Quality of recycling: Towards an operational definition

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Quality of Recycling

Towards an operational definition

Qualité de recyclage :

les bases d'une définition opérationnelle

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Abstract

As the quantity of recycling increases, a high quality of recycling is necessary to ensure that secondary raw materials produced are suitable for use in product applications with more demanding requirements, enabling a more circular economy. Defining the concept of "quality of recycling" is the starting point for any assessment of what is meant by 'high quality'. This study develops an operational definition of "quality of recycling", defined as the extent to which, through the recycling chain, the distinct characteristics of the material used within products are preserved or recovered to maximise their potential to be used as secondary raw materials in the circular economy. To enable assessments of quality, the study proposes a set of quality categories for common packaging materials (glass, papers, PET, and HDPE/PP), based on key characteristics of secondary raw materials and sorted packaging outputs that differentiate their suitability for use in manufacturing different types of products.

The definition of quality of recycling and the accompanying framework for quality assessments can be used by a range of organisations to understand the current quality of recycling outputs and track progress towards improving the quality of recycling at the level of an individual plant or a whole recycling chain.

Résumé

Alors que le recyclage augmente en termes de quantité, une qualité élevée de recyclage est nécessaire pour assurer que les matières premières secondaires produites soient aptes à être utilisées dans des applications présentant des exigences plus strictes, afin de rendre possible une économie plus circulaire. Définir le concept de « qualité de recyclage » est le point de départ de toute évaluation de ce que signifie « haute qualité ». Cette étude élabore une définition opérationnelle de la « qualité du recyclage », définie comme la mesure selon laquelle, à travers la chaîne de recyclage, les caractéristiques spécifiques du matériau utilisé dans les produits sont préservées ou récupérées, afin de maximiser son potentiel d'utilisation en tant que matière première secondaire dans l'économie circulaire. Afin de permettre d'évaluer la qualité, l'étude propose un ensemble de catégories de qualité pour les matériaux d'emballage courants (verre, papiers, PET et PEHD/PP), sur la base des caractéristiques clés des matières premières secondaires et des productions d'emballage triés qui se distinguent par leur adéquation à être utilisés dans la fabrication de différents types de produits.

La définition de qualité du recyclage, et le système d'évaluation de la qualité correspondant, peuvent être utilisés par toute une gamme d'organisations, afin de comprendre la qualité actuelle des matières recyclées et de suivre la progression vers l'amélioration de la qualité du recyclage au niveau d'une installation individuelle ou d'une chaîne de recyclage entière.

Executive Summary

Report context

This report has been produced for the Joint Research Centre (JRC) project *Plant level data collection analysis on sorting and recycling of household packaging waste*. The purpose of the project is to support the work of DG JRC in developing knowledge around the quality, quantity and fate of household packaging recycling, by identifying and examining the influence of internal and external drivers and parameters to sorting and recycling plants that receive and process these materials.

The project aimed to:

- Develop a definition of "quality of recycling" for household packaging plants in the EU in relation to dry recycling, plastics, paper and glass plants.
- Understand which factors impact the quality and quantity of recycling outputs, with particular consideration to:
  - material input composition and quality (including collection systems, deposit return scheme arrangements);
  - loss rates and cross-contamination at each process stage and impacting factors;
  - equipment, process and technology;
  - management of plants;
  - product and industry standards; and,
  - commercial and regulatory considerations (market impacts and PRO arrangements).

The project's findings will ultimately inform the formulation of operationally and commercially viable measures to increase both the quantity and quality of household packaging recycling. The implementation of these measures may be across the various sorting plants, processes, technologies and commercial/ regulatory contexts included in the study.

This report develops an operational definition of "quality of recycling" and a framework through which to assess this. As part of this framework, the report proposes an initial set of quality categories for some common packaging materials (glass, paper, PET, and HDPE/PP). These are based on key characteristics of the secondary raw materials and sorted packaging outputs which differentiate the suitability of the recycled output for use in the manufacturing of different products. Sorting and reprocessing plant outputs, whether secondary raw materials or sorted packaging outputs, can be grouped into these proposed quality categories.

A definition of "quality of recycling"

The proposed definition for the 'quality of recycling' is:

'The extent to which, through the recycling chain, the distinct characteristics of the material (the polymer, or the glass, or the paper fibre) are preserved or recovered so as to maximise their potential to be re-used in the circular economy.'

These characteristics vary by material but may include for example food-contact suitability, structural characteristics (i.e. uniformity and viscosity), clarity and colour form, and odour.

This definition is based on the practical utility of the material in the circular economy, and on easily identifiable characteristics of materials within the recycling chain. As such, it can be used as the basis for an operational approach to assessing the quality of recycling.

Why define quality?

A lack of clarity on what ‘quality’ means is likely to hamper attempts to form policy relating to quality; interpretations could be as disparate as relating to chemical purity, or to environmental benefit.

Higher quality secondary raw materials are necessary for expanding the use of recycled content in broader product applications, enabling a more circular economy. Producers using secondary raw materials frequently raise concerns about the quality of sourced material. Particularly for plastics, the inability to source material of sufficient quality is a key limitation on the amount of secondary raw material that can be utilised.

Whereas recycling keeps resources in circulation within the material economy; *high quality* recycling preserves the characteristics of materials which make them most useful (avoiding the loss of material characteristics relevant to its re-use in key product sectors). A definition framed in this way would give grounding to a renewed policy focus on assessing and improving the quality of recycling output by a whole recycling chain. It would therefore also help to ensure that measures taken with the aim of improving quality actually result in a greater level of resource circularity.

Finally, the definition allows for the quality of recycling to be assessed independently of related concepts such as material value and environmental benefit (although higher quality recycling will often have a higher sale value and an improved environmental benefit, this is not always the case).

An operational definition

It is important that the definition is ‘operational’, meaning that it can be practically applied in assessing the quality of material at stages throughout the recycling chain.

At the upper end of the achievable quality spectrum, secondary raw materials will have comparable characteristics to virgin material. In practice, the qualities reprocessors aim for depend on the specifications stipulated by users of secondary raw materials, and quality is judged by the *sufficiency* of a material for a particular remanufacturing processes.

The proposed definition equates higher quality recycling with practical increased utility of a material in the circular economy. Given this context, assessments of quality ought to be based on the standards and specifications for secondary raw materials which detail their suitability for use in given applications. This approach requires minimal additional analysis since existing gradings and classifications are currently measured in practice. Complementary assessments can also be conducted on the actual circularity of product uses, and the extent to which a material achieves a given degree of circularity.

In order to link the two approaches, a quality assessment framework would require a systematic mapping of product uses by material against output quality specifications.

Quality of sorted outputs and economic framework

The overall aim of implementing standards for the measurement of recycling quality is to ensure that sorted material is *suitable for input to the next stage in the sorting or recycling process that ends with production of a secondary raw material of a certain quality.*

In practice, the suitability of an input for the production of quality secondary raw materials is dependent on the plant's economic balance, as well as the material's characteristics. Measures proposed to increase quality may impact processing costs, revenues for outputs and costs for disposal that occur for a plant. This is turn affects the relative feasibility of measures.

Plants will require a robust business case for the implementation of measures. Where it is likely that costs to a plant will increase, the demand and value of high-quality materials needs to be sufficiently high to cover these.

An operational interpretation of the quality of recycling in terms of the output from a sorting plant could therefore be:

'The suitability of a sorted output for the next stage of the recycling process for that output, within input specifications determined by the economic balance of receiving plants.'

Quality framework

Under the overarching definition of quality, a framework is outlined within which to assess the quality of recycling at different levels as outlined in Table E- 1:

Table E- 1: Levels in the quality assessment framework

Level	**Assessment**	**Data on which to base assessment**
Use of secondary raw materials in products	Circularity of outcomes	Product uses of secondary raw materials
Secondary raw material*	Suitability of plant outputs for applications requiring different qualities of secondary raw materials	Output grades and specifications related to product applications
	Suitability for circular outcomes	
Sorted packaging	Possibility for quality outcomes	Grades and purity levels of sorted material
* Since paper mills use sorted paper outputs directly in production processes, this level of assessment can be conducted on the sorted packaging outputs from paper sorting plants		

The broad quality categories applicable to recycling outputs (the second level of the framework above) of different core packaging materials are summarised below.

Quality Categories within the Framework

For glass, the quality categories proposed (based upon the characteristics required of the secondary raw material) are outlined in Table E- 2.

Table E- 2: Categories of specifications by quality/value (glass cullet)

Category	Quality/Value Dimensions	Rationale
A	Maintains colour, limits specific contaminants and other physio-chemical glass types	Suitable for input into colour-specific container glass manufacture, fully circular
B	Limits on specific contaminants and other physio-chemical glass types	May be suitable for input into darker colour container glass, or other re-melt markets, or use as abrasive
C	Limits on specific contaminants	Suitable for bespoke non-re-melt applications (i.e. water filtration)
D	Limits on overall contaminants	Suitable for some non-re-melt applications, such as use in ceramics or as fluxing agent in brick production
E	Wide tolerance for contaminants	Only suitable for aggregate uses, unlikely to displace virgin material

For papers, the EN643 standard is well developed as an existing classification of paper sorting plant outputs for use in paper mills. The range of grades extracted from household paper collections are relatively limited, and the categories proposed are outlined in Table E- 3.

Table E- 3: Categories of specifications by quality/value (Papers)

Quality Category	Quality/Value Dimensions	Specifications (EN643)	Rationale
A	Maintain fibre characteristics, homogeneity of grade	De-inking grade (1.11) OCC[1] grade (1.04 – 1.05)	Suitable for recycling to the same grade of product Suitable for corrugated cardboard manufacture
B	Mixed fibre characteristics, some variation in grade	Mixed papers (1.02)	Suitable for manufacture of other grades of product (components of corrugated cardboard, tissue manufacture)
C	Mixed fibre characteristics, lower grade fibres	Other fractions not graded to EN643	May yet be suitable for products with less structural fibre requirements

[1] Old corrugated containers/cardboard

The quality categories proposed for PET plastic (based upon the characteristics required of the secondary raw material) are outlined in Table E- 4. For plastics, each quality category is further interpreted into the characteristics firstly of secondary raw materials, and secondly of sorted packaging at any point prior to reprocessing.

Table E- 4: Categories of specifications by quality/value (PET)

Quality Category	Quality/Value Dimensions	Rationale
A	Maintain/preserve intrinsic viscosity (IV), product type, transparency, colour; and food contact suitability	Preserves colour separation and suitable for use in the production of the same food-contact items
B	Maintain/preserve IV, product type, transparency, and colour	Preserves colour separation and suitable for use in colour-specific non-food-contact uses requiring high purity flake
C	Maintain/preserve IV, product type	Mixed colour bottle flake can be used for non-colour-sensitive applications that nonetheless require high enough IV (e.g. fibres and strapping). Separated trays can be separately reprocessed with lower losses compared to processing mixed with bottles
D	Other	Mixed, un-colour-separated bottle and tray flake that may need further sorting

Beyond this initial set of quality categories, a more detailed mapping exercise of the specifications required by key product uses for HDPE, PP and LDPE secondary raw materials would be necessary to further refine the quality categories. This is due to the variation in grades of polyolefin polymers used in different products.

For each material, a supplementary framework is presented which classifies end markets against three criteria: the quality of the secondary raw material output (as above); the extent to which the end use displaces virgin material; and the onward recyclability of the product. These are combined into initial suggestions for a singular circular economy hierarchy of end uses for each material type, though more work is required to develop these.

Using the framework

The quality definition and framework developed by this study are intended for operational use, as an approach to practically measuring the quality of recycling alongside the quantity of recycling. It has potential applications by different actors for a range of strategic and/or operational contexts. These uses include:

- Assessing the current quality of recycling outputs;
- Tracking change in qualities produced; and
- Assessing the quality benefit from changes to recycling outputs.

Assessments can be made at different levels for different purposes:

- By plant operators or waste management companies to use as a performance metric (alongside recycling rate), thus tracking the impact of changes on the quality of outputs, and defining the quality impact of their sorting and reprocessing operations.
- By municipalities or producer responsibility organisations (PROs) contracting sorting plants to assess the quality of outputs produced for determination of further sorting needs; specify output grades within different quality categories to be produced; and/or differentiate payment by quality category (aligned with any strategy for increasing output qualities at a whole system level).
- By PROs by way of administering Extended Producer Responsibility (EPR) schemes, or regional/national governments to quantify the overall quality of packaging recycling output, track changes in quality resulting from interventions, support or development of local or national markets, and use as a basis for targeting specific quality improvements.

The use of the definition and framework in guiding measures and interventions for improving quality will initially require the identification of improvements desired in the quality bands for each material.

Whilst the selection of output grades and qualities by sorters and reprocessors is generally governed by what is economically achievable in the context of market prices and the consistency of demand for different output materials, there is scope for PROs to have an impact in helping to ensure that quality improvements are made where these are currently economically marginal.

In addition, PROs and regional/national authorities could also take a longer-term perspective on strategies for increasing quality of recycling by shifting the economic picture more fundamentally. This may be by targeting research and development to reduce costs; influencing demand for recycled content; developing EPR mechanisms that ensure cost recovery for operators for achieving the desired levels of quality; or supporting the development of higher quality reprocessing routes for specific portions of materials.

Synthèse

Contexte du rapport

Ce rapport a été produit pour le projet du Centre Commun de Recherche (CCR) *Analyse des données recueillies auprès des centres de traitement sur le tri et le recyclage des déchets d'emballage ménagers.* L'objectif du projet est de soutenir le travail du CCR pour développer les connaissances relatives à la qualité, la quantité et la destination des emballages ménagers recyclés, en identifiant et en examinant l'influence des facteurs et des paramètres internes et externes sur les usines de tri et de recyclage, qui reçoivent et traitent ces matériaux.

Le projet avait pour but de :

- Développer une définition de la « qualité du recyclage » pour les usines d'emballages ménagers dans l'UE qui traitent des déchets mixtes ou de plastique, papier et verre.
- Comprendre quels facteurs ont un impact sur la qualité et la quantité des matières recyclées, en prenant particulièrement en compte :
    - La composition et la qualité des matériaux entrants (y compris les systèmes de collecte et les dispositifs de consigne) ;
    - Les taux de perte et de contamination croisée à chaque étape du processus et les facteurs ayant un impact ;
    - Les équipements, processus et technologies ;
    - La gestion des installations ;
    - Les normes relatives au produit ou au secteur, et
    - Les considérations commerciales et réglementaires (impacts sur le marché et dispositions des éco-organismes).

En définitive, les conclusions du projet permettront de définir en connaissance de cause la formulation de mesures viables sur le plan opérationnel et commercial, afin d'augmenter la quantité et la qualité du recyclage des emballages ménagers. Ces mesures pourront être mises en œuvre parmi les diverses usines de tri, processus, technologies et contextes commerciaux/réglementaires inclus dans l'étude.

Ce rapport élabore une définition opérationnelle de la « qualité de recyclage » et un système selon lequel évaluer celle-ci. Dans ce cadre, le rapport propose un ensemble initial de catégories de qualité pour certains matériaux d'emballage courants (verre, papier, PET et PEHD/PP). Celles-ci sont basées sur les caractéristiques clés des matières premières secondaires et des emballages triés qui se distinguent selon leur adéquation à être utilisés dans la fabrication de différents types de produits. Les produits de sortie des usines de tri et de retraitement, qu'il s'agisse de matières premières secondaires ou de déchets d'emballages triés, peuvent être groupés dans ces catégories de qualité proposées.

Une définition de la « qualité de recyclage »

La définition proposée pour la « qualité du recyclage » est :

« La mesure selon laquelle, par le biais de la chaîne de recyclage, les caractéristiques spécifiques du matériau (le polymère, le verre ou la fibre de papier) sont préservées ou récupérées, afin de maximiser leur potentiel de réutilisation dans l'économie circulaire. »

Ces caractéristiques varient entre les matériaux, mais incluent par exemple, l'adaptation au contact alimentaire, les caractéristiques structurelles (c.-à-d. l'uniformité et la viscosité), la clarté et la couleur, et l'odeur.

Cette définition est basée sur l'utilité pratique des matériaux dans l'économie circulaire et sur des caractéristiques facilement identifiables de matériaux dans la chaîne de recyclage. À ce titre, elle peut être utilisée comme base d'une approche opérationnelle pour évaluer la qualité du recyclage.

Pourquoi définir la qualité ?

Un manque de clarté sur ce que signifie la « qualité » serait une entrave à toute tentative de formuler une politique relative à la qualité ; les interprétations pourraient être aussi diverses que la pureté chimique ou les avantages environnementaux.

Des matières premières secondaires de plus haute qualité sont nécessaires pour développer l'utilisation du contenu recyclé dans des applications plus diverses, permettant une économie plus circulaire. Les producteurs qui utilisent fréquemment des matières premières secondaires ont fait part de leurs préoccupations quant à la qualité des matériaux d'origine. En particulier pour ce qui concerne les plastiques, l'incapacité à obtenir des matériaux de qualité suffisante est une limitation clé sur la quantité de matière première secondaire qui peut être utilisée.

Alors que le recyclage maintient les ressources en circulation dans l'économie matérielle, un recyclage *de haute qualité* préserve les caractéristiques des matériaux qui les rendent le plus utile (en évitant la perte des caractéristiques des matériaux pertinentes à leur réutilisation dans les secteurs clés). Une définition structurée de cette manière donnerait un fondement à une orientation stratégique renouvelée pour évaluer et améliorer la qualité de la production recyclée par une chaîne de recyclage tout entière. Par conséquent, il serait également utile de s'assurer que les mesures prises dans le but d'améliorer la qualité aient pour conséquence un niveau plus élevé de circularité des ressources.

Enfin, la définition permet d'évaluer la qualité du recyclage indépendamment des concepts liés à celui-ci, tels que la valeur des matériaux et les avantages environnementaux (bien qu'un recyclage de plus haute qualité aura souvent des débouchés ayant une valeur commerciale plus élevée et des avantages environnementaux supérieurs, ceci n'est pas toujours le cas).

Une définition opérationnelle

Il est important que la définition soit « opérationnelle », ce qui signifie qu'elle puisse être appliquée en pratique pour évaluer la qualité des matériaux aux diverses étapes de la chaîne de recyclage.

À l'extrémité supérieure de l'éventail de qualité réalisable, les matières premières secondaires auront des caractéristiques comparables au matériau vierge. En pratique, les qualités auxquelles le retraitement tente de parvenir dépendent des spécifications stipulées par les utilisateurs de matières premières secondaires et la qualité est jugée par la *suffisance* d'un matériau pour un processus de fabrication particulier.

La définition proposée équivaut à un recyclage de plus haute qualité avec une utilité pratique augmentée d'un matériau dans l'économie circulaire. Dans ce contexte, les évaluations de qualité devraient être basées sur les normes et les spécifications pour les matières premières secondaires, qui détaillent leur aptitude à être utilisées dans des applications données. Cette approche nécessite une analyse supplémentaire minimale étant donné que les catégories et les classifications existantes sont actuellement mesurées en pratique. Des évaluations complémentaires peuvent également être menées sur la circularité réelle des utilisations du produit et dans quelle mesure le matériau atteint un niveau donné de circularité.

Afin de lier les deux approches, un cadre d'évaluation de la qualité nécessiterait une cartographie systématique des utilisations des matériaux par produit, par rapport au cahier des charges sur la qualité des matières recyclées.

Qualité des productions triées et cadre économique

L'objectif global d'une mise en œuvre de normes pour la mesure de la qualité du recyclage est d'assurer que les matériaux triés sont *adaptés à la phase suivante du processus de tri et de recyclage qui se termine par la production d'une matière première secondaire d'une certaine qualité.*

En pratique, l'adéquation d'un intrant pour la production de matières premières secondaires de qualité dépend de l'équilibre économique de l'usine, ainsi que des caractéristiques du matériau. Les mesures proposées pour augmenter la qualité peuvent avoir un impact sur les coûts de traitement, les revenus générés par la production, et les coûts d'élimination survenant dans une usine. Ceci affecte également la faisabilité relative des mesures.

Les usines auront besoin d'une analyse de rentabilité robuste pour la mise en œuvre des mesures. Lorsqu'il est probable que les coûts d'une usine vont être amenés à augmenter, la demande et la valeur des matériaux de haute qualité doivent être assez élevées pour couvrir ces coûts.

Par conséquent, une interprétation opérationnelle de la qualité du recyclage en termes de production d'une usine de tri pourrait être :

« L'adéquation d'une matière triée à être utilisée par l'étape suivante du processus de recyclage pour cette matière, selon les spécifications pour les matériaux entrants déterminées par l'équilibre économique des installations recevant ces matériaux. »

Système de qualité

Sous la définition globale de la qualité, un système est décrit et permet d'évaluer la qualité du recyclage aux différents niveaux, comme décrit dans le Table E- 1 :

Tableau E- 5 : Niveaux dans le cadre d'évaluation de la qualité

Niveau	**Évaluation**	**Données sur lesquelles baser l'évaluation**
Utilisation des matières premières secondaires dans les produits	Circularité (tenant en compte la finalité des matériaux)	Utilisations des matières premières secondaires dans des produits
Matières premières secondaires*	Adéquation des matériaux triés ou recyclés à des applications nécessitant différentes qualités de matières premières secondaires	Catégories et spécifications des extrants par rapport aux applications dans les produits
	Adéquation à une production circulaire	
Emballage trié	Possibilité d'un tri de qualité	Catégories et niveaux de pureté des matériaux triés
* Étant donné que les papeteries utilisent des déchets de papier triés directement dans les processus de production, ce niveau d'évaluation peut être mené sur les matériaux triés issues des usines de tri de papier		

Les diverses catégories de qualité applicables au recyclage (le second niveau du cadre ci-dessus) de différents matériaux d'emballage sont résumés ci-dessous.

Catégories de qualité au sein du système

Pour le verre, les catégories de qualité (basées sur les caractéristiques requises d'une matière première secondaire) sont décrites dans le Table E- 2.

Tableau E- 6 : Catégories de spécifications par qualité/valeur (calcin de verre)

Catégorie	Qualité/Valeur Dimensions	Bien-fondé
A	Maintien de la couleur, limites de contaminants spécifiques et autres types de verre physico-chimique	Adapté comme intrant dans la fabrication de verre d'emballage de couleur spécifique, entièrement circulaire
B	Limites sur des contaminants spécifiques et autres types de verre physico-chimique	Peut être adapté en tant qu'intrant dans des verres d'emballage de couleur plus foncée ou autres marchés de refonte ou utilisé en tant qu'abrasif
C	Limites sur des contaminants spécifiques	Adapté à des applications de non-refonte sur mesure (c.-à-d. filtrage d'eau)
D	Limites sur des contaminants spécifiques	Adapté à des applications de non-refonte, comme l'utilisation dans les céramiques ou en tant qu'agent de fluxage dans la production de briques
E	Large tolérance pour les contaminants	Uniquement adapté pour les utilisations en agrégats, peu de chance de remplacer le

		matériau vierge

Pour les papiers, la norme EN643 est bien développée en tant que classification existante des productions d'usine de tri du papier utilisé dans les papeteries. L'éventail de catégories extraites des collectes de papier ménager est relativement limité et les catégories proposées sont décrites dans le Table E- 3.

Tableau E- 7 : Catégories de spécifications par qualité/valeur (papiers)

Catégorie de qualité	Qualité/Valeur Dimensions	Spécifications (EN643)	Bien-fondé
A	Maintien des caractéristiques des fibres, homogénéité de la catégorie	Catégorie pour désencrage (1.11) Catégorie carton ondulé[2] (1.04 – 1.05)	Adapté au recyclage selon la même catégorie de produit Adapté à la fabrication de carton ondulé
B	Caractéristiques de fibres mélangées, variation de la qualité	Papiers et cartons mêlés (1.02)	Convient à la fabrication d'autres catégories de produits (composants du carton ondulé, fabrication de tissus)
C	Variation élevée dans les fibres	Autres fractions non catégorisées	Pourrait convenir à des produits nécessitant moins de fibres structurelles

Les catégories de qualité proposées pour le plastique PET (basées sur les caractéristiques requises d'une matière première secondaire) sont décrites dans le Table E- 4. Pour les plastiques, chaque catégorie de qualité est davantage interprétée dans les caractéristiques, premièrement des matières premières secondaires et, deuxièmement des emballages triés à n'importe quel moment avant le retraitement.

Tableau E- 8 : Catégories de spécifications par qualité/valeur (PET)

Catégorie de qualité	Qualité/Valeur Dimensions	Bien-fondé
A	Maintenir/Préserver la viscosité intrinsèque (VI), le type de produit, la transparence, la couleur et l'aptitude au contact alimentaire	Préserver la séparation des couleurs et l'aptitude à une utilisation dans la production d'articles similaires pour contact alimentaire
B	Maintenir/Préserver la VI, le type de produit, la transparence et la	Préserver la séparation des couleurs et l'aptitude à une utilisation dans les usages sans contact alimentaire, de couleur spécifique, nécessitant des paillettes de grande pureté

[2] Caisses carton ondulé usagées

	couleur	
C	Maintenir/Préserver la VI, le type de produit	Les paillettes de bouteille de couleurs mélangées peuvent être utilisées pour les applications non sensibles à la couleur, qui nécessitent néanmoins assez de VI (p. ex. fibres et cerclage). Les barquettes séparées peuvent être retraitées séparément avec moins de pertes que lors du traitement de barquettes mélangées avec des bouteilles
D	Autre	Bouteilles non triées par couleur et paillettes de barquette mélangées qui peuvent avoir besoin d'être davantage triées

Au-delà de cet ensemble initial de catégories de qualité, un exercice de cartographie plus détaillé des spécifications requises par les applications clés pour les matières premières secondaires en HDPE, PP et LDPE serait nécessaire pour affiner davantage les catégories de qualité. Ceci est dû à la variation des catégories de polymères polyoléfines utilisés dans différents produits.

Pour chaque matériau, un cadre supplémentaire est présenté pour classifier les marchés finaux par rapport à trois critères : la qualité de la production de matière première secondaire (comme ci-dessus) ; la mesure dans laquelle l'utilisation finale remplace des matériaux vierges ; et la recyclabilité ultérieure du produit. Ceux-ci sont combinés en suggestions initiales pour une hiérarchie unique des utilisations finales selon des critères d'économie circulaire, pour chaque type de matériau ; des travaux plus poussés restent nécessaires pour développer ceux-ci.

Utilisation du système

La définition de la qualité et le système élaborés par cette étude sont destinés à l'utilisation opérationnelle, comme approche pour mesurer en pratique la qualité du recyclage, parallèlement à la quantité de recyclage. Différents acteurs peuvent potentiellement les appliquer dans un éventail de contextes stratégiques et/ou opérationnels. Ceux-ci incluent:

- L'évaluation de la qualité actuelle des productions de matières recyclées ;
- Le suivi de l'évolution de la qualité ; et
- L'évaluation des bénéfices résultant de l'amélioration de la qualité des produits recyclés.

Les évaluations peuvent être faites à différents niveaux pour différents objectifs :

- Par les exploitants d'usine ou les sociétés de gestion des déchets pour les utiliser en tant que mesure de la performance (parallèlement aux taux de recyclage), en suivant ainsi l'impact des changements sur la qualité de la production et en cernant l'impact sur la qualité de leurs opérations de tri et de retraitement.
- Par les municipalités ou les éco-organismes qui passent un accord avec les usines de tri pour évaluer la qualité des matières traitées, afin de déterminer les besoins en tri supplémentaires ; de spécifier différentes catégories de qualité parmi les matières traitées et/ou de différentier le paiement selon les catégories de qualité

(en s’alignant aux stratégies pour augmenter les qualités de retraitement le long de toute la chaîne).

- Par les éco-organismes dans leur gestion des programmes de Responsabilité Élargie des Producteurs (REP) ou par les gouvernements régionaux/nationaux pour évaluer la qualité globale des emballages recyclés, pour suivre les changements dans la qualité à la suite d’interventions, pour soutenir ou développer les marchés locaux ou nationaux et pour les utiliser comme base permettant de cibler des améliorations spécifiques de la qualité.

L'utilisation de la définition et du système dans les mesures d’orientation et d’intervention nécessitera au départ l'identification des améliorations souhaitées dans les catégories de qualité pour chaque matériau.

Alors que la sélection des catégories et des qualités de production par les trieurs et les retraiteurs est généralement soumise à ce qui est commercialement réalisable dans le contexte des prix du marché et de l'homogénéité de la demande pour différents matériaux produits, les éco-organismes peuvent avoir un impact en aidant à s’assurer que les améliorations de qualité soient faites là où celles-ci sont actuellement marginales sur le plan économique.

En outre, les éco-organismes et les autorités régionales/nationales pourraient aussi adopter une perspective à plus long terme relative aux stratégies pour augmenter la qualité du recyclage en modifiant plus fondamentalement la situation économique. Ceci pourrait être fait en ciblant la recherche et le développement afin de réduire les coûts ; en influençant la demande de contenu recyclé ; en développant des mécanismes de REP qui assurent la récupération des coûts pour les exploitants qui atteignent les niveaux souhaités de qualité ou en soutenant le développement de voies de retraitement de plus haute qualité pour des fractions spécifiques de matériaux.

Table of Contents

Table of Contents 19
Glossary 20
1. Introduction 22
2. The quality of recycling 23
2.1. Quality/value of recycling and the circular economy 27
2.1.1. Approaches to assessing quality of recycling of secondary raw materials 29
2.1.2. Quality of recycling of outputs from sorting plants 31
2.2. A framework for assessing quality of recycling 34
3. Classification of quality/value of recycling 36
3.1. Glass 36
3.1.1. Framework based on material specifications 37
3.1.2. Framework based on circularity of product outcomes 38
3.1.3. Illustrative example of increase in quality 39
3.2. Paper 40
3.2.1. Framework based on material specifications 40
3.2.2. Framework based on circularity of product uses 41
3.2.3. Illustrative example of increase in quality 41
3.2.4. Further research needed 41
3.3. Plastics 42
3.3.1. Framework based on material specifications 44
3.3.2. Notes on quality measurement points 52
3.3.3. Framework based upon circularity of product uses 52
3.3.4. Illustrative example of increase in quality 54
3.3.5. Further research needed 55
4. Quality of recycling: existing standards 55
4.1. Quality of recycling: glass 55
4.1.1. Industry standards for sorting plant outputs 55
4.1.2. Industry current practice: glass recycling standards 56
4.2. Quality of recycling: paper 57
4.2.1. Industry standards for sorting plant outputs: EN643 57
4.2.2. Industry current practice: paper recycling standards 58
4.2.3. Quality standards used in the study paper sorting plants 59
4.2.4. Relevance of sorting plant output standards to quality of recycling 60
4.3. Quality of Recycling: plastics 61
4.3.1. Industry reference standards for recycling plant outputs 61
4.3.2. Industry current practice: recycling plant outputs 61
4.3.3. Industry reference standards for sorting plant outputs 61
4.3.4. Industry current practice: sorting plant outputs 64
5. Using the quality framework 68
Appendices 72
A1.1 EN643 Grades 72
A2.1 Other Industry Standards 75

Glossary

Definitions	
Contaminants	Non-target material or chemicals that alter the physical or chemical properties of the secondary raw material.
DRS	Deposit Return Scheme: Collection system in which consumers pay a deposit on products, and get refunded when the product packaging is returned to a collection point.
Impurities	Contaminants or non-target material.
Losses	Losses of target material during sorting or reprocessing
Non-target material	Other material present alongside a target material in an input waste stream to a sorting or recycling plant.
PRO	Producer Responsibility Organisation, Organisation that coordinates the collection and end-of-life management of waste, generally from a specific sector, to fulfil producers' obligations according to regulations on Extended Producer Responsibility (EPR).
Recycling chain	Set of sorting and reprocessing processes up to the point of production of a secondary raw material.
Reject/Reject fraction	Material rejected from sorting processes and not included in process outputs destined for recycling.
Secondary raw material (SRM)	Material that has been sorted and prepared so that it is suitable for use directly in new product manufacture, without further sorting or preparation, (such as a clean, dry polymer flakes, pellets, or compound)
Sorted fraction	A grade of material that has been sorted post collection but has not been sufficiently prepared to be a Secondary Raw Material.
Target material	The material or mix of materials that is targeted by the subsequent sorting or reprocessing operation, i.e. PET bottles in a bale of PET bottles.
Associations and Organisations Referenced	
ARA	Altstoff Recycling Austria, Austrian PRO for packaging
APR	American Plastics Recyclers
CEN	The European Committee for Normalisation
COREPLA	Italian PRO for plastic packaging
DSD	Duales System Deutschland AG, German PRO for packaging, managed by Der Grüne Punkt.
Ecoembes	Spanish PRO for packaging
FERVER	European Federation of Glass Recyclers
PRE	Plastic Recyclers Europe
Materials	
CPET	Crystalline PET
EPS	Expanded Polystyrene
HDPE	High Density Polyethylene
LDPE	Low Density Polyethylene
LLDPE	Linear Low Density Polyethylene
OCC	Old corrugated cardboard
PA	Polyamides (nylon)
PE	Polyethylene
PET	Polyethylene Terephthalate
PET-G	PET with added glycol
PLA	Polylactide, a thermoplastic aliphatic polyester derived from crops
PO - Polyolefins	Collective term for PE and PP thermoplastics

PP	Polypropylene
PS	Polystyrene
PUR	Polyurethane
PVC	Poly-vinyl chloride
Other Terms	
IV	Intrinsic viscosity, a measure of viscosity used for PET
MFI	Melt-flow index, a measure of viscosity used for polyolefins

1. Introduction

This report has been produced for the Joint Research Centre (JRC) project *Plant level data collection analysis on sorting and recycling of household packaging waste.* The aim of the project is to support the work of DG JRC and the Circular Economy and Industrial Leadership Unit in developing knowledge of the drivers and parameters, internal and external to sorting and recycling plants that influence the quality, quantity and fate of household packaging recycling.

The project carried out study visits to 25 recycling plants across 11 EU countries and involved the following number and type of plants:

- 11 plants sorting collected streams of light packaging fractions (various mixtures of dry recycling including plastics only inputs) and sorting out at least one grade of plastic. Some of these plants also conducted some reprocessing operations;
- 2 plants conducting a second sort of specific plastic fractions output from sorting plants (mixed PET and mixed HDPE/PP);
- 8 plants primarily reprocessing sorted plastic fractions into secondary raw materials, whilst also conducting some sorting operations;
- 2 paper sorting plants; and
- 2 glass sorting plants.

Alongside achieving higher recycling rates, it is important to ensure that the recycling is of high quality. Producers using secondary raw materials frequently raise concerns about the quality of sourced material. Particularly for plastics, the inability to source material of sufficient quality is a key limitation on the amount of secondary raw material that can be utilised. This report provides an operational definition of the quality of recycling, to underpin the investigation of the project's key research aims (set out below). It is accompanied by another report 'Analysis of Drivers Impacting Recycling Quality', which provides analysis of the collected data in relation to investigating the project's key research aims.

This study contributes to an operational definition of the quality of recycling that is sufficiently grounded in practice within the industry. It also proposes a framework that can be used in differentiating and assessing the quality of both secondary raw materials and sorting plant outputs, at the level of an individual plant or the whole recycling chain.

Key research aims

The key research aims the project has investigated can be summarised as follows:

- To develop a definition of "quality of recycling" for household packaging plants in the EU in relation to dry recycling, plastics, paper and glass plants.
- To provide clear qualitative and quantitative descriptions of the relevant processes at a representative set of plants.
- To understand which factors impact quality and quantity of recycling outputs, including particular consideration of: material input composition and quality (including collection system, deposit return scheme arrangements); loss rates and cross-contamination at each process stage and impacting factors; equipment, process and technology; management of plants; product and

industry standards; commercial and regulatory considerations (market impacts and PRO arrangements).

- To develop an understanding of which operationally and commercially practicable measures could be implemented in order to increase recycling quantity and quality, for the various sorting plants, processes, technologies and commercial/regulatory contexts included in the study.

The sections in this report cover:

- In the section 'The quality of recycling' (Section 2):
  - An introduction to the quality of recycling concept, covering approaches to assessing the quality of recycling of a) secondary raw materials and b) sorting plant outputs earlier in the recycling chain.
  - An introduction to the proposed framework approach for categorising quality and value in recycling.
- In the section 'Classification of quality and value in recycling' (Section 3), for each main packaging material type:
  - The key dimensions that comprise quality and/or value specific to that material.
  - Classifications of quality and value based on a) grouping of output specifications by quality and value and b) groupings of product uses by circularity.
  - Commentary on data availability and additional research needs.
- In the section 'Quality of recycling: existing standards' (Section 4):
  - A concise overview of existing industry standards applicable to different secondary raw material types.
  - A commentary on current practice (the extent to which these standards are applied and used in practice) based on study plant interviews.
- In the section 'Using the quality framework' (Section 5):
  - A summary of the key potential applications of the framework in assessing quality by different organisations (e.g. plant operators, producer responsibility organisations (PROs), or national governments)

2. The quality of recycling

Any attempt to make progress in answering the study question must start with clarifying what is meant by 'quality of recycling', from both a conceptual and a practical perspective.

The idea of 'quality' for secondary raw materials is captured by two interlinked concepts:

- 'Virgin-like' secondary raw materials – how closely comparable the secondary raw materials from a recycling chain is to the virgin material originally used in the product being recycled. Subsequently, how substitutable the secondary raw materials is for virgin material with little or no detrimental impact on the final product.

- ‘High value’ secondary raw materials – the extent to which secondary raw materials produced is of comparable value to virgin polymer, in terms of value to the user, and associated monetary value.

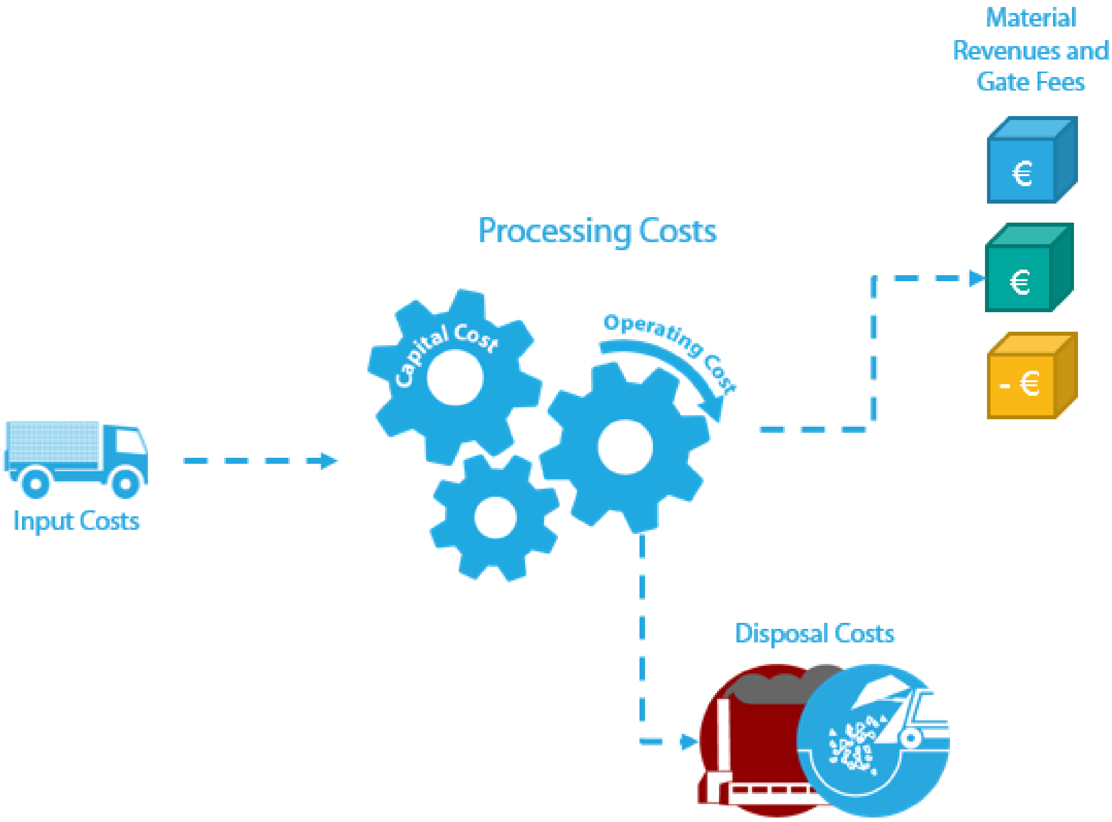
An operational framework for ‘quality of recycling’ also needs to be grounded in economic realities; taking account of the economic context within which collectors, sorters and reprocessors operate. The quality of recycling achieved by sorting plants and reprocessors are strongly influenced by these contexts, which vary depending on the role of the plants in the recycling chain. The achievement of a higher quality of recycling must be made economically practicable if it is to be realised.

Plant operators either buy input material or are paid to process it. Operational costs are incurred in sorting and/or reprocessing the material, including paying off capital investments. Plant operators may sell outputs to offtakers under various arrangements (under contract to a PRO, on the open market, etc), or the ownership of the material may reside with another actor in the recycling chain (i.e. PRO, municipality). Disposal costs will also arise for the reject fraction, which often fall to the plant operator.

Plant costs are further impacted by the amounts of impurities (non-target material and contamination) in the input received. Operators may have to increase processing costs to maintain quality standards. Also, higher amounts of impurities lead to greater amounts of reject material (with associated disposal costs) and lower quantities of saleable output.

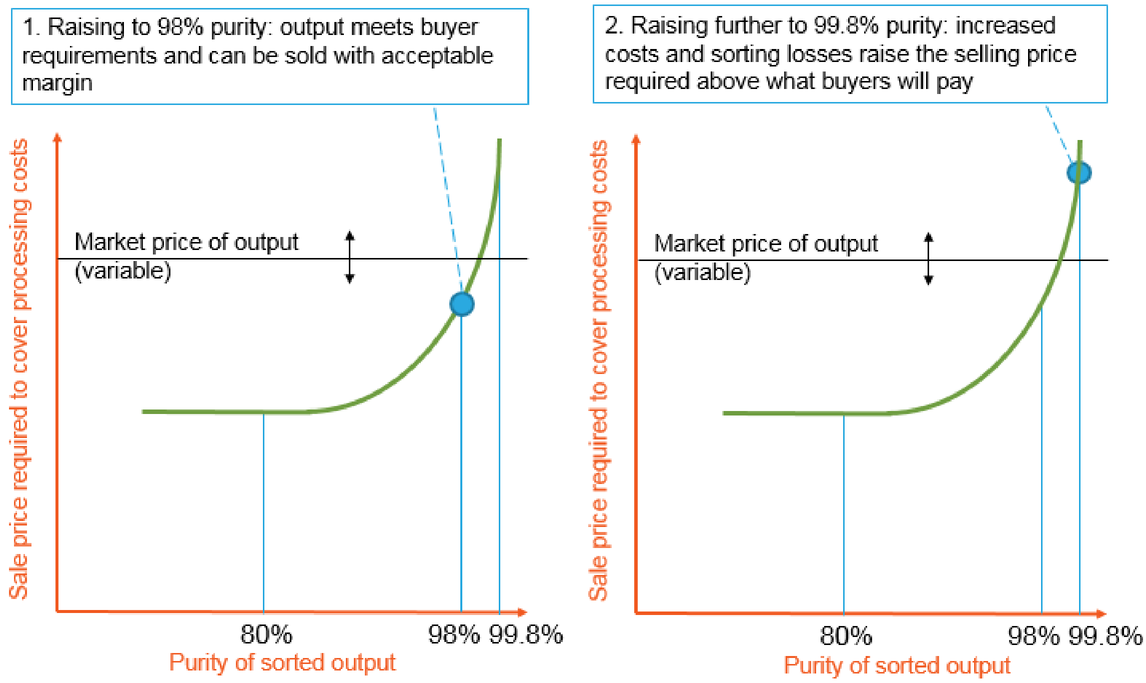
The economic features discussed above are illustrated in Figure 1.

Figure 1: Economic framework for sorting plants and reprocessors



Economic viability is a key consideration for operators of sorting plants and reprocessors if they are to achieve higher quality recycling outputs. The costs of improving the purity of the sorted material fraction - and of increasing the amount of suitable material captured into these fractions - tend to follow a cost curve on which the removal of all or some of the remaining impurities begin incurring considerable costs beyond a certain point. Likewise, the costs associated with capturing a target material for a particular output also increase as you move towards recovering the last fraction of material (through the need to introduce additional sorting steps on reject streams).

Figure 2-2: Illustrative Economic Viability of Producing Higher Quality Sorted Output



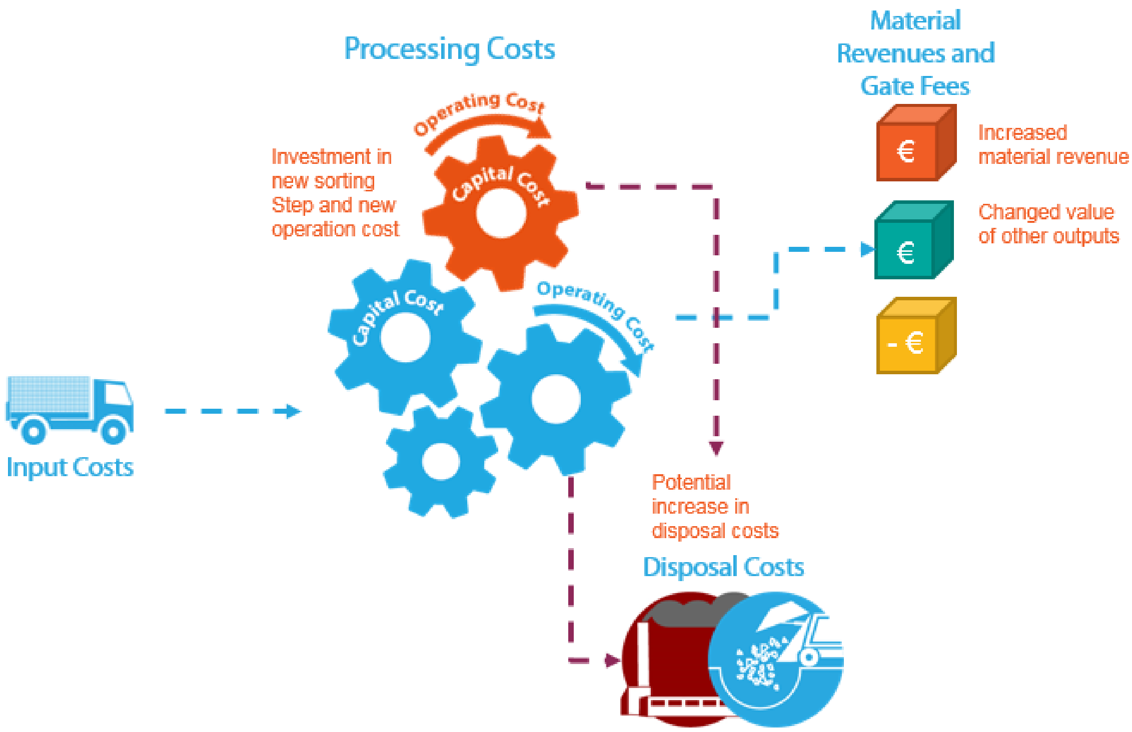
In order to make the additional sorting and/or processing steps economically viable, there needs to be sufficient change in the economic balance. The demand and value received from higher quality material needs to be sufficient to meet increased sorting and/or processing costs and to cover other potential changes in costs, as follows:

- Changes in disposal costs resulting from higher removal of impurities to enable a higher quality output, leading to higher tonnages going to disposal (conversely, increasing the capture of the targeted material reduces the amounts disposed).
- Changing revenues from other sorted fractions, due to how the increased quality affects the composition or level of impurities in other target sorted fractions. For example, separating transparent PET from a mixed colour PET fraction will make the mixed PET fraction darker, which has a lower sales value than lighter coloured mixed PET (with a higher transparent PET content).

Such increased material value would also need to be sufficiently reliable for a plant operator to consider that there is a business case for producing a higher quality output. If quality is required to increase, by changes in legislation or by PROs, then plants would only be able to continue operating if increased costs are balanced out by additional revenues (or a change in payments).

The economics of increasing the quality of outputs at sorting plants and reprocessors are illustrated in Figure 3.

Figure 3: Economics of increasing quality



2.1. Quality/value of recycling and the circular economy

A circular economy is one which minimises raw material inputs to production by preserving the value in material in use within the economy. Representations of a circular economy typically depict concentric cycles of material use where inner cycles represent better outcomes by preserving more of the value of the material in successive uses, and outer cycles involve more processing.

An operational definition for the quality of recycling should therefore be one that supports the circular economy by helping to identify the features of 'quality' or 'value' that can and should be protected during sorting and recycling processes. This aims to maximise the material kept in the inner circular loops. It should be acknowledged that some degree of leakage to outer cycles via other forms of recovery, or to disposal, is always likely.

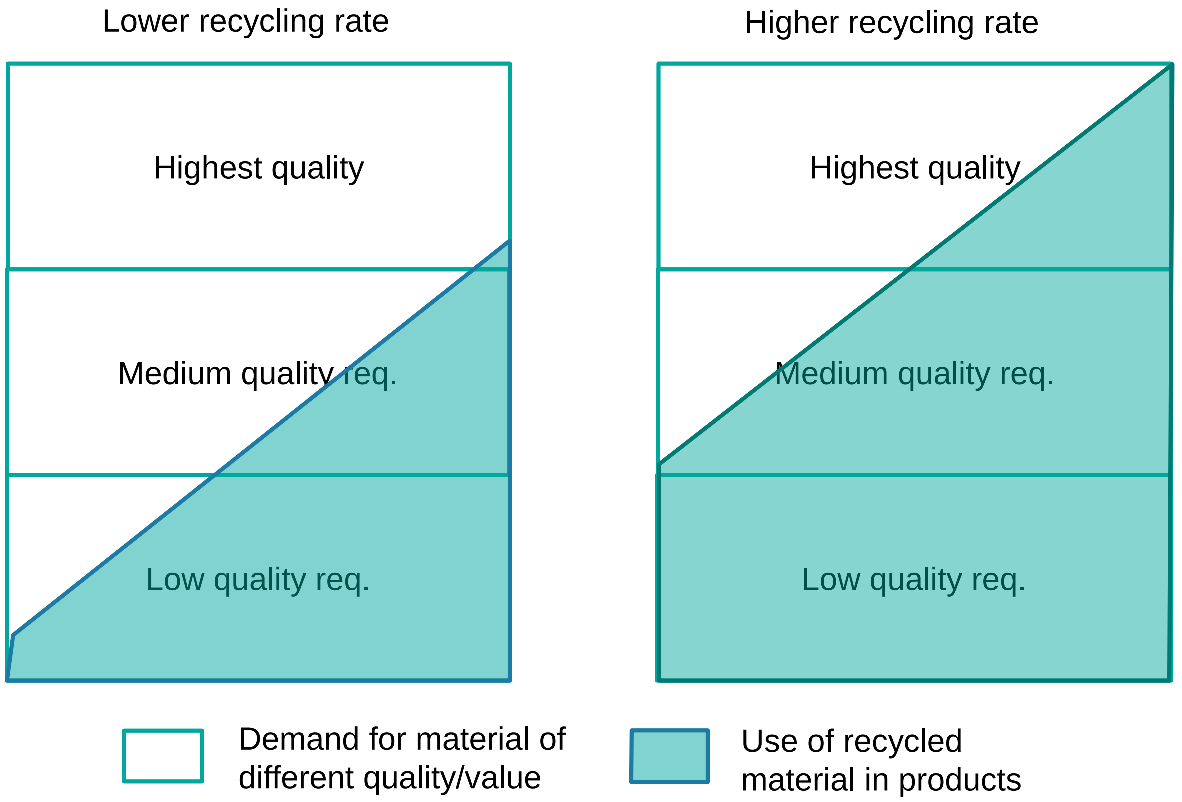
The definition should attempt to move beyond a binary classification such as 'does the material displace virgin polymer demand or does it instead displace demand for an alternative material', to capture these additional dimensions:

- the extent to which properties of the material are preserved that it is unfeasible or costly to recover once lost (e.g. transparency, colourform); and
- the onward recyclability (and length of useful lifetime) of the product made from recycled material.

Considering that virgin material has the highest degree of value, it is likely to be most cost effective at a whole system level to concentrate virgin material input into the system for products with quality specifications most specific to virgin material (i.e. at the top of the quality hierarchy). Secondary raw materials – for which some degradation in quality may have occurred through manufacturing, use, collection and sorting – are more cost-effectively utilised for applications that do not have as demanding requirements, whilst still displacing virgin material use. It is broadly recommended to collect and sort material in a way that preserves value so as to allow the material to be used as high up in the cascade as is practicable.

Moving to higher recycling rates also requires the development of new routes for integrating recycled content into applications, as the demand for recycled content in lower quality applications is by nature limited to a certain proportion of total virgin use. Figure 4 illustrates that, with a higher recycling rate, a greater proportion of secondary raw materials would need to feed into more product applications with higher quality requirements.

Figure 4: Use of recycled content in products at different recycling rates



Increasing recycling rates of packaging material therefore requires *greater* emphasis on preserving the quality of the material embedded in products throughout sorting and recycling processes, in order to facilitate the recycling of material into products in tighter circular economy loops. Understanding the variation in quality of recycling is therefore the first step in developing a systematic approach to analysing how to sustain or improve quality. Sustaining and improving qualities should allow for an increase in uptake of recycled content and the meeting of circular economy objectives.

A suggested definition of 'quality of recycling' is therefore:

'the extent to which, through the recycling chain, the distinct characteristics of the material (the polymer, or the glass, or

the paper fibre) are preserved or recovered so as to maximise their potential to be used as raw materials in the circular economy.'

These characteristics vary by material but may include factors like food-contact suitability, structural characteristics (i.e. uniformity and viscosity), clarity and colour form, and odour.

2.1.1. Approaches to assessing quality of recycling of secondary raw materials

At the point of the production of a secondary raw material, the following concept is widely acknowledged:

A high quality secondary raw material is one that can be used in subsequent manufacturing processes in place of high quality virgin material.

For a secondary raw material to be used in place of virgin material, it would need to meet regulatory standards, such as limitations on substances harmful to health or the environment.

Evidently the *highest* quality of secondary material is one that is 100% constituted of the target material; is free from impurities of any kind (both non-target material and remaining traces of products, inks and other features of the product packaging that physically or chemically contaminate the material); and has comparable material characteristics to the virgin raw material. This is reflected in measurements of quality which typically assess:

- substances that alter the physical or chemical properties of the secondary raw material when manufactured into products;
- substances harmful to health (human or environmental); and
- other non-target materials (which therefore don't typically contribute mass to the secondary raw material).

Any criteria applied to measure quality of recycling is in practice targeted to ensure the quality is *sufficient for particular manufacturing processes*. Where it is intended that the secondary raw material is used in place of virgin material, quality criteria should ensure that the secondary raw material can be effectively substituted to create a product of comparable quality. For instance, where manufacturing processes can use material with certain impurities within tolerances, the judgement of the quality of recycling will relate to these tolerances. If a secondary raw material falls outside of these tolerances then it is not of sufficiently high quality for that process, though it may still be utilisable in other processes. A second key driver for quality specifications, with particular relevance to outputs from sorting plants, is to ensure that the price paid for the material by weight reflects the value of the target material purchased. As a simple example, limits on moisture content ensure the buyer is not paying material prices per tonne for the extra weight of water.

An assessment of quality could therefore be based on suitability for use in a given application or group of applications with similar quality requirements, based on the input specification requirements of different users of secondary raw materials. Different users of secondary raw materials will have different specification requirements for input material, involving quality criteria. The specifications of users of secondary raw materials also tend to be clear measurable standards against which secondary raw materials are currently assessed in practice. Furthermore, the specification of quality by buyers is important in determining the quality aimed at by sorters and reprocessors, since quality will generally be targeted to meet, rather than exceed, the requirements of the buyer. This approach was used in recommending End-of-Waste Criteria for Glass: the proposal for the End-of-Waste criteria was based on a review of existing input specifications.[3] It was developed as a single binary set of criteria, applicable only to glass cullet for 're-melting' – glass cullet sent for recycling in a process that involved re-melting in a glass furnace. For other materials, it may be more appropriate to define a clearer hierarchy of qualities. It should be noted that it may not always be possible to define a linear hierarchy as different uses of secondary raw materials may have varying tolerances for different impurities or characteristics (for instance, for recycled plastics, clarity, odour and mechanical characteristics vary in importance according to the application).

As noted above, operationalising a concept of quality for secondary raw materials should more broadly support a shift towards a more circular resource economy. Quality should therefore distinguish between output uses where the material is kept in tighter loops involving more value preservation, from those where value is lost. A further distinction is the number of successive uses of a material, prior to being lost from use and new virgin material input being required. As such, a second scale for measuring quality of recycling could be based upon descriptions of product uses of secondary raw materials, corresponding to 'tighter' or 'looser' circularity.

In some cases, product uses of secondary raw materials with 'tighter' and 'looser' circularity have differing quality requirements. For instance, PET bottle-to-bottle manufacturing requires higher intrinsic viscosity (IV) recycled PET than for production of film, and higher clarity (lower levels of colour pigment) than for strapping applications. In some applications, secondary raw materials (e.g. plastic flake/pellet or glass cullet) of a higher quality correspond to more circular uses. In other instances, however, some non-recyclable products may have a need for secondary raw materials meeting demanding specifications (i.e. in technical applications). Conversely, some low-grade circular applications, such as some injection-moulded plastic products, may have relatively low quality requirements for secondary raw materials.

Distinctions between quality requirements can be enhanced by legislation, typically to protect the health and safety of product users. A key example is food contact regulations under which plastic recycling processes intended for food-contact uses must be risk-assessed by the EFSA and authorised by the Commission, unless there is a plastic functional barrier between the recycled material and the food.[4] Since the EFSA have not (as of 2019) established criteria for assessing the safety of recycling processes for polymers other than for PET, these regulations effectively limit the use of recycled HDPE, PP and LDPE in food packaging.

In summary, there are two different ways quality of recycling can be understood when material has been prepared as a secondary raw material:

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[3] JRC, IPTS (2011) *End-of-Waste Criteria for Glass Cullet: Technical Proposals*

[4] Commission Regulation (EC) No 282/2008 controls the use of recycled plastic for food contact applications. Article 4 sets out the conditions for the authorisation of recycling processes. The European Food Safety Authority (EFSA) publishes scientific opinion papers evaluating the safety of specific recycling processes, and has also published a paper on the criteria they use for the safety evaluation of a mechanical recycling process to produce rPET, available from http://www.efsa.europa.eu/en/efsajournal/pub/2184.

1. The standards or specifications that the secondary raw material achieves indicating its suitability for use in a given application or group of applications with similar quality requirements.
2. The circularity of product uses and the extent to which a material achieves a given degree of circularity:
    - When assessed on the basis of standards or specifications that the secondary raw material achieves, these standards or specifications would be linked to the capability of the material to achieve a given degree of circularity.

For the first approach, the quality assessment would require a classification and banding/grading of *specifications* according to different quality bands.

For the second approach, the quality assessment would require a classification/banding of *products* according to circularity, and an identification of associated standards/specifications.

In order to link the two approaches, the quality assessment would require a mapping of a secondary raw material's product uses against its associated quality specifications in a more systematic way than has previously carried out.

2.1.2. Quality of recycling of outputs from sorting plants

Prior to the production of a secondary raw material, the concept of quality of recycling can be applied to the output from sorting plants, and is defined similarly to that of secondary raw material itself.

As with secondary raw materials, the highest quality sorted output at any stage is 100% target material free from any impurity, though the target material tends to be defined as a subset of packaging items rather than as a specific material. Quality measurements for sorted outputs tend to identify the levels of problematic materials, including:

- Substances or products that would impact the physical or chemical properties of the secondary raw material produced;
- Substances harmful to health (human or environmental); and
- Other non-target materials (how much of the material is specifically target material, and what other materials are in the mix).

The measurement or distinguishing of quality of recycling through quality standards or specifications is in practice targeted to ensure the sorted material is *suitable for input to the next stage in the sorting or recycling process that ends with production of a secondary raw material of a certain quality.*

The judgement of whether material is of 'sufficient quality' is based largely on what composition of input material subsequent recycling plants are designed to accommodate. This is considered in terms of technical design and quality needs, and also critically from an economic perspective. The price of secondary raw materials is typically bounded by the price of the respective virgin materials, except in some specific circumstances where the secondary raw material is valued higher that virgin. For the economic balance of the plant to be viable, revenues from outputs need to cover cost of input bales, processing costs, disposals costs of rejects, and provide a profit margin for the operator.

Table 2-1: Examples of related reprocessor input material and output secondary raw material quality specifications

	Input to reprocessor, sorted fraction quality standards applied	Output from reprocessor, secondary raw material quality
rPET produced for bottle-to-bottle	>98% PET bottles Minimal tray content Clear, Transparent Sourced from DRS (>95% food contact, low levels of PVC)	High IV Clear, Transparent Suitable for Food Contact Decontamination PVC limit
White rHDPE produced for packaging applications	White opaque HDPE bottles Limit on general impurities	White opaque De-odorised

Later steps in the recycling chain can involve further sorting operations to separate by colour/polymer or to tackle contaminants harder to remove earlier in the recycling chain. Float-sink separation of flake polymers, which cannot be done effectively prior to flaking operations, is one such example. Sorting plants and reprocessors are often technically able to introduce additional sorting or processing steps to adapt for 'lower quality' inputs. Whether implementing these additional steps is viable or not depends on the *economic balance* of the plant, with respect to the balance of cost of inputs, processing costs, revenues for outputs and costs for disposal. Reprocessing plants are set-up to reprocess a specific mix of output grades from input material with a certain composition, and both the technological set up and contract finances relate to an assumed input composition (with some tolerance for variation). If input material falls outside these tolerances it is deemed of insufficient quality for that specific plant, yet may be sufficient quality for another plant with a different process set up and/or economic balance. Therefore, material in an input of insufficient quality for one plant process may yet be sorted and/or reprocessed into high quality output in a different plant. In some cases, some remainder output fractions do not contain sufficient value to be further sorted or reprocessed, and are likely to be either used in lower-value applications or are at risk of being (in the case of plastics and papers) sent for energy recovery. Input specifications therefore relate to:

- Limiting products that are likely to contain substances problematic for quality of secondary raw materials, and that are hard or expensive to sort out subsequently (e.g. opaque PET or PVA in PET recycling, or biodegradable film for PE recycling).
- Ensuring sufficient target material in inputs (i.e. specific material with any colour or product use specification) to fit the economic balance of the plant.

In the paper sector for example, the EN643 standards reflect these aims – sorted paper outputs are marked out as sufficient to go into the next stage in recycling processes. The standards also provide reprocessors with clearer expectations of what input material their plants need to be set up to reprocess (in both process design and economic balance). In practice, paper reprocessors accept deviations from EN643 quality standards for input material where they are able to secure an adequate balance of input material qualities overall.

An operational interpretation of the quality of recycling for any particular output from a sorting plant could be:

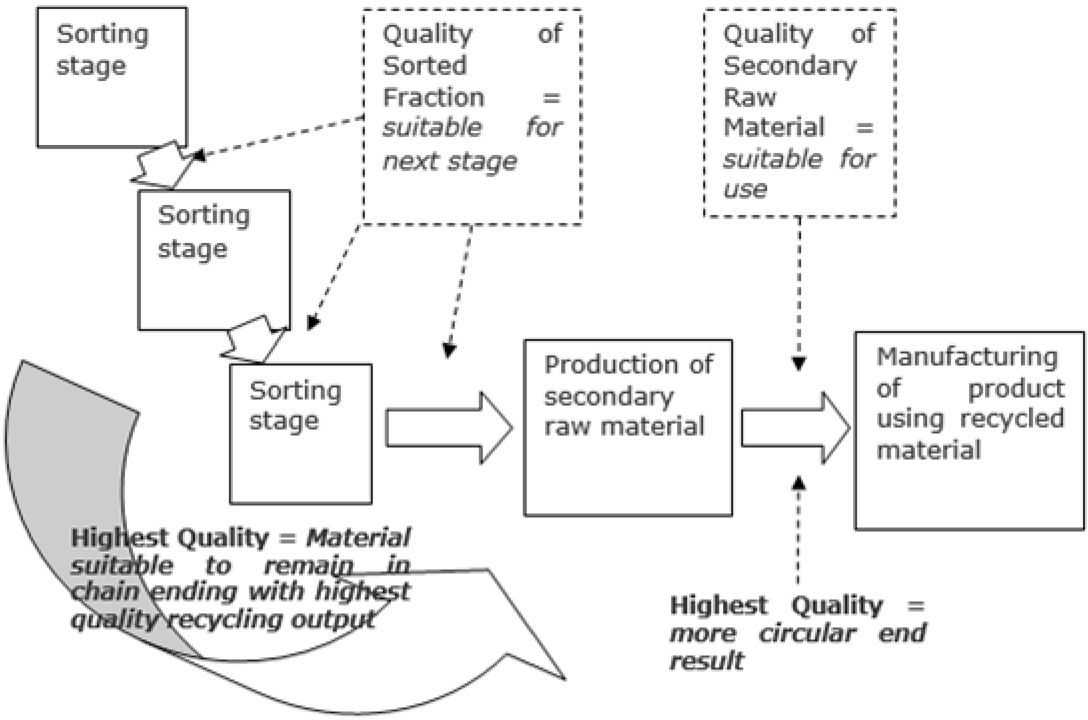
The sorted output produced is suitable for the next stage of the recycling process for that output, within input specifications determined by the economic balance of receiving plants.

As it is possible to distinguish between the different qualities of recycling suitable for different final uses, it may be possible to differentiate between different qualities of output from sorting plants suitable for input to different kinds of plants. High quality sorted outputs will be suitable for applications in the recycling chain which end in higher quality recycling.

In line with the overall definition of quality of recycling in section 2.1, a 'higher quality' set of outputs from a sorting plant would be one that preserves, maintains or recovers the relevant characteristics of the material in sorting. So, in addition to meeting offtaker specifications for outputs that are produced, more degrees of sorting by relevant characteristics (colour, product form, etc) would equate to a higher quality set of outputs. As already noted, plants later in the recycling chain may also conduct further sorting (perhaps more economically than plants earlier in the chain), so this assessment of quality would not necessarily be linked to overall secondary raw material qualities output from the chain.

There are technical components to specifications for sorted outputs that reflect the contaminants that cause technical difficulties and cannot be subsequently sorted out effectively and/or degrade the physical or chemical properties of the material. There are also economic components, reflecting levels of impurities that are possible to clean or remove but which are outside the parameters required by the economic mass balance, including not enough target or valuable materials in the mix.

Figure 5: Diagram of quality of recycling



Considering that specification requirements are related to prevailing economic conditions, an important implication is that quality standards for sorted packaging outputs are not possible to define absolutely, but in the longer term would vary depending on changes in markets and demand for secondary raw materials of different qualities, technological developments, and levels of subsidies, amongst other variables. In the long-term, as conditions improve over time (for instance, new market demand or higher subsidies) the economic balance shifts, and may cause subsequent shifts in the quality standards necessary at earlier points in the recycling chain for the economic balance to work at later stages.

The study also seeks to address the usefulness of establishing standards for outputs from sorting plants, particularly in the context of sorted plastics. Variation in reprocessors' input requirements will reflect variations in plant design, input material composition, regional material mixes, and contract finances, rather than solely being based on output quality. From the definition above it seems reasonable to suggest that the usefulness of any standardised set of quality standards for outputs from sorting plants will depend on:

- How harmonised and uniform the stages in the recycling processes are;
- How harmonised and uniform the economic balance is between plants; and
- The extent to which different sorting outputs (i.e. mixes of packaging materials or levels of impurities) practically determine the end fates of material sent for recycling.

The more the stages in the recycling process are uniform and harmonised, the more similar reprocessors' input specifications (sorting plant output quality requirements) should be, though they are likely to also reflect different economic conditions. A forward-looking quality standard might be based upon input specifications used in those systems that are currently maximising the capture of recycling into more circular outputs, whilst acknowledging that the economic balance would have to be replicated elsewhere in order for these standards to be applicable.

In time, more harmonised sorted output quality standards might be expected to provide clearer expectations across the system, and standardise what earlier sorting plants are designed to achieve in terms of output quality. Unless the economic balances of plants are aligned more precisely to these standardised qualities (which would only happen over the longer term), decisions on what input material to accept and what to output would still be based on specific and varied circumstances in practice.

2.2. A framework for assessing quality of recycling

This section sets out a framework that identifies the options for conducting assessments of the quality/value of recycling at different points in the chain, and sets out the necessary research and analysis tasks for developing this framework further. It looks at three levels of assessing quality:

- The level of use of secondary raw materials in products (how circular are the applications?);
- The level of the output secondary raw material specification:
    - The technical quality of the secondary raw material outputs; and

    - The suitability of secondary raw material outputs for 'more circular' products; and
- The level of sorted packaging outputs (the qualities of the bales of sorted packaging).

For each stage, it sets out:

- What the objective of the assessment is;
- The type of data that needs to be gathered in order to conduct such assessment; and
- The framework against which the results could be assessed.

Table 2-2: Framework for Quality Assessments

Stage	**Sorted Packaging**	**Secondary Raw Material**		**Use in Recycled Product**
Assess:	**Possibility for quality outcomes** Technical feasibility of subsequent recycling routes *Value of output compared to disposal cost*	**Quality of outputs** The suitability of secondary raw material outputs for applications requiring varying 'qualities' or specifications.	**Suitability for circular outcomes** The circularity of recycling	**Circularity of outcomes** The quality and circularity of recycling
Type of Data to Gather:	Quality Standards Levels of key prohibited impurities Target material content	Output Specifications related to sets of product applications with similar quality requirements	Output Specifications related to sets of product applications with similar quality requirements	Product use of recovered raw material by main product group
Assessment Framework:	Tiered quality categories for sorted packaging bales (see relevant tables in section 3)	Tiered groupings of product specifications differentiating quality (see relevant tables in section 3)	Tiered groupings of product specifications corresponding to a circular recycling hierarchy (see relevant tables in section 3)	Tiered product categories corresponding to a circular recycling hierarchy (see relevant tables in section 3)

3. Classification of quality/value of recycling

3.1. Glass

The different properties of glass cullet relevant to quality, value and end destination include:

- Physico-chemical composition;
- Colour;
- Content of impurities; and
- Homogeneity (variation within the given specification).

Container glass is all soda-lime glass. Container glass is among the most versatile glass types (along with flat glass cullet) as it can be used to manufacture a large proportion of all glass products. Glass of other physico-chemical compositions (lead crystal tableware, wired glass, glass ceramics, lamp glass, borosilicate glass) have higher melting points and cannot be used in container glass manufacture.

The colour of glass cannot be recovered: making clear glass products requires clear cullet with low levels of coloured glass, amber glass products can be made from cullet with some green and clear glass, whilst green glass products can be made cullet containing much higher quantities of other colours. Colour separated glass cullet (to clear or to amber cullet) tends to have higher value. Mixed colour cullet can also be used for non-colour-specific products such as insulation wool.

Different contaminants cause different problems for quality, if still present beyond low limits when the cullet goes to re-melt (for a summary of these limits see 4.1.1). Ferrous metals and organics cause unwanted coloration in final glass products. Non-ferrous metals are found to attack and cause defects in the walls and bottom of the glass furnaces, leading to shortened furnace life. Non-metal, non-glass inorganic materials (ceramics, porcelain, stones and pyro-ceramics) cause fatal defects in the final manufactured glass products because they have a higher melting point than glass, which may even lead to health hazards for consumers if the product breaks when used. They are also particularly difficult to sort out.

Glass cullet particle size matters at a certain stage of the sorting process, since colour sorting becomes un-economic at smaller particle sizes. In addition, different manufacturing processes (i.e. container glass vs insulation wool) have tended to have different input cullet particle size requirements, though these requirements may change over time as processes evolve.

Broadly, quality requirements are similar across re-melt applications, though mineral wool manufacturers sometimes can accept higher impurities (e.g. of non-glass, non-metal inorganics) than other glass manufacturing sectors.

The WRAP PAS 102 standard identifies quality requirements of different non-re-melt applications (see section 4.1.1).

Both plants visited in this study produced cullet from container glass primarily for re-melt in new container glass manufacture.

3.1.1. Framework based on material specifications

Table 3-1 shows the features of quality and value that tend to be set by specifications for different end markets.

Table 3-1: End markets for recycled glass and corresponding specifications

Secondary Raw Material Use End Market	Corresponding Specifications
Re-melt for container glass	Physico-chemical, Colour, Limits on contaminants
Re-melt for insulation	Physico-chemical, Limits on contaminants
Decorative applications (tiles/flooring/synthetic marble)	Physico-chemical, Colour, Limits on contaminants
Use as an abrasive	Physico-chemical, Limits on contaminants
Use as water filtration media	No organics, limits on other contaminants
Additive (fluxing agent) in brick and ceramics production	Limits on total contaminants
Aggregate	None

Aside from slightly different tolerances for individual contaminants, there are relatively few grounds for establishing quality between remelt applications in terms of purities and decontaminants. The only key distinguishing feature is the extent of colour preservation or separation. This suggests that, going by output specifications alone, three broad quality categories can be identified as in Table 3-2.

Table 3-2: Categories of specifications by quality/value (glass cullet)

Quality Category	Quality/Value Dimensions	Rationale
A	Maintain colour, limits on specific contaminants and other physico-chemical glass types	Suitable for input into colour-specific container glass manufacture, fully circular
B	Limits on specific contaminants and other physico-chemical glass types	May be suitable for input into darker colour container glass, or other re-melt markets, or use as abrasive
C	Limits on specific contaminants	Suitable for bespoke non-remelt applications (i.e. water filtration).
D	Limits on overall contaminants	Suitable for some non re-melt applications, like use in ceramics or as fluxing agent in brick production
E	Wide tolerance for contaminants	Only suitable for aggregate uses, unlikely to displace virgin material

3.1.2. Framework based on circularity of product outcomes

The specification-based framework above is based on identifying characteristics of the materials preserved in recycling, without regard to the actual end uses of the material in new products. A framework that also takes into account the circularity of end uses (product outcomes) should additionally capture:

- The extent to which the resulting product displaces use of virgin polymer; and
- The onward recyclability of the product.

Product outcomes could therefore be mapped against these three dimensions as in Table 3-3.

Table 3-3: Classifying end markets for glass

Secondary Raw Material Use End Market	Material specification quality/value category as above (A/B/C/D/E see Table 3-2)	Displaces virgin glass production (Y/N)	Onward Recyclability (1 = capable of many recycling loops) (2 = limited additional recycling) (3 = unrecyclable)
Container Glass (Same colour)	A	Y	1
Container Glass (Darker colour)	B	Y	1
Insulation Foam	B	Y	2
Use as abrasive	B	Y	3
Use as water filtration media	C	N – replaces sand	3 (though re-use often viable)
Use in ceramic sanitary ware/as fluxing agent in brick manufacture	D	N – replaces feldspar	3
Use as aggregate	E	N	3

From this mapping, a firmer hierarchy could be created by combining the columns to form a single scale – from preserving value within closed-loop cycles at the top, to low value output to unrecyclable products that don't displace virgin material at the bottom. An initial example of such a hierarchy is set out in Table 3-4. Though the top of this hierarchy is clearly more circular than the bottom, the ordering of the middle levels is somewhat subjective and the 'better outcome' for the material is likely to be best assessed in the context of specific options and counterfactuals with accompanying LCA studies.

Table 3-4: Potential circular economy hierarchy

Secondary Raw Material Use End Market		End markets example
Colour-separated cullet, displacing virgin, into equivalently recyclable product	Maintain colour grade	Container glass of same colour
	Darker colour grade	Container glass darker colour

Colour-separated cullet, displacing virgin, into product of limited recyclability	Maintain colour grade	Glass crafts Tiles/flooring[5]
	Mixed/darker colour grade	Insulation foam
Colour-separated cullet, displacing virgin, into non-recyclable product		Use as abrasive
Cullet, displacing alternative material	Limits of specific contaminants	Use as water filtration media
	No limits on specific contaminants	Use as fluxing agent
Cullet, not displacing virgin material, into limited or unrecyclable product		Use as aggregate New product lines created due to supply of recycled glass

3.1.3. Illustrative example of increase in quality

The glass sorting process involves sorting to remove unwanted material from cullet streams for re-melt, creating a fraction containing high levels of impurities (metals, ceramics etc) but also a high level of glass material blown out by sorting equipment along with the impurities. In this example, the glass sorter implements an additional washing, crushing and drying step to reintegrate target material from that fraction back into container glass outputs. Additionally, the sorting process is adjusted to increase capture into other specific colour grades from the green fraction.

Table 3-5: Resulting change in output qualities in the glass quality framework

Quality Category	Description	Before, % of input material output in grade:	After, % of input material output in grade:
A	Glass output to same colour cullet grade	40%	60% (additional amber sorted fraction)
B	Glass output to lower colour cullet grade	50%	37%
C	n/a	-	-
D	n/a	-	-
n/a (residue	Requires further processing: may in varying	10%	3%

[5] Craft glass and tiling glass applications for recycled glass are listed by for example Camacho Recycling, though use of container glass for these applications may be limited: see http://www.camachorecycling.es/aplicaciones.php

Quality Category	Description	Before, % of input material output in grade:	After, % of input material output in grade:
fraction)	proportions be stored, sold to third party or landfilled		

Changes in the economic model include:

- Increased capital and processing costs from additional colour sort and new line for processing the reject/fines; and
- Higher revenues from both higher quantities of saleable cullet output overall, and higher prices for the additional amber output.

3.2. Paper

Benchmark standards for the quality of recycling of paper and board in relation to sorting plant outputs (and inputs to paper mills) are generally well defined and agreed upon within the European paper industry. This is due largely to the development and adoption of the EN643 standard by the paper processing industry throughout Europe.

However, study findings indicate that within the main EN643 grades, tolerances for undesired material are in practice deviated from depending on the requirements of individual paper mills.

3.2.1. Framework based on material specifications

Recording data on quantities of bales sold into mills broadly corresponding to different EN643 grades (and on sorted quantities that do not meet any EN643 grade standard), should provide a sufficient and practical level of detail on which to base an assessment of quality of recycling. As some EN643 grades are subject to further sorting (e.g. within sorting stages at paper mills), the measurement should ideally be taken at the point at which no further sorting is done and the sorted grade is input into the final recycling process.

An initial proposed categorisation of specifications by quality is set out in Table 3-6.

Table 3-6: Categories of specifications by quality/value (papers)

Quality Category	Quality/Value Dimensions	Specifications (EN643)	Rationale
A	Maintain fibre characteristics, homogeneity of grade	De-inking grade (1.11) OCC[6] grade (1.04 – 1.05)	Suitable for recycling to the same grade of product Suitable for corrugated cardboard manufacture
B	Mixed fibre characteristics, some variation in grade	Mixed papers (1.02)	Suitable for manufacture of other grades of product (components of corrugated cardboard, tissue manufacture)
C	Mixed fibre characteristics, lower grade fibres	Not meeting a specified EN643 grade	May yet be suitable for products with less structural fibre requirements

[6] Old corrugated cardboard

It might be possible to distinguish further by quality within the mixed papers grade B, based on further characterising the nature of the paper mix and levels of unsuitable paper material and non-paper material, and thus the suitability of the output for production of recyclable paper and board grades compared to low fibre strength single-use applications such as tissues and some forms of protective packaging. The quality category 'C' covers any sorted paper outputs that are not graded to any EN643 standard grade. One study plant produced an output fraction not meeting any EN643 standard grade, for offtakers including producers of tissue.

3.2.2. Framework based on circularity of product uses

For the 'outcome' based framework, data would similarly need to be gathered on the use of recycled household paper and cardboard at the point of entry to the final recycling process, but would be categorised by the product or product group made by that recycling process in the mill.

3.2.3. Illustrative example of increase in quality

In this example, a paper sorter chooses to add an additional step to increase capture of material into de-inking grades.

Table 3-7: Resulting change in output qualities in the paper quality framework

Quality Category	Description	Before, % of target material input output in grade:	After, % of target material input output in grade:
A	De-inking and OCC grades	85%	87% (additional de-inking grade recovered)
B	Mixed papers grade	15%	13%
C	n/a	-	-
n/a (reject)		0%	0%

Changes in the economic model include:

- Increased capital and operating costs from adding a recovery step on the mixed papers line to sort additional target material into de-inking grades
- Higher revenues from the higher value de-inking grade (though a potential drop in value of the mixed papers output as de-inking materials is removed, depending on the market for that material)
- There is no change in disposal costs since all materials are output in a sold grade

3.2.4. Further research needed

EN643 grades primarily classify sorting plant outputs. In order to map EN643 grades to products, a clearer mapping is needed between some EN643 grades produced from household recycling streams and inputs to particular paper product manufacturing processes, in particular for different mixed papers outputs. The correspondence between EN643 grade and end use is clearer for higher grade EN643 products (de-inking and OCC grades).

3.3. Plastics

There are a number of reasons why an assessment of recycling quality for plastics is more complex than for paper or glass.

There is wide variation in the different characteristics of plastics required for specific applications (e.g. transparency, flexibility, barrier properties, impact strength, colour). Therefore, there is also variation in quality requirements for secondary raw materials going into different recycled plastic products. The quality requirements specific to secondary raw materials for some product groups are still being understood, as demand for secondary raw materials develops in different sectors. For some products, converter's equipment can be adapted to use secondary raw materials, though without these adaptions the secondary raw material could not be used as a substitute for virgin polymer.

There is a greater variation in the recycling chain: a wide variety of end of use packaging items of different polymers and resins tend to be collected together, and there is a complex and wide variety of different sorting steps employed to separate out these materials to reprocessable grades and to reprocess material into secondary raw materials. The different steps can be concentrated in one plant or spread out over a number of plants and locations. Some plants are more vertically integrated and cover initial sorting to extrusion, while others output different mixes of intermediate sorted packaging or flake. There is additional variation based on whether plastics are collected separately or collected mixed with other materials such as papers and glass.

The quality of an output may not determine its end use, since the material may be subsequently mixed with higher quality material (where the mix is acceptable for the desired quality of the output) and would ultimately go to a higher quality end use. Plants producing flake or extrusion can have multiple different input specifications targeted at material from different sources, aiming to achieve an overall balance that works for the range of outputs produced. This approach can be true for other materials: for instance, household paper grades can be mixed with cleaner commercial streams to feed into higher quality recycling output.

There is a greater complexity in the input materials, predominantly packaging, themselves than for glass or paper, with the range of materials continuously increasing, and increasingly including multilayer and complex materials.

The quality considerations for recycled plastic output differ according to the polymer and product group, with key differences between polymer types (PET, PE, PP) and product types (food-contact material, other packaging and film).

For PET, the key differentiators of quality indicated by the literature and from study visits to reprocessors are:

- IV;
- Transparency;
- Suitability for food-contact material;
- Colour (and presence of non-target colour); and
- Presence of metals, paper, polyolefins, PA and PVC.

IV, measured in deciliters per gram (dl/g), is an important aspect of quality for PET. Bottle manufacture requires PET with high IV (0.75 dl/g for flat water and up to 0.84

dl/g for carbonated soft drinks). Trays can made with PET of a lower IV (0.70 dl/g) and textiles lower still (0.4-0.7 dl/g).[7]

Most PET packaging production requires transparent PET (whether clear or tinted), and opacifying pigments cannot be removed in mechanical recycling. Similarly, colour pigments cannot be removed, so clear PET bottle production requires clear PET flake sourced from clear PET products. PA and PVC cause haze and discoloration in flake. Paper fibres can pass all stages of sorting and washing and cause higher losses in extrusion and filtration. For production of food-contact bottles, the input must be >95% food-contact PET, and an additional decontamination step is required.

Clear and light blue transparent PET flake from a beverage bottle stream (either sourced from a deposit return scheme – DRS – or sorted from separate collection), for instance, has high transparency due to opaque PET not generally being used for beverage bottles, and low presence of contaminants that cause haze such as PA and PVC. It is suitable (if the right decontamination process is applied) for food-contact applications and bottle-to-bottle recycling. Secondary raw materials with higher levels of contaminants and made from mixed colour or opaque PET is used for other applications such as strapping.

For HDPE and PP, the key differentiators of quality indicated from the literature and from reprocessors visited are:

- Melt-flow index (a measure of the viscosity of the polymer melt at a given temperature, force, and time period);
- Colour;
- Odour; and
- Structural characteristics (including consistency, and varying according to specific end-uses).

The melt-flow index varies depending on the type of polymer used within the product (whether a homopolymer or copolymer, and whether in compounds with additives). Secondary raw material output produced from a mix of different products with varying levels of copolymers and additives can vary in melt flow index. Blow-moulding, for instance, requires low and consistent melt-flow index.

Natural coloured HDPE bottles where present in sufficient volumes are typically reprocessed separately and have a higher market value. White HDPE is also in demand for packaging applications. Particular colours of other HDPE containers can in some cases be sorted out: one operator commented that in Spain their plant can separately process yellow HDPE bleach bottles for separate pellet production and recycling back into the same containers. Otherwise, outputs vary from light to dark (light secondary raw materials will more effectively take up added colour and so have greater potential for use in coloured applications).

Odour is a limiting factor for some product uses (e.g. packaging applications) which are sensitive to odour. Others uses such as pipes and plant pots don’t face the same restrictions.

HDPE and PP secondary raw materials have the additional complexity, in comparison to PET secondary raw materials, that additives are often added to adjusted properties

[7] Delta Engineering, PET, available from https://delta-engineering.be/pet?lang=hu; Equipolymers, available from https://www.equipolymers.com/pet-market.

of the secondary raw materials (as with virgin material) to meet customer requirements. These additives can modify the flow rate, improve impact strength and stiffness of the products made from the secondary raw material, increase UV and heat resistance and vary the colour of the secondary raw materials. In the HDPE/PP reprocessing plants visited in the study, different colour grades of HDPE/PP compounds were produced from clear to dark. The impact of some additives used on onward recyclability (the recyclability of the recycled product) is unclear and requires further research.

3.3.1. Framework based on material specifications

Some packaging uses of recycled PET, along with what the study has identified as the main quality specifications applicable, can be broadly categorised as in Table 3-8.

Table 3-8: Packaging end markets for recycled PET and corresponding specifications

Secondary Raw Material Use End Market	Corresponding Specifications
Transparent Bottle (Food grade)	High IV, Transparency, Colour separation, Food-grade decontamination, Limits on PVC/PA/metals/paper/polyolefins
Transparent Bottle (Non-food-grade)	High IV, Transparency, Colour separation, Limits on PVC/PA/metals/paper/polyolefins
Opaque Bottle (Food grade) – n.b. no current commercial production using secondary raw materials	*High IV, Food-grade decontamination, limits on metals, paper, polyolefins*
Opaque Bottle (Non-Food grade)	IV, Limits on metals, paper, polyolefins
Transparent Sheet/Trays (Food grade)	Tray IV, Transparency, Colour separation, Limits on PVC/PA/metals/paper/polyolefins, food-grade decontamination
Transparent Sheet/Trays (Non-food grade)	Tray IV, Transparency, Colour separation, Limits on PVC/PA/metals/paper/polyolefins
Opaque sheet/trays	Tray IV, Limits on PVC/PA/metals/paper/polyolefins

Table 3-9 groups specifications according to a quality hierarchy based on the different quality dimensions identified. Further investigation of the quality requirements for film, fibre and strapping applications would be needed to extend and confirm the categories applied here.

Table 3-9: Categories of specifications by quality/value (PET)

Quality Category	Quality/Value Dimensions	Rationale	Sorted Packaging Quality Specifications	Flake Quality Specifications
A	Sorted by IV product form, transparency, colour; and food contact	Preserves colour separation and suitable for use in the production of the same food-contact items	**Product:** Sorted transparent clear/light blue beverage bottles, or sorted trays **Source:** If DRS collection is in place, then from DRS systems; otherwise, separate collection **Limits on impurities:** Limits on non-target material including other colours and opacity, trays, in addition to PVC, metals, paper, polyolefins	**Product:** Transparent single-colour (e.g. clear, light blue, or green) bottle *or* tray flake **Source:** guaranteed >95% food contact origin **Limits on impurities:** Limits on PVC, PA, metals, paper, polyolefins
B	Sorted by IV, product form, transparency, colour	Preserves colour separation and suitable for use in colour-specific non-food-contact uses requiring high purity flake	**Grade:** Sorted transparent bottles *or* trays *or* opaque bottles, of a specific colour grade (clear/light-blue/green/white/other); **Source:** Separate collection or sorted from mixed waste **Limits on impurities:** Limits on non-target material including other non-target colours, trays, in addition to PVC, metals, paper, polyolefins	**Product:** Single-colour (e.g. clear, light blue, or green) bottle *or* tray flake **Source:** Any **Limits on impurities:** Limits on PVC, PA, metals, paper, polyolefins
C	Sorted by IV, product form	Mixed colour bottle flake can be used for non-colour-sensitive applications that nonetheless require high enough IV (e.g. fibres and strapping).	**Grade:** Sorted bottles *or* trays, mixed colour **Source:** Separate collection or sorted from mixed waste **Limits on impurities:** Limits on non-target material including other non-	**Product:** Single-colour (e.g. clear, light blue, or green) bottle *or* tray flake **Source:** Any **Limits on impurities:** Limits on PVC, PA, metals, paper,

Quality Category	Quality/Value Dimensions	Rationale	Sorted Packaging Quality Specifications	Flake Quality Specifications
		Separated trays can be separately reprocessed with lower losses compared to processing mixed with bottles	target colours, trays, in addition to PVC, metals, paper, polyolefins	polyolefins
D	Other	Mixed, un-colour-separated bottle and tray flake that may need further sorting	**Grade:** PET, mixed bottles and trays **Source:** Separate collection or sorted from mixed waste **Limits on impurities:** Limits on non-target material PVC, metals, paper, polyolefins	**Product:** Single-colour (e.g. clear, light blue, or green) bottle flake **Source:** Any **Limits on impurities:** Limits on PVC, PA, metals, paper, polyolefins

The classification of quality could be improved through a more comprehensive review of specifications set by users of recycled flake, particularly by understanding the quality requirements of different sheeting, fibre and strapping applications in more detail.

The main uses of recycled HDPE can be broadly distinguished as in Table 3-10, and those of PP as in Table 3-11. Odour can be at least partly reduced through the temperature and type of washing process. To enhance the structural properties of the secondary raw materials and make the output suitable for use in place of virgin material for a broader range of products (e.g. back into bottles or paint containers) reprocessors use finer mesh filtration to reduce impurities and improve consistency, and add additives to improve impact strength and adjust the melt-flow rate. However, odour issues often remain, thus reducing the quality of the secondary raw materials for end users, and colour uses can be limited, though a variety of light to dark coloured products are offered. Using additives may affect the onward recyclability of products made from the resulting secondary raw materials: the extent of the impact of additives on onward recyclability is unknown.

Table 3-10: End market for recycled HDPE and corresponding specifications

Secondary Raw Material Use End Market	Corresponding Specification Requirements
HDPE Bottle (food grade)*	Polymer, Colour (natural, white or other specific colour), Food-grade decontamination
HDPE Bottles (non-food-grade)	Polymer, Colour (natural, white or other specific colour), Odour reduction
Other HDPE Packaging or Odour-sensitive products	Polymer, Colour (or shade/lightness), Structural characteristics, Odour reduction
Pipes and other injection-moulded products, polymer-specific	Polymer, Structural characteristics
Injection-moulded Products, HDPE/PP blend	Defined structural characteristics with lower structural consistency
*Currently limited to some circular recycling of natural HDPE milk bottles	

Table 3-11: End market for recycled PP and corresponding specifications

Secondary Raw Material Use End Market	Corresponding Specifications
PP Non-food packaging*	Polymer, Lightness, Structural Characteristics, Odour
Injection-moulded Products (i.e. Vehicle parts, Bottle crates)	Polymer, Lightness, (i.e. light vs dark), Structural Characteristics
Injection-moulded Products, HDPE/PP blend (garden furniture, crates)	Lightness
*There are no current food-grade uses for recycled PP: if these were to develop, they would require food-grade decontamination, suitable structural characteristics and specific transparency or colours.	

A similar approach as used for PET could be taken to setting a hierarchy of quality/value categories onto which individual product specifications could be matched.

As with PET, this could be based on the different aspects of quality that are required for the secondary raw material to be suitable for the application.

Table 3-12 presents an initial hierarchy of secondary raw material specification groupings according to the different quality dimensions identified (and where, applicable, the corresponding specifications for sorted packaging outputs). However, because of the variation in polyolefin polymers used in different products, a more detailed mapping exercise of the specifications required by key product groups would be necessary to further refine this specification-based quality assessment.

Table 3-12: Categories of specifications by quality/value

Quality Category	Quality/Value Dimensions	Rationale	Sorted packaging quality specifications	Secondary raw material quality specifications
A	Specified polymer, melt-flow index and other structural characteristics, colour, odour limit, product type origin (e.g. milk bottles) and food contact decontamination	This material can be recycled into food-contact packaging (N.B not believed to be produced currently in the EU27)	e.g. **Product:** Sorted polymer-specific, single colour, product-specific stream **Source:** Separate recycling collections **Limits on impurities**	**Product:** Specified polymer and product type source Melt-flow Index Homogenous structural characteristics Low odour >95% food contact
B	Specified polymer, melt-flow index and other structural characteristics, colour, odour limit, product type origin (e.g. bleach bottles)	This material can be recycled into same colour-specific, odour-sensitive product type (e.g. bottle packaging for HDPE)	**Product:** Sorted polymer-specific, single colour, product-specific stream **Source:** Separate collection or sorted from mixed waste **Limits on impurities**	**Product:** Specified polymer, colour and product type source Melt-flow Index Homogenous structural characteristics Low odour
C	Specified polymer, melt-flow index and other structural characteristics, lightness, odour limit, may be modified by additives	This material has potentially wide application due to light colour, odour-free and enhanced structural characteristics (that otherwise might not exist due to product variation).	**Product:** Sorted polymer-specific, single colour, product-specific stream **Source:** Separate collection or sorted from mixed waste **Limits on impurities**	**Product:** Specified polymer, lightness Melt-flow Index Homogenous structural characteristics Low odour
D	Specified polymer, melt-flow index and other structural characteristics,	This material has potentially wide application due to its light colour, and enhanced structural	**Product:** Sorted polymer-specific, light colour, product-specific stream **Source:** Separate collection or	**Product:** Specified polymer, lightness Melt-flow Index Homogenous structural

Quality Category	Quality/Value Dimensions	Rationale	Sorted packaging quality specifications	Secondary raw material quality specifications
	lightness	characteristics (that otherwise might not exist due to product variation). But this category is more limited due to odour.	sorted from mixed waste **Limits on impurities**	characteristics
E	Specified polymer, melt-flow index and other structural characteristics	This material is a darker output than in category D, which additionally restricts uses to dark products.	**Product:** Sorted polymer-specific, mixed colour, product-specific stream **Source:** Separate collection or sorted from mixed waste **Limits on impurities**	**Product:** Specified polymer Melt-flow Index Homogenous structural characteristics
F	Polymer blend, melt-flow index and other structural characteristics	This material is a polymer blend and so has wider structural variation and more limited product applications (i.e. to injection moulded applications). It can still be extruded to have colour differentiation and more consistent structural characteristics (impact strength etc.)	**Product:** Sorted polymer-specific, single colour, product-specific stream **Source:** Separate collection or sorted from mixed waste **Limits on impurities**	**Product:** PO compound Melt-flow Index Homogenous structural characteristics
G	Polymer blend, variable melt-flow index and structure	This output is only suitable for low-quality applications with low structural demands	**Product:** Sorted polymer-specific, single colour, product-specific stream **Source:** Separate collection or	**Product:** PO compound

Quality Category	Quality/Value Dimensions	Rationale	Sorted packaging quality specifications	Secondary raw material quality specifications
			sorted from mixed waste **Limits on impurities**	

3.3.2. Notes on quality measurement points

The measurement point of quality for any secondary raw material is ideally at the point immediately before conversion into a new product. For plastics, this is typically the point at which a certifiable plastic secondary raw material (flake, extrusion or regranulate) output from a reprocessor is sold to an end market (plastic converter) for use in production. Since flake produced from food-contact PET can be either used directly or cleaned to be suitable for reuse in food-contact PET, the measurement point for an assessment of quality of recycling at the level of the whole recycling chain should again ideally be at the point of input to a converter when there are no further cleaning steps, rather than at the point of output from reprocessors.

3.3.3. Framework based upon circularity of product uses

For a circularity assessment of quality, a classification would need to be developed for uses of recycled plastic based upon value preservation within a circular economy. This ought to capture the dimensions of at least:

- The extent to which properties of the material are preserved that are unfeasible or costly to recover once lost (transparency, colour form);
- The extent to which the resulting product displaces use of virgin polymer; and
- The onward recyclability of the product.

This framework can be applied in two ways:

- To the whole mix of output secondary raw materials used in different end markets for a polymer. This would not reveal the extent to which value was being preserved (without information on what the input products were), so would need comparing to the composition of products in waste.
- To the subset of output secondary raw materials produced from a specific product type (e.g. transparent PET bottles). This would show for that specific product type the extent of circularity achieved in a recycling chain.

From this mapping, a firmer hierarchy could be created by forming a single scale - from preserving value within closed-loop cycles at the top, to low value output to unrecyclable products that don’t displace virgin material at the bottom.

Table 3-13: Classifying end markets for plastics secondary raw materials by circularity

Secondary Raw Material Use End Market	Material specification quality category as above (A/B/C/D)	Displaces virgin production (Y/N)	Onward Recyclability (1 = capable of many recycling loops) (2 = limited additional recycling) (3 = unrecyclable)
PET Bottle clear transparent food-grade	A	Y	1
PET Bottle clear transparent	B	Y	1
PET Bottle colour food-grade	B	Y	1

Secondary Raw Material Use End Market	Material specification quality category as above (A/B/C/D)	Displaces virgin production (Y/N)	Onward Recyclability (1 = capable of many recycling loops) (2 = limited additional recycling) (3 = unrecyclable)
PET Bottle opaque food-grade	C	Y	1
PET Tray clear food-grade	B	Y	1
PET Tray clear	C	Y	1
PET Multi-material Tray	C	Y	3
PET Bottle opaque	C	Y	2/3
PET Tray opaque	D	Y	2/3
PET Film	C	Y	2/3
PET Multi-material film	D	Y	3
Strapping	C	Y	2
Polyester Fibre	D	Y	2/3
Other injection moulded products	D	Y/N	2/3

The distinct dimensions could be combined to create a single hierarchy as follows in Table 3-14. Beyond the top level, the ordering of the middle levels is somewhat subjective and the 'better outcome' for the material is likely to be best assessed in the context of specific options and counterfactuals with an accompanying LCA study. In particular, it must be decided which dimension takes higher priority – comparing for instance the clear bottle PET incorporated in coloured PET secondary raw material, to clear bottle PET used in transparent tray manufacturing.

Table 3-14: Classifying end markets for plastics secondary raw materials by circularity, example for PET

Secondary Raw Material Use	End markets example
Into recyclable product displacing virgin material	
A Food-grade	e.g. Bottle to beverage bottle production Tray flake to food tray production
B Colour-separation, product-separation	e.g. Bottle flake to other non-food-contact bottle production Tray flake to other non-food-contact tray production
C Product separation	
D No product separation	e.g. Bottle to production with lower IV (trays)
Into product of lower recyclability displacing virgin material	

Secondary Raw Material Use	End markets example
B Colour-separation, product-separation	Bottles to colour-specific (i.e. transparent) film Trays to colour-specific (i.e. transparent) film
C Product separation	Bottle flake to fibres production
D No product separation	Mixed flake to fibres production
Into unrecyclable product displacing virgin material	
A Colour-separation, product-separation	Bottles to colour-specific (i.e. transparent) film Trays to colour-specific (i.e. transparent) film Clear trays or bottles to multi-material multi-layer trays
B Product separation	Bottle flake to fibres production
C No product separation	Mixed flake to textile production
Into product not displacing virgin polymer	
Not displacing virgin material, into limited or unrecyclable product	Into plastic board and lumber materials

3.3.4. Illustrative example of increase in quality

In this example, a sorter separates out natural and white HDPE from mixed colour HDPE to produce a grade which can be de-odourised for use in packaging manufacturing

Table 3-15: Resulting change in output qualities in the HDPE quality framework

Quality Category (see Table 3-12)	Description	Before, % of HDPE output in grade:	After, % of HDPE output in grade:
B	Separated colour, to be de-odourised for packaging applications.	-	10%
E	Separated polymer, mixed colour, odour, to go to dark coloured, less odour-sensitive injection-moulded applications	100%	90%

Changes in the economic model include:

- Increased capital and operating costs from adding an additional sorting step and quality control step to separate out a white opaque sorted fraction;
- Higher revenues per tonne available for the separated out white opaque fraction from growing demand in the packaging sector. No change in revenue per tonne for remaining darker colour HDPE output.
- No change in disposal costs.

3.3.5. Further research needed

There is a lack of collated information available on specific quality requirements of major groups of HDPE and PP products (requiring different grades of HDPE and PP) across packaging and other applications. There is also a lack of information on the impact of different additives, which enhance certain structural characteristics of the secondary raw materials to suit specific applications, on the onward recyclability of the polymer.

4. Quality of recycling: existing standards

The discussions below about glass, papers and plastics packaging streams pull together the study findings on quality standards and specifications used for the outputs of study plants and what is known about the subsequent destinations of the material, together with existing quality specifications for recycled material.

4.1. Quality of recycling: glass

Technical specifications and standards are widely used in the glass industry, typically referring to one or more of the following properties:

- Physico-chemical composition;
- Content of impurities;
- Physical size and shape; and
- Homogeneity, i.e. the variation within the given specification.

The technical proposals for End-of-Waste (EoW) Criteria for glass summarises the situation as follows:

> *"There are a number of technical specifications developed by industrial or recyclers organizations (FERVER, BSI/WRAP), or independent consultant groups, and which are applied in certain member states and in individual market transactions on a case-by-case basis. Additionally, member states in some cases have developed technical standards for glass cullet. Feedback from the TWG pointed out that these standards may vary significantly from country to country. These national standards are usually strictly linked to the quality of the collected cullet, to the technical structures of local glass industries and to the national commercial situation."* [8]

4.1.1. Industry standards for sorting plant outputs

Various specifications have been produced by industry groups across Europe including:

[8] JRC, IPTS (2011) *End-of-Waste Criteria for Glass Cullet: Technical Proposals*

- FERVER specifications;
- CEN guidelines; and
- BSI specification.

These are reviewed in detail in the technical proposals for the End-of-Waste (EoW) Criteria for Glass Cullet.

The EoW criteria proposed specifies the following limits on non-glass components (based on a review of these industry standards and specific to re-melt applications):

- Ferrous metals: 50 ppm;
- Non-ferrous metals: 60 ppm;
- Non-metal non-glass inorganics:
  - 100 ppm for cullet size > 1mm
  - 1500 ppm for cullet size ≤ 1 mm
- Organics: 2000 ppm

The higher limit on non-metal non-glass inorganic impurities for smaller cullet size relates to the finding in the EoW study that several glass manufacturing processes are able to accept cullet containing concentrations higher that 100ppm of inorganic contaminants, as long as the cullet is finely crushed to less than 1 mm and metal contaminants are removed prior to crushing below 1 mm.[9]

4.1.2. Industry current practice: glass recycling standards

One of the two glass plants included in the study produces outputs categorised under the trade/industrial classification „Glasscherben zum Einsatz in der Behälterglasindustrie" (GEB) or „ofenfertige Glasscherben", generally compliant with the guideline limits on contaminants set out in the GEB guidelines, though they note that tolerances in practice vary between the different offtakers. They also commented that the glass producing industry is striving to enforce tightened purity limits, for example with a maximum of 10 ppm ceramics, stones and other inert non-glass ('CSP') under discussion. The other plant output cullet based on specification set directly by their owner (a glass manufacturer) to which the outputs were supplied.

Table 4-1: Glass Quality Standards in Use in Study Plants

End Market	Specifications applied	Guideline limits on contaminants
Study Plant 1		
Cullet glass for container manufacture	GEB guidelines, T120 resp. TR 310.	-ceramics, stones, other inert non-glass (CSP): <20ppm -non-ferrous metals <3ppm, -Fe-metals <2 ppm -glass ceramics <5 ppm (for particles above 10mm) and <10 ppm (for particles smaller 10mm) -loose organic substances <300ppm Colour limits – see below
Reject fractions to grinding for insulation material	None specified	None specified

[9] JRC, IPTS (2011) *End-of-Waste Criteria for Glass Cullet: Technical Proposals, p75*

Study Plant 2		
Flint cullet for remelt to high end clear bottles	None specified	Less than 35g per tonne
Coloured flint cullet for green bottle manufacture	None specified	Less than 35g per tonne

The quality specifications related to colour variation tolerances in different cullet colour fractions are identified below in Table 4-2.

Table 4-2: Glass Colour Specifications in Use in Study Plants

Colour-sorted cullet	Study Plant 1 - Input	Study Plant 1 - Output	Study Plant 2
Flint	3% off-colour	amber: ≤ 0.3% green: ≤ 0.2% other colour: ≤ 0.2%	Not specified
Amber	8% off-colour	minimum 80% amber green ≤ 10 %	Not specified
Green	5% off-colour	minimum 75% green amber ≤ 10%	Not specified

4.2. Quality of recycling: paper

Benchmark standards for the quality of recycling of paper and board in relation to sorting plant outputs (and inputs to paper mills) are generally well defined and agreed upon within the European paper industry. This is due largely to the development and adoption of the EN643 standard by the paper processing industry throughout Europe.

4.2.1. Industry standards for sorting plant outputs: EN643

EN643 is this European list of standard grades of paper and board for recycling, last updated in 2013. EN643 defines the grades of paper for recycling and quality requirements (including setting limits on tolerance levels of non-paper components. The EN643 standards secure 'comparable' requirements for paper for recycling across Europe, and the standardised grades defined within it assist trade.[10]

The fact that the industry was involved in developing the standards has meant that the technical and economic factors that relate to defining recycling quality, and the composition of outputs, have been incorporated into the guidance. The development of EN643 by industry clearly took into account good industry practice, along with economic and technical pragmatism.

There are a wide range of paper and board grades described within EN643 (see Table 0-1 in the Appendices), providing much more variety than simply seeking to distinguish low and high-grade paper, cardboard, newspaper and magazines, etc. The types of paper / board, can – very broadly – be characterised as:

- Mixed papers (waste and scrap paper and cardboard);
- Newspapers and magazines (paper or paperboard mainly manufactured from mechanical pulping processes and with printed material);
- High grades (mostly manufactured from bleached mechanical pulping); and
- Corrugated and kraft (unbleached paper/board).

[10] CEPI (2013) *Why use the new EN643?* Available from http://www.cepi.org/system/files/public/documents/publications/recycling/2013/EN643_page.pdf

In addition to describing the type of paper/board included in the grade, the EN643 standard looks to ensure quality through:

- The exclusion of specific 'prohibited materials' which affect quality of output or processing, e.g. glues and Carbon Copy Papers (CCP) for some grades;
- Placing limits on 'unwanted materials' (either non-paper, or papers of other grades, or e.g. magazine inserts) affecting equipment operation, plant economics, and in some cases quality of output;
- Proving deinking requirements for some grades; and
- Proving shredding minimum sizes, where appropriate.

EN643 also distinguishes grades based on whether the paper/board is collected separately, or as part of mixed collections, and specifically excludes paper/board from refuse collections (i.e. extracted from mixed residual fractions), reflecting different expectations about the quality of material from each source.

These factors are accounted for and well defined in EN643, in a form which the paper and board recycling industry is able to agree and work to. Thus, the defining of recycling quality for paper and card has, to a great extent, already been carried out by the industry, and is embodied in the specifications included in EN643.

4.2.2. Industry current practice: paper recycling standards

The paper and board recycling industry in Europe widely adopts the grades as defined by EN643, these are effectively a common language where different parties have a good shared understanding of the characteristics of the grade. For example, "1.02" will be almost universally understood as a mixed paper and board grade, with unwanted materials removed to below a specified percentage.

Another example of a common EN643 grade is 1.11, "Sorted graphic paper for deinking". In addition to limits on non-paper components in common with other sorted EN643 grades, it also has a limit on the proportion of non-deinkable paper and board (1.5%). The definition of grade 1.11 prior to the 2013 revision explicitly stated that the maximum allowable proportion of non-deinkable paper and board should be negotiated between buyer and seller, moving over time to not exceed 1.5% by weight of the material. Therefore, a degree of pragmatism is woven into the EN643 standards, reflecting their close alignment with industry practice.

In practice plants may continue to work within the tolerances of their production processes, and deviate from strict application of EN643 standards. Operators of both plants visited reported that tolerances for unwanted material varied according to different paper mills, with some mills having tolerance for higher levels of non-paper and/or non-deinkable paper and board than included in the EN643 specification for the grade in question. There can be customer specific agreements (for example, allowing board content at 3.5% rather than 1.5% in deinking grade 1.11). One mill indicated that mixed paper grades typically contain significantly more than the 1.5% non-paper content in the specification (typically between 6-8%). If this is reflective of more general practice, EN643 is a well-used definition of different grades, but the tolerances set within EN643 grades are common reference points which are adapted to in practice to the context of specific paper mills requirements and arrangements with sorting plant suppliers.

4.2.3. Quality standards used in the study paper sorting plants

Both paper sorting plants visited received source separated mixed paper and board from municipal sources. The composition of paper/board delivered to one plant was noted as highly variable, with noticeable consistent differences between deliveries from different geographical areas. The inputs are mixed in the reception hall in order to produce a more homogenous mix of material to be input to the process. The plant operator described the input material as broadly conforming to EN643 grade 1.01. The outputs of the plants are described as EN643 grades 1.02, 1.04 and 1.11, with one plant also producing an ungraded output of smaller sized mixed papers. The quality standards applied by the plant operators to output grades are summarised in the Table 4-3. Both paper sorting plant operators noted that the paper mill requirements were often in practise more flexible than that prescribed in EN643.

Four light packaging fraction sorters in the study also output sorted papers:

- Two of these were in France (where the collection stream includes all papers), and both of these plants output a 1.05 grade (corrugated cardboard) with >95% corrugated cardboard content, rather than grade 1.04 (with 70% corrugated board).
- One was in Germany, where the output grade 'Paper from lightweight packaging' was comprised of the packaging card included in the light packaging fraction collected.
- From one plant in Hungary (where the collection from some more rural areas included papers), the paper mix output was sent to a co-located paper sorter for sorting, rather than sold as a sorted output grade.

Table 4-3: Quality standards in use in study plants (sorted paper outputs/inputs)

Type of Quality Specification	Target Material	Description	Limits on Impurities
Inputs			
Described as broadly conforming to EN 643 grade 1.01	Source separated used paper and board from households	Variable, mainly a combination of: * Sack collections usually with higher content of graphic paper. * Bin collections with higher cardboard content.	Small-sized pieces of paper; though would prefer to not have these, as they increase the amount of lower quality "Fibre-mix" outputs.
Outputs			
EN 643 grade 1.02	Mixed paper	Mixture of various qualities of paper and board, containing a maximum of 40% of newspapers and magazines	Unsuitable fibres and non-fibre materials: 1.5% Moisture: 12%
EN 643 grade 1.04	Corrugated paper & board	Used paper and board packaging, containing minimum of 70 % of corrugated board, the rest being other packaging papers, other paper and board products	Non-fibre materials: 1.5% Moisture: 12%
EN 643 grade 1.05.01 (output by French LPF sorter)	Corrugated board	Used boxes and sheets of corrugated board of various qualities, containing minimum 95% corrugated board	Non-fibre materials: 1.5 Total unwanted materials, including non-fibre and unsuitable fibres: 2.5% Moisture: 12%
EN 643 grade 1.11	Graphic paper for	Sorted graphic paper from households, newspapers and magazines consisting of a	Non-fibre materials: 0.5% Print products not suitable for deinking: 1.5%

Type of Quality Specification	Target Material	Description	Limits on Impurities
	deinking	minimum of 80 % newspapers and magazines, but at least 30 % newspapers and 40 % magazines (higher percentages of one or the other paper product are subject of supply agreements)	Total unwanted materials, including non-fibre and unsuitable fibres: 3% Moisture: 12% There can be customer specific agreements (for example, allowing board content at 3.5% rather than 1.5%).
EN 643 ungraded "Fibre-mix"	Smaller sized mixed paper	Mixture of sorted used paper <150 mm in dimension with low content of corrugated and board materials	Non-fibre materials 3% Total unwanted materials, including non-fibre and unsuitable fibres: 3% Moisture: 12%
DSD/DKR Fraction 550 (output by German LPF sorter)	Paper from lightweight packaging	>90% paper, board, cardboard from lightweight packaging At the study sorting plant, this grade was often mixed into other outputs from a co-located paper sorting plant.	Liquid packaging boards: 4% Plastic items: 3% Metal items: 0.5% Other residues: 3.5%

4.2.4. Relevance of sorting plant output standards to quality of recycling

In most respects EN643 provides an excellent baseline understanding of different grades and types of product that can be produced from paper recycling. This is a key contributor to defining quality of recycling, in that it allows us to define grades of papers that can achieve a circular fate in the economy; for example, newsprint that can be deinked and pulped in order to manufacture newsprint again.

The quality of the fibres in paper material decrease through repeated recycling, and the quality is also affected by the presence of unwanted other paper fibre types, pigments, and contamination by other materials such as food waste, oils, and laminates. Sorted EN643 grades for deinking paper and corrugated board preserve specific and distinct paper fibre types and qualities relevant for, respectively, recycled printing paper (including notably newsprint) and the structural components of board packaging. The mixed papers EN643 grade can have a wide range of different paper materials and fibre types depending on the specific mix of other paper and board products, but as a rule (if not subject to further sorting) can be used for applications requiring less fibre integrity and strength such as less structural components of corrugated board. A portion of sorted paper and board (primarily from a subset of the 'mixed papers' grades) is used for applications which do not require lower fibre strength, such as tissue paper and some forms of moulded protective packaging, which form a useful last stage in the paper recycling cascade. One of the study plant's output products is described as "fibre-mix", consisting of a mixture of different types of used paper of <150 mm in dimension with low content of corrugated and board materials. This material is not assigned an EN643 grade, and is likely to go to a low-quality recycling fate, such as production of tissue paper. The other grades produced by the plant (in particular EN643 1.04 and 1.11, but also 1.02) are all more likely to be pulped in paper mills to produce new paper and board products that can be recycled again.

In summary, the EN643 grades can form the basis of an operational assessment of high quality recycling for paper and board: outputs are higher quality recycling if they conform to, or are closely guided by, the EN643 grades which are likely to be remanufactured into paper/board products that can again be recycled into similar grades (de-inking and corrugated cardboard grades). By contrast, mixed paper grades are less likely to be recycled into similar grades, and some grades of mixed papers of lower fibre quality, fibre quality degraded though collection, storage and transport, and/or higher levels of non-paper material and other impurities, are more likely to end up as low-fibre-strength, single use material. A higher quality recycling chain is likely to maximise captures into deinking and corrugated cardboard grades, whilst fully utilising remaining mixed papers grades. If a plant is able to reduce the proportion of outputs going to non-circular paper recycling, and concurrently able to increase the proportion that adheres (either exactly, or pragmatically) to an EN643 grade which can readily be recycled again thereafter, that would indicate a tangible and easily understandable transition from lower to higher quality recycling.

4.3. Quality of Recycling: plastics

There is wider variation in specifications and grades of polymers than for paper and greater variation in the recycling chain and number of steps and sorting operations.

There are however clear general quality characteristics identifiable, and a small amount of detail is available on the key differences in, for example, structural characteristics.

4.3.1. Industry reference standards for recycling plant outputs

Standards for secondary raw materials referenced within EUCertPlast certification are EN standards for the characterisation of plastic secondary raw materials, the quality aspect of which is covered in the 'required characteristics' in table 1 of the relevant EN Standard. These standards are:

- EN15342 for polystyrene secondary raw materials
- EN15344 for polyethylene secondary raw materials
- EN15345 for polypropylene secondary raw materials
- EN15346 for poly(vinyl chloride) secondary raw materials
- EN15348 for poly(ethylene terephalate) secondary raw materials

These standards do not distinguish different qualities of secondary raw materials. In practice, reprocessors create outputs to the specific quality requirements of end users.

4.3.2. Industry current practice: recycling plant outputs

In practice, reprocessors also create outputs to the specific quality required by end users (including particularly where they utilise the output themselves in product manufacture).

4.3.3. Industry reference standards for sorting plant outputs

Plastics Recyclers Europe (PRE) has produced bale quality guidelines aiming to 'drive market transformation towards circularity', which outline key prohibited impurities and impurities allowed up to certain levels (to be set by the buyer according to their requirements).

Table 4-4: Summary of quality guidelines for sorted plastic packaging, PRE

	Prohibited Impurities	Limited Impurities	Grade variation
All:	Minerals, Rubber, Wood, Sacks, Hazardous Waste, Medical Waste, Glass, Oxo or degradable material, Food, Silicones		
PET Bottle grades	PET-G (PET with added glycol for flexibility) CPET (crystalline PET suitable for ovens)	Max 5% of PET from non-food consumer applications Metals Paper/Cardboard PVC Transparent Colours Opaque Colours Monolayer trays Other plastics	Clear: Max 5% light blue PET, no opaques Clear Blue: Max 20% of blue PET, no opaques Light Blue: >20% light blue PET, no opaques Coloured >80% transparent mixed colours, max 5% opaque colours
HPDE Bottles, Mixed Colour	Foams Polyurethane (PUR)	Max 5% of HDPE from non-food consumer applications Metals Paper/Cardboard PP Other Plastics	n/a
PP Films	Expanded Polystyrene (EPS) & PUR	Metals Paper/Cardboard PVC, LDPE, HDPE, LLDPE Other Plastics Other Impurities	Variations in minimum content for: PP
PE Films	EPS & PUR	Metals Paper/Cardboard PVC PP Other Plastics Other Impurities	Variations in minimum content for: LDPE LLDPE HDPE

In North America, the trade association APR (The Association of Plastic Recyclers) has produced standards intended for use as benchmarks for suppliers. These go further than PRE's standards in outlining specifications for PET thermoforms and PP small rigids.

These standards reflect a set of generic issues relevant to plastics processing:

- Environmental issues – no medical or hazardous waste;
- The problems that dirt, mud and rocks cause to machinery;
- Other problematic material (film in processes designed to shred rigid plastics); and
- The impurity that can be caused by oils and grease, or corrosive and reactive products.

They also distinguish the following specific problematic materials affecting the quality of output:

- Chemically incompatible low temperature melting materials:
  - PS; and
  - PLA plastic.
- Chemically incompatible high temperature melting materials – blocking filters/channels, causing holes, such as silicones (which has the same density as PET); and
- Chemically compatible low temperature materials, such as PET-G, PET Glycol, created by the copolymerisation of PET and ethylene glycol;
- Chemically compatible but opaque materials:
  - CPET, Crystalline PET, partially crystallised and therefore opaque, standardly used for microwaveable and oven ready food packaging. Affects colour and brittleness of output.
- Materials affecting output colour or quality:
  - PVC, causing discoloration even in small quantities from dehydrochlorination, and the resulting corrosive gasses also degrade the target polymer; and
  - Other coloured PET (depending on the output grade).
- Material affecting quality in other ways:
  - Presence of oxo or bio-degradable additives (more of an issue in film due to more film with these properties).

They also contain some material specific prohibitions related to impurities degrading the quality of the output:

- PVC in HDPE bottles and PVDC layers in PE film;
- Plastics with PLA or foaming agents (HDPE); and
- Film with oxo or bio-degradable additives.

Lastly, they contain non-target materials that the system isn't set up to cope with:

- Bulky HPDE rigids, which require a different recycling process; and
- Metallised labels or films, multi-material pouches, and silicone coated film.

A range of other potentially recyclable materials are listed (e.g metals) which are allowable within tolerances determined by the economic balance of the plant.

There are also standards and quality specifications set by national producer responsibility organisations (PROs). For example, Germany's Der Grüne Punkt ('The Green Dot') recycling system requires that transparent PET bottles are sorted to 98% purity.

4.3.4. Industry current practice: sorting plant outputs

In practice, the quality of outputs can diverge from the industry standards as detailed above with regard to tolerance levels for material on the 'prohibited impurities' list. Offtakers for HDPE and PP outputs are reported by some sorting plants to tolerate higher levels of impurities than those set in PRO-proscribed standards. The quality aimed at by sorters of LDPE films has increased due to lower demand and more competition for offtakers.

For sorters operating outside of arrangements with PROs (for instance in Hungary), purity levels are individually agreed with the offtakers and can thus vary within certain limits. However, since they compete for the same offtakers as sorting plants sorting to PRO set standards, their outputs tend to be comparable to international standards (American Plastics Recycling, ARA, and/or DSK/DSD specifications).

Table 4-5 below shows quality standards applied to sorted fractions of plastics output from study plants (either output from sorting plants or input into subsequent sorters or reprocessors)

Table 4-5: Quality standards in use in study plants (sorted packaging outputs/inputs)

Plant code and type of Quality Specification	Standard Applied	Material Targeted	Target	Prohibited Impurities	Allowable Impurities where provided
PET					
P4 Input Specification		Clear PET bottles, DRS	>98%	PVC	Metals Coloured bottles <1% Paper <1% PO bottles <0.25% Dirt <2% Moisture <5%
P4 Input Specification		PET bottles, yellow bag	>98%	PVC <0.1% Large metal or inert material PET-G <0.5% Foamed plastics incl. EPS <0.5%	Coloured bottles <1% Opaques, other PET packaging and other polymers <2% Metals <0.5% Dirt <2% Other material <2%
P5 Input Specification	DSD/DKR 328-2 (from D7)	PET mixed 70/30	>98% >70% PET bottles	Metallic or mineral impurities with a unit	<2% total; <0.5% other metal; <2% other

Plant code and type of Quality Specification	Standard Applied	Material Targeted	Target	Prohibited Impurities	Allowable Impurities where provided
				weight of > 100 g are not permitted! PVC <0.1%	plastic; <2% other residues
D1 and D2 Output Quality	CITEO	PET (including trays)	>98%		
D5 Output Quality	DSD/DKR 325	PET bottles (clear, light blue, green)	>94% >98%	EPS <0.5% PVC <0.1%	Opaques, other PET packaging and other polymers <2% Metals <0.5%
D6 Output Quality	Ecoembes	PET Bottles (mixed colour including trays)	>95.5%	PVC < 0.25%	< 4% of other polymers; <0.25% metals.
D7 Output Quality	DSD/DKR 328-2	Mixed PET 70 bottles/30 trays, deviation possible	As above	As above	As above
D8 Output Quality	ARA SN 57130/408 /415 /416	PET Bottles (clear, light blue, green)	>98%		
D8 Output Quality	ARA SN 57130/499	PET Other	>95%		
D9 Output Quality	DSD/DKR 328-2	PET Mixed 70/30	As above	As above	As above
P1 Output Quality	COREPLA CTLM	PET Bottles clear		PVC <0.5%	Light blue <2% Colour and opaque <0.7% Polyolefin <1.5% PET trays <1% Other <2.5%
P1 Output Quality	COREPLA CTAM	PET Bottles light blue		PVC <0.5%	Colour and opaque PET <2.7% PET trays <1% Polyolefin <1.5% Other <2%
P1 Output Quality	COREPLA CTCM	PET Bottles coloured		PVC <0.5%	Opaque PET <4% PET trays <1% Polyolefin <2% Other <2.5%

Plant code and type of Quality Specification	Standard Applied	Material Targeted	Target	Prohibited Impurities	Allowable Impurities where provided
P1 Output Quality	COREPLA	PET Bottles opaque		PVC <1%	PET trays <2% Polyolefin <2.5% Other <1.5%
P1 Output Quality	UNI 11038 - 1	PET flake			
P2 Output Quality		PET Mixed (40% bottle, 60% tray)	Approx.. 95%		
P5 Output Quality		PET Clear	>98%		
P5 Output Quality		PET Coloured	*>98%*		
P5 Output Quality		PET Opaque	*>98%*		
P5 Output Quality		PET trays	N/A		
P6 Output Quality	Food contact specification	PET bottles and trays	>95%		
HDPE/PP					
Output Quality (comparable to APR HDPE spec)		HDPE/PP			Metals <0.5% Other plastic items <4% Other residues items <4%
P7 Input Quality	DSD/DKR 329 "give some quite good orientation"	HPDE	>94%	Metallic or mineral impurities with a unit weight of > 100 g and cartridges for sealants	Metals <0.5% Rigid PP <3% by mass EPS <0.5% Plastic films <5% Other <3%
P7 Input Quality	DSD/DKR 324 "give some quite good orientation"	PP		Metallic or mineral impurities with a unit weight of > 100 g and cartridges for sealants	Metals <0.5% Rigid PE <1% by mass EPS <0.5% Plastic films <2% Other <3%
D2 Output Quality	CITEO	HDPE/PP	>95%		
D5 Output Quality	'internationally recognised specifications'	HDPE/PP			

Plant code and type of Quality Specification	Standard Applied	Material Targeted	Target	Prohibited Impurities	Allowable Impurities where provided
D6 Output Quality	Ecoembes	HDPE Bottles (mixed colour)	>90%		<7% polyolefin; < 2% paper / card <0.5% metals
D7 Output Quality	DSD/DKR 324	PP	>90%	Noted above	Noted above
D7 Output Quality	DSD/DKR 329	PE	>90%	Noted above	Noted above
D8 Output Quality	ARA SN 57118/406	HDPE Containers			
D8 Output Quality	ARA SN 57118/402	HDPE Hollow Items			
P1 (Sorting) Output Quality	COREPLA	HDPE Bottles			PET <1% PVC <1% PP <10% Other <1.5%
P1 (Reprocessing) Output Quality	UNI 10667	HDPE pellet			
Films					
Output Quality (PE transparent		PE Transparent, LDPE mixed colour			Metals <0.5% Other plastic items <4% Other residues items <4%
D9 Output Quality	DSD/DKR 310	Pre-sorted plastic film	>92%Within specifications, deviation possible		Metals <0.5% Other plastic <4% Other residues <4%
P1 Output Quality	COREPLA FILM	PE			Smaller films <20% Metals and inerts <2% Other <5.5%
Mixed Plastics					
D6 Output Quality	Ecoembes	Mixed Plastics	>80%		HDPE, PET and Films <10%, other plastics (non containers) <10% board / metal / other <4% paper /

Plant code and type of Quality Specification	Standard Applied	Material Targeted	Target	Prohibited Impurities	Allowable Impurities where provided
D7 Output Quality	DSD/DKR 322	Plastic hollow bodies and	>94%		Metals <0.5% Other plastic <3% Other residues <3%
D7 Output Quality	DSD/DKR 323	MPO (mixed polyolefin items)	>85%		Papers <5% Other non PO plastic <7.5% PVC <0.5% Other <3% Undersize fraction <2%
D8 Output Quality	ARA SN 77118/412	PS/PP			
D9 Output Quality	DSD/DKR 322	Plastic hollow bodies	Within specifications, deviation possible		As above

5. Using the quality framework

The quality definition and framework developed here is intended for operational use, as an approach to practically measuring the quality of recycling alongside the quantity of recycling. It has potential application by different actors for a range of strategic and/or operational contexts. These uses include:

- Assessing the current quality of recycling outputs;
- Tracking change in qualities produced; and
- Assessing the quality benefit from changes to recycling outputs.

This assessment could be made at different levels for different purposes:

- By plant operators or waste management companies to use as a performance metric (alongside recycling rate), to track impact of changes on quality of outputs, and define the quality impact of their sorting and reprocessing operations.
- By municipalities or producer responsibility organisations (PROs) contracting sorting plants to assess the quality of outputs produced, specify output grades within different quality categories to be produced, and/or differentiate payment by quality category, aligned with any strategy for increasing output qualities at a whole system level.
- By regional/national governments to quantify the overall quality of packaging recycling output, track changes in quality resulting from interventions/support/development of local or national markets, and use as a basis for targeting specific quality improvements.

The framework provides a route for categorising recycling outputs by their quality. It puts outputs into a defined scale so that current quality performance can be assessed and improvements can be measured. The assessment is based on simple features of sorted outputs (prior to reprocessing operations) or secondary raw materials produced, and it does not require extensive tracking of end uses. There is scope for expansion to accommodate the end use of the material if this information can be gathered.
The quality categories outlined within the framework prioritises effective separation and preservation of the distinct useful characteristics of the material, with *either:*

- the broadest utility (e.g. natural, de-odourised HDPE which can be adapted for use in most HDPE products); and/or
- distinct and specific circular utility (e.g. recycling captured for specific closed-loop recycling cycles, such as yellow bleach HDPE back into yellow bleach HDPE bottles)

As such it is 'doing the best that can be done' *from a resource perspective* with the material that is collected for recycling, and preventing the loss of use value of the material.

The further the material remains in mixed outputs with neither specific nor broad utility, the closer to the bottom of the hierarchy it sits, and the less useful it is to the system, though it may still be used productively to displace virgin polymer use.

By defining these broad bands (the strongest determiners of quality of recycling outcomes), the quality bands do not capture effectively differences in quality *within the bands* (i.e. distinguishing between different levels of PVC in mixed PET outputs, or distinguishing between quite odorous and very odorous polyolefin outputs).

There are some areas of the classification that require further definition to remove remaining subjectivity. For instance, distinguishing between HDPE, PP, and PE film secondary raw materials that are 'suitable for odour-sensitive applications' and those that are not, and mapping in more detail the quality requirements of different users of secondary raw materials both for packaging and non-packaging applications. For the assessment of the quality of plastics recycling, the categories should be seen as a first outline. A more systematic and comprehensive study of the quality requirements of specific product groups, beyond the scope of this study, would enable the categories to be further refined.

<u>Assessing the current quality of recycling outputs</u>

The starting point of using the framework would be to collect information on output quantities of different materials segmented by quality categories.

- Plant operators could categorise their outputs according to the quality categories;
- Those contracting sorting plants could require reporting from sorting plants according to the quality categories, and could (if aligned to strategic development in qualities or to incentivise marginal quality improvements) vary payments according to quality category;
- PROs or national governments could seek to collect data from reprocessors that would enable them to assess the overall quantity of recycling outputs within each quality category.

<u>Tracking change</u>

Use of the framework over time would allow a quantitative assessment of changes in the 'quality of recycling'. If they had little impact on quantities recycled, these changes would otherwise be obscured by a simple recycling rate metric.
Tracking change over time would allow:

- A plant operator to:
    - show the benefit to quality from changing processes to improve capture into higher quality category outputs; or
    - track achievement against quality targets (see below).
- A PRO or national government to assess the impact of changes in policy (or in other factors such as investment, market demand, etc) on the development of higher quality recycling.

Targeting improvements in quality

The analysis of the quality of material output by the whole recycling chain would be a useful starting point for a discussion about how and where qualities can and should be increased.

Using the framework as a guide for intervention (for municipalities or PROs contracting plant operators, or for company/regional/national level strategies for increasing quality) means first identifying what improvements in quality bands overall are desirable for which materials.

The choice of output grades and qualities by sorters and reprocessors is primarily determined by market prices available and consistency of demand for outputs of certain qualities. This results in the arrangement of outputs that receives the most revenue or subsidy in relation to the costs of sorting and processing.

In any economic context, improvements in quality that haven't already been made are likely to come at additional cost, and (depending on local markets) may not result in significant environmental benefit where lower quality outputs can also be used to displace virgin material. A full recycling chain view is crucial as improving the quality categories of outputs from sorting plants, particularly small-scale sorting operations, may be unnecessary or counter-productive if sorting into higher quality recycling categories occurs later (and more cost-effectively) in larger subsequent sorting operations.

Plant management, municipalities and PROs can have an impact in helping to ensure the realisation of improvements in recycling quantities and qualities that are currently economically marginal.[11]

In addition, producer organisations and regional/national authorities could also take a longer-term perspective on strategies for increasing quality of recycling by shifting the economic picture more fundamentally. This could be by targeting research and development to reduce costs; influencing demand for recycled content; or supporting the development of higher quality reprocessing routes for specific portions of materials.

[11] Eunomia Research & Consulting Ltd (2020) Analysis of Drivers Impacting Recycling Quality, report for European Commission Joint Research Centre, March 2020.

Table 5-1: Summary of quality framework applications by organisation

Organisation	Usage of the Quality Framework
Plant management	Gather data on sorting plant outputs by category band. Use as performance metric (alongside recycling rate) to track impact of changes on quality categories.
Waste management company	Collate data on outputs at the point where they leave the management of the company (sorted and/or reprocessed outputs). Define the quality impact of sorting and recycling activities from their operations
Contractor of sorting plant (Municipality/PRO)	In the context of a tender process, assess as part of tender process the quality categories of the grades of outputs planned to be produced. Specific output grades within different quality categories to be produced, aligned with any strategy for increasing output qualities at a whole system level (see below). Where PROs buy the material, use as the starting point for differentiating payments for differing quality outputs (adjusted away from a simple reflection of expected onward sale values), again aligned with any strategy for increasing output qualities at a whole system level.
System and policy design (PROs / National Government)	Gather data on sorting plant outputs by category band. Quantify the overall quality of packaging recycling output produced from in-country sorting and recycling chains. This data can accompany statistics on overall recycling rates for different packaging materials. Track changes in quality resulting from interventions/support/development of local or national markets. To use the framework as a guide for intervention, identify what improvements in quality bands overall are desirable for which materials (in the context of demand for higher quality outputs from international, national and local industries).

Appendices

A1.1 EN643 Grades

Table 0-1: Summary of EN643 Standard for paper and packaging

	Grade Title	Materials not allowed at any level	Conditions for meeting grade and other allowable materials
Grade 1: Ordinary Grades	Mixed paper and board, unsorted, but unusable materials removed	-	No restrictions on short fibre content
	Mixed papers and boards (sorted)	-	Maximum 40% newspapers and magazines
	Grey board	Corrugated material	-
	Corrugated paper and board packaging	-	Minimum 70% corrugated board, the rest being other packaging papers and boards
	Ordinary corrugated paper and board	-	Minimum 70% corrugated board, the rest being other paper and board products
	Corrugated paper and board	-	Minimum 80 % of corrugated board, the rest being other paper and board products
	Ordinary corrugated board	-	Maximum 10% other packaging papers and boards
	Corrugated board	-	Maximum 5% other packaging papers and boards
	Magazines	-	Can allow glue
	Magazines without glue	Glue	-
	Magazines with product samples	-	Can allow glue. Can contain non-paper components as attached product samples.
	Telephone books	-	Glue and shavings allowed.
	Newspapers and magazines	-	Minimum 30% each of newspaper and magazines
	Sorted graphic paper for deinking	-	Minimum 80% newspapers and magazines: at least 30% newspapers and 40% magazines. Print products not suitable for deinking limited to 1.5%.
Grade 2: Medium Grades	Newspapers	-	Maximum 5% of newspapers / advertisements coloured in the mass
	Unsold newspapers not intended for deinking	Additional inserts (not originally circulated with publication)	Paper products not suitable for deinking are allowed.
	Unsold newspapers	Additional inserts (not originally circulated with publication)	-
	Lightly printed white shavings	-	-
	Lightly printed white shavings without glue	Glue	-
	Heavily printed white shavings	-	-

	Grade Title	Materials not allowed at any level	Conditions for meeting grade and other allowable materials
	Heavily printed white shavings without glue	Glue	-
	Ordinary sorted office paper	Carbonless copy paper (CCP) / no carbon required (NCR)	Minimum 60% wood free paper. Less than 10% unbleached fibres. Less than 5% newspapers and packaging
	Sorted office paper	CCP / NCR	Minimum 80% wood free paper. Less than 5% unbleached fibres.
	Ordinary sorted coloured letters	CCP / NCR, manila envelopes, file covers, newspapers, cardboard	Minimum 70% wood free paper.
	Sorted coloured letters	CCP / NCR, manila envelopes, file covers, newspapers, cardboard	Minimum 90% wood free paper.
	White woodfree bookquire	Hard covers	Maximum 10% coated paper
	White mechanical pulp-based bookquire	Hard covers	Maximum 10% coated paper
	Coloured woodfree magazines	Non-flexible covers, bindings, non-dispersible inks, adhesives, poster papers, labels, label trim	Maximum 10% mechanical pulp-based papers
	Bleached woodfree PE-coated board	-	-
	Other PE-coated board	-	Can allow unbleached board and paper
	Mechanical pulp-based computer print-out	-	Can allow recycled fibres
	Multigrade	Newsprint	Maximum 10% other wood containing papers. Maximum 2% paper with plastic layer.
	Coloured log end tissue	-	May contain printed material.
	White log end tissue	-	May contain printed material.
Grade 3: High Grades	Mixed lightly coloured printer shavings	-	Minimum 50% wood free papers
	Mixed lightly coloured woodfree printer shavings	-	Minimum 90% wood free papers
	Woodfree binders	-	Maximum 2% paper with a plastic layer. Maximum 10% mechanical pulp-based paper
	Special woodfree binders	Plastic layered and mechanical pulp-based papers	-
	Tear white shavings	Glue, wet-strength paper, paper coloured in the mass	-
	White woodfree letters	Cash books, carbon paper, non-water soluble adhesives	Maximum 5% mechanical pulp-based paper
	White woodfree letters unprinted	Cash books, carbon paper, carbonless paper, non-water soluble adhesives	-
	White business forms	-	-
	Printed bleached sulphate board	Glue, polycoated or waxed materials	-
	Lightly printed bleached sulphate board	Glue, polycoated or waxed materials	-
	Multi printing	Wet-strength paper, paper coloured in the mass	-
	Medium printed multi	Wet-strength paper, paper	-

	Grade Title	Materials not allowed at any level	Conditions for meeting grade and other allowable materials
	printing	coloured in the mass	
	White heavily printed multiply board	Grey and brown piles	-
	Mixed white heavily printed multiply board	-	Maximum 20 % grey and brown plies.
	White lightly printed multiply board	Grey piles	-
	White unprinted multiply board	Grey piles	-
	White newsprint	Magazine paper	-
	White mechanical pulp-based coated and uncoated paper	-	-
	White mechanical pulp-based paper containing coated paper	-	-
	White coated woodfree paper	Glue	-
	White woodfree papers	Glue	-
	White shavings	Newsprint and magazine paper, glue	Minimum 60% wood free paper. Maximum 10% coated paper.
	White woodfree shavings	Glue	Maximum 5% coated paper
	White woodfree uncoated shavings	Glue, coated paper	-
	White envelope cuttings	Coated paper	Can allow glue
	Unprinted bleached sulphate board	Glue, polycoated or waxed materials	-
	Unprinted tissue coloured in the mass	Packaging materials	-
	White unprinted tissue	Packaging materials	-
Grade 4: Kraft grades	New shavings of corrugated board	-	-
	Unused corrugated kraft	-	Kraft liners only
	Used corrugated kraft 1	-	Kraft liners only
	Used corrugated kraft 2	-	Kraft liners or testliners having at least 1 liner made of kraft
	Used kraft sacks	-	-
	Unused kraft sacks	-	-
	Used kraft	-	-
	New kraft	-	-
	New carrier kraft	-	-
Grade 5: Special Grades	Mixed papers	-	-
	Mixed packaging	Newspapers and magazines	-
	Used liquid board packaging	-	Minimum 50% fibres (by weight)
	Unused liquid packaging board	-	Minimum 50% fibres (by weight)
	Wrapper kraft	Bitumen or wax coatings	-
	Wet labels	-	Maximum 1% glass content. Maximum 50% moisture, without other unusable materials.
	Dry labels	-	-
	Labels with base layer	-	-
	Paper release liner for self-adhesive labels	Labels, cores and other contaminants	-
	Unprinted white wet-	-	-

	Grade Title	Materials not allowed at any level	Conditions for meeting grade and other allowable materials
	strength woodfree papers		
	Unprinted white and coloured wet-strength papers	-	-
	Printed white wet-strength woodfree papers	-	-
	Printed white and coloured wet-strength wood-free papers	-	-
	Cores	Metal ends	-
	Carbonless copy paper (NCR)	-	-
	Printed white envelope	-	-
	Mixed envelopes	-	-
	Blister pack	-	Plastic layers and inserts allowed
	Used kraft sacks	-	Papers with a plastic layer allowed
	Used kraft sacks with plastic layer papers	-	-
	Unused kraft sacks	-	Papers with a plastic layer allowed
	Unused kraft sacks with plastic layer papers and poly liners	-	-
	Used paper cups and other used tableware	-	Minimum 75% fibres (by weight)
	Unused cups and other tableware	-	Minimum 75% fibres (by weight)

A2.1 Other Industry Standards

In North America, the trade association, The Association of Plastic Recyclers (APR), have produced a set of guideline standards for sorted packaging that are intended for use as benchmarks for suppliers and provide an indication of the quality standards that are likely to meet the requirements of their reprocessors. A summary of the 'hard' and 'soft' limits for different sorted packaging outputs are below.

Table 0-2: Summary of Quality Standards for Plastic Packaging

	Contaminants not allowed at any level	Conditions for allowable contaminants and type of contaminants	Grade variation
All:	Plastic bags or plastic film, wood, glass, oils and grease, rocks, stones, mud, dirt, medical and hazardous waste		
PET Bottles	PVC, chemically incompatible low temperature melting materials, including PS and PLA plastic, as rigid or foam, chemically compatible low temperature materials,	Total weight of contaminants should not exceed the required % of PET per grade: HDPE rigid containers, LDPE rigid plastic containers, PP rigid plastic containers, aluminium, metal containers or cans, paper or cardboard, liquid residues, primarily	% PET fraction (by weight) Grade A: 94% or above Grade B: 83 – 93% Grade C: 73 – 82%

	such as PETG, items containing degradable additives	water (2% max weight)	Grade F: 72% or below
PET Thermoforms	items containing degradable additives	Total weight of contaminants must not exceed 5% and total weight of individual contaminants by material must not exceed 2%: aluminium, metal containers and cans, loose paper or cardboard, polystyrene, PLA, PVC, PETG, liquid residues (primarily water)	N/A
PP Small Rigid Plastics	electronics scrap, items with circuit boards or battery packs, products with degradable additives, containers which held flammable, corrosive or reactive products, or pesticides or herbicides.	Total weight of contaminants should not exceed 8% and total weight of individual contaminants by material must not exceed 2%: metal, paper/cardboard, liquid or other residues, HDPE, any other plastic containers or packaging including PET, PVC, PS, Other	Considered Bulky PP if greater than 5 gallons
PE Clear Film	Metallised labels or films, multi-material pouches, silicone coated film, film with oxo or bio-degradable additives, PVDC layers, acrylic coatings, rubber bands	Total weight of contaminants should not exceed 5% Pigmented polyethylene films, non-polyethylene other plastics, labels, loose paper, strapping, twine or tape, food waste, liquid residue (2% max. weight)	Grade B: 80% clear, up to 20% colour, clean and natural LDPE and / or LDPE films Grade C: 50% clear, 50% colour, dry, LDPE or LLDPE films
HDPE Bulky Rigid Plastics	Items with circuit boards or battery packs Products with degradable additives Containers which held flammable, corrosive or reactive products, or pesticides or herbicides.	Total weight of the following materials must not exceed 10%: Polypropylene Total weight of the following materials must not exceed 4%: Plastic resins – PET, PVC, LDPE, PS, Other Total weight of the following materials must not exceed 2%: Metal, liquid / other residues, paper/ cardboard	N/A
HDPE Coloured Bottles	Bulky rigids, any plastics with PLA or foaming agents, PVC, HDPE motor oil or other automotive fluids	Total weight of contaminants should not exceed the required %s of HDPE per grade Total weight of individual contaminants by material must not exceed 2% Other non-HDPE rigid plastic containers or packaging, including PET, LDPE, PP, PS	% HDPE fraction (by weight): Grade A: 95% or above Grade B: 85 – 94% Grade C: 80 – 84% Grade F: 79% or below

		and Other, liquid residues, aluminium, paper or cardboard	

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