PolyCE

Post-Consumer High-tech Recycled Polymers for a Circular Economy

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Summary

An important strategy in a transition to a circular economy for WEEE plastics is mechanical recycling. Recently, several companies have pledged to increase the use in recycled plastics in the upcoming years. However, the demand for recycled plastics is still relatively low due to the mistrust in the materials' capabilities of fulfilling the needs of the manufacturers. The uniform grading system for recycled plastics is designed to facilitate and stimulate the international trade of post-consumer recycled plastics from WEEE. Three stakeholder groups where the grading system should be applied in two different phases of the supply chain are identified: the phase between pre-processor and plastic recycler, where plastics are exchanged in the form of mixed plastic flakes and the phase between plastic recycler and product manufacturer, where recycled plastics are present in the form of granulates.
Interviews with OEMs and recyclers helped to obtain a picture of current needs and to identify the relevant grading criteria to be included in a grading system. A three-pillar model was developed containing the following three categories: quality, reliability and availability. These three pillars are considered to support a harmonized and transparent communication in the value chain by providing a defined set of relevant criteria that can be used for grading by the downstream stakeholders.

Content

1 Introduction: The need for grading

One of the main objectives of the European Strategy for Plastics in A Circular Economy is developing markets and boosting the demand for recycled plastics [1]. Today this is estimated at only 6 % of the plastics market. According to the European Commission one of the reasons for this low demand is the doubt of many Original Equipment Manufacturers (OEMs), that recycled plastics will not meet their needs for a reliable, high-volume supply of materials with constant quality specifications [1]. In order to increase the trust of manufacturers in the capabilities of recycled plastics to fulfil high-quality requirements and replace virgin plastics without compromises, as well as to increase the trade of recycled plastics by and improved communication and transparency, the PolyCE project has developed a grading system for recycled plastics.

2 Plastic recycling value chain

The requirements that a plastic needs to fulfil are mostly defined by OEMs, governments or by the European Union [2], [3]. Quality needs are translated into material requirements and thresholds for substances to ease the search for suitable materials are mostly based on requirements for virgin plastics [4]. No general definition of quality for recycled plastics is possible and measurable quality requirements are strongly dependent on the final application [5], [6]. Recyclers have the objective to produce recycled plastics at a high quality to satisfy customers and to achieve a good price. This is challenging due to the long chain of different recycling processes and multiple actors in the value chain.

In the PolyCE project the recycling value chain for WEEE plastics has been characterized by 7 phases:

- ➔ Collection: Collection of End-of-Life products
- ➔ Pre-Processing: Main focus is decontamination
- ➔ Metal Sorting: Removal from mixed plastics from metal
- ➔ Plastic Sorting: From mixed plastics to single streams
- ➔ Primary Compounding: First compounding step (e.g. melt filtration, additives)
- ➔ Secondary Compounding: Special compounding (e.g. glass fibers) or blending with virgin
- ➔ Product Manufacturing: Production of a plastic component

All phases of the value chain contribute to the final success of producing a recycled plastic that is suitable to the needs of an equipment manufacturer. However, two phases have been identified to be mainly subject to trade and communication between different companies that are involved in the supply chain and cover the several phases of WEEE plastics recycling. The first point in the value chain that requires the development of a grading system for more transparency and support for trade is the plastic sorting.

Plastic sorting is carried out by specialized plastic recycling companies. While some larger companies cover the pre-processing, metal sorting, plastic sorting and primary compounding, there are several smaller companies that are not involved in the pre-processing and metal sorting and need to buy a mix of plastic flakes as an input material for their processes. Also large recyclers are being supplied with additional input material for their plastic recycling processes by pre-processors or metal recyclers, that separate plastics, but do not have the necessary equipment to treat them. Literature review and discussion with industry representatives revealed that transparency for a mixed of plastic flakes, often still containing metal or other contaminants, is especially underdeveloped and companies often rely on the pre-processors based on experience. Some initiatives have been carried out by Plastics Recyclers Europe, that developed guidelines for the quality assessment for plastic bales, often used in the recycling of plastics from packaging waste.

The second point in the value chain is the phase of product manufacturing. OEMs look for material that is able to fulfil their requirements and are often unexperienced with the supply and use of recycled plastic. Plastics are traded at this point in from of granulates and OEMs buy their material form large plastic producers or distributes specialized in sales. Commonly the communication of the plastics quality takes place in form of material datasheets and safety datasheets that are supplied by the material producers. However, these datasheets mostly contain typical values and are not subject any form of reliability or guarantee. Therefore, smaller plastic recyclers that are not broadly known on the market and have not yet earned the trust of some OEMs, are disadvantaged compared to large virgin producers.

In this report two grading systems for recycled plastics are presented, one for mixed plastic flakes that serve as an input in a plastics recycling facility and one for the final plastic granulates that are ready to be used for the production of plastic components.

3 Grading system for plastic flakes

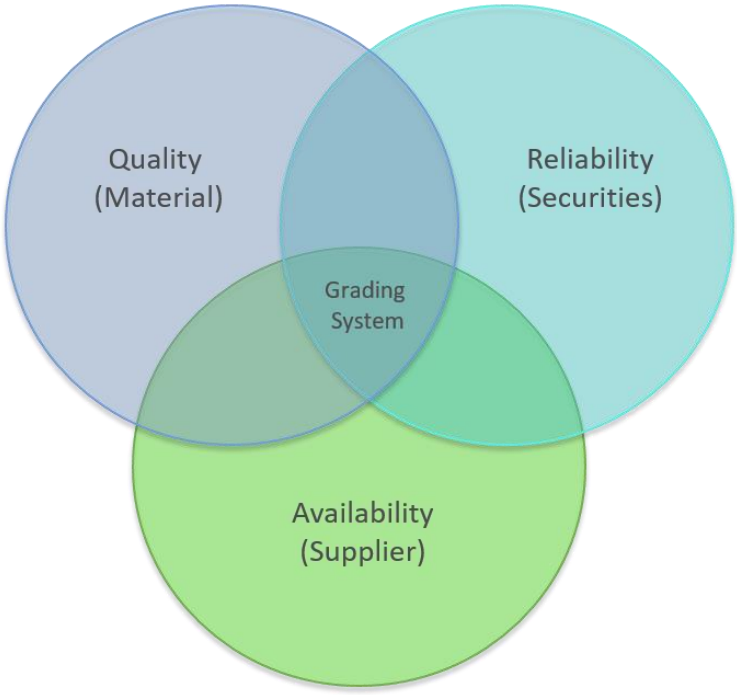


Figure 3-1. 3-pillar model of a grading system for recycled plastics.

The grading system for plastic flakes aims to facilitate the international trade of mixed plastic flakes from WEEE in order to support the sourcing of input material for recyclers. The trade of mixed plastic flakes typically involves the pre-processors and plastic recyclers or metal recyclers that produce an untreated fraction of mixed plastics and want to sell it to plastic recyclers. The grading system is composed of the three categories Quality, Reliability and Availability as displayed in Figure 3-1.

3.1 Interviews

Surveys with industry experts were carried out in the format of one on one interviews with 5 European recyclers to define the most relevant criteria for mixed plastic flakes. The interview results were summarized and criteria that were considered too specific and only relevant for a specific application, too costly to perform the required tests were excluded. However, criteria that are not suitable to be included in the grading system, but could be of significantly added value are discussed. The remaining criteria are presented and interpreted in this paper and form the basis for a uniform grading system for recycled plastics.

3.2 Results and discussion

In the context of this research, mixed plastic flakes are mostly produced by pre-processors and in some cases a separated fraction in metal recycling. Trade of mixed plastic flakes is done with plastic recyclers that use them as input material in their recycling plants. The section provides an overview of the most relevant criteria to be used in an uniform grading

system. The questionnaire used for the interviews and the results of the interviews can be found in the annex.

3.2.1 Quality

For recyclers, the most important quality criteria of mixed plastic flakes are related to the material composition (wt %): type of plastics, the presence of contaminants that could cause problems in the recycling process; and the presence of fillers in the plastics. Combined with physical characteristics, such as flake size and fines content, this information allows recyclers to predict the expected yield of their recycling process [7]. The colour composition was only considered relevant by recyclers that have colour sorting in place, which allows them to separate the white plastics with higher economic values. Another major criteria is the presence of bromine, which should be lower than 2000 ppm to be considered "bromine free" and is mostly related to flame retardants, some of which are subject to substance regulation such as RoHS and REACH. Most WEEE recyclers have systems in place to remove plastics containing brominated flame retardants which results in lower yields. Furthermore, mixed flakes containing brominated flame retardants can be considered hazardous waste, which is subject to difficulties in waste shipment (especially cross-border) and can require the recyclers to possess specific permits to treat it. In addition to the bromine content, also the communication of cadmium, lead, mercury and chromium (RoHS directive [8]) are encouraged.
Recyclers have also indicated that the source of the mixed plastic flakes could help them estimate material compositions, expected yield and potential quality threats. The source could be given at sector level (e.g. WEEE, automotive, household waste or packaging) and at collection category level (e.g. small household appliances, large household appliances, etc for WEEE) and if possible even at product level (fridges, freezers, etc.).
The processing history should indicate which of the following main processing steps have been applied: The processes that should be indicated are decontamination (EN 50625), size-reduction, magnetic-, Eddy-current-, sink-float-, colour-, electrostatic-, spectroscopic-sorting. This is complementary information with the material composition, but is considered helpful for recyclers to estimate the quality of the mixed plastic flakes.
Finally, a picture of the mixed plastic flakes could be included. Beyond the colour and size of the mixed flakes, a picture was considered by the interviewed experts to also deliver information on possible contaminants, as well as on how the material is stored.

Table 3.1. Summary of criteria for a grading system for mixed plastic flakes – Quality.

Quality	
Material composition	**Standard/Legislation/Declarations**
Plastic types	wt% Estimation
Metals	wt% Estimation
Rubber	wt% Estimation
Glass, Ceramic	wt% Estimation
Wood, paper	wt% Estimation
Foams	wt% Estimation
Other materials	wt% Estimation

Presence of Talc/CaCO3 /Glass fibre fillers	wt% Estimation
Size	
Fines<3mm	Sieving
Size	Estimation (shredder screen dimensions)
Compliance	
Bromine content	EN 14582
Waste Stream	
Source composition	WEEE/Automotive/..
Collection categories (WEEE directive)	LHA/SHA,…
Processing History	
Main processing steps	Decontamination/size reduction/magnetic-/Eddy current-/sink-float-/colour/electrostatic-/spectroscopic-sorting
Other	
Picture of mixed plastic flakes	
Reliability	
Use of international standards	EN/ISO/UL/..
Quality Management	
ISO 9000	Certificate
ISO 14001	Certificate
WEEELABEX	Certificate
Availability	
Supplier name and address	
Region of availability	
Production scale	
Sale	Spot/contract
Form	Granulates/flakes

3.2.2 Reliability

In general, two levels of reliability can be defined, the reliability of the material or consistency on the indicated quality and the level of the recycling company's reliability or trustworthiness. The reliability criteria for mixed plastic flakes are similar to those for the plastic granulates, including both material and company reliability. Due to a higher heterogeneity at flake level, the variation in material properties is of even higher importance. To deliver information on the variation of composition data, systematic testing would need to be in place, which is currently not the case. In addition to the testing, the importance of proper sample taking procedures is of high importance to overcome the heterogeneity and provide reliable information on material properties to the recycling companies.
As for the reliability of granulates, also for the mixed plastic flake the use of international standards and proof of quality management systems in place are indicators to be included in a grading system to cover the company reliability of pre-processors. Declaring the possession of ISO 9000, ISO 14001 and WEEELABEX certificates are considered to be of value to increase the trustworthiness and to give an indication on the companies ways of working.

In the future, it should be investigated if background checks (e.g. VAT number, law clearance certificates,..) could be suitable measures to be included in a reliability grading.

Table 3.2. Summary of criteria for a grading system for mixed plastic flakes – Reliability.

Reliability	
Use of international standards	EN/ISO/UL/..
Quality Management	
ISO 9000	Certificate
ISO 14001	Certificate
WEEELABEX	Certificate

3.2.3 Availability

Most recyclers are looking for long-term suppliers of material and try to build up reliable sources for their processes. For the recyclers, the amount of material available is valuable information so they can exclude suppliers with insufficient volumes for their application needs. However, the production capacity (tonnes available per month/year) is considered sensitive information for recycling companies. Nevertheless, companies are highly encouraged to provide information on the availability of recycled material, now and in the future. In the meanwhile, different types of offers, such as single spot or contract offers can already give an indication on whether the material is only offered at the moment or if long-term purchases are possible. Furthermore, recyclers indicated the value of information on the supplier name and address, as well as the region where the material will be available.
Pre-processors producing mixed plastic flakes are encouraged to provide information on requirements for reporting of the suppliers, which can be needed based on national law or for audits. One example is the declaration of the percentage of plastics that can be recycled and the percentage that will be incinerated or documentation confirming the ability to treat mixed plastics with bromine. A major difference of mixed plastic flakes is that the region of availability is influenced by waste shipment regulations. Depending on national law, mixed plastics can be seen as waste, which influences shipment procedures and permits.

Table 3.3. Summary of criteria for a grading system for mixed plastic flakes – Availability.

Availability	
Supplier name and address	
Region of availability	
Production scale	
Sale	Spot/contract
Form	Granulates/flakes

3.3 Determination of quality criteria for mixed plastic flakes

The determination of the material composition in the grading system is based on estimations by the supplier. The recyclers indicated in the interviews that testing would be beneficial, especially to determine the types of polymers and bromine present in the mixed flakes, but did not consider it a necessity. High costs of testing and the need for reliable sample taking procedures are seen as the main reasons why the material composition should be estimated rather than tested. Estimations can be done by visually inspecting the material, based knowledge of typical compositions based on the origin of the material or experience. In addition, the declaration of main processing steps that were applied to the material, this can give a good representation on the expected composition.
However, testing of the material composition can provide more detailed information, as well as a higher certainty in the composition data and is, for this reason, highly encouraged. To assure representative results the sampling procedures are crucial. Examples for representative sampling are given by Gy et al. [9]–[13]. For the specific case of sampling WEEE there are several working protocols and standards mentioned in the WEEELABEX documentations, such as EN 14899.
The only quality criteria that requires a measurement is the presence of bromine (and other RoHS restricted elements), which cannot be estimated. Handheld XRF scanners have been reported as suitable field-equipment for bromine determination and some bromine determination procedures are described in WEEELABEX documentation [14].
A cheap and practical technique to estimate the mixed flake composition is to test the weight of material that sinks or floats in selected density ranges. These results of estimated composition per density range could be communicated in addition to the total estimated material composition. However, no standard procedures are known to the authors.
Research showed that automated testing by manual composition analysis, FTIR, XRF and computer vision allows to analyse the types of polymers, presence of some fillers, presence of RoHS restricted elements, the amount of metals, glass, wood, and other materials [7]. While today such analysis could be performed by third-party testing institutions, they are still quite labour intensive and expensive and further research is required to enable a higher degree of automation of the testing to increase the economic viability of better and more systematic testing.

An example of such an automated testing procedure is being developed by KU Leuven and relevant innovations have been presented in previous deliverables 4.3 and 4.4. The testing system is composed of a manual composition analysis, a computer vision system, an automated FTIR spectrometer and a XRF spectrometer to analyse, the material composition including plastic type and filler composition, the size & colour distribution and the RoHS elements Br, Cd, Pb, Hg (Figure 3-2).

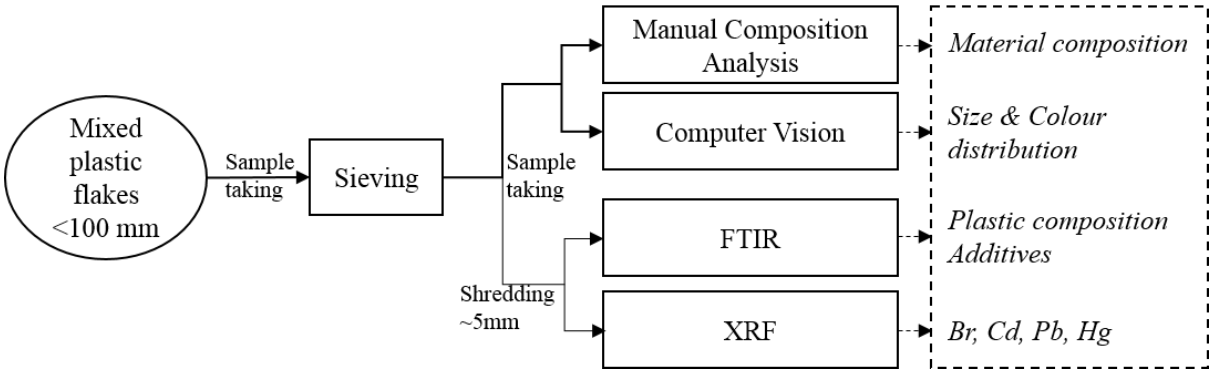


Figure 3-2. Systematic testing system for mixed plastic flakes [7].

4 Grading system for plastic granulates

The grading system on granulate level aims to facilitate the search of manufacturers for recycled plastics. It allows to improve the trading of post-consumer plastics by determining the most relevant criteria between different actors in the value chain and increases the transparency. Further, it reduces mistrust in post-consumer recycled plastics by implementing reliability criteria. The system includes the most relevant criteria in the search for new materials and can be used directly or included in an online platform.

4.1 Interviews

A unstructured list of relevant criteria that should be included in a grading system for recycled plastics was worked out in a brainstorming session with PolyCE partners. The criteria were clustered and integrated in a 3-pillar model with the categories quality, reliability and availability. Interviews with 5 OEMs were carried out to extend and prioritize the relevant criteria, which were finally formulated in a grading system for recycled plastic granulates from WEEE.

4.2 Results and discussion

Recycled plastic granulates are produced by plastic recyclers and mostly subject to trade between the recyclers or distributers and OEMs. The section provides an overview of the most relevant criteria to be used in an uniform grading system. The questionnaire used for the interviews and the results of the interviews can be found in the annex.

4.2.1 Quality

Based on the interview findings, most OEMs do not differentiate between quality criteria of recycled plastics and virgin plastics. Many properties mentioned by OEMs (Table 1) can already be found on most datasheets provided by recyclers. However, previous research showed that these basic properties are not able to adequately answer application specific quality needs of OEMs and physical application testing is always needed to make a final decision in a material selection process [4]. In addition, the following properties were considered important, but only for specific types or applications: Shrinkage (ISO 294), tensile

stress at break (ISO 527), tensile strain at yield (ISO 527), heat deflection temperature (ISO 75), filler content (and filler type) (ISO3541/D5630) and flammability rating (UL 94). Next to material properties, the declaration of one or more targeted processes of the plastic, such as injection moulding, extrusion, thermoforming,.. should be declared by the material producer. Further, communication of pictures showing application cases in which the material was used, was requested by the OEMs to give a better impression on the quality. While most OEMs supported the idea, recyclers indicated that they would rely on approval of OEMs, which is why the communication of such pictures can only be voluntary and not included in a grading system. Compliance to substance regulations like REACH and RoHS (in the context of WEEE plastics), was considered of major importance by OEMs. This can be interpreted as mistrust in the quality, as described by the EU [1], because also virgin plastics need to comply to these substance legislations.

Next to the recycled content and origin from post-consumer or post-industrial sources, the OEMs also expressed the need to be informed about the environmental advantage for their products of using granulates from recycled plastics. Quantifying such environmental benefits is not straightforward for a number of reasons. First, the benefits of secondary resources are generally shared between different product systems: the one generating and the one using the recycled material. However, the appropriate allocation remains a topic of discussion among most LCA-practitioners and clear rules are necessary to avoid double counting. Second, limited data are available related to the potential quality losses or the substitutability of recycled material for virgin material which would allow to compare their performance for a specific functionality. Third, in practice, the granulates will not be produces from 100% recycled material but the maximum allowed recycled content will depend on the quality of the recycled flakes used to produce the granulates.

"Circularity" which can be defined as the ability to conserve both the quantity and the quality of the material is another measure that could be used to describe the contribution of the recycled granulates to a more circular or less resource intensive economy. For example, the content of recycled material used could be calculated with the 'upstream' circularity measure from the UL 3600 standard [15]. However, it should also be emphasized that a completely circular product is one that is produced from recycled materials and that is designed to be recycled.

Table 4.1. Summary of criteria for a grading system for recycled plastic granulates – Quality.

Quality	
Properties	**Standard/Legislation/Declarations**
Colour	ISO 11664
Flexual Modulus	ISO 178
Tensile Strength	ISO 527
Strain at Break	ISO 527
Charpy impact strength - notched	ISO 179
Density	ISO 1183
Melt flow Index	ISO 1133
Compliance	
REACH	1907/2006/EC
if applicable	

RoHS	*2011/65/EU*
Toy Grade	*EN 71*
Food contact recycled plastics	*1935/2004/EC*
Environmental	
Recycled content	UL 2809 or EN 15343
Origin	Post-consumer/Post-industrial/virgin
Other	
Target Process	Injection moulding/Extrusion/..

4.2.2 Reliability

When recycled plastics are purchased by OEMs, reliability is the most important topic they want to be informed about. This reliability information can reduce the mistrust and misbelieve of many OEMs that recycled plastics are inferior in quality compared to virgin plastics. The survey showed that international standards should be used for testing and declaring the criteria. In addition, statistical data to reflect the inherent variability of material properties would significantly improve the ability to manage the risks associated with using recycled plastic in a reliable way. However, this information is considered confidential by recyclers and is only communicated in exceptional cases to long-term customers. Nevertheless, quality testing by independent institutions is highly encouraged as it increased the trustworthiness of the declared criteria for many OEMs. However, as many recyclers possess the capabilities of testing material properties according to international standards and because third-party testing will entail additional costs, a criteria for third party testing is not included in the grading system.
On company level, OEMs that want to use recycled plastic in their products are confronted with entirely new and significantly smaller companies compared to the virgin producers. The communication of quality management systems in place is seen as a suitable measure to support the reliability on company level. In addition, certifications, such as ISO 9000, ISO 14001 and EUCertPlast, increase the trustworthiness in the manufacturing practices of recyclers. As this is considered important for many OEMs, a reference to the according certificates should be included if available.

Table 4.2. Summary of criteria for a grading system for recycled plastic granulates – Reliability.

Reliability	
Use of international standards	EN/ISO/UL/..
Quality Management	
ISO 9000	Certificate
ISO 14001	Certificate
EUCertPlast	Certificate

4.2.3 Availability

The criteria for availability for recycled plastic granulates do not differ significantly compared to mixed plastic flakes. In contrary to flakes, the OEMs are both interested in spot and in contract sales, depending on the company and application.

Table 4.3. Summary of criteria for a grading system for recycled plastic granulates – Availability.

Availability	
Supplier name and address	
Region of availability	
Production scale	
Sale	Spot/contract
Form	Granulates/flakes

4.3 Grading system

The aim of the surveys was to define criteria relevant for grading in a systematic and uniform context for WEEE plastics recycling. The grading system is intended to establish first points of contact for trade. The establishment of long-term contract relationships between stakeholders might require more detailed information and additional criteria.
The system defines a set of criteria for the communication between the supplier and the customer in the plastics recycling supply chain (**Fehler! Verweisquelle konnte nicht gefunden werden.**). A 3-pillar structure categorizes the defined criteria and results in a qualitative overview in form of a percentage of information that is actually provided. This forms the basis for actual grading by weighting and ranking of the criteria in function of the defined quality requirements of a downstream stakeholder. This approach is necessary as quality and availability requirements strongly depend on the specific company and application needs. At the same time, a structured and harmonized communication of the most relevant criteria to make a material pre-selection is necessary.
Different types of grading were considered, shown in an overview in **Fehler! Verweisquelle konnte nicht gefunden werden.**2. Grading by a star rating is considered an alternative for the percentage grading of the information provided. Both deliver a simplified information without any weighting or ranking required, which could induce bias. In addition, the amount of criteria that can be included are unlimited, which allows the grading system to be extended. The use of an ABC grading or the traffic light model require ranking into good or bad property values. The use of more complex grading, such as the honeycomb-star model or the circle diagram, which are often found on food packaging, are a good way to convey a limited amount of criteria. However, in the view of the authors the criteria for recycled plastics cannot be limited to an amount that would be suitable for this kind of grading.

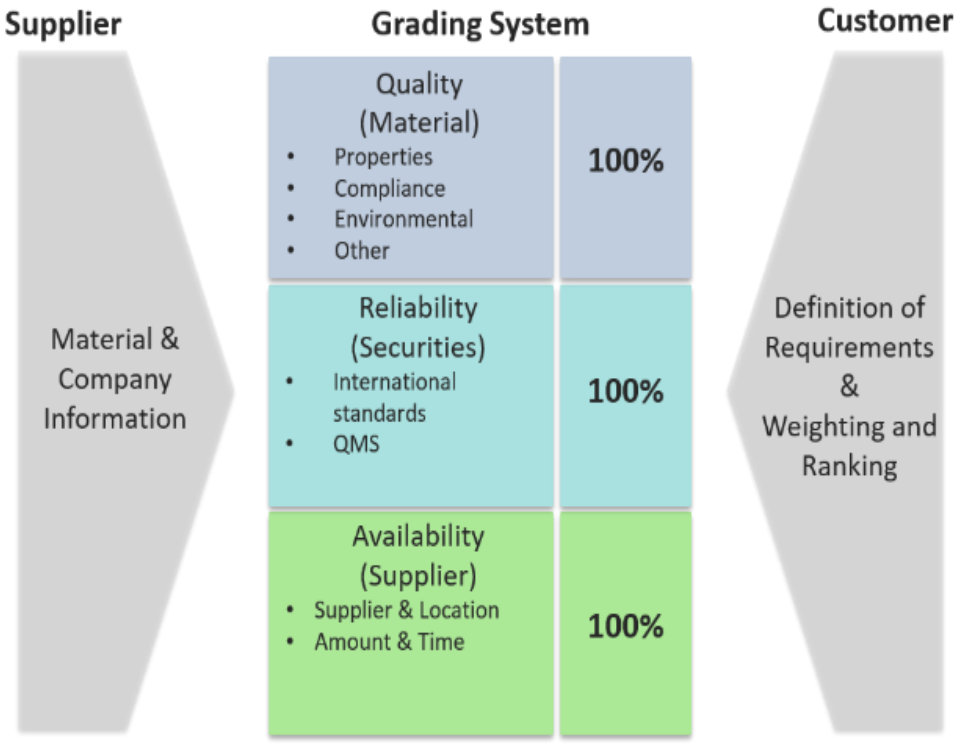


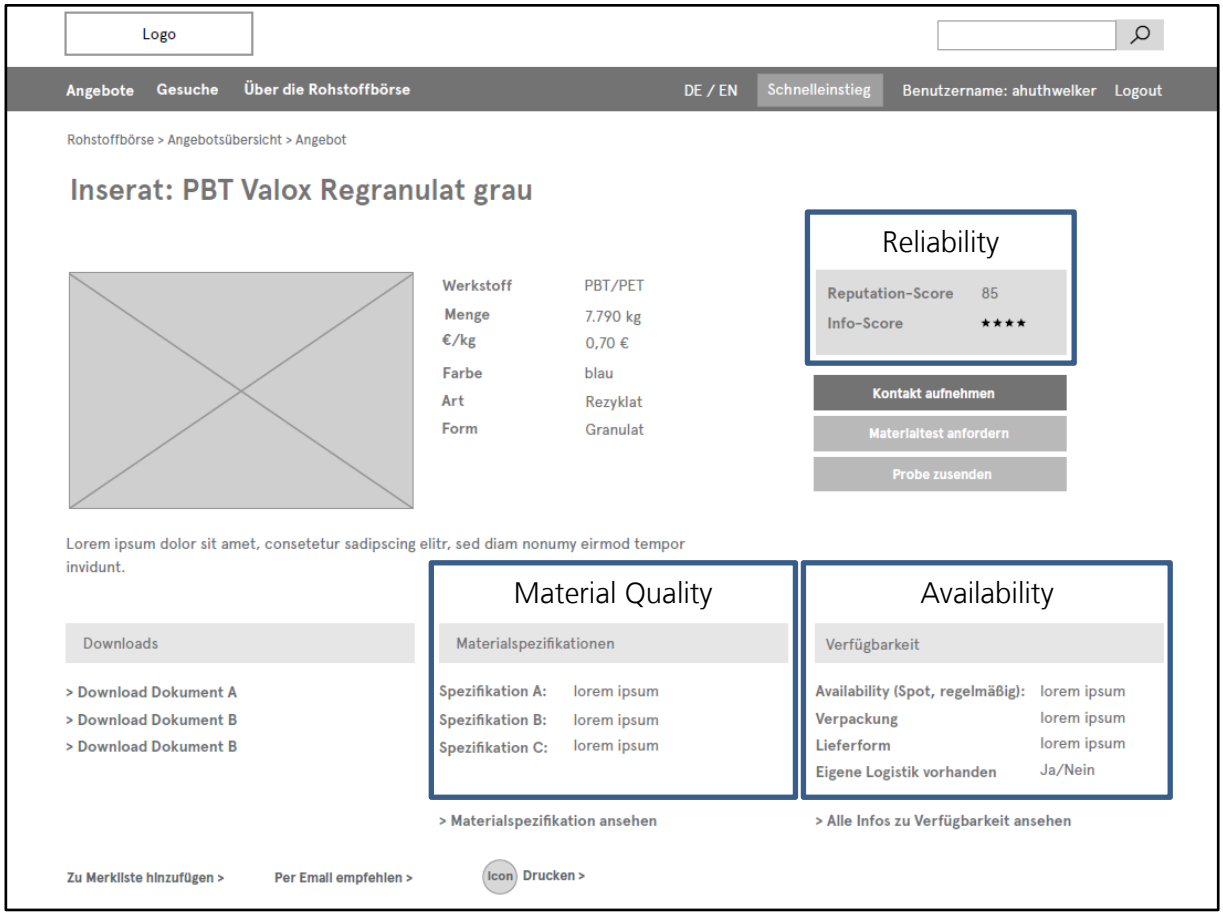
Figure 4-1. Grading system for the communication between supplier and customer.

Table 4.4. Overview of grading types.

System	Simplification	Criteria-Weighti	Amount of criteria
Star rating	high	no	unlimited
Percentage	high	no	unlimited
ABC grading	high	yes	unlimited
Traffic light model	high	yes	unlimited
Honeycomb-Star-model	medium	yes	limited
Circle diagrams	medium	yes	limited

5 Applications of the grading system in an online market platform

The grading system was used to communicate important information on the point of sale respectively the material trading website. A UX/UI Workshop has been carried out to draw a user story map for the website to see desired information and tools. The conceptual grading system was translated into graphical wireframes (stage 1) and technical realisation



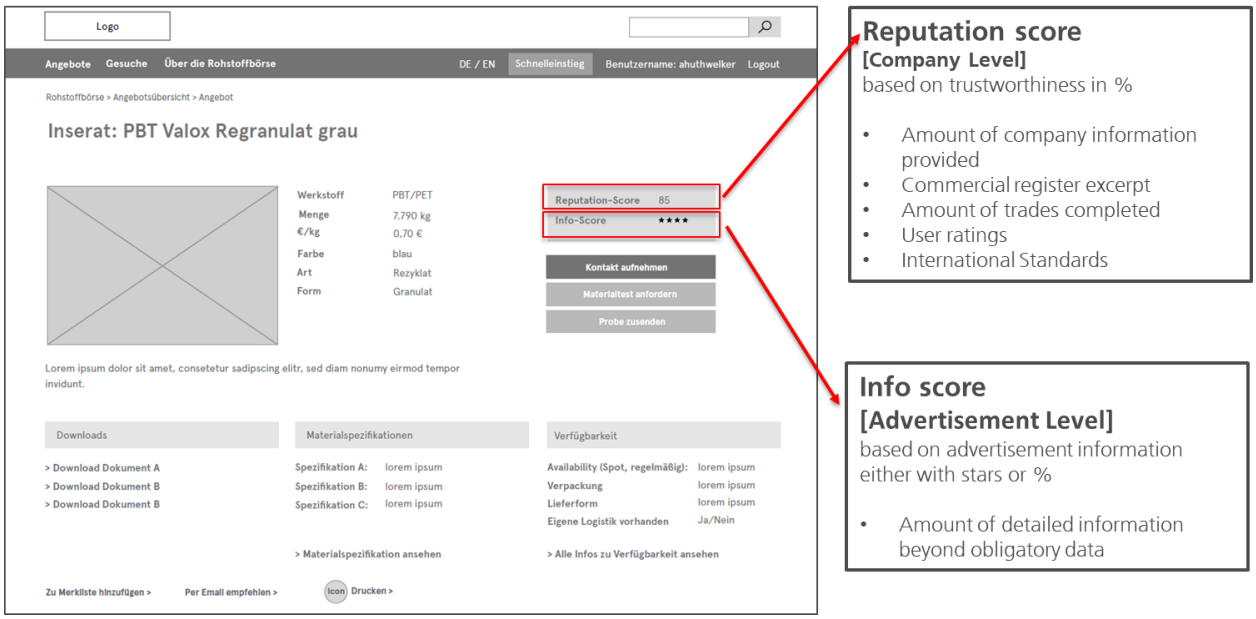
(programming/development, stage 2) requirements for the material trading platform concept (Task 6.3). Necessary layout, content and functions have been derived for all wireframes/ throughout the entire website to attract users and offer convenient trading.

The existing platform and users are USPs, as a market place lives from a critical amount of users and offers. To provide familiarity to the existing users on the new platform, the transition was smoothened by using/adapting same core elements (stylesheets with color, font, frames, and arrangements) of the existing platform. For stage1, the graphical part, Wireframes have been prepared as a pre-setup and basis for discussion and revision of the platform:

Above figure shows a wireframe (exemplary for "detailed offer") where the three core elements from the grading system have been translated into the platform. In total over 50 graphical frames where prepared that communicate "availability, material quality and reliability" throughout the entire website.

Looking into detail for reliability, a reputation score was developed, measured in percent, based on:

- Amount of company information provided
- Commercial register excerpt
- Amount of trades completed
- User ratings
- International Standards



Especially important for search purposes, the material specification and availability dimension has been defined. Mandatory (M) or obligatory (O) fields on availability and price are requested on the webstie when creating a new offer:

- Availability (M)
  - One-time / spot
  - Continously / contract
- Frequency (O) – if continously
  - Weekly / monthly / per quarter / per year
- Available quantity (O)
- Delivery specification / INCO terms (O)
- Storage location country (O)
- Storage location postcode (O)
- Price per kg in EUR (O)

For material specifications, following basic specifications have been fixed (detailed material characteristics are not finally defined):

- Color (M): Fixed set of options
- Form (M): Fixed set of options
- Packaging (M): Fixed set of options
- Certificate (O): Yes / no

The systematic approach from grading system, to user story mapping and wireframe implementation allowed to identify the best trade of between most valuable information to the buyer and the effort to create an offer by the seller. Alpha testing of the platform will be used to work visually and identify further elements (starting M40).

6 Conclusions and future work

Surveys with OEMs and recyclers showed that the reliability of the material and supplier are a major concern to engage with new suppliers. The experts interviewed indicated that the use of international standards and quality management systems allows to improve the reliability of companies and future research should further investigate measures that can support the transparency and availability of information in the supply chains of plastic recycling. Therefore, a grading system is developed and presented in this research, which compiles a set of criteria and related standards that are considered relevant for trading with unknown suppliers. Due to various application and company specific requirements, the percentage grading of providing the defined criteria is chosen over other grading options fobergamin.90210
r a uniform grading system for recycled plastics. The grading system can structure and harmonize the communication in the plastics recycling supply chain. Quantitative grading

requires weighting or ranking of criteria and can only be done for a material or application specific context.
The interviews highlighted that the origin of the material plays a key role for the estimation of the expected composition and can be used as a quality indicator. However, long-term expertise in the field is needed. The limited availability of information on waste compositions remains a limitation for recycling and can only be overcome by increased transparency of the supply chains and systematic testing of waste streams. This should be supported by standards and technologies for testing of mixed plastics. Future research should focus on the development of testing procedures that allow to systematically test mixed plastics by reducing the cost of testing.

7 References

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8 Appendix

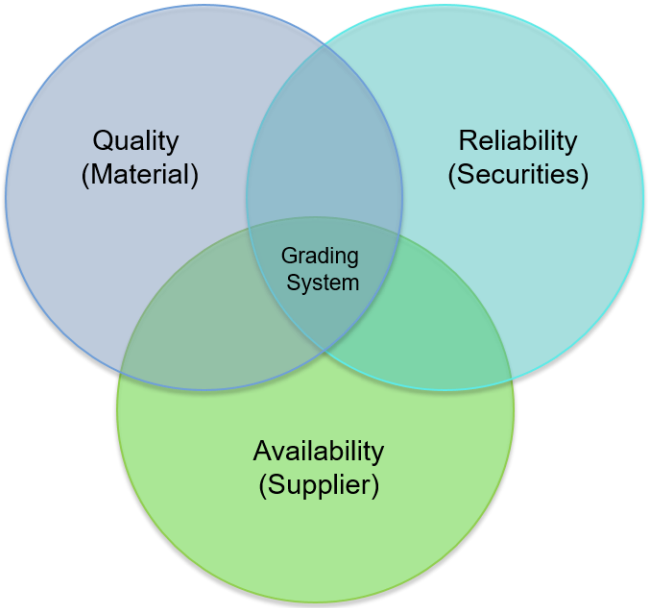
8.1 Grading system interviews questionnaire – mixed plastic flakes

The objective of a grading system

To purchase mixed plastic flakes from new suppliers (possibly online) a grading system should help to identify the most relevant information and allow to already give some indication of the suitability for the recycler.

Development of a uniform grading system that can be used for trading of Post-Consumer Recyclates (PCR) between the different actors of the value chain either directly or through an online platform. The grading system should classify the PCR according to their material properties and final application, to improve the industrial cooperation among all actors of the value chain and increase the use of PCR in Europe.

Previously in a workshop at the last GA a 3-Pillar structure has been developed that should be the basis for the questionnaire.



Quality

8.1.1 Do you agree that the list of minimum requirements reflects the most relevant properties to be communicated at flake level? Are there properties that you consider relevant to add or remove?

Quality requirements	**Rating (1 not relevant – 5 very relevant)**
Plastic composition	

Metals	
Rubber	
Glass, Ceramic	
Wood, paper	
Foams	
Other materials	
Fines<3mm	
Colour	
Size	
Bromine	
Cadmium	
Lead	
Mercury	
Chromium	
Talc	
Calcium carbonate	
Glass fibres	
Others, please specify….	

8.1.2 In what detail should the relevant quality requirements be communicated?

Should the properties be measured or are estimations good enough?

Quality requirements	**Rating (1 rough estimation – 5 very detailed)**	**Example**
Plastic composition		(1) estimation – (5) FTIR analysis on plastic types
Metals		(1) estimation – (5) analysis on metal types
Rubber		
Glass, Ceramic		
Wood, paper		
Foams		
Other materials		
Fines<3mm		(1) estimation – (5) size distribution
Colour		(1) estimation – (5) colour distribution
Size		(1) estimation – (5) size distribution
Bromine		(1) estimation – (5) element concentrations
Cadmium		
Lead		
Mercury		
Chromium		
Talc		(1) estimation – (5) filler concentrations
Calcium carbonate		

Glass fibres		
Others, please specify….		

8.1.3 Do you consider a picture to be included interesting to communicate quality?

Quality is often difficult to communicate and pictures could help to improve this communication. For this reason, a picture of the material that is traded can be included in the material specification overview. Do you consider a material picture relevant?

- Yes
- No
- Other possibility

8.1.4 Are there additional aspects that you consider relevant to include for the reflection of the quality of a material?

Availability

8.1.5 Is the information tones/month sufficient to express the availability of a material?

Reliability

8.1.6 Is generic information on the source of the material important for communication? What kind of metadata would you considered relevant to be systematically communicated?

Generic Information	**Rating (1 not relevant – 5 very relevant)**
Company name and address	
Sample identification code	
Date sample was send	
Sample size	
Inventory Control/Shipping	
Target Fraction Description	
Waste stream information (WEEE, Automotive,…)	
Collection category information (LHA, SHA,…)	
Product composition information (fridges, freezers,…)	

Treatment (e.g. EN 50625-1)	
Others, please specify….	

8.1.7 What information on previous processing do you consider relevant and how to provide this information?

Processing information	**Rating (1 not relevant – 5 very relevant)**
Manual sorting	
Size reduction technique (hammer mill, granulator,..)	
Sieving size	
Magnetic sorting	
eddy current sorting	
sink-float separation	
colour sorting	
Decontamination (e.g. EN 50625-1)	
Others, please specify….	

8.1.8 What is the best way for you to communicate the reliability of a material and supplier?

The reliability of the information that is included in the grading system and the ability to deliver a constant quality can be very important aspects for purchase decisions. What are the criteria used in your opinion to evaluate the reliability of a supplier or the offered material?

Reliability information	**Rating (1 not relevant – 5 very relevant)**
International standards	

Quality management system	
Quality Control	
Compliance schemes (RoHS, REACH,…)	
Testing by independent institutions	
Traceability and publishing of properties and other information over long timeframe	
Variation in tested properties (min, max, mean)	
Reputation system, reference list	
Others, please specify…	

8.2 Grading system interviews results – mixed plastic flakes

	Recycler 1	**Recycler 2**	**Recycler 3**	**Recycler 4**	**Recycler 5**
Quality requirements					
Question 1	**Do you agree that the list of minimum requirements reflects the most relevant properties to be communicated at flake level? Are there properties that you consider relevant to add or remove?**				
Plastic composition	4	5	1	5	5
Metals	4	5	1	3	3
Rubber	5	5	1	3	4
Glass, Ceramic	4	5	3	1	4
Wood, paper	5	5	3	1	1
Foams	5	5	3	3	3
Other materials	4	5	1		
Talc	4	2	4	5	3
Calcium carbonate	4	2	1	5	3
Glass fibres	4	2	4	5	4
Colour	2.5	1	1	3.5	2
Fines<3mm	5	5	5	3.5	4
Size	4	4	2	4	3

Bromine	4	5	1	4	4
Cadmium	4	2.5	1	1	1
Lead	4	2.5	1	1	1
Mercury	4	2.5	4	1	1
Chromium	4	2.5	4	1	1
Others, please specify….				P FR (can disturb recycling process - degradation) – knowing it from the origin! Measuring phosphorus is not easily measureable.	

Remark	**Amount of materials that is below 1,1 density -> for yield estimations**	**Info mainly for yield estimations**		**The required quality infromation is dependent on the history and source of the material**

Question 2

In what detail should the relevant quality requirements be communicated?

Rating					
Plastic composition	1.5	4	2	1	5
Metals	1.5	1.5	2	1	3
Rubber	4	1.5	2	1	2
Glass, Ceramic	1.5	1.5	2	1	3
Wood, paper	4	1.5	2	1	1
Foams	4	1.5	2	2	1
Other materials	1.5	1.5	4	2	
Talc	1.5	2	2	4	3
Calcium carbonate	1.5	2	1	2	3
Glass fibres	1.5	2	1	4	4
Colour	1.5	1	1	3	3
Fines<3mm	4	1.5	4	3	1

Size	1.5	3	1	3	2
Bromine	1.5	4	1	4	4
Cadmium	1.5	2	3	2	1
Lead	1.5	2	3	2	1
Mercury	1.5	2	5	2	1
Chromium	1.5	2	5	2	1
Others, please specify….					

Question3	**Do you consider a picture to be included interesting to communicate quality?**				
Answer					
	yes	yes	yes	yes	yes

Question 4	**Are there additional aspects that you consider relevant to include for the reflection of the quality of a material?**				
Answer	Information on waste source of the materials and country				

Availability

Question 5	**Is the information tones/month sufficient to express the availability of a material?**				
Answer	Seasonality – differences in volume per season. E.g. refrigerator is characterized with season peaks (country dependent)	Delivery form (packaging, delivery container,..)	yes	yes, also the buffer rate in case of a hickup	Longer term : ton per year or ton per 6 months

Reliability

Question 6	**Is generic information on the source of the material important for communication? What kind of metadata would you considered relevant to be systematically communicated?**

Answer					
Company name and address	5	5	5	5	5
Sample identification code	1	1	5	1	3
Date sample was sent	1	4	5	4	3
Sample size	1	4	5	4	4
Inventory Control/Shipping/Delivery	5	5	was not included in questionnaire		
Target Fraction Description	4.5	was not included in questionnaire			
Waste stream information (WEEE, Automotive,…)	4.5	5	4	5	4
Collection category information (LHA, SHA,…)	4.5	5	4	5	4
Product composition information (fridges, freezers,…)	1	3	2	5	4
Treatment (e.g. EN 50625-1)	1	was not included in questionnaire			
Others, please specify….	-VAT number, -registration number, legal check, requirements for reporting	-country of origin, -date sample was taken			

Question 7	**What information on previous processing do you consider relevant and how to provide this information?**				
Answer					
Manual sorting	2	2	1	5	1
Size reduction technique (hammer mill, granulator,..)	2	2	3	5	5
Sieving size	2	2	3	4	3
Magnetic sorting	2	2	3	3	4
eddy current sorting	2	2	3	3	4
sink-float separation	2	2	3	5	4
colour sorting	2	2	4	5	4
Decontamination (e.g. EN 50625-1)	4.5	was not included in questionnaire			
Others, please specify….				Triboelectrostatic separation	
Remark		If quality information is available, then it is not relevant			Important for efficiency

Question 8	What is the best way for you to communicate the reliability of a material and supplier?				
Answer					
International standards	3	3	4	All this is obligatory according the law already	4
Quality management system	3	4	1	4	3
Quality Control	3	was not included in questionnaire			
Compliance schemes (RoHS, REACH,…)	Not applicable	5	4	1	1
Testing by independent institutions	3	3	4		1
Traceability and publishing of properties and other information over long timeframe	3	3	3		1
Variation in tested properties (min, max, mean)	3	5	2	4	1
Reputation system, reference list	3	3	1	2	1
Others, please specify….	WEEELABEX, R2	-credit checking, owner background check			WEEELABEX
Remark	All are important for reliability but none of the measures are sufficient to assure reliability so that self-checking can be replaced				

8.3 Grading system interviews questionnaire – recycled plastic granulates

The objective of a grading system

Development of a uniform grading system that can be used for trading of Post-Consumer Recyclates (PCR) between the different actors of the value chain either directly or through an online platform. The grading system should classify the PCR according to their material properties and final application, to improve the industrial cooperation among all actors of the value chain and increase the use of PCR in Europe.

Previously in a workshop at the last GA a 3-Pillar structure has been developed that should be the basis for the questionnaire.

Quality	Availability	Reliability
Properties Minimum requirements **Source** Post-Consumer/Post-Industrial/virgin from WEEE, from packaging **Target Grade** thin-willed/thick walled injection moulding/extrusion Food contact/toy grade/EEE grade…. **Environmental Performance** environmental aspect **Delivery form** shape granules/flakes	tons/month	expected variation in the future/next months Depth of traceability (controlled source) legal compliance (e.g. REACH & RoHS) 3rd party certificate (technical properties, legal compliance) Reputation system

Quality

8.3.1 Do you agree that the list of minimum requirements reflects the most relevant properties to be communicated at datasheet level? Are there properties that you consider relevant to add or remove?

Minimum Requirements
Colour
Shrinkage at production

Flammability Rating
Tensile stress at break
Tensile Strain at Yield
Tensile Strain at Break
Flexural modulus (23°C)
Tensile modulus (23°C)
Tensile strength (23°C)
Charpy unnotched (23°C)
Charpy notched (23°C)
Density
Melt Flow Rate
Vicat softening point
Heat Deflection (un-annealed)
Gloss
Tensile stress at yield
Filler Content
Food Contact approval
Recycled Content
RTI

8.3.2 Do you think that communicating potential target application is a good way to communicate quality?

Do you think this is a good way to communicate the quality of a recycled plastic? Is it sufficient for the supplier to declare possible applications or is it important to include some form of proof (by case studies, confirmation of other clients, independent testing institutions,..)? Which categories do you consider relevant from the following list:

Option 1 target grade:

- Food grade
- Toy grade
- Electronic grade (RoHS, REACH)
- Automotive grade
- Others, please specify …

Option 2 target process:

- Extrusion grade
- Injection moulding grade
- Blow moulding
- Others, please specify

Option 3 self-declared target applications:

- For the application in screen housings
- For the application in structural components
- Clarity, optical applications

- Others, please specify

8.3.3 Do you consider a picture to be included interesting to communicate quality?

Quality is often difficult to communicate and pictures could help to improve this communication. For this reason, a picture of the material that is traded can be included in the material specification overview. Do you consider a material picture relevant?

Another option is to include pictures of products that were produced with this recycled plastic. For example, if the material has been used in a vacuum cleaners by one of the customers of the supplier a picture of a vacuum cleaner produced with this material could be included. Do you consider such a product image relevant?

- Yes
- No
- Other possibility

8.3.4 Are there additional aspects that you consider relevant to include for the reflection of the quality of a material?

Environmental Performance

- Environmental aspect
- Recyclability
- Energy savings

Delivery Form

- Shape
- Granulates/flakes
- Size

Availability

8.3.5 Is the information tones/month sufficient to express the availability of a material?

Other information on the availability could be the definition of regions, where the material can be supplied to. Further information on the location, where the material will be delivered from.

- Region of availability
- Supplier name
- Company size
- Product portfolio
- Location of production
- Tones/year
- Min purchase amount
- Delivery time (from purchase until delivery)
- Technical source

- Availability now & future

Reliability

8.3.6 What is the best way for you to communicate the reliability of a material and supplier?

The reliability of the information that is included in the grading system and the ability to deliver a constant quality can be very important aspects for purchase decisions. What are the criteria used in your opinion to evaluate the reliability of a supplier or the offered material?

- International standards
- Certified quality management systems
- Different forms of labels (if a label is assigned by an independent institution)
- Compliance schemes (RoHS, REACH,..)
- Testing by independent institutions (especially for compliance)
- Traceability and publishing of properties and other information over long timeframe (Phase gate approach)
- Variation in tested properties (min, max, mean)
- Reputation system
- UL listing for the use in the American market (will provide reliability as it looks into consistency, third-party, also for the EU market just for reliability)
- Others, please specify….

Would you be interested that a testing institute can test and certify your material that you offer or search (towards minimum specifications or grading system)?

8.3.7 Is it important to compile information to grades, e.g. A, B or C grade, or is it preferred to have always more detailed and quantitative information available?

The grading system can define relevant information to be included and categorize this information to focus on the availability and quality of information. Otherwise the information can be compiled to some form of grade that is then used to identify suitable materials. An example is the booking of a hotel room, where a grading for the location and other information is displayed in more detail. Which of the prior mentioned information should be combined into a grade and which should be made available?

8.4 Grading system interviews results – recycled plastic granulates

		OEM 1	OEM 2	OEM 3	OEM 4	OEM 5
Quality						
Properties (+ISO, EN)	**Standard**					
Colour (Range)	ISO 11664	1	1	1	1	1
Gloss	ISO 2813	1	0	1	1	1

Shrinkage at production	ISO 294	1	1	1	1	1
Tensile stress at break	ISO 527	1	1	1	1	1
Tensile Strain at Yield	ISO 527	1	1	1	1	1
Tensile Strain at Break	ISO 527	1	1	1	1	1
Tensile modulus (23°C)	ISO 527	1	1	1	1	1
Tensile strength (23°C)	ISO 527	1	1	1	1	1
Tensile stress at yield	ISO 527	1	1	1	1	1
Flexural modulus (23°C)	ISO 178	1	1	1	1	1
Charpy unnotched (23°C)	ISO 179	1	1	1	1	1
Charpy notched (23°C)	ISO 179	1	1	1	1	1
Charpy notched (0°C)	ISO 179	*0*	*0*	*0*	*1*	*0*
Charpy notched (-20°C)	ISO 179	*0*	*0*	*0*	*1*	*0*
Density	ISO 1183	1	1	1	1	1
Melt Flow Rate	ISO 1133	1	1	1	1	1
Vicat softening point	ISO 306	1	1	1	1	1
Heat Deflection	ISO 75	1	1	1	1	1
Filler Content (& type)	ISO 3541 or D5630	1	1	1	1	1
Flammability Rating (if V0 or V1 + FR type)	UL94	1	0	1	1	1
Recycled Content (+Post-consumer/post-industrial)	UL 2809 or EN 15343	1	1	1	1	1
RTI	UL746B	*0*	*0*	*0*	*0*	*1*
Compliance						
Food Contact			0	1	1	1
RoHS		1	1	1	1	1
REACH		1	1	1	1	1
Environmental Performance						
Impact (better defined)		0	1	1	0	1
Recyclability	*EN 45555*	*0*	*0*	*1*	*0*	*0*
Energy savings		*1*	*0*	*0*	*0*	*0*
Delivery Form						
Granulates/flakes		1	1	0	1	1
Size & shape		1	1	0	0	1

Availability						
Supplier & Location						
Supplier name		1	1	0	0	1
Region of availability		1	1	0	1	0
Location of production		1	1	**1**	**0**	**1**
Company Size		0	1	0	0	0
Product portfolio		1	1	0	0	0
Source		*0*	*1*	*0*	*0*	*0*

Amount & Time					
Tones/year	1	1	0	0	1
Min purchase amount	*0*	*1*	*0*	*0*	*0*
Delivery time	*0*	*1*	*0*	*1*	*0*
Availability now & future	*0*	*0*	***0***	***1***	***0***

Reliability					
Consistency					
International standards	0	0	1	1	1
Certified quality management systems	**1**	**0**	**0**	**0**	**1**
Variation in tested properties (min, max, mean)	0	0	1	1	1
Traceability					
Traceability and properties over long timeframe	**0**	**0**	**0**	**0**	**1**
Compliance schemes (RoHS, REACH,..)	1	1	0	0	1
Trustworthiness					
Reputation system	1	0	0	0	0
Labels (independent institution)	1	0	0	0	1
Testing by independent institutions (compliance)	1	0	1	1	1
UL listing (reliability, third-party, American market)	*0*	*0*	*0*	*1*	*0*

Header (voluntary information)					
Target Application (Electronic, automotive, food, ….)	0	1	1	1	0
Target Process (Injection moudling, extrusion, …)	1	1	1	1	0
Self-declared target application (screen housings, …)	0	0	1	1	0
Picture/communication of cases	1	1	1	1	0
Grading or Transparency					
Transparency	1	1	1	0	1