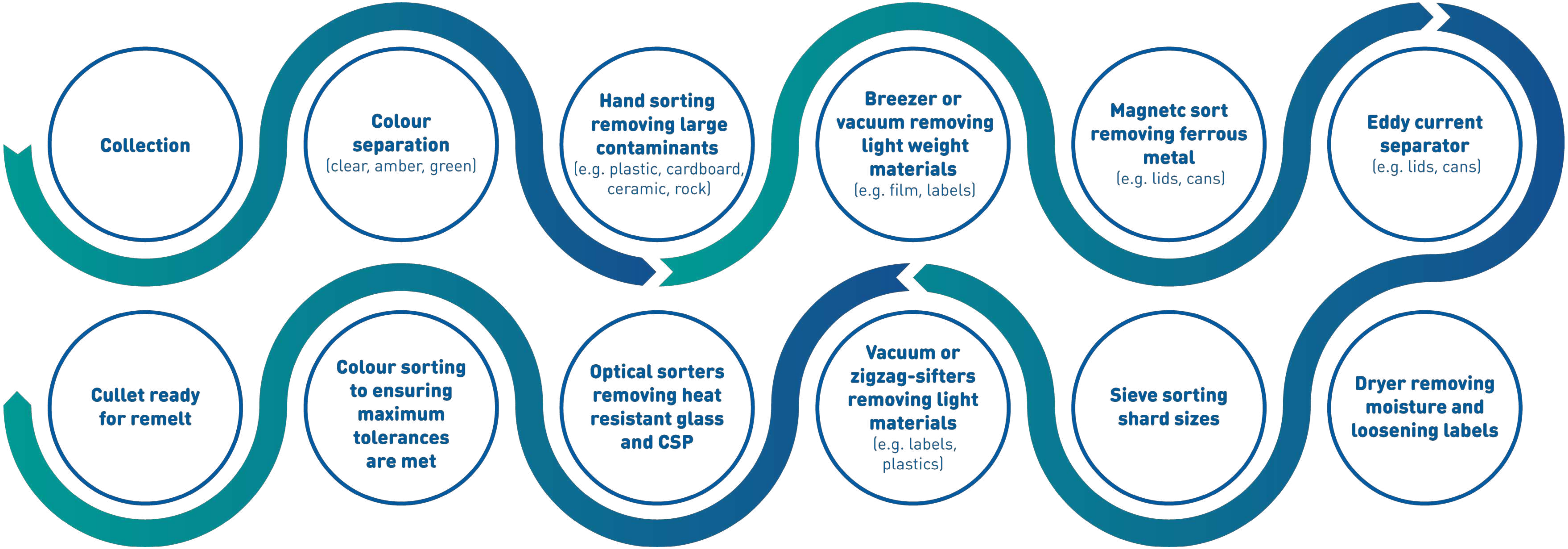
- Plastics, such as bags used for collections;
- Ferrous and non-ferrous metals from lids;
- Paper from boxes or labels;
- Other glass such window glass, car glass, crystal glass and fireproof glass such as laboratory glass, Ceran®, Pyrex®;
- Ceramics, stone and porcelain, often referred to as CSP.

In addition, even collection by separated colours will mean that wrong coloured glass will inadvertently find its way into collection through user error. Figure 14 shows the material from green glass collections in Germany prior to removal of contamination and colour sorting.

The glass recycling process is not standardised across the regions or even within a single country. The sequence of individual steps may vary, and some recyclers might omit a step depending on the quality of input and necessary output specifications, but the process is broadly as outlined in Figure 15 below.

Figure 14:
Collected Container Glass from Bring Banks in Germany

Figure 15:
Container Glass Recycling Process



CASE STUDIES

The case studies below provide an overview of the current collection and recycling systems and infrastructure in four countries: Germany, France, the UK and the US. Each case study presents the mass flows of glass in the respective country and notes the stages at which leakage occurs.

A1.0

Germany

A 1.1 Industry Overview

Germany has a comprehensive collection system for container glass which dates to 1974. The standard collection method is through a network of approximately 250,000 bring banks. Glass is predominantly collected in separate colour streams of clear, green and amber glass. In some instances, amber and green glass or mixed coloured glass are collected together to reduce transport impacts or to accommodate the lack of space for multiple bring banks in highly built-up areas. According to industry experts, collecting amber and green glass does not provide too many issues as the two colours are very tolerant of each other. A fully mixed colour glass collection makes up only approximately 15% of the entire collections market. Other collection methods include glass bottles returned from the single-use DRS system as well as rejects from refillable beverage bottles and yoghurt jars. These are however fairly small quantities each having a maximum 10% share of the entire collections.

The collection and recycling of post-consumer glass packaging are the responsibility of the dual systems, for which there are currently 11 different operators in Germany.
In 2019, there were approximately 20 glass recycling plants in Germany covering the entire country's glass consumption. Most of these plants are located in close proximity to a glass manufacturing plant.

Glass recyclers in Germany work towards strict quality guidelines, which are detailed in Table 5 to Table 7 below.

Table 5:
Non-Target Material Tolerances[64]

Contaminant	Average Contamination (within 250 t or one month)
CSP	20 g/t
Non-Ferrous Metals	3 g/t
Ferrous Metals	2 g/t
Glass Ceramic	>10mm: 5 g/t ≤10mm: 10 g/t
Moisture	-2%
Loose Organics	300 g/t
Heavy Metals (Pb, Cd, Cr(VI), HG)	200 ppm

Table 6:
Non-Target Colour Tolerances per Colour Fraction[65]

Colour Fraction	Maximum and minimun colour content of >8mm cullet (average in 250 t on one month)
Clear	Green: max. 0.2% Amber: max. 0.3% Coloured (green/amber): max. 0.2%
Green	Green: min. 75% Amber: max. 10%
Amber	Green: max. 10% Amber: min. 80%
Coloured (green/amber)	Green / Amber: min. 80%

Table 7:
Cullet Size Tolerances[66]

Size	Minimum Size Limits of Cullet (average in 250 t on one month)
< 6.3 mm square	18%
< 1 mm square	5%

In addition to the collection and recycling infrastructure of single-use glass, Germany operates an extensive refillable system for glass beverage bottles and some glass yoghurt jars, which provides a robust circular material solution in this market.

A 1.2 Circularity of Single-use Glass

In 2019, Germany produced just under 4.2 Mt of container glass. Germany is considered a net exporter of container glass, exporting slightly more than a quarter of all container glass it produces. This means just over 3 Mt of container glass were placed on the market (POM) in Germany in 2019, of which nearly two-thirds were beverage bottles (see Figure 16).

Figure 16:
Container Glass POM in Germany, 2019

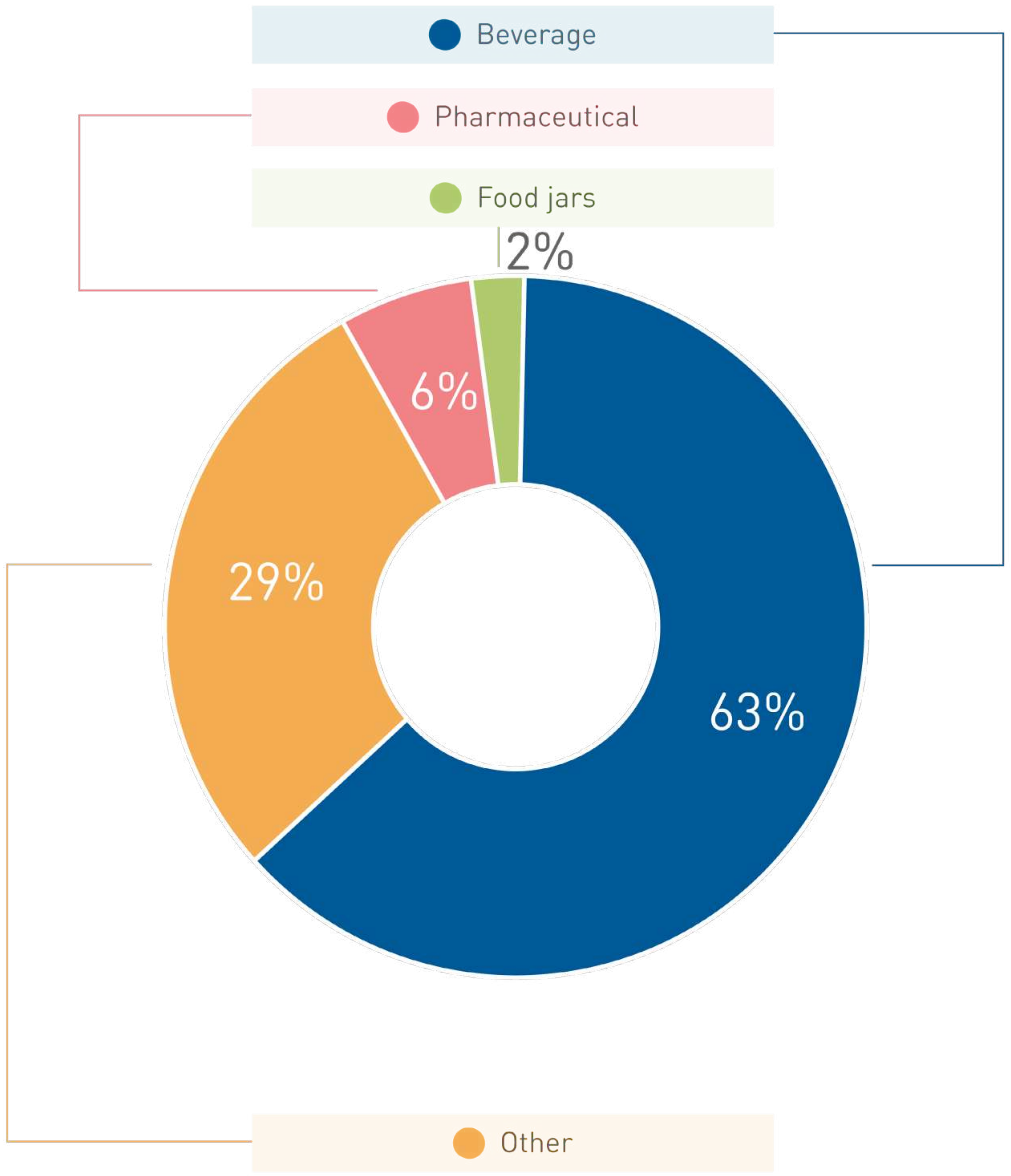
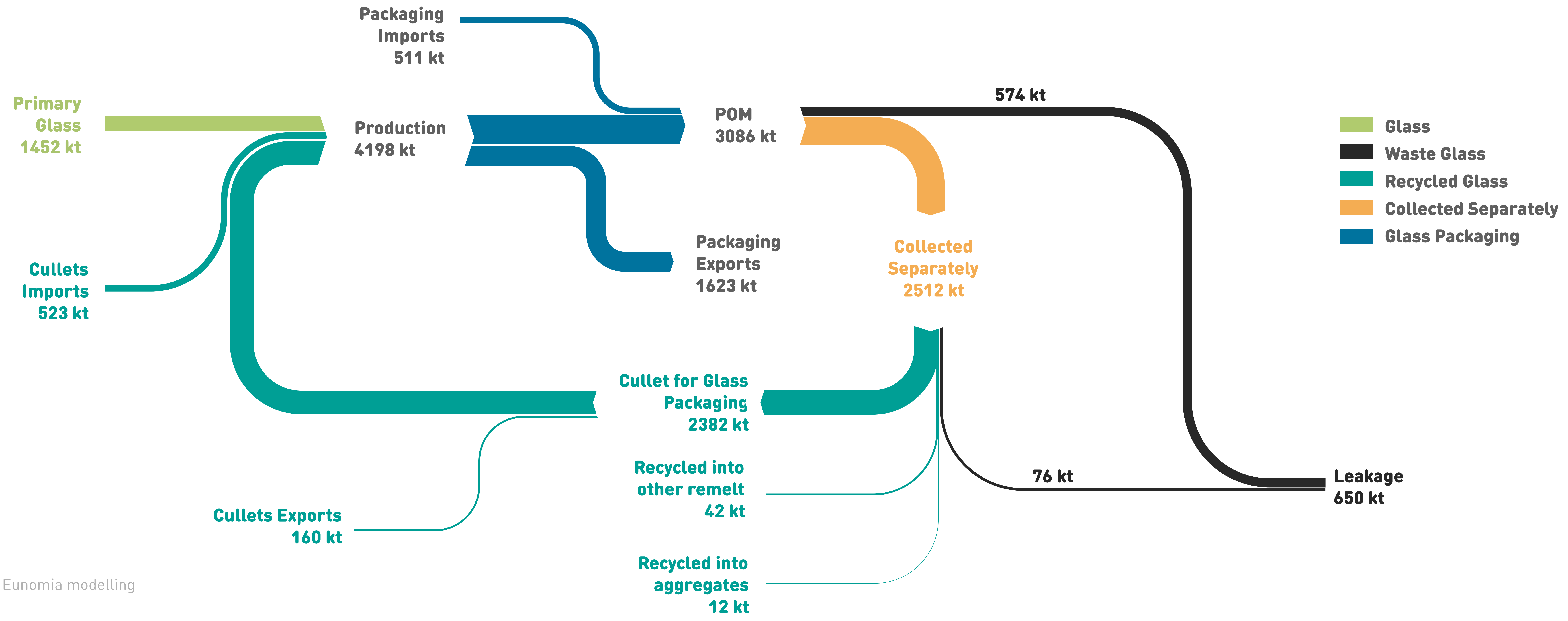


Figure 17 displays the glass mass flows for Germany. The data included in this Sankey diagram includes only container glass and does not include any contamination present from collections. Germany's collections encompass approximately 2.6 Mt of material, comprising approximately 2.5 Mt of glass and 0.1 Mt of contamination (including metal lids, labels and incorrectly disposed of material such as plastic bags, porcelain, rocks or lead glass). This means approximately 81% of container glass material POM is captured in collection systems and 19% is lost from the system, ending up as leakage either in residual waste collections or in the environment.

Figure 17:

Mass flows for Glass Packaging in Germany, 2019



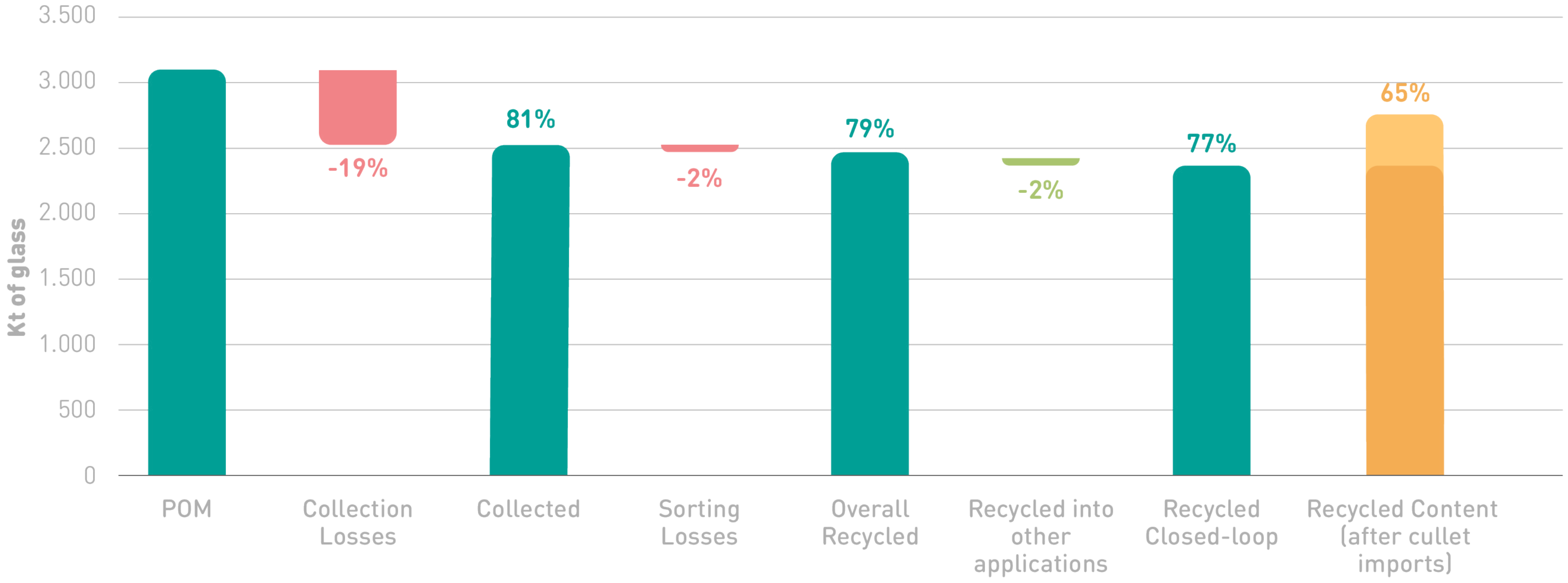
Source: Eunomia modelling

The largest loss of glass within the sorting and recycling process occurs at the process step for sorting for CSP Due to the stringent quality guidelines on CSP content in the product for remanufacture in the container glass industry, the sorting process ejects perfectly good container glass. Despite additional sorting, this still makes up to 20-40% of the CSP fraction. In addition, glass that is lacquered or has difficult-to-remove labels is falsely identified by the sorting technology as CSP. This could be up to 50% of the CSP fraction in total and is likely not recovered through traditional sorting mechanisms, as it is indistinguishable from CSP due to its lack of transparency. In total, we see approximately 2% of container glass placed on the market lost during the sorting process.

In 2019, 2.4 Mt of container glass cullet was available for local recycling applications. Most of this material (98%) was used in a closed-loop, manufactured back into container glass. A further 1.5% was used into other remelt applications (e.g. insulation materials) and 0.5% was used in aggregates (i.e., in the production of cement).

After considering exports and imports, an additional 0.4 Mt of cullet was imported into Germany for remelt application into new container glass. This means a total of 2.8 Mt used cullet from used container glass was deployed to produce new container glass – giving a recycled content of approximately 65%. The closed-loop recycling rate (only considering recycling into container glass) is 77%. Considering all permissible recycling end markets (container glass, other remelt, such as insulation, and aggregates (not used for landfilling or backfilling)), the recycling rate rises to 79%. This equates to a recycled content rate of 65%, when considering the total production of container glass in Germany. The recycled content is likely higher as the use of cullet from the flat glass industry is not considered in this calculation.

Figure 18 : Recycling and Recycling Content Rates, Germany, 2019 data



Source: Eunomia's own modelling using available market data

A2.0

France

A 2.1 Industry Overview

There are 14 treatment centres and 17 glass manufacturing facilities in France. The vast majority of these are owned by Verallia and Owens Illinois. Treatment facilities where contaminants are removed are often vertically integrated with glass manufacturing facilities. The average distance between the manufacturer and end user is 230 km. With such an extensive network of treatment facilities and manufacturers effectively reducing the distance between stages of recycling/remanufacture, remelt applications are likely to become more economically viable.

Glass containers placed on the market in France totalled 2.9 Mt in 2019.

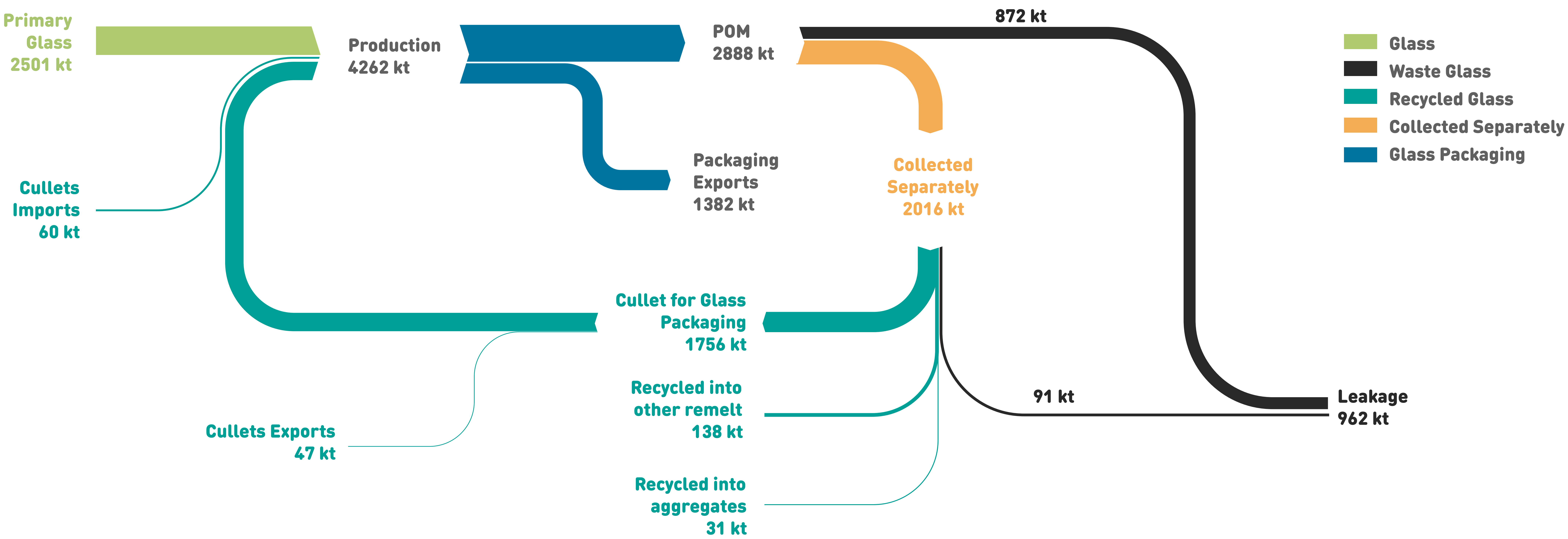
85% of household glass packaging waste is collected at bring banks, with around 200,000 collection points in use. The remaining 15% is collected door-to-door. Glass is generally collected in one mixed colour stream, with just 2% of residents served by a co-mingled collection. Data on the specific tonnage from co-mingled collections in France was unavailable; since the proportion of residents receiving such a collection was low and unlikely to have significant influence on the total, the same losses were assumed for all collection methods. 95% of the hollow glass collected goes directly to material recovery – that is, recycling or pre-treatment before recycling. The remaining 5% goes through a sorting facility. There is no existing deposit return scheme (DRS) in France. The bill on Climate Change & Resilience was expected to introduce a DRS for glass packaging, but the final wording has been criticised as non-committal, with no concrete plans for action in place.

A 2.2 Circularity of Single-Use Glass

In 2019, France produced just over 4.2 Mt of container glass. France is considered a net exporter, exporting almost a third of all container glass it produces. This means 2.9 Mt of container glass were placed on the market (POM) in France in 2019.

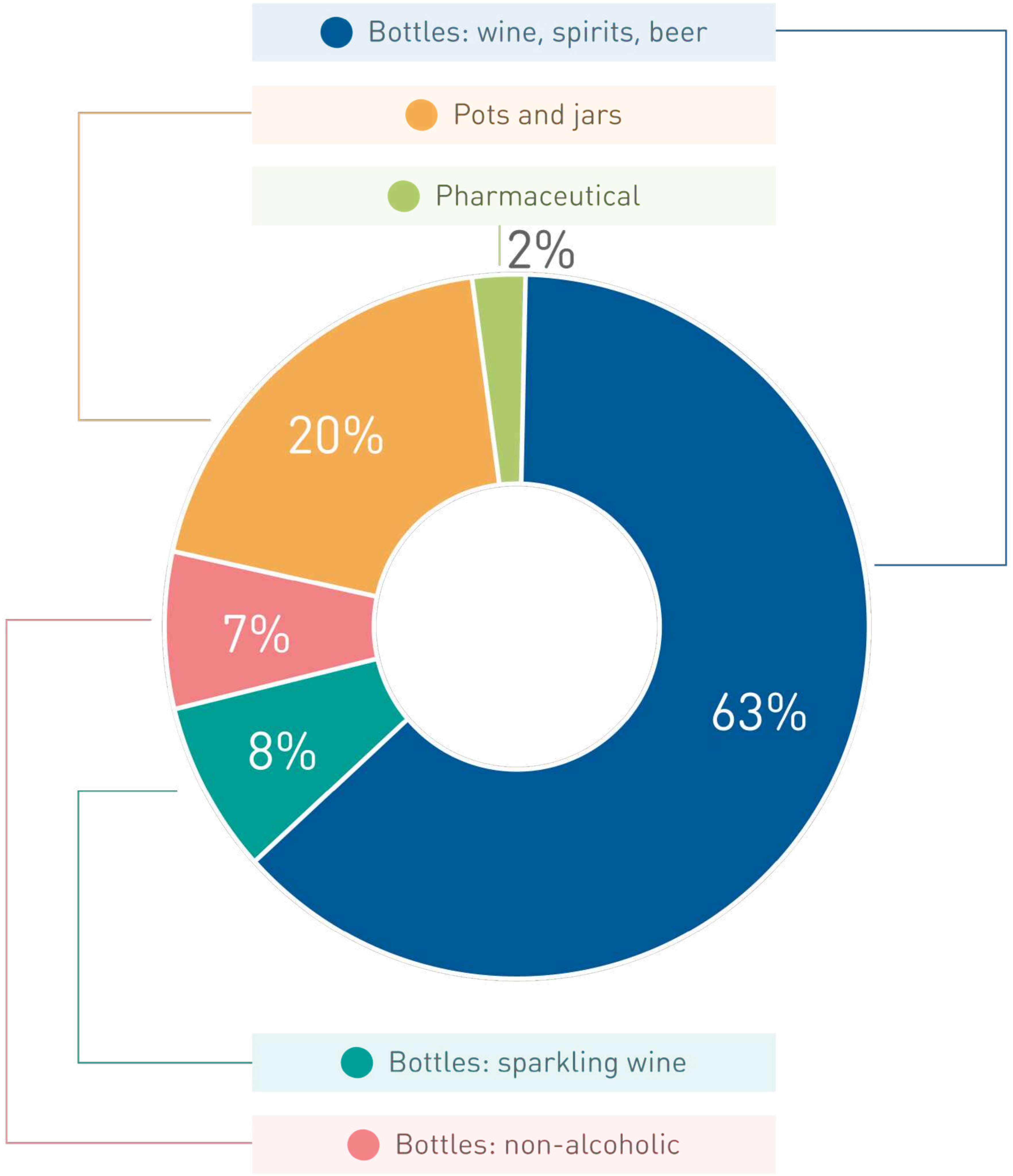
France's collections encompass approximately 2.2 Mt of material, as shown in Figure 19. This includes approximately 2 Mt of glass and 0.2 Mt of contamination (including metals and CSP). This means approximately 70% of container glass material POM is captured in collection systems and 30% is lost from the system, ending up as leakage either in residual waste collections or in the environment.

Figure 19:
Mass flows for Glass Packaging in France, 2019



Source: Eunomia modelling

Figure 20:
Container Glass POM in France, 2018

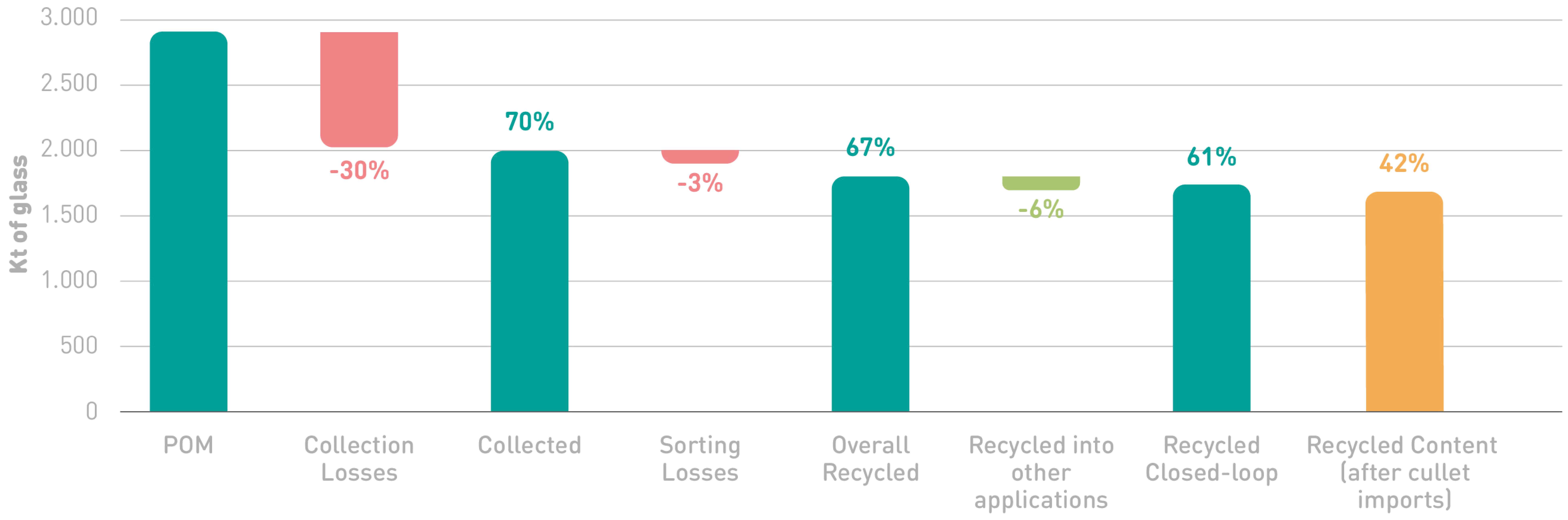


1 Mt of glass waste is collected from household sources, whilst 0.1 Mt is collected from non-household sources. The rate of material collected including contamination (vs POM), which stems from households, is much higher that from non-households at 84% and 20% of the glass POM respectively. In total, approximately 3% of container glass placed on the market is lost in the sorting process. This is mostly lost when glass fines and dust is removed to remove CSP contamination.

In 2019, 1.9 Mt of container glass cullet was available for local recycling applications. 91% of this material was used for closed-loop applications, i.e., manufactured back into container glass. 7% of the recyclate available was used in other remelt applications (e.g., insulation materials) and 2% was used in aggregates (i.e., in the production of cement).

After considering exports and imports, a net additional 0.1 Mt of cullet was imported into France for remelt application into new container glass. This means a total of 1.8 Mt used cullet from used container glass was deployed to produce new container glass. This equates to a recycled content of approximately 42%, when considering the total production of container glass in France. The recycled content is likely higher as the use of cullet from the flat glass industry is not considered in this calculation. Since France exports a high volume of manufactured glass containers, this results in less material on the market available for recycling and so the recycled content is likely to be lower than it could be.

Figure 21:
Recycling and Recycling Content Rates, France, 2019 data



Source: Eunomia's own modelling using available market data

A3.0

United Kingdom

A 3.1 Industry Overview

Glass containers placed on the market in the UK totals 2.5 Mt for 2019.

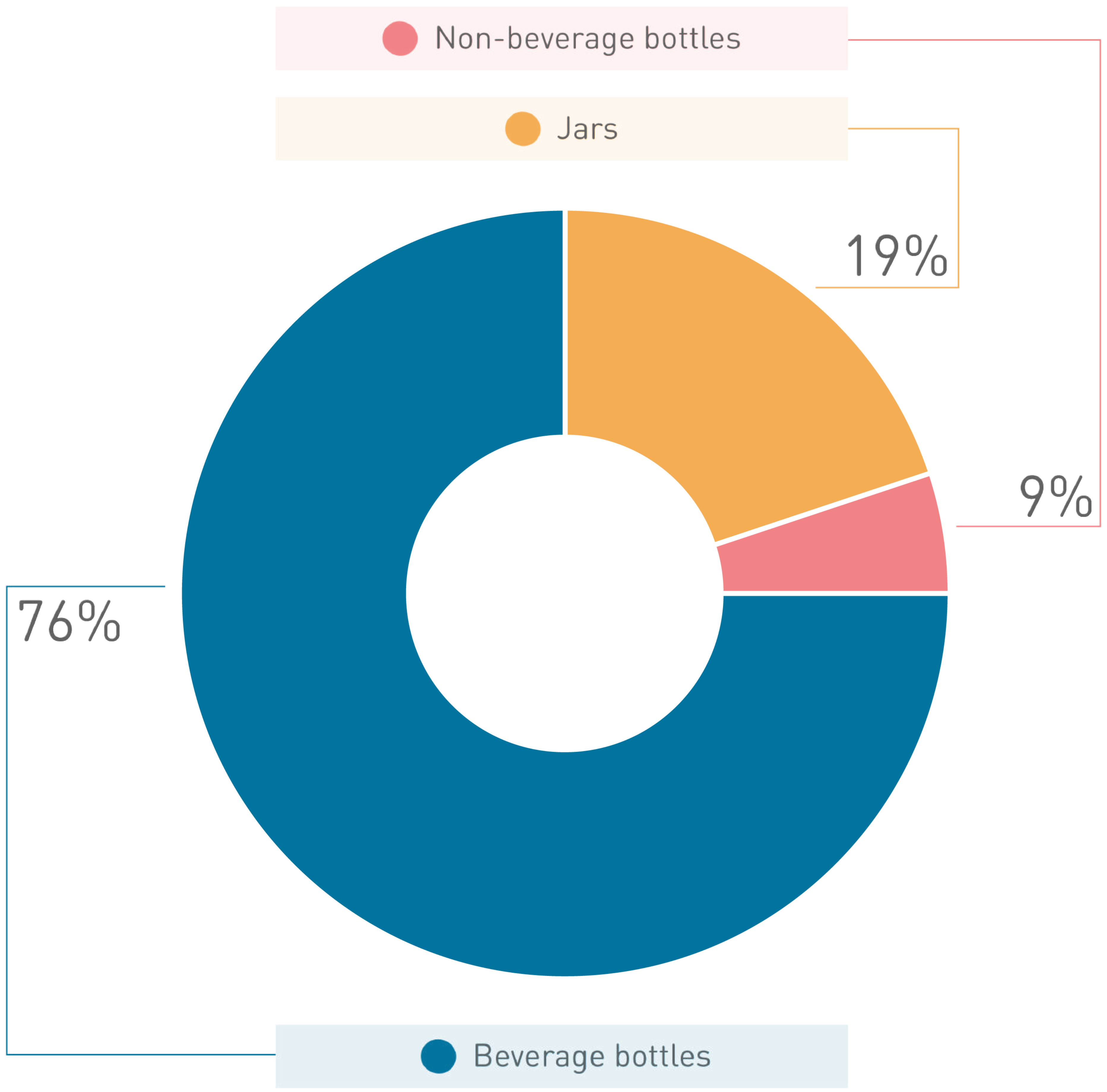
In the UK, glass containers are most (55%) commonly collected door-to-door co-mingled with other materials; however, glass can also be collected door-to-door in a separate stream (32%) or via bring banks (10%) and household recycling centres (3%). Glass collected from households is prepared for reprocessing or recycling at materials recovery facilities operated by the waste collectors and specialist glass reprocessing facilities. Commercial collections have been assumed to be co-mingled. Additional to these collection methods, a DRS is incoming for Scotland in 2023 to include glass beverage bottles. The other nations of the UK – England, Wales and Northern Ireland – are unlikely to introduce a scheme until 2024. Wales will likely include glass, while England and Norther Ireland have plans to not include glass within the scope of DRS.

The UK's recycling is supported by producer responsibility regulations. Obligated packaging recyclers are required to purchase packaging recycling evidence known as packaging waste recovery notes (PRNs) or packaging waste export recovery notes (PERNs). PRNs can be issued at various stages of the supply chain, depending on when it meets EU End of Waste Criteria; this can be either when glass cullet is produced for remelt applications or when it is deemed suitable for other applications, such as road aggregate, concrete products, filtration media or shot blast abrasive. Glass PRNs and PERNs are only issued at the point when the material is no longer waste, meaning it excludes any contamination such as caps, closures and corks.

A 3.2 Circularity of Single-Use Glass

In 2019, the UK produced 2.4 Mt of container glass. The UK is a net importer of container glass, with slightly more (0.1 Mt) imported than exported. It is understood that the UK imports high volumes of green glass due to its consumption of wine and beer from Europe, and exports high volumes of clear glass from its whisky, gin and other spirits industries. This means 2.5 Mt of container glass were placed on the market (POM) in the UK in 2019, of which over three-quarters were beverage bottles (see Figure 22).

Figure 22:
Container Glass POM in the UK, 2019



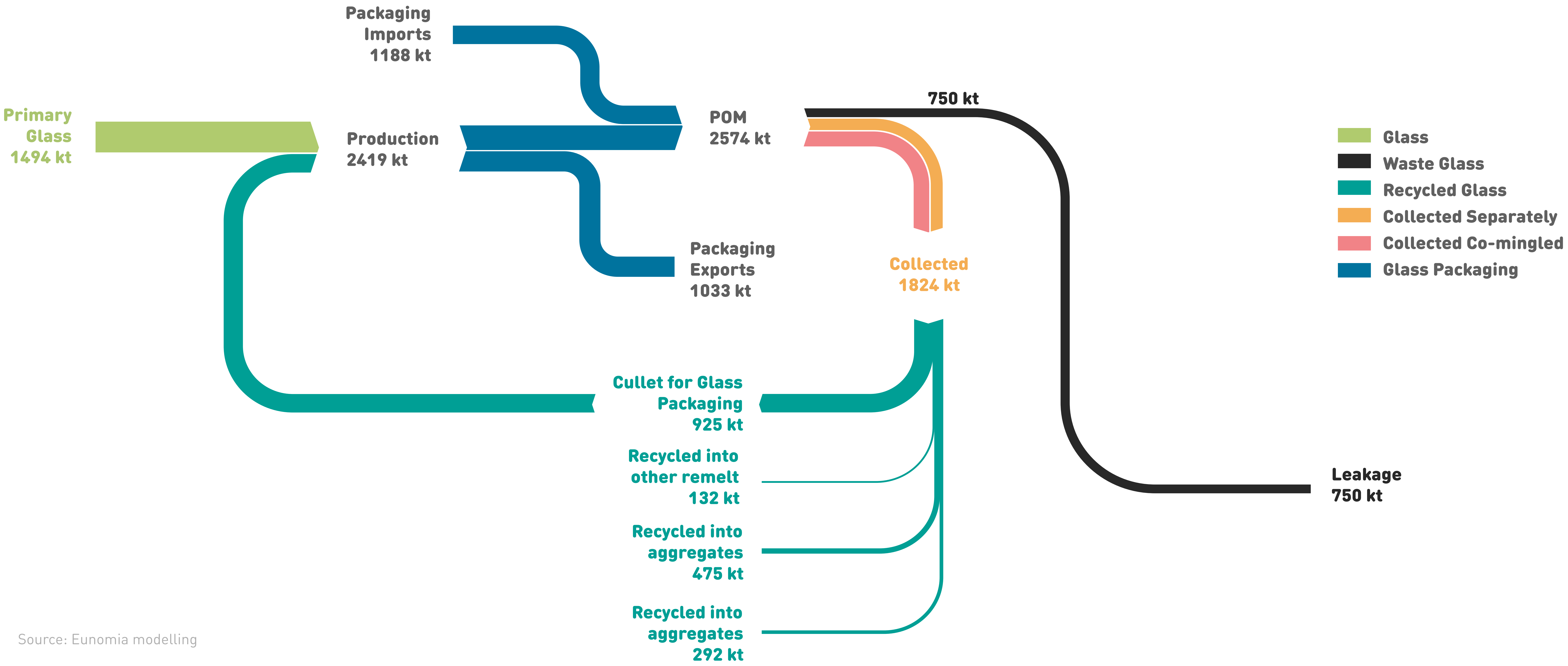
UK's collections encompass approximately 1.8 Mt of material, as shown in Figure 23. This data is taken from the Valpak GlassFlow reports, which are based on PRN and PERN values, and therefore do not include contamination. In the UK sorting losses are not separately reported in available data sources. It is likely that loss of glass is relatively low due to CSP typically being sorted to aggregate use. The remaining potential for loses will be where glass is sorted with other contaminants or in mixed collections, with other packaging items.

Of the 1.8 Mt of glass collected, 0.3 Mt is exported for recycling. This means approximately two-thirds of container glass material POM is captured in collection systems and a third is lost, ending up as leakage either in residual waste collections or in the environment. Approximately 0.5 Mt of material is collected separately, and 1 Mt is collected co-mingled. Commercially collected material is being treated as co-mingled, which has higher associated loss rates; this is so as not to overestimate the recycling coming from commercial streams.

A detailed mass flow of collected material is shown in Figure 24. Data for destinations of glass collected, split by collection method, was not available for the UK. For this reason, likely proportions to destinations from other markets were extrapolated to the UK data. Exports have been equally removed from both co-mingled and separately collected material since there is no market data to suggest an alternative split. Material collected separately is assumed to have a lower rate of loss associated with contamination (e.g. plastic caps and closures) than material collected co-mingled, since there is naturally more non-glass material when glass is collected with other materials like cans, plastics, paper and card. Co-mingled material must be sorted at an MRF before being sent for further sorting and processing. The glass is further crushed and compacted by this process, creating smaller fractions. As a result, a higher proportion of the glass collected co-mingled goes to lower-value applications, since smaller glass fines are not suitable for remelt applications. Of the glass collected via co-mingled collections, the majority goes to be recycled into these non-remelt applications, e.g. fluxing agents, aggregates, decorative cut glass and fine glass material such as sand substitute. In the process of making cullet for remelt applications, some glass fines are removed along with the contaminant CSP. This has not been removed from the mass flow since it is assumed that this glass is recycled with the CSP via the 'other' PRN, i.e. the non-remelt applications listed above.

Figure 23:

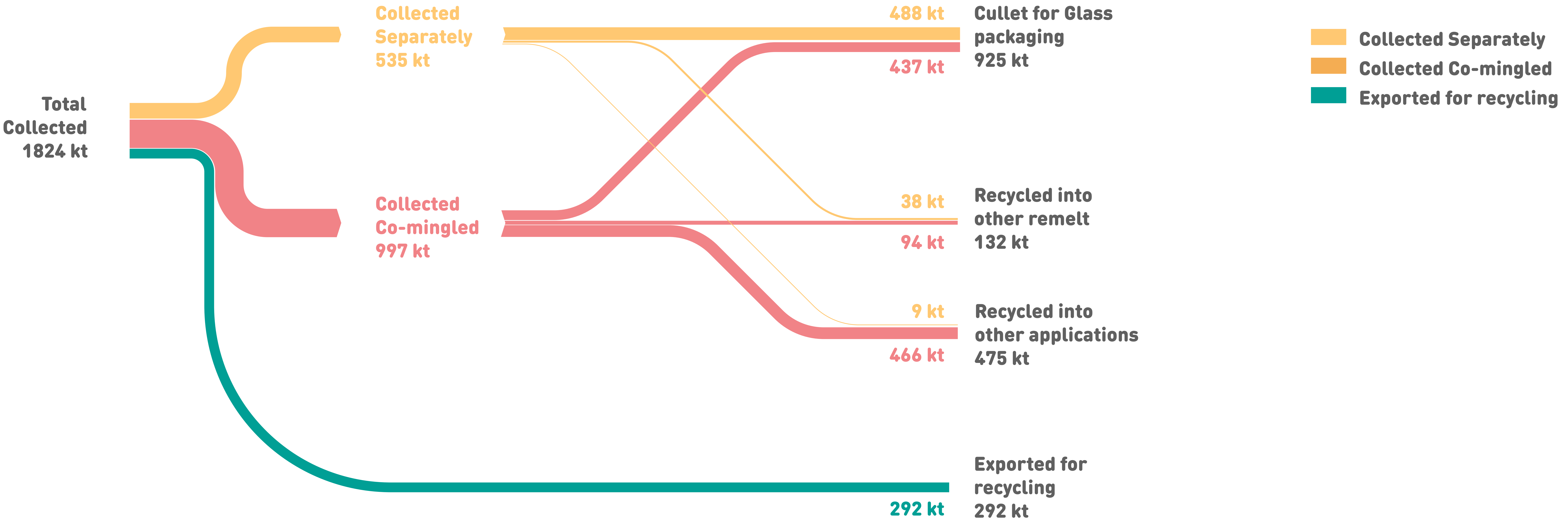
Mass flows for Glass Packaging in the UK, 2019



Source: Eunomia modelling

Figure 24:

Detailed Mass Flow of Glass Packaging Collected for Recycling in the UK, 2019



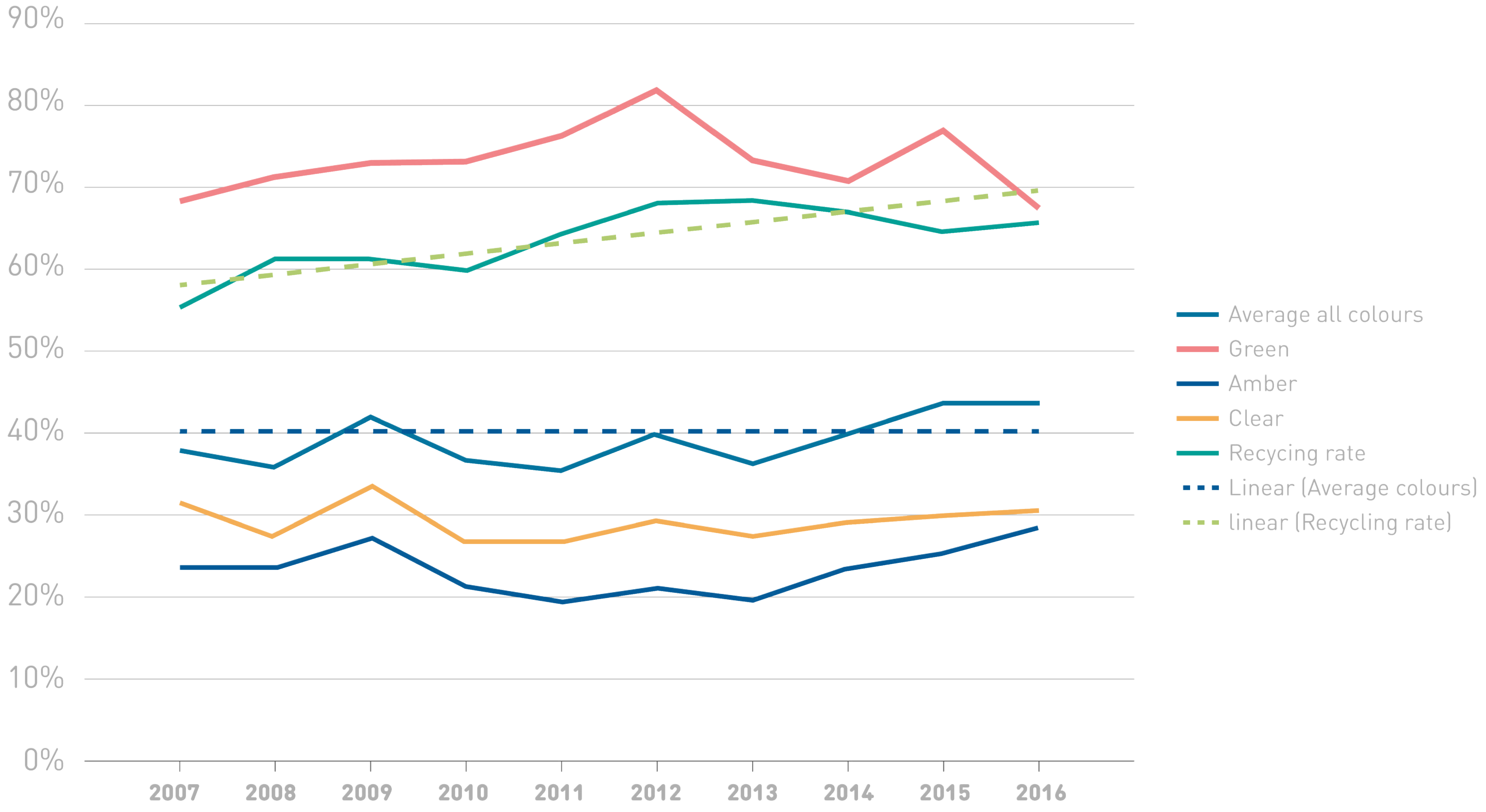
Source: Eunomia modelling

In 2019, 1.5 Mt of container glass cullet was available for local recycling applications and 0.3 Mt was exported for recycling. Of the locally recycled material, 60% was used for closed-loop applications, i.e. manufactured back into container glass, 9% of the recyclate available was used in other remelt applications (e.g. insulation materials) and 31% was used in other applications listed above. It is unclear what recycling end destination the exported cullet might have, and it was allocated using the same factors used in the domestic recycling for the purposes of this study.

There was no data available on exports and imports of glass cullet and so it is assumed that 0.9 Mt of cullet was used in the production of new container glass. This equates to a recycled content of 38% when considering the total production of container glass in the UK. This corroborates data from British Glass, putting the recycled content of UK manufactured glass at an average of 37% for all colours of glass, as shown in Figure 25.

Figure 25:

Recycled Content of UK Manufactured Glass Packaging (2007 - 2016)

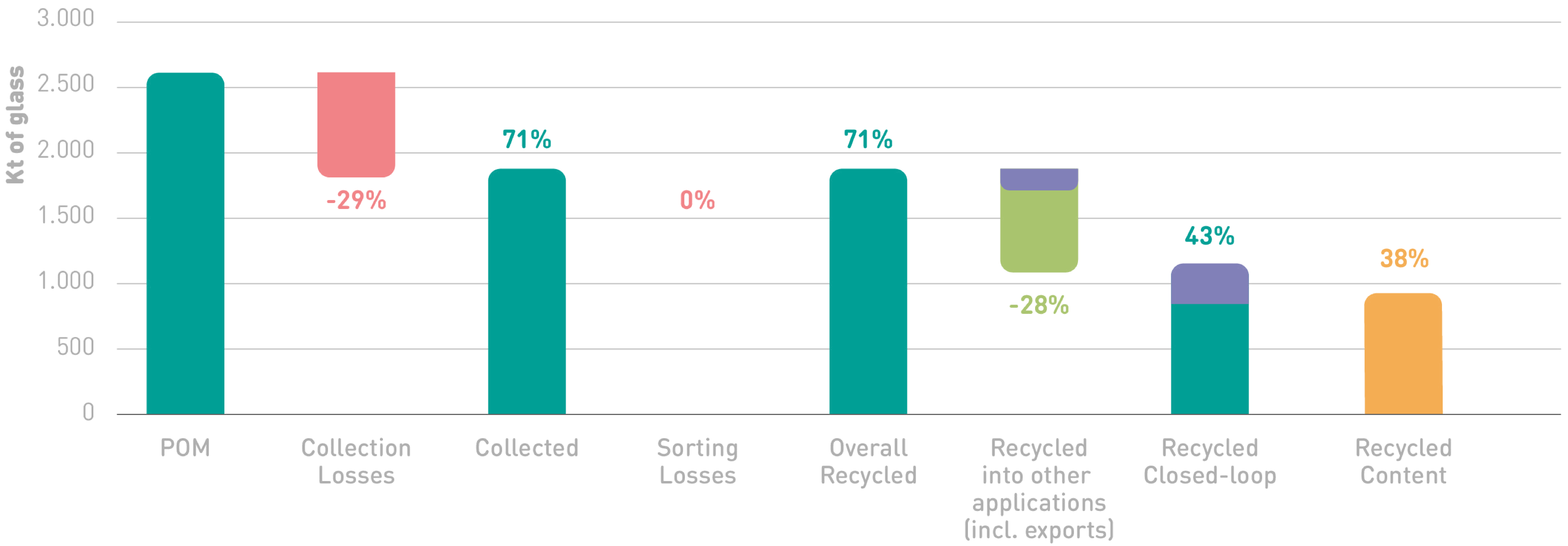


Source: recycled content – British Glass, recycling rates – Eurostat env_waspac

Because the UK is a net importer of glass, more glass is POM than is produced. This means that the recycled content of glass produced in the UK is higher than the closed loop recycling, as shown in Figure 26.

Figure 26:

Detailed Mass Flow of Glass Packaging in the US



Source: Eunomia modelling; purple area depicts assumed recycled cullet after processing of exports

A4.0

United States

A 4.1 Industry Overview

Co-mingled kerbside collection is the most common collection method for households in the US, responsible more than half of the glass captured. The rest of the material is collected through source separated methods such as depots and deposit return systems (DRS). How material is collected influences its subsequent destination, as can be seen in Figure 30. Some of the major post-collection players are described below.

There are 59 secondary glass processing facilities in the US, with 30 glass processing facilities operated by Strategic Materials Inc. Only two other operators own more than one secondary processing plant, Momentum Recycling and Carry all Products (CAP) Glass, each of whom operate two facilities.

There are 42 glass container manufacturers using recycled container glass in the US. Owens-Illinois is the largest player with 16 plants. Ardagh Glass follows with 13 plants, and Anchor Glass is the third player with 6 plants.

There are 41 fibreglass plants using recycled glass containers in their process in the US. The two largest players are Owens-Corning and Johns Manville with 15 and 10 facilities, respectively.

A 4.2 Circularity of Single-Use Glass

There is no federal EPR program for container glass in the United States. Three state legislatures (Maine, Oregon and Hawaii) have recently passed state-wide EPR programs[68]. Maine's and Oregon's governors have both signed these into law, but Hawaii's governor has not yet signed the bill. With no federal regulation, container glass is not collected in a homogenous fashion across states.

There are three main glass collection systems in the United States:

- Kerbside collected;
- Depot (bring site) collected;
- Deposit Return Systems.

There are 10 states with a DRS in place. The other 40 states collect glass through a combination of depots and kerbside recycling programs. Table 7 shows the generation of glass containers in DRS vs non-DRS states.

Table 8:
Glass Placed on Market in US

	Placed on market in Deposit States	Placed on Market in Non-Deposit States	Total Placed on Market
Tonnes	2,793,000	5,781,000	8,574,000

Although only one-fifth of states have a DRS, around one-third of container glass in the US is sold into states which have one. This is because 28% of the US population lives in the 10 states with a DRS in place. Recycling rates in these states are significantly higher on average than those in non-deposit states (see Figure 27).

Figure 27:
Glass Recycling Rate in DRS vs Non-DRS States

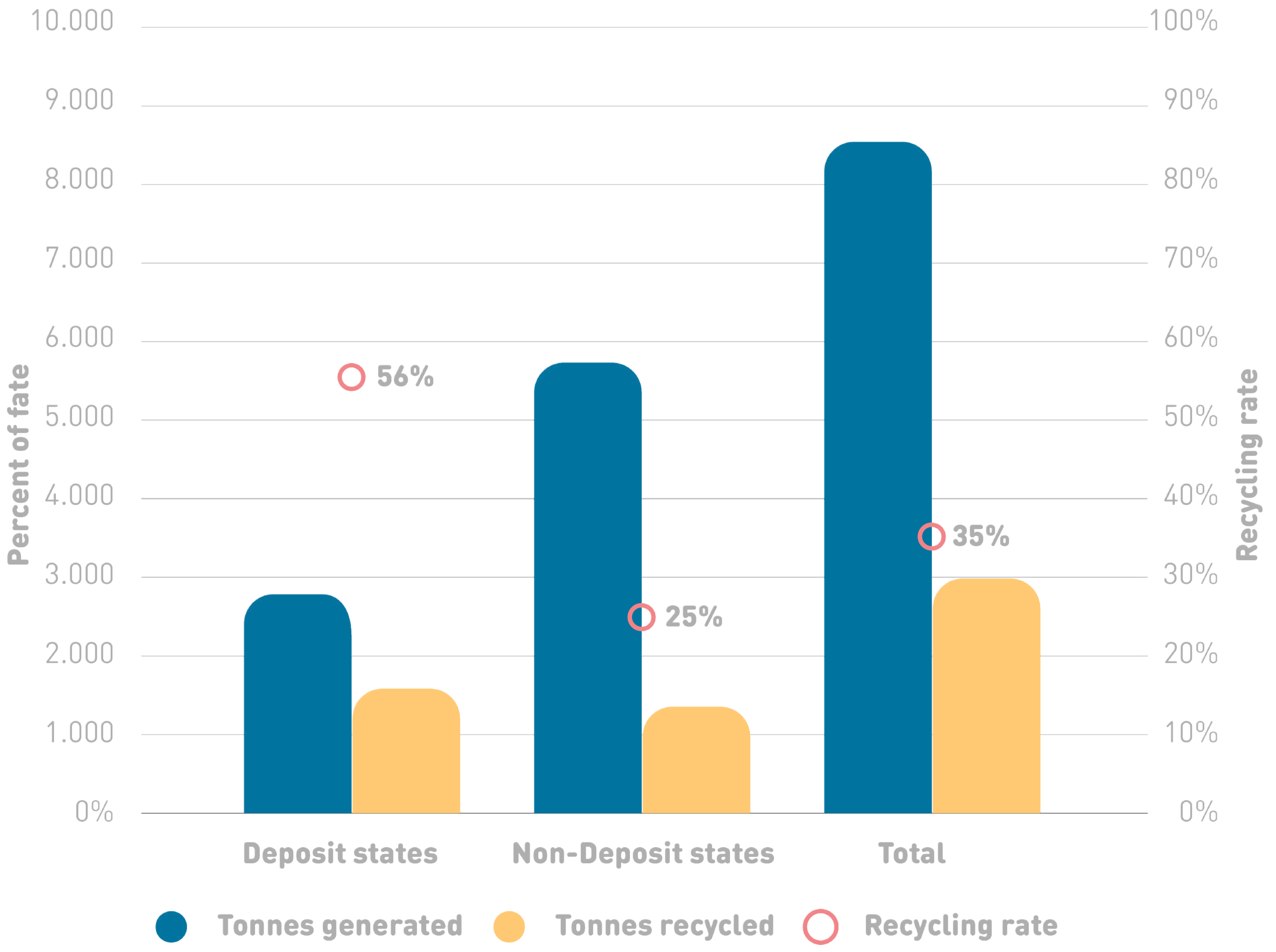
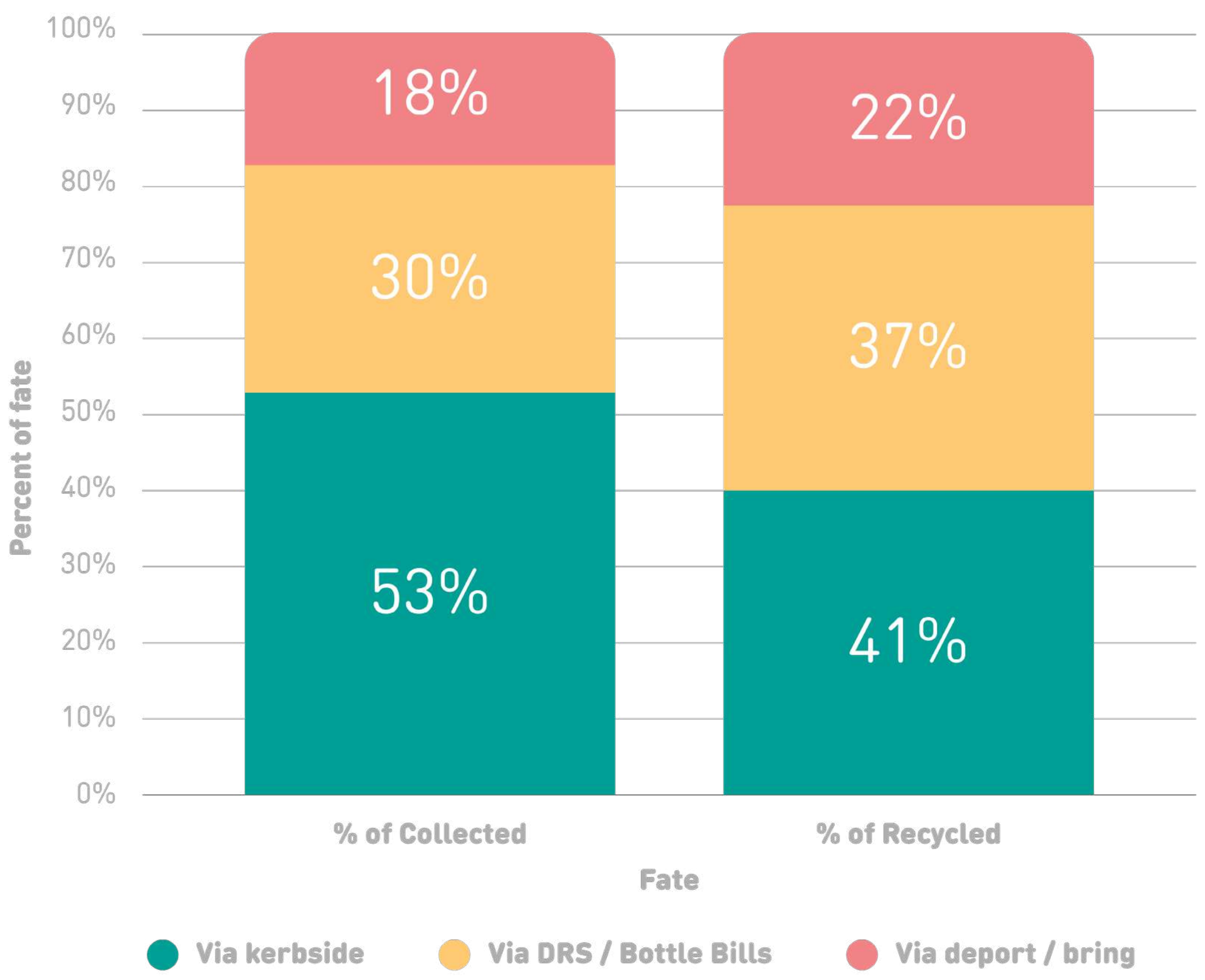


Figure 28:
Characterisation of Collected and Recycled Glass



Eunomia estimates that kerbside collection captures the most container glass at 53%, while DRS programs are responsible for 30%. However, in terms of the source of recycling tonnages, the gap between kerbside and DRS returned containers tightens, at 41% and 37%, respectively. This tightening between the collected and recycled columns is due primarily to a portion of MRF sorted glass ending up in landfills, either disposed or as alternative daily cover.

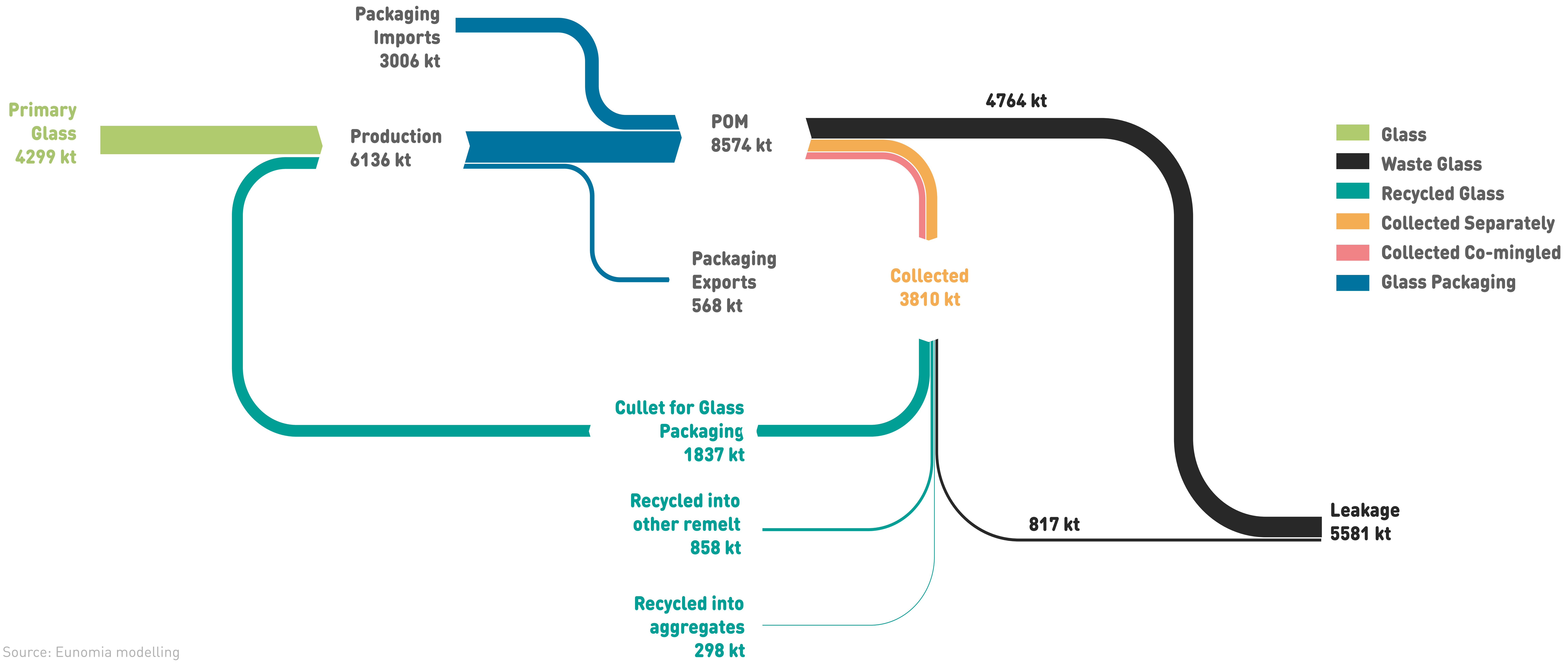
8574kt of glass container packaging is placed on the market in the US annually, 6136kt of which is produced domestically. Of this 8574kt, 3810kt are collected for recycling, while 4764kt are not collected through recycling programs. Of the 3810kt collected for recycling, 1801kt are collected separately from other recyclables, either through depot collection or deposit return systems in 10 states.

After the collection stage, 817kt of glass container material is lost to either sorting losses at material recovery facilities or crushing losses at secondary glass processors. These 817kt of loss, combined with 4764kt of material not collected for recycling, produces a total disposal amount of 5581kt.

Material collected separately is estimated to be more likely to be recycled into new glass packaging. 1364kt (or 75%) of separately collected material is estimated to be turned into new glass packaging. By contrast, 24% of co-mingled collected glass, or 473kt, is estimated to be recycled into new glass packaging. In total, an estimated 1837kt of recycled material is turned into new glass packaging.

20% of separately collected glass, or 346kt, is recycled into other remelt applications, such as insulation. Similarly, 25% of co-mingled collected material, or 512kt, is recycled into other remelt products. Combined, 858kt of recycled glass is processed and sent into remelt applications other than new glass packaging.

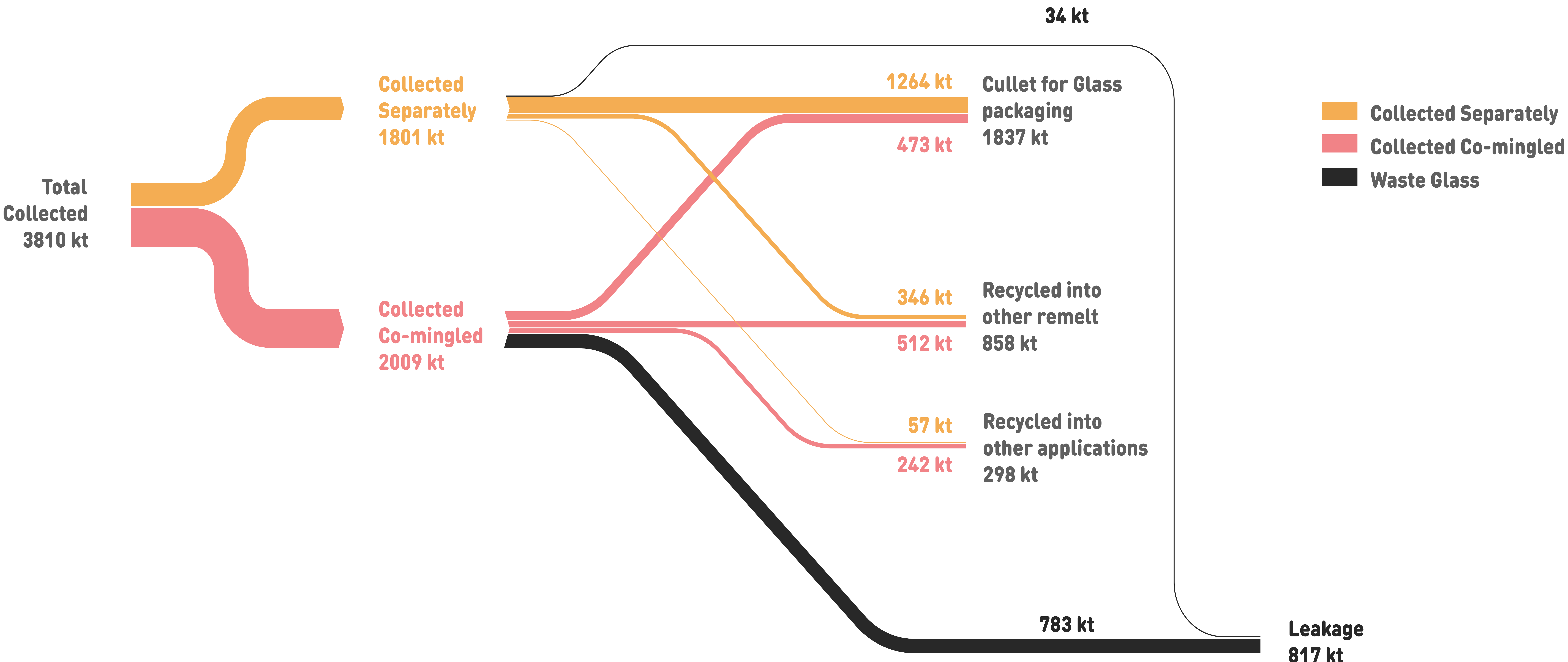
Figure 29:
Mass Flow of Glass Packaging in the US



Source: Eunomia modelling

Figure 30:

Detailed Mass Flow of Glass Packaging in the US



Source: Eunomia modelling

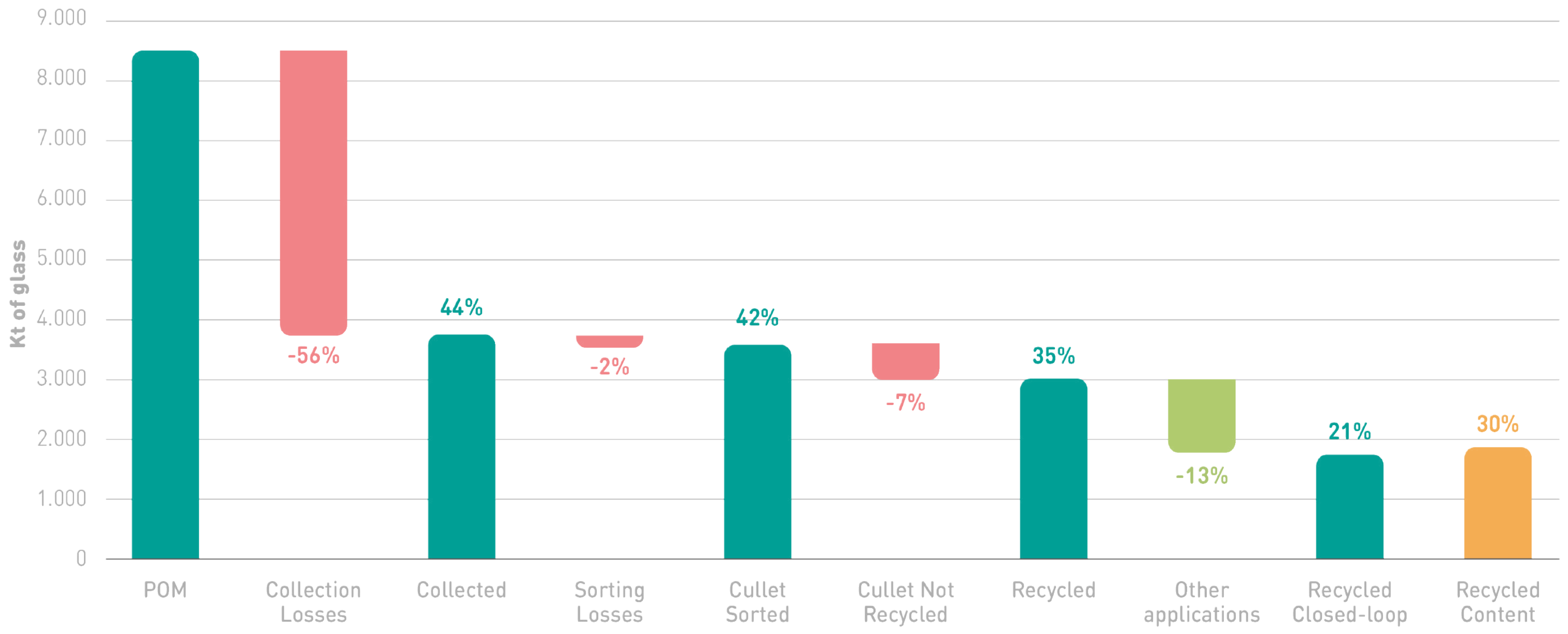
Lastly, 298kt total of collected glass is recycled into aggregate for road use. Only 57kt of this total are from separately collected sources. Co-mingled collected material makes up the majority (81%) of the total. This is sent for aggregate production at both the MRF sorting stage and the secondary processor stage. MRFs in the Northeast and South-eastern US report that 8% and 15% of their sorted glass is sent directly to aggregate, respectively.

Because the US is a net importer of glass containers, three different recycling metrics can be calculated:

1. The overall recycling rate, which divides the total tonnage of recycled glass by the tonnage placed on the market;
2. The closed-loop recycling rate, which divides the tonnage of material recycled into new containers by the tonnage placed on the market;
3. Recycled content rate of domestic production of containers, which divides the tonnage of material recycled into new containers by the tonnage of glass domestically produced.

The results are shown in Figure 31.

Figure 31:
Recycling and Recycling Content Rates, US, 2019 data



The recycled content of domestic production of containers is higher than the closed-loop recycling rate because the denominator for this metric is the domestic total of containers produced (6163kt), rather than the overall tonnage of material placed on the market (8574kt). The placed on market figure includes imports, resulting in a larger figure than domestic production.

Notes

1 COMMISSION IMPLEMENTING DECISION (EU) 2019/ 665 - of 17 April 2019 - amending Decision 2005/ 270/ EC establishing the formats relating to the database system pursuant to European Parliament and Council Directive 94/ 62/ EC on packaging and packaging waste - (notified under document C(2019) 2805)

2 Collection and recycling rates are based on single-use glass packaging placed on the market; recycled content rate is based on production of single-use glass packaging

3 Different packaging materials collected together (e.g. glass collected with paper, plastic and/or metal packaging)

4 Glass collected separately without any other packaging materials

5 Reloop (2020) Global Deposit Book 2020 https://www.reloopplatform.org/wp-content/uploads/2020/12/2020-Global-Deposit-Book-WEB-version-1DEC2020.pdf

6 PALPA, Deposit-Based System https://www.palpa.fi/beverage-container-recycling/deposit-refund-system/#who-pays-for-the-recycling-of-beverage-packages

7 EUROPEAN PARLIAMENT AND COUNCIL DIRECTIVE 94/62/EC- of 20 December 1994- on packaging and packaging waste https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:01994L0062-20150526&from=EN

8 Glass Packaging Institute (GPI), A Circular Future for Glass, https://www.gpi.org/a-circular-future-for-glass

9 Gesetz über das Inverkehrbringen, die Rücknahme und die hochwertige Verwertung von Verpackungen (2017), https://www.verpackungsgesetz.com/wp-content/uploads/gesetz_verpackg_final_fassung_ab_20220101.pdf

10 DEFRA (2022) Extended Producer Responsibility for Packaging, Summary of consultation responses and Government Response https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1063589/epr-consultation-government-response.pdf

11 Ibid.

12 Megale Coelho, P., Corona, B. and Worrell, E., 2020. Reusable vs single-use packaging. A review of environmental impacts. [online] Zero Waste Europe and Reloop. Available at: <https://zerowasteeurope.eu/wp-content/uploads/2020/12/zwe_reloop_report_reusable-vs-single-use-packaging-a-review-of-environmental-impact_en.pdf.pdf_v2.pdf> [Accessed 29 June 2022].

13 Schonert, M., Motz, G., Meckel, H., Detzel, A., Giegrich, J., Ostermayer, A., Schorb, A. and Schmitz, S., 2002. Ökobilanz für Getränkeverpackungen II / Phase 2. [online] Berlin: Umweltbundesamt. Available at: <https://www.umweltbundesamt.de/sites/default/files/medien/publikation/long/2180.pdf> [Accessed 29 June 2022].

14 Megale Coelho, P., Corona, B. and Worrell, E., 2020. Reusable vs single-use packaging. A review of environmental impacts. [online] Zero Waste Europe and Reloop. Available at: <https://zerowasteeurope.eu/wp-content/uploads/2020/12/zwe_reloop_report_reusable-vs-single-use-packaging-a-review-of-environmental-impact_en.pdf.pdf_v2.pdf> [Accessed 29 June 2022].

15 Brogaard, L., Damgaard, A., Jensen, M., Barlaz, M. and Christensen, T., 2014. Evaluation of life cycle inventory data for recycling systems. Resources, Conservation and Recycling, 87, pp.30-45 Brogaard, L., Damgaard, A., Jensen, M., Barlaz, M. and Christensen, T., 2014. Evaluation of life cycle inventory data for recycling systems. Resources, Conservation and Recycling, 87, pp.30-45

16 COMMISSION IMPLEMENTING DECISION (EU) 2019/ 665 - of 17 April 2019 - amending Decision 2005/ 270/ EC establishing the formats relating to the database system pursuant to European Parliament and Council Directive 94/ 62/ EC on packaging and packaging waste - (notified under document C(2019) 2805)

17 COMMISSION IMPLEMENTING DECISION (EU) 2019/ 665 - of 17 April 2019 - amending Decision 2005/ 270/ EC establishing the formats relating to the database system pursuant to European Parliament and Council Directive 94/ 62/ EC on packaging and packaging waste - (notified under document C(2019) 2805)

18 Different packaging materials collected together (e.g., glass collected with paper, plastic and/or metal packaging)

19 Glass collected separately without any other packaging materials

20 https://www.reloopplatform.org/wp-content/uploads/2020/12/2020-Global-Deposit-Book-WEB-version-1DEC2020.pdf

21 https://www.palpa.fi/beverage-container-recycling/deposit-refund-system/#who-pays-for-the-recycling-of-beverage-packages

22 Northeast Recycling Council - MRF Glass Survey Report.pdf (nerc.org)

23 https://www.serdc.org/resources/Documents/SERDC%20MRF%20Report%202020%20Final.pdf

24 https://www.recovery-worldwide.com/en/artikel/glass-recycling-current-market-trends_3248774.html

25 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:01994L0062-20150526&from=EN

26 Glass Packaging Institute (GPI) https://www.gpi.org/a-circular-future-for-glass

27 https://www.verpackungsgesetz.com/wp-content/uploads/gesetz_verpackg_final_fassung_ab_20220101.pdf

28 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1063589/epr-consultation-government-response.pd

29 Ibid.

30 https://www.verpackungsgesetz.com/wp-content/uploads/gesetz_verpackg_final_fassung_ab_20220101.pdf

31 https://www.reloopplatform.org/wp-content/uploads/2020/12/2020-Global-Deposit-Book-WEB-version-1DEC2020.pdf

32 https://www.palpa.fi/beverage-container-recycling/deposit-refund-system/#who-pays-for-the-recycling-of-beverage-packages

33 https://www.glassrecycles.org/industry-tools-1/mrf-glass-certification

34 https://www.reloopplatform.org/reloops-global-deposit-book-2020/

35 Life Cycle Assessment of Beverage Packaging, Brock et al. 2020

36 Examining Material Evidence: The Carbon Fingerprint, Voulvoulis et al. 2020

37 https://www.sciencedirect.com/science/article/pii/B9780123884442000129

38 Best Available Techniques (BAT) Reference Document for the Manufacture of Glass, Scalet et al., 2013

39 https://www.sciencedirect.com/science/article/pii/S2590174521000088

40 https://feve.org/wiegandbmppartnerforgreenerbottle/

41 https://www.bvglas.de/en/detail/news/bv-glas-and-gwi-complete-their-hyglass-project/

42 https://www.sciencedirect.com/science/article/pii/S2590174521000088

43 https://feve.org/about-glass/furnace-for-the-future/

44 https://www.annualreports.com/HostedData/AnnualReportArchive/b/LSE_BVIC_2015.pdf

45 https://www.packworld.com/design/package-design/article/21198535/aluminum-wine-can-for-revelshine-delivers-rugged-luxury

46 https://www.alcircle.com/news/vintage-wine-estates-to-launch-new-wine-beverage-in-aluminium-bottles-47203

47 https://wineindustryadvisor.com/2022/05/16/beyond-the-standard-bottle-wineries-are-embracing-greener-packaging

48 https://www.packworld.com/design/materials-containers/article/13364237/paperboy-paper-wine-bottle-a-us-first

49 Assessment of options for reinforcing the Packaging and Packaging Waste Directive's essential requirements and other measures to reduce the generation of packaging waste: Appendix A - Problem Definition, COWI, October 2021

50 https://glass-catalog.com/eu-en/catalog/details/75cl-bd-preziosa-ts-1#color=G7

51 https://www.beveragedaily.com/Article/2019/10/10/French-gin-manufacturers-prefer-lightweight-bottles-while-cognac-sticks-to-heavyweight-glass

52 https://ec.europa.eu/environment/topics/plastics/single-use-plastics_en

53 https://aluminium-stewardship.org/climate-change

54 https://www.verpackungsgesetz.com/wp-content/uploads/gesetz_verpackg_final_fassung_ab_20220101.pdf

55 https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2021-08-04_texte_116-2021_mehrweggetraenkeverpackungen_2019.pdf, p. 65

56 https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000041553759

57 https://www.legifrance.gouv.fr/loda/id/JORFTEXT000043458675

58 Amienyo, D, Gujba, H, Stichnothe, H & Azapagic, A 2013, 'Life cycle environmental impacts of carbonated soft drinks', International Journal of Life Cycle Assessment, vol. 18, no. 1, pp. 77-92. https://doi.org/10.1007/s11367-012-0459-y

59 Megale Coelho, P., Corona, B. and Worrell, E., 2020. Reusable vs single-use packaging. A review of environmental impacts. [online] Zero Waste Europe and Reloop. Available at: <https://zerowasteeurope.eu/wp-content/uploads/2020/12/zwe_reloop_report_reusable-vs-single-use-packaging-a-review-of-environmental-impact_en.pdf.pdf_v2.pdf> [Accessed 29 June 2022].

60 Schonert, M., Motz, G., Meckel, H., Detzel, A., Giegrich, J., Ostermayer, A., Schorb, A. and Schmitz, S., 2002. Ökobilanz für Getränkeverpackungen II / Phase 2. [online] Berlin: Umweltbundesamt. Available at: <https://www.umweltbundesamt.de/sites/default/files/medien/publikation/long/2180.pdf> [Accessed 29 June 2022].

61 Megale Coelho, P., Corona, B. and Worrell, E., 2020. Reusable vs single-use packaging. A review of environmental impacts. [online] Zero Waste Europe and Reloop. Available at: <https://zerowasteeurope.eu/wp-content/uploads/2020/12/zwe_reloop_report_reusable-vs-single-use-packaging-a-review-of-environmental-impact_en.pdf.pdf_v2.pdf> [Accessed 29 June 2022].

62 Zero Waste Europe, Deutsche Umwelthilfe, We Choose Reuse and #GetBack, 2022. The need to set essential criteria for setting up managed pool systems. Policy Briefing. [online] Available at: <https://zerowasteeurope.eu/wp-content/uploads/2022/05/ZWE_-Pool-Systems-Policy-Briefing.docx.pdf> [Accessed 28 June 2022].

63 GVM, 2019. Marktanalyse Individual-Mehrwegflaschen für Bier, Wässer und Erfrischungsgetränke. [online] Mainz: BGVZ Bund Getränkeverpackungen der Zukunft GbR. Available at: <https://www.bgvz.de/downloads/pdfs/Bericht-Individual-Mehrwegflaschen_20190513.pdf> [Accessed 25 May 2022].

64 BV Glas, BDE, bvse, 2014. Leitlinie „Qualitätsanforderungen an Glasscherben zum Einsatz in der Behälterglasindustrie" Standardblatt T 120. s.l.:s.n

65 Ibid

66 Ibid

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HOW CIRCULAR IS GLASS?