CREATOR
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Deliverable report

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CREATOR CONSORTIUM

PARTICIPANT NUMBER	ABBREVIATION	ORGANISATION
1	ICT	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung – Institut für Chemische Technologie
2	VLB	Volbas S.A.
3	MOS	Machinefabriek Otto Schouten BV
4	CLR	Coolrec BV
5	REL	Treee SRL
6	GKR	Fundacion Gaiker
7	TCK	Transfercenter fur Kunststofftechnik GmbH
8	RMA	Erema Engineering Recycling Maschinen und Anlagen Ges.m.b.H
9	CTB	Centre Scientifique & Technique De L'industrie Textile Belge
10	MAI	Maier S. Coop.
11	DAW	DAW SE
12	CYC	Cyclefibre S.L.
13	CID	Fundacion Cidaut
14	KLU	Kuhne Logistics University GmbH
15	OVM	Openbare Vlaamse Afvalstoffenmaatschappij
16	RWE	RWEnergia Robert Wudarczyk
17	ITB	ITRB Group LTD

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CREAToR consortium		Support to the study

LIST OF ABBREVIATIONS

ABBREVIATION	DESCRIPTION
ABS	Acrylonitrile butadiene styrene
BAT	Best available technique
EPR	Extended producer responsibility
HBCD	Hexabromocyclododecane
HDPE	High density polyethylene
LDPE	Low density polyethylene
MFI	Melt flow index
PA	Polyamide
PBDE	Polybrominated diphenyl ether
PC	Polycarbonate
PET	Polyethylene terephthalate
PETE	Polyethylene terephthalate
PMMA	Polymethyl methacrylate
POP	Persistent organic pollutant
PP	Polypropylene
PS	Polystyrene
PU	Polyurethane
PVC	Polyvinyl chloride
POPs regulation	Regulation (EU) No 2019/1021 of the European Parliament and of the Council of 20 June 2019 on persistent organic pollutants

REACH regulation	Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals

1 INTRODUCTION

The objective of the CREAToR project, funded by the European Union's Horizon 2020 research and innovation program, is to develop a profitable approach to recycling complex waste streams containing hazardous brominated flame retardants. These substances, such as hexabromocyclododecane (HBCD) in polystyrene (PS) insulation panels, and polybrominated diphenyl ethers (PBDEs) in waste from electrical and electronic equipment and the automotive and aeronautic sectors, are now restricted in new products. The project aims to establish a comprehensive business model that spans the entire value chain of waste recycling and covers:

- The development of a reverse logistics process for efficient collection of waste;
- The development of new sorting and quality control technologies for the detection of brominated flame retardants, that can be implemented in existing sorting processes;
- The development and scale-up of a continuous purification process based on extractive extrusion with supercritical CO_2 and natural deep eutectic solvents (NADES), in which the contaminants are dissolved during the extrusion process;
- Readditivation and demonstration of recycled polymers in new products (3D-printing, thermoplastic foaming and injection moulding techniques);
- The development of a labeling system to easily share information on the material properties and quality of the recyclates.

The project brings together 17 partners from various sectors including industry, research and public authorities to encompass the entire value chain. The presence of prominent industry and recycler partners within the consortium guarantees the practical application and commercial viability of the developments, leading to swift market adoption after the completion of the project.

In this study we wish to identify and quantify the barriers that plastic convertors experience when using - or making the transformation to use more – recycled plastics. Although recycling technologies are rapidly evolving and the quality of recyclates is steadily increasing, the material properties of recycled plastics are not directly comparable with virgin plastics that are produced from a non-sustainable petrochemical feedstock, such as natural gas or crude oil. The use of recycled plastics in new products therefore imposes significant **technical challenges** for plastic convertors. Furthermore, to protect the consumer, product-specific product legislation can put strict requirements on raw materials used in new products, and in order to protect human health and the environment, waste legislation regulates how certain waste streams have to be dealt with. In some cases, these regulations may impose **legal barriers** limiting the use of plastic recyclates. Finally, **financial and market factors** can also influence the uptake of plastic recyclates. Volatile raw material prices, uncertain return on investment or a negative market perception of products with recycled content may make plastic convertors hesitant to adapt their production processes.

In a first phase of the study, in-depth interviews with representatives from the plastic industry - mainly plastic convertors - were performed, in which we collected information on their experiences with using plastic recyclates in their products and what they find to be the main problems and potential solutions. For this an interview guideline was developed, with open questions that address a wide range of topics (technical, legal, financial, …).

In a second phase of the study, a set of twenty-two barriers that were identified from the first round were presented to plastic convertors across Europe through a digital survey. The purpose of this survey was to quantify the extent to which the identified barriers are shared across the industry. The survey also asks for the most critical technical parameters of plastic recyclates that influence the production process and determine the quality of the final product.

The final goal of this study was two-fold:

- The identification of technical requirements that end-users place on recycled plastics, and process limitations for using them. Where possible, appropriate pre-treatment steps to help meet these demands and more general recommendations were identified in order to optimise the CREAToR-

process and business model. These are listed in chapter 5: General recommendations and possible pre-treatment steps for the CREAToR-process;

- Legal, economic and other barriers were identified to provide public authorities with updated information and knowledge for policy making. These problems and possible solutions suggested in the in-depth interviews are summarised in chapter 6: Policy recommendations. This information will be used as input for the CREAToR policy brief, in which a broader set of policy and research recommendations will be provided.

2 METHODOLOGY

The purpose of this study is to reveal barriers experienced by end-users (and potential end-users) of plastic recyclates. The end-users in this case are plastic convertors who convert plastic granulate (the raw material for plastic products) into finished plastic products ready to be sold on the market, or semi-finished products that are part of a more complex end product. To find out, on the one hand, what barriers are experienced by individual plastic processors and, on the other hand, to study the extent to which these barriers are shared within the industry, the research was divided into an inductive and a deductive part.

2.1 INDUCTIVE PART – IN-DEPTH INTERVIEWS WITH PLASTIC CONVERTORS

In the first part of the research, we conducted in-depth interviews with plastic processors with the aim of identifying barriers experienced by individual plastic processors. Under the guidance of OVM, and with the cooperation of the partners, we developed an interview guide covering various topics. While the interviewer was encouraged to keep the conversation as open as possible, the interview guide provided a number of possible questions the interviewer could use to address each topic. The interview guide can be found in Appendix 1.

Companies were selected based on contacts within the partnership and through membership lists of sector federations of plastic converting industries. Given the relevance to the project, processors of thermoplastics were initially targeted, but producers of thermosets or other industries are also included to a lesser extent. Both processors that already apply plastic recyclate in their products and those that do not currently do so, are included in the scope.

To reach representatives from different member states, a working group was formed with consortium partners from the different countries who conducted interviews in the home country in the native language to reduce the language barrier. To streamline the working group's responses into a manageable format, OVM and KLU prepared an interview adressing three areas of interest:

- Background information on the company and products they produce;
- The company's current use of and strategy towards the use of plastic recyclates;
- The company's vision on what can be done on an EU level to stimulate a more circular economy for plastics.

The working group (Table 1) met twice digitally: a first time to plan and gather feedback on a first version of the interview guideline, and a second time to discuss an updated version of the guideline and agree on the plan of action and timeline. Further follow-up of the interviews and support with contacting companies was carried out via email.

Table 1: List of partners actively involved in the study

PARTNER	COUNTRY	LANGUAGE
OVM (lead)	Belgium	Dutch
KLU	Germany	German
ICT	Germany	German

CID	Spain	Spanish
GKR	Spain	Spanish
ITB	Spain	Spanish
TCK	Austria	German
RMA	Austria	German
REL	Italy	Italian

28 interviews were conducted between Sept. 28, 2021, and Oct. 28, 2022. These took place both digitally and in person at the company site. Where possible, the interview was coupled with a company visit to get an even better picture of the challenges faced. A report of each interview was prepared by the interviewer and forwarded to OVM who was responsible for analysing the data.

The collected data was analysed and screened for barriers or technological requirements. A total of 237 statements were categorized into 22 distinct barriers. In addition, a set of 13 technical parameters which came up regularly in the interviews was selected.

Besides defining barriers that plastic convertors may encounter, technical solutions and policy recommendations were also gathered in these conversations. When mentioned multiple times, and when consistent throughout the entire research, these were included as policy recommendations in chapter 6.

2.2 DEDUCTIVE PART – DIGITAL SURVEY

In the second research phase, the results from the initial inductive research (interviews) were verified by a quantitative analysis involving a larger group of participants from the plastics processing sector. A digital survey was created to gather feedback from plastic processors, which included questions on company-specific information, the 22 identified barriers, and the extent to which participants perceived these as problematic. Additionally, the survey asked participants about the importance of 13 technical parameters when utilising plastic recyclate in their products.

A first version of the survey was submitted directly to the industrial partners within the project and at the K-fair in Düsseldorf on October 25 and 26, 2022, to a total of 11 companies and research institutions. Here the questionnaire was tested for clarity, consistency and completeness. After revision, the questionnaire was distributed using contacts within the partnership, sector federations and individual companies. Data was collected between November 2022 and January 2023.

3 RESULTS FROM IN-DEPTH INTERVIEWS

In this chapter, 30 interviews with plastic convertors and other members of the plastic industry, are analysed to identify their main drivers for using plastic recyclates (section 3.2), their technical requirements for the use of plastic recyclates (section 3.3) and the general barriers they encounter and possible solutions (section 3.4). In section 3.5 we focus more deeply on the problems that are most often mentioned, and divide these into a set of distinct barriers that are presented to a broader group of respondents in chapter 4.

3.1 ANALYSIS OF INTERVIEWEES

In this section, a short numerical description of the interviewed companies is provided by geographical area (section 3.1.1), size (section 3.1.2) and processing type (section 3.1.3).

3.1.1 INTERVIEWEES BY GEOGRAPHICAL AREA

A total of 30 in-depth interviews were performed, spread out over 5 EU member states. Most of the respondents are based in Belgium (47 %), Germany (30 %) and Spain (13 %). Figure 1 shows the relative spread among different countries, and a detailed representation is given in Table 2.

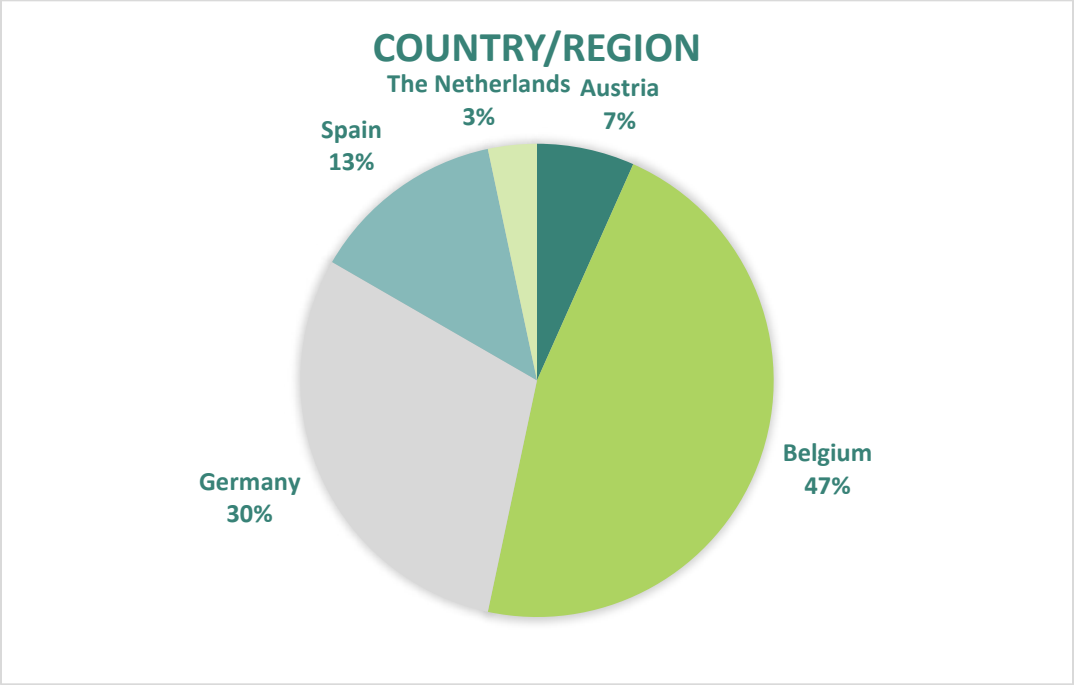

Figure 1: Interviewees by country

Table 2: Details of interviewees by country

COUNTRY	RESPONDENTS	COUNTRY	RESPONDENTS
Belgium	14	Austria	2
Germany	9	The Netherlands	1

Spain	4	**Total**	**30**

3.1.2 INTERVIEWEES BY PRODUCTION SIZE

In terms of processing capacity, expressed in tonnes of plastics (virgin and recyclate) converted each year into new products, the interviewed companies vary greatly from companies converting less than 100 tonnes each year to companies producing over 100 kt. However, two thirds of the companies convert between 1 kt and 10 kt (34 %) or between 10 kt and 100 kt (40 %) (Figure 2).

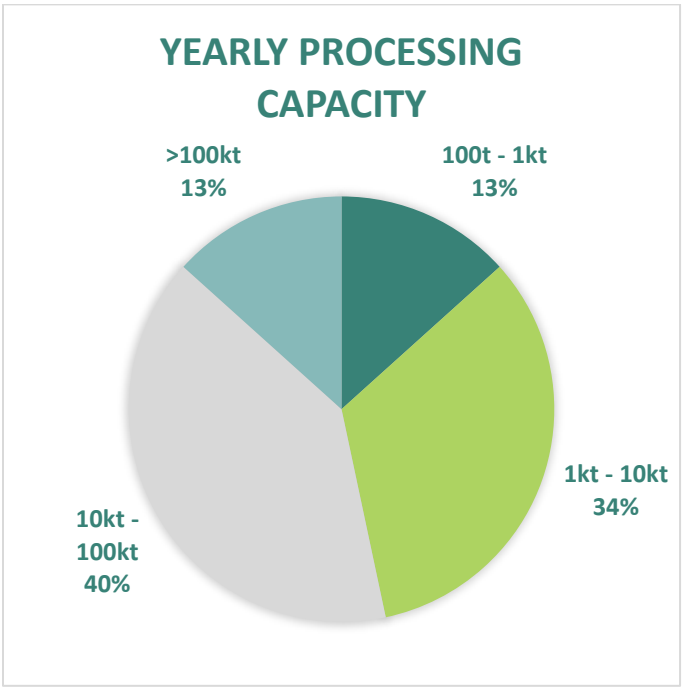

Figure 2: Interviewees by processing capacity

3.1.3 INTERVIEWEES BY TYPE

The majority of survey respondents are plastic convertors who produce for various industries. The main group produces for building and construction (10 companies) followed by electronics (7 companies). Fewer responses were received from the packaging, automotive and transportation sectors (4 companies) and producers of consumer goods (2 companies). Two companies indicated involvement in other sectors, recycling member associations (1) and polymer production. An overview is provided in Figure 3.

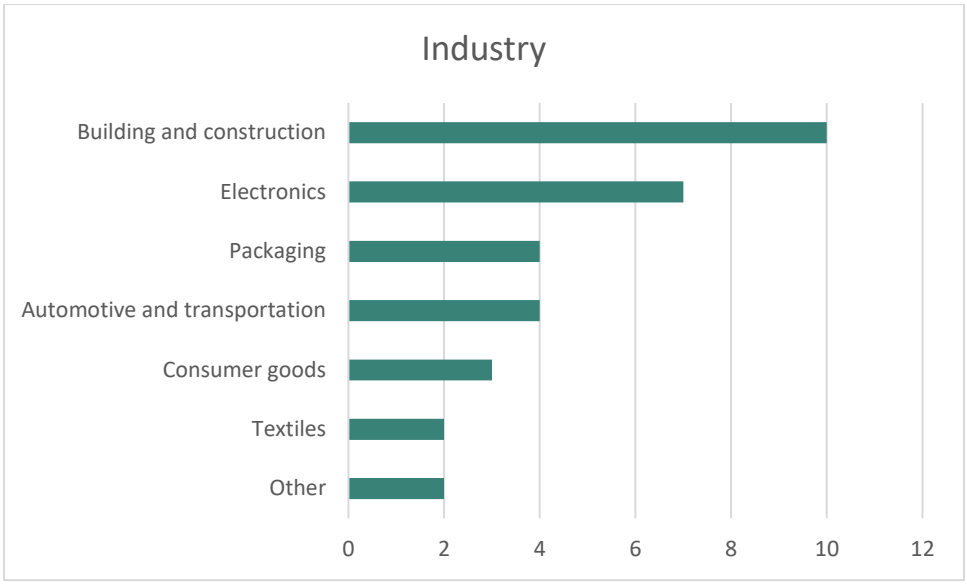

Figure 3: Interviewees by industry

The primary plastic processed by the largest group of respondents is PP (13), followed by ABS (7) and/or LDPE (6). The most commonly used processing technology is injection moulding (6), followed by blow moulding (4), tubing extrusion (4), and rotation moulding (4). Figure 4 provides a summary of respondents by polymer type and processing technology.

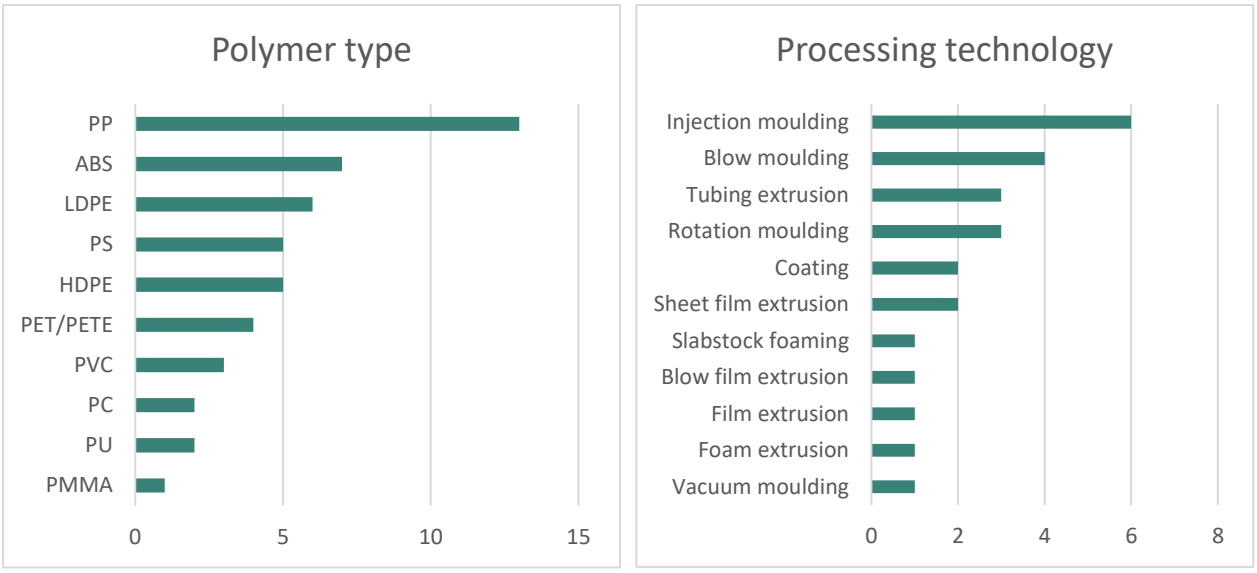

Figure 4: Respondents by polymer type they process (left) and by plastic converting technology (right)

Thirteen companies reported using post-consumer waste, and eleven reported using post-industrial recyclates in their products. Nineteen companies indicated that they reuse their own production scraps (which are not considered recycled material in this study). Figure 5 displays the respondents categorised by type of recyclate and the average proportion of recycled content used in their products. The calculation of recycled content only includes post-industrial and post-consumer recyclates (excluding own production scraps).

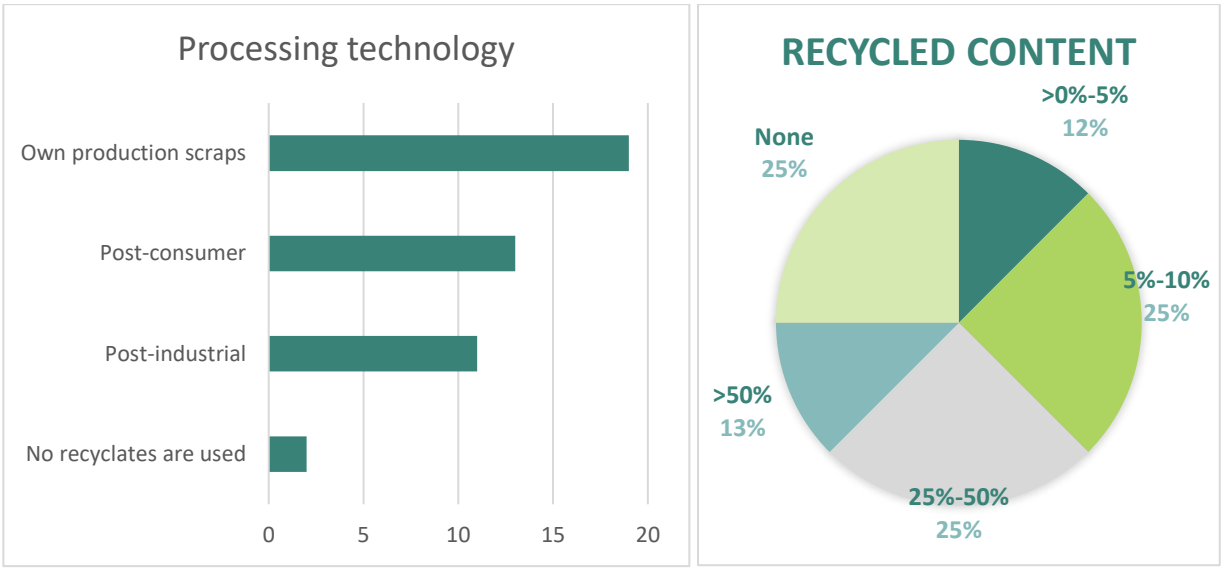

Figure 5: Interviewees by type of recyclates (left) and average recycled content in their products (right)

3.2 DRIVERS FOR USING PLASTIC RECYCLATES

Out of the 30 respondents, 22 gave one or more reasons why they are currently using plastic recyclates or own production scrap in their products. Figure 6 shows the number of companies that mention a certain driver as relevant for their use of plastic recyclates[1].

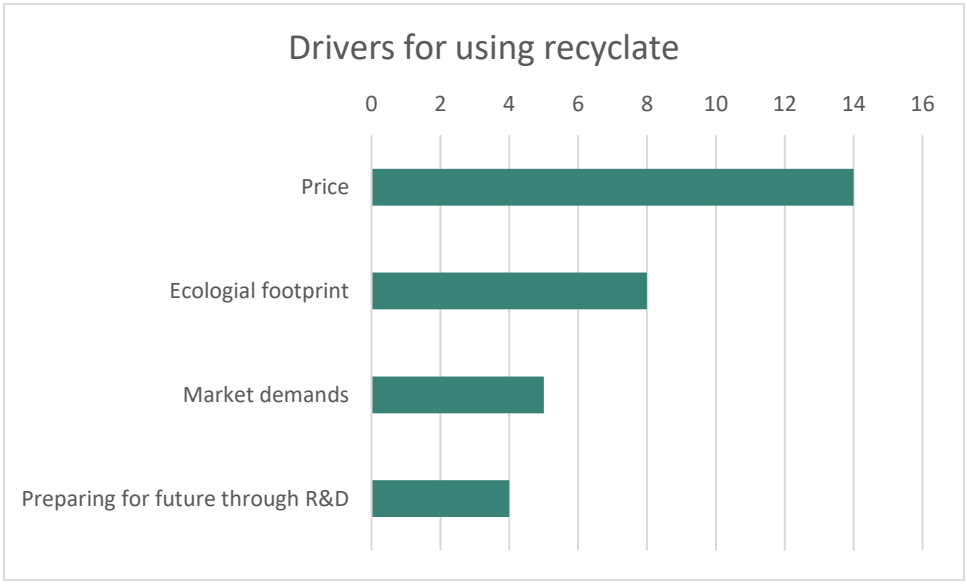

Figure 6: Number of responses by "Driver for using plastic recyclates"

[1] The numbers presented in this section should be interpreted with caution, as they are the result of open discussions. The frequent mention of a particular driver may be an indication of its importance, but this is not conclusive. A more quantitative analysis follows in the next chapter.

The most common answer to the question of why a company is using plastic recyclates, is "Price". 14 respondents noted that using recycled plastics reduces the material costs in their products and that this supersedes the higher costs for adapting the production process or quality control. 10 of these companies explicitly gave this as the main reason. Most of the convertors who use their own production scrap see this as a quick win for reducing costs. The material properties are well known and can therefore be used in a very controlled way in similar products or products with lower quality demands.

> ***Our use of plastic recyclates is mainly price driven. Our customers are currently not asking for recycled content, but are willing to buy these products at a lower price – Environmental expert***

8 companies mention the reduction of the ecological footprint of their products as an important incentive for using recyclates, of which 5 said that this is their main driver. These companies are actively looking to reduce their environmental impact and find the use of recycled material in their products a good way of doing so.

> ***Our company is working very hard on circularity and sustainability in general company policy. Large budgets are spent on this […] we don't make more money on green products – Plant Manager***

Two other reasons that are given for using plastic recyclates are: to be prepared for the future by conducting research and development, and because the customer is gaining interest in products with recycled content. The latter is mainly influenced by increased public awareness and targets set by governments.

> ***In some countries demands are set on the ecological footprint of certain materials. Using recyclates gives our products a better score for this – QSE Manager***

Several drivers exist for companies to use plastic recyclates in their products. Many convertors or their customers are gaining awareness about the sustainability of their products, but price remains a major if not the main factor.

3.3 TECHNICAL ISSUES

This section summarises the technical aspects related to the use of plastic recyclates, as they were discussed in the interviews. We distinguish between material parameters relevant to plastic recyclates and the technical measures taken by processors in the production process to incorporate plastic recyclates in place of virgin materials. We provide information on how many companies mention certain issues, but these numbers should be interpreted with caution as they are the result of open discussions. The frequent mention of a particular technical issue may be an indication of its importance, but this is not conclusive. A more quantitative analysis follows in the next chapter.

3.3.1 MATERIAL PARAMETERS OF PLASTIC RECYCLATES

27 companies provided feedback on the technical requirements that recyclates must meet to be used in their products. Figure 7 shows the number of companies that cited a particular technical parameter in the interview as crucial for the production process or for the quality of the final product.

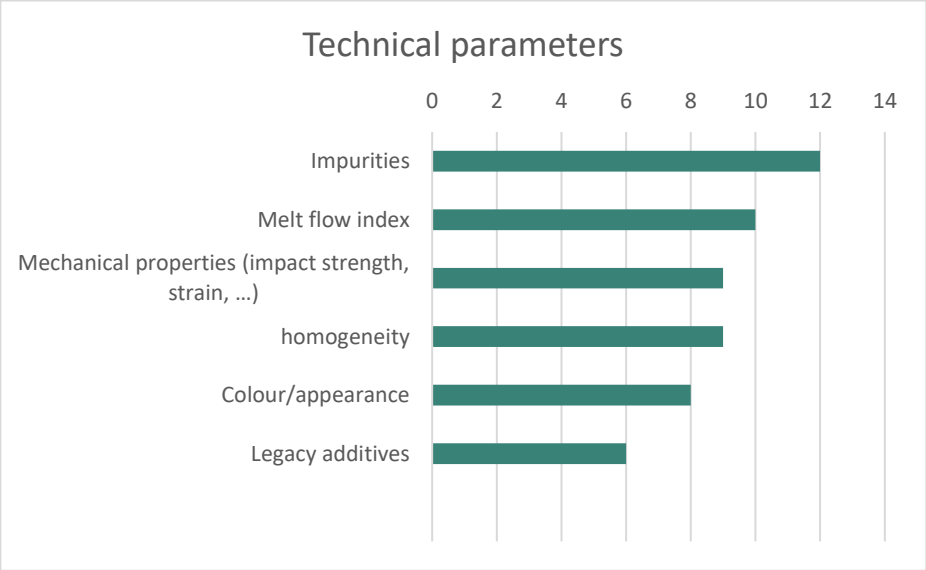

Figure 7: Relevant technical parameters when using recyclates by number of responses

The most frequently cited parameter affecting the quality of recyclate is the presence or absence of impurities (12 companies). These impurities, for instance microscopic pieces of dirt, can cause damage to equipment, lead to cracks in film production, or result in visual defects in the final product. Also wrongly sorted polymer types present in the recycled material behave differently during processing and lead to unwanted mechanical properties of the final product.

> ***Recyclers have enough customers for 400 µm filtrated recyclates. We require filtration of 20 µm - Business Development Manager***

Another frequently cited parameter is the melt flow index (MFI) (10 companies). 7 of them refer to this parameter as the most important one for the proper functioning of their production process. The MFI is a measure of the viscosity of the molten polymer, or how "fluid" the polymer is (does it flow easily like water or is it syrupy like honey?). For many technologies, ranging from injection moulding to film extrusion and foam extraction, this parameter is crucial for keeping the production process running properly. Deviating values

can easily lead to interruption of the production process, with associated material losses, production time loss, damage to production machinery and financial consequences.

The general mechanical properties of the material (impact strength, elongation at break, elasticity,...), are another important factor (9 companies). In general, the properties of recyclates are perceived as inferior to those of virgin material, which means that they cannot be used for all applications, or only in a low concentration with an admixture of virgin material.

Mentioned by 9 companies, homogeneity of material over multiple batches is also an important factor. Most production processes can handle a limited amount of variable material input, provided that some production parameters are adjusted for each batch. However, each adjustment to the production process can lead to production time losses and production failures. To be able to work for longer time with the same production parameters, several batches are sometimes "homogenised", by mixing them in large silos. However, this does not necessarily improve the overall quality. Blending of different batches may give a constant average value for each technical parameter over a larger amount of material, but also increases their variance within a single batch.

> ***One must get the input as pure as possible. You cannot make good material out of bad. Blending to unify lowers quality – QHSE Manager***

Colour and appearance remain important issues when using recycled plastics. Since colour cannot be controlled in the same way as for virgin plastics and microscopic impurities (dirt or other polymers) can cause distortions at the surface, the use of recyclates in electric and electronic devices, or the automotive industry, is mainly limited to invisible parts, or within the inner layer of multilayer products. But also where appearance is not essential, such as for protective packaging or PS insulation panels, variation in colour is sometimes seen by the customer as a sign of inferior quality. However, it is often possible to explain to customers that varying colour doesn't affect the overall quality of the product, and they can become accustomed to a slight colour variation. Nonetheless, certain customers prefer a specific colour, mostly for marketing reasons or because they are used to it.

> ***For colour we had to teach the customer that different shades of green had no impact on the quality – Global Innovation Manager***

Legacy additives in plastic waste is a final limiting factor for using plastic recyclates. Additives from the past can give rise to unwanted properties such as odors leaving the final product or mineral fillers influencing the production process. Of course substances of concern, or substances restricted by the POPs regulation (persistent organic pollutants), REACH regulation, or specific product legislation are also a significant challenge. These chemicals cannot be easily detected and chemical analyses in general are only performed on a statistical base. Most of the convertors rely on an attest of conformity provided by the recycler. Obviously, the scale of this problem depends heavily on the type of application the recyclate is used for. For example, product legislation for food-contact materials or toys is much stricter than legislation for building and construction materials.

3.3.2 TECHNICAL MEASURES TAKEN IN THE PRODUCTION PROCESS

12 companies mention that they apply recyclate only in a selection of their products. These are often products for which product requirements are less strict, or which are easier to produce. Examples include

- Deployment of recyclate in thicker agricultural films, not in the thinner films or films with specific requirements (UV and chemical resistance, colour)

- Deployment of recyclate in invisible parts with lower mechanical requirements in electronic devices or automotive parts
- Deployment of recyclate in non-food packaging

11 companies mention that they perform extensive testing on recycled material before using it in their products. They don't rely on the information provided by the recycler, or the required information is not present. Generally, convertors like to work with a known set of recyclers whom they can trust. When problems occur with a batch of material, sometimes this material is used in small amounts in lower quality products, but most of the time it is sent back to the recycler. When problems persist, the contract with the recycler is terminated.

4 companies indicated that they made significant adjustments to the production process to incorporate plastic recyclates. Examples are adding extra purification steps, or continuous control in the production line.

> ***The varying melt flow index of recyclate means that the thickness of the film can vary greatly during production. This is controlled and adjusted per palette by adjusting the amount of recyclates – R&D engineer***

3.4 Towards a European circular economy for plastics – Problems and solutions

In this section we provide an overview of frequently cited issues related to European or local legislation, the European market and public awareness that companies encounter when trying to make the transition to more circular production. Coming into contact with these problems on a daily base, companies often have clear ideas about possible solutions to specific problems. These are presented here as well.

3.4.1 Legislation

Presence of substances of concern

The presence of substances of concern or other unwanted legacy additives in certain waste streams is found to be a big obstacle to the use of plastic recyclates. Especially for post-consumer waste, where the exact source of the material is unknown, one cannot always be sure that the recycled material is free of hazardous substances that are restricted by POPs regulation and REACH regulation, or product legislation, unless extensive chemical analyses are performed.

One solution for this is to install legislation that assists **traceability of products and materials**. The idea behind this is that a producer labels its plastic products (e.g. by a QR-code or watermark) so that the recycler can recognise this product to be free of contaminants or suited for recycling for specific purposes e.g. food contact material. Alternatively, such a system can also be used for producers to recognise their own products easily and take them back to reuse or recycle the material in their own new products. Besides helping to recognise products and the material they are made of, a thorough traceability program can help with building trust about the composition and potential contaminants in the mix.

Advanced purifying technologies or chemical recycling to most companies looks like an interesting possibility to deal with certain waste streams, or guarantee that recyclates meet high demands set by some product legislation. However, producers don't really care about which technique is used, as long as the material is safe. Moreover, these technologies are not considered mature enough to produce at large scale. Further stimulation of research and projects to scale up these technologies might be useful.

Due to the impossibility to perform migration tests on every batch, product tracing through barcodes is necessary. However, because of too large volumes, this [installation of a tracking system] need not be an insurmountable problem . – QHSE Manager

Strict regulation or (voluntary) standards

Very much related to the previous problem is the feeling that overly **strict regulation or voluntary standards** are limiting the use of plastic recyclates. Although in many cases strict product regulation is necessary to guaranty safe products and to protect human health, and high standards are justified, some ban recycled material even if its use could be safe. For example, new technologies, such as multi-layer extrusion, can safely introduce recycled material in the inner layer of a product, without the risk of hazardous substances migrating to the surface, yet in some standards and legislation such solutions are directly or indirectly prohibited.

It's not possible to increase recycling and also reduce toxic products at the same time. Legislation should try to find a balance between the two goals – R&D Manager

Different collection schemes throughout the EU

The large difference in the way waste is collected across the EU has a significant negative affect on the uniformity of the waste streams and consequently the recycling streams. Not only does this complicate the search for well suited materials, but it also hinders effective design for recycling.

The quality of recycling starts with separate collection and sorting at the source. **Uniform rules for product-specific collection and sorting across Europe** are needed to make waste streams more uniform, allowing recyclers to better match their process to the available streams. This will increase recycling rates and result in more high-quality recycling. Moreover, this allows producers to design their products to be effectively recycled, regardless of where in Europe they are marketed. Finally, there is a need to establish uniform packaging regulations that facilitate the creation of recyclable packaging, which would make it easier for producers to adopt sustainable packaging practices.

> ***Different collection schemes and recycling streams over different countries prevent the development of designed for recycling products. – Business Development Manager***

Mandatory recycled content

Some companies note that the introduction of a mandatory recycled content for specific product categories might help to overcome the problem that high-quality recyclates are often more expensive than virgin material. This may stimulate recyclers to produce more recyclates that meet product-specific demands, and can stimulate R&D for using more recycled material in plastic products. However, an equal amount of companies warn about side effects of this measure, such as

- The introduction of mandatory recycled content in one sector can cause problems for other sectors that are using the same recycled material.
- Skyrocketing recyclate prices in case of scarcity on the market.
- Risk of lack of availability on the market to reach targets.

Moreover, to be effective, regulations should be accompanied by clear, EU-wide definitions of recycled content (for example whether post-industrial waste counts or only post-consumer, or calculation rules for recycled content of recyclates produced in chemical recycling).

3.4.2 ECONOMIC INCENTIVES

Pricing

The price of recyclates remains a major bottle neck in the use of more plastic recyclates. Many companies argue that recyclates that meet their high requirements are more expensive than virgin material, or that the price difference doesn't compensate for the extra costs and efforts needed to adapt the production process. Also, the price difference between low-quality recyclates and high-quality recyclates is not high enough to stimulate recyclers to produce more of the latter. Most of the respondents believe that having an incentive or reward for using recycled plastic will definitely drive a higher percentage of usage.

Positive financial incentives that reward the use of recycled plastic enjoy broad support among those surveyed. Examples given are financial stimuli for recyclers that produce high-quality recyclates, and rewards for plastic producers that use recycled plastics or make plastic recyclates cheaper.

The idea of a virgin tax is seen by a part of the respondents as a way to make plastic recyclates economically more favourable. However, others argue that this is a risky measure that might undermine the competition of our European plastic industry.

A virgin tax is very logical and our company is not necessarily against the idea, provided that it is required for all products on the EU market and controls on imports are put in place – Plant manager

Given current raw material prices, the introduction of a virgin tax is risky- CEO

Public tenders

In certain sectors, public tenders make up 50 % of the market, and these are mentioned as a major lever to increase the demand for recyclates. If public procurement includes a requirement to use products with plastic recyclate, or to include it as a positive assessment point, this can provide a significant boost. Such initiatives in the Netherlands give a clear example of how, in addition to price, the sustainability aspect of the entire production process can be given equal weight.

3.4.3 AWARENESS AND INFORMATION

Consumer awareness

Most companies notice a clear shift of consumer awareness towards more sustainable products made out of recyclates. This is mostly the case for big consumers for whom recycled content and sustainability is increasingly important (e.g. automotive industry), or individual consumers. However, many are not yet willing to pay more for a product containing recycled plastics. Other sectors, like agriculture or small contractors, are not yet convinced and mostly just care about the quality and the price.

Consumers can be made aware that the recycling and conversion of recycled plastics is not that straightforward, and that as a consequence products made of recycled plastics are not necessarily cheaper than those made out of virgin material. Another problem is that consumers mostly only see post-consumer waste as true recycled material, while post-industrial waste is not. This is problematic, since a major ecological gain can also be made in these waste streams. Finally, if customers would be willing to lower certain demands, like very specific RAL colours, or surface texture, more recyclates could be inserted.

Recyclability of products

Design for recycling is a crucial precondition to establishing a circular economy. The development of legislation that puts pressure on design for recycling is seen as an important stepstone for increasing the amount of plastics being recycled. The stimulation of mono-materials, inks for labelling that are easily washable, and limitations in allowed mixtures and additives are concrete examples of how this could be achieved. On the other hand, it is also argued that regulating the standardised use of plastics for recycling will hamper innovation and new product development.

A significant percentage of the interviewed companies indicate they are involved in projects to make their own products more recyclable with current recycling methods. These projects involve finding alternatives for or new types of glue, looking for thermoplastic alternatives for products made out of thermoset material, and making their products out of mono-material.

Our company makes it a point to be as recyclable as possible. Currently, 97 % of our products are already recyclable and by 2023 we aim to make the entire range recyclable – Plant manager

Total life cycle

Although many companies indicate that including plastic recyclates into their products lowers their overall ecological footprint, some note that it remains important to take the entire picture into account. It is suggested that life cycle analyses (LCAs) are important tools to investigate the ecological benefit of recyclates in their sector.

In defining recyclability of foils, we should mind the trap of favouring thick simple products that use a lot of material, over products that use less recyclate, but also use less virgin material. – Business development manager

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3.5 IDENTIFICATION OF END-USERS' BARRIERS FOR USING PLASTIC RECYCLATES

In this study a total of 30 interviews were carried out with plastic convertors and other stakeholders in the plastic converting industry, resulting in a large set of textual data. 239 quotes made during the conversations could be linked to issues with using plastic recyclates, or to solutions to the problems encountered.

These quotes were analysed and grouped according to distinct barriers that hamper the use of (more) plastic recyclates, or that are resolved by a certain measure taken by the company. For instance, both statements "*Homogeneity is very important and a problem when using recyclates*" (problem) and " *We have an entire department called supplier quality improvement that's working closely in improving the supplier processes*" (solution) are classified into the barrier "L4. Lack of quality standards for recyclates or insufficient communication between recyclers and convertors", although the first quote refers to an encountered problem or barrier, while the second quote is a solution for the same problem.

Table 3 shows the result of this exercise. 15 barriers were identified that were referred to at least 3 times during the interviews. They are subdivided into 4 main themes: "Financial barriers", "Legal barriers", "Market barriers" and "Technical barriers".

It is important to note that these barriers are mentioned in open semi-structured conversations, and that interviewees were not directly asked to identify them. In order to quantify to what extent a barrier is important throughout the entire sector, in a next research phase a digital survey was developed that asks plastic convertors to indicate the extent to which these barriers apply to their individual situation. The 15 barriers listed in Table 3 served as input for a first version of the survey presented in the next chapter (after a test at the K-fair in Düsseldorf, the set was extended to a total of 22 barriers).

Table 3: Fifteen barriers identified in interviews, ordered by theme

BARRIER	THEME
Use of recyclates increases risk of production time loss and material loss, thus posing financial risk	Financial
Price difference between high-quality recyclates and virgin material is not high enough to compensate for extra financial costs or risks	Financial
Rapidly evolving and unclear legislation hampers investments in new technologies	Legal
Non-uniform regulation across EU (end-of-waste status, transboundary shipments, differing collection schemes,…)	Legal
Legal or voluntary standards are unnecessarily strict and prevent the use of plastic recyclates	Legal
Lack of quality standards for recyclates or insufficient communication between recyclers and convertors	Legal
Using plastic recyclates is not necessarily the most sustainable option for our products	Legal
Legal requirements rightfully prevent the use of plastic recyclates	Legal
Low or insecure availability of high-quality recyclates on the market	Market
Lacking interest of consumers or marketing	Market
Quality of recyclate on the market is not sufficient	Market
Use of recyclate could be increased if customer would question some non-essential demands or would change product design	Market
Use of recyclates requires extensive quality control to control production process or quality of end product	Technical
The use of recyclate has a negative impact on the quality of the final product	Technical
The use of recyclates requires technical research and investments into the production process	Technical

4 DIGITAL SURVEY

In order to perform a quantitative analysis of the problems that are encountered by the plastic converting industry when using plastic recyclates, a digital survey was developed and distributed among plastic converters in Europe. The survey is divided into two parts: one that investigates potential barriers and one that probes specific material parameters.

In the first version of the survey, the 15 barriers identified in the in-depth interviews were presented and companies were asked to what extent they experienced each as a limiting factor in the use of more plastic recyclates in their products. This survey was evaluated at the K-fair Düsseldorf in October 2022, and adjusted based on feedback received and after final discussion with partner KLU. Some of the initial barriers were split into two distinct ones to obtain a more nuanced answer. Also, a new category was added that grouped issues related to the sustainability of using recyclates and sustainability targets of companies. This resulted in a new list of barriers that consisted of 22 barriers divided in 5 different themes:

- Financial barriers
- Legal barriers
- Market barriers
- Sustainability barriers
- Technical barriers

Furthermore, the survey looked into more detail at technical parameters that are relevant for using plastic recyclates. This information can be used to identify crucial parameters for the CREAToR project to consider, helping it to deploy extra processing steps in order to deliver plastic recyclates that meet the demand of general market or specific customers.

4.1 ANALYSIS OF RESPONDENTS

The survey was completed by a total of **51 respondents** spread over multiple countries, company sizes and companies using different types of processing technologies and material. Within the subgroup of plastic convertors, which is the largest group of respondents, companies using all kinds of plastic convertor technologies, processing many different types of plastics, were targeted and reached.

4.1.1 RESPONDENTS BY GEOGRAPHICAL AREA

A total of 51 responses to the digital survey were received, spread out over 12 EU member states, representing almost half of the member states and 72.8 % of the total EU population[2]. Most of the respondents are based in Spain (23 %), Germany (13 %), Belgium (1 2%) and the Netherlands (12 %). Figure 8 shows the relative spread among different countries, and a detailed overview is given in Table 4.

Figure 8Figure 8: Respondents by country

Table 4: Details of respondents by country

COUNTRY	RESPONDENTS	COUNTRY	RESPONDENTS

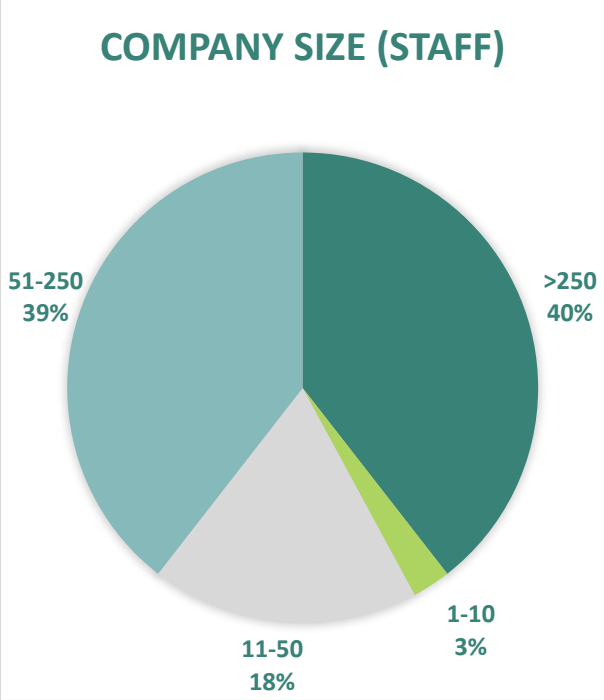
[2] Calculated from **Demographics of the European Union - Wikipedia**

Spain	12	France	1
Portugal	5	Finland	1
The Netherlands	6	Europe (outside EU)	1
Luxembourg	1	Czech Republic	2
Lithuania	1	Belgium	6
Italy	3	Austria	5
Germany	7	**Total**	**51**

4.1.2 Respondents by size

38 of the respondents gave an estimate of the size of their company in terms of people employed. 40 % of these identified their company as a large enterprise with over 250 persons employed, 39 % as a medium sized company employing 51-250 persons, and 21 % as a smaller organisation.

In terms of processing capacity, expressed in tonnes of plastics (virgin and recyclate) converted each year into new products, responses vary greatly from companies converting less than 100 tonnes each year to companies producing over 100 kt. However, out of the 39 respondents that gave an estimate of their yearly processing capacity, two thirds convert between 1 kt and 10 kt (31 %) or between 10 kt and 100 kt (30 %) (Figure 9).



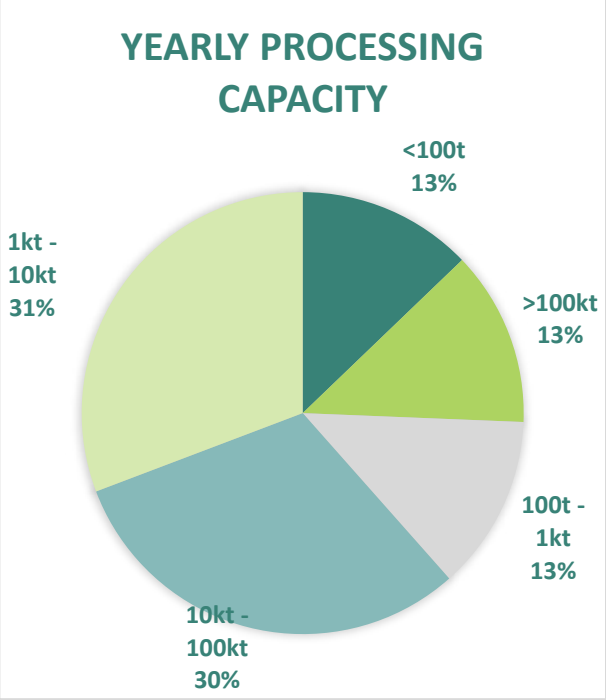


Figure 9: Respondents per company size in terms of persons employed (left) and processing capacity (right)

4.1.3 RESPONDENTS BY TYPE

Most of the respondents to the survey are plastic converters producing for all kinds of industries. The two largest groups indicated that they produce plastic products or semi-finished products for building and construction, such as insulation panels or window profiles (17 companies), or for packaging (16 companies). Automotive and transportation is another sector with a relatively high number of respondents (11). For electronics and textile sectors, two responses were received each time. Six companies indicated that they produce plastic products for other industries, such as medical devices (1), or comfort foams (1) or didn't indicate for what specific sector they produce (2). Figure 10 provides a schematic overview.

Out of the 51 respondents, 8 indicated that they were active in other industries/sectors, namely recyclers (2), plastic compounding (2), research (2), member association (1) and machine manufacturer for the plastic converting industry (1). Although these are not the initial target group, their answers are included in the final analysis of barriers experienced.

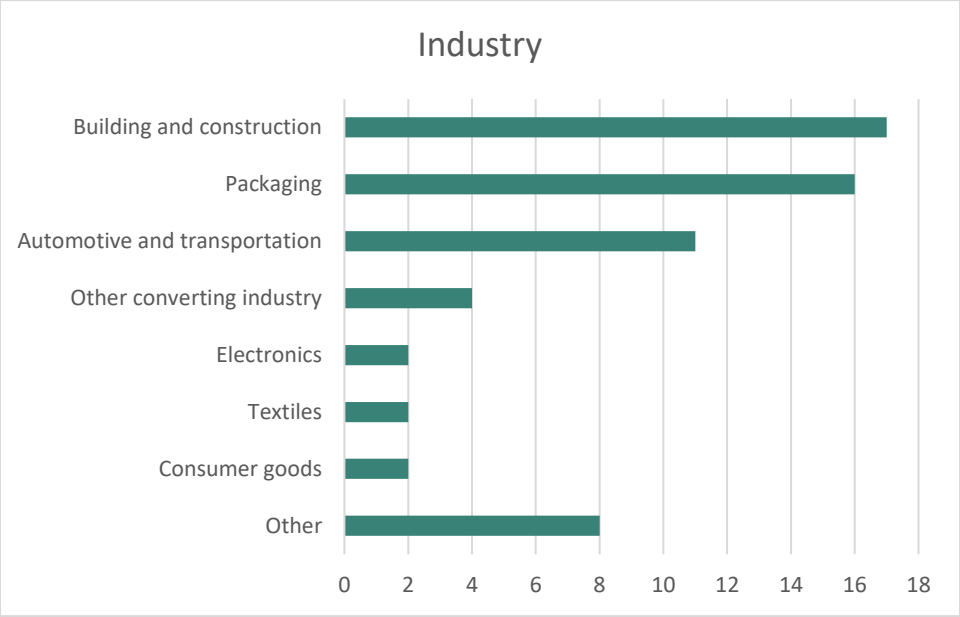


Figure 10: Respondents by industry

Concerning the types of plastics that are converted, the largest group indicated that they process PP (32), followed by HDPE (24) and/or PS (20). The main processing technologies used by the respondents are injection moulding (25), followed by sheet film extrusion (12) and film extrusion (10). An overview of respondents by polymer type and processing technology is given in Figure 11.

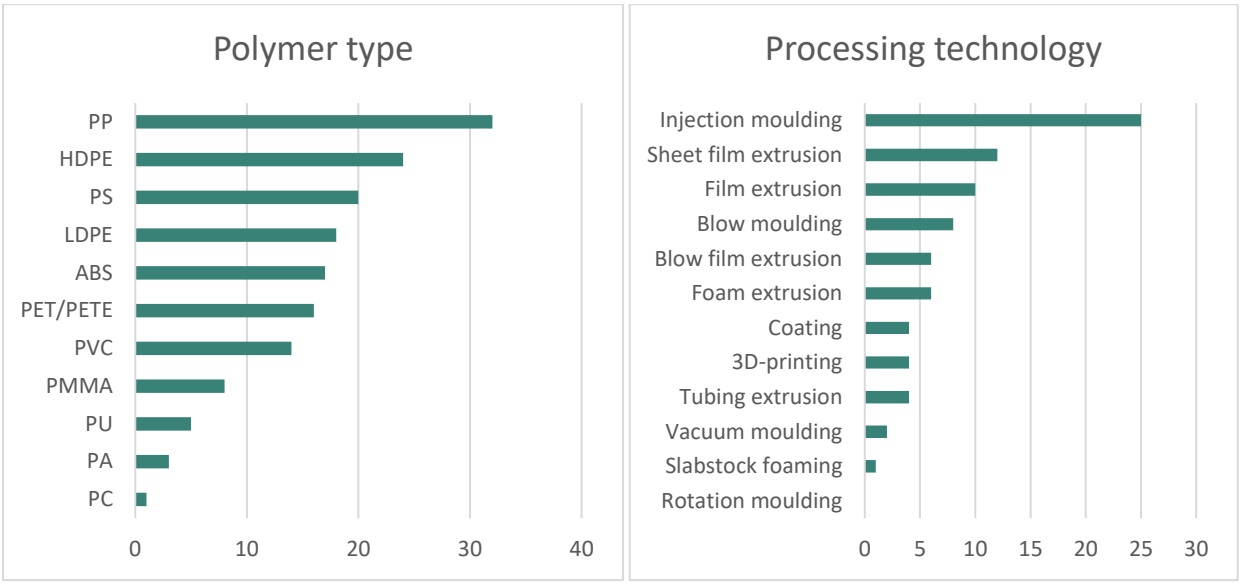


Figure 11: Respondents by polymer type they process (left) and by plastic converting technology (right)

Thirty-two and thirty-one companies respectively mentioned that they use post-industrial waste and post-consumer recyclates in their products. Thirty-six companies indicated that they reuse their own production scraps (which is not considered as recycled material for this study). Figure 12 shows the respondents classified by type of recyclate and the average amount of recycled content used in their products. To measure the recycled content, only post-industrial and post-consumer recyclates are taken into account (own production scraps are excluded).

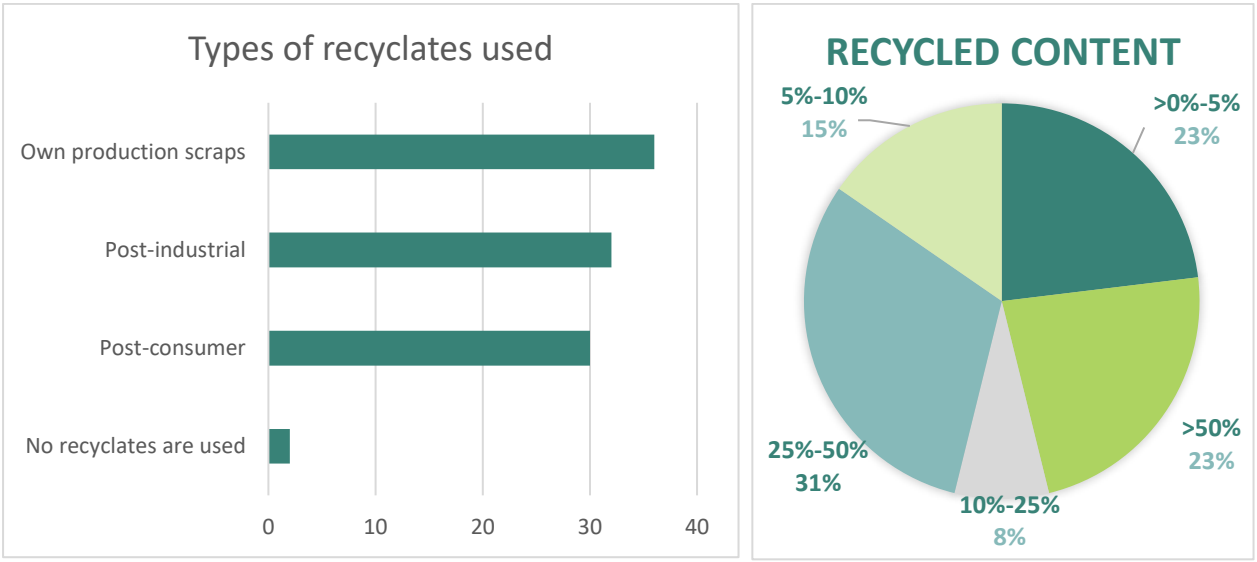


Figure 12: Respondents by type of recyclates (left) and average recycled content in their products (right)

4.2 END-USERS' BARRIERS FOR USING PLASTIC RECYCLATES

The first part of the survey aims to determine the barriers that plastic convertors may experience when using plastic recyclates. Based on the in-depth interviews, and subsequently adapted after a test round at the K-fair in Düsseldorf, a list of 22 barriers was presented to the respondents. The questions are formulated as "To what extent do you agree with following statements for using more plastic recyclates in your products", followed by a number of barriers in one of the 5 selected categories: financial, legal, market, sustainability and technical. For each of the barriers, respondents had to indicate whether they "strongly disagreed", "rather disagreed", "rather agreed" or "strongly agreed" with the statement.

Based on the collected answers, each barrier is given an average score that is calculated as

$$S_x = \frac{0 * N_{x,No\ barrier} + 1 * N_{x,Limited\ barrier} + 2 * N_{x,Significant\ barrier} + 3 * N_{x,Main\ barrier}}{N_{x,total}} - 1.5$$

Where $N_{x,No\ barrier}$, $N_{x,Limited\ barrier}$, $N_{x,Significant\ barrier}$, $N_{x,Main\ barrier}$ is the number of respondents that strongly disagreed, rather disagreed, rather agreed and strongly agreed with statement x respectively, and $N_{x,Total}$ is the number of respondents that gave an answer to statement x.

The score is a number between -1.5 and +1.5. Statements with more disagreements have a negative score, those with more agreements are positive, while an equal spread results in a score near zero.

For instance, the average score of F1. Financial risk (see Table 5) is calculated as

$$AS_{F1} = \frac{0 * 9 + 1 * 24 + 2 * 15 + 3 * 2}{9 + 24 + 15 + 2} - 1.5 = \frac{60}{50} - 1.5 = 1.2 - 1.5 = -0.3$$

This score is an indication of how much a specific barrier is experienced **on average** by the respondents. This number does not include information on the spread of the answers, which is why we also include histograms that give a more complete overview of the answers.

4.2.1 FINANCIAL BARRIERS

The first theme relates to the financial barriers that plastic convertors may experience when using plastic recyclates. In this section, barriers are included that relate to direct financial costs. The results of the answers are summarised in Table 5 and Figure 13.

Table 5: Questions and answers regarding financial barriers

	STRONGLY DISAGREE, NO BARRIER	RATHER DISAGREE, LIMITED BARRIER	RATHER AGREE, SIGNIFICANT BARRIER	STRONGLY AGREE, ONE OF OUR MAIN BARRIERS	AVERAGE SCORE
F1. Using recyclates poses unpredictable financial risks for us (e.g. due to possible increased production time and material loss, insecure delivery, volatile prices)	9	24	15	2	**-0.3**
F2. Using plastic recyclates in our products is more expensive than using virgin plastics	9	17	12	12	**0.04**
F3. Using plastic recyclates requires significant financial investments (e.g. research,	4	15	23	8	**0.20**

modification of the existing production process, product redesign)					
F4. Using recyclates requires a lot of continuous effort for our company (e.g. higher production costs, handling of additional materials)	6	19	17	8	**0.04**

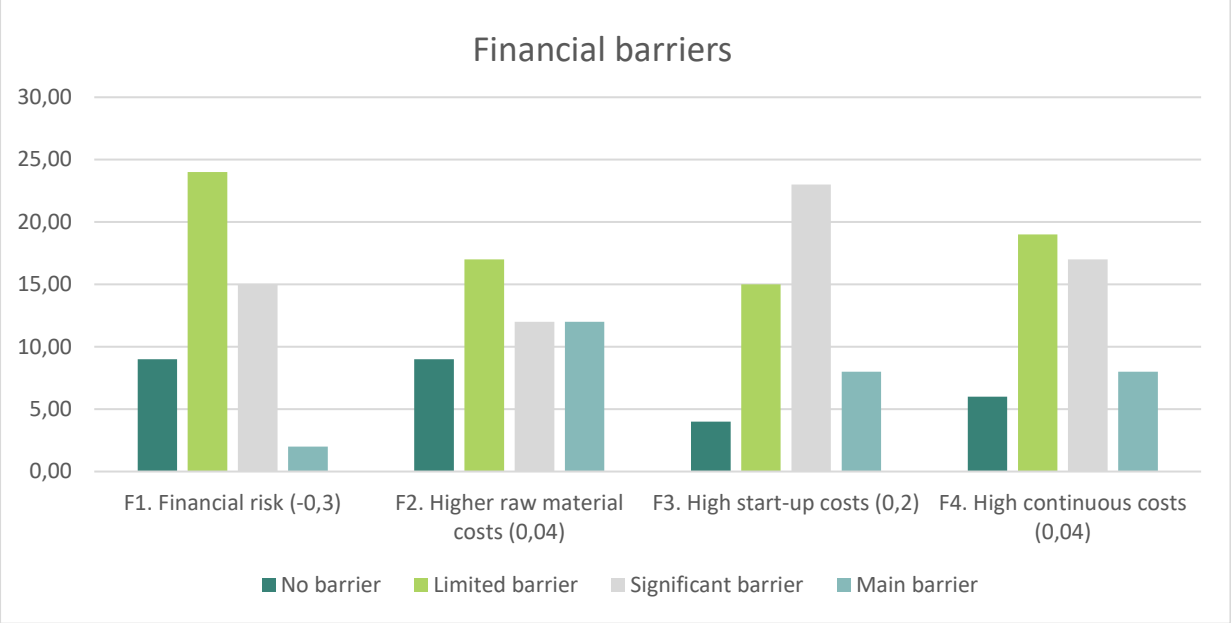


Figure 13: Answers regarding financial barriers

Looking at the calculated scores in Table 5, with an average score of **0.2**, the most important financial barrier is **"high start-up costs"** that are associated with the use of plastic recyclates (adding extra steps in the production process, buying specific machines, etc.). Thirty-one respondents out of fifty rather agreed or strongly agreed with the statement.

"Higher raw material costs" and **"high continuous costs"** both have an average score of **0.04** which is slightly positive. On average these barriers are rather small yet existing. Looking at Figure 13 a difference can be seen between the two barriers when it comes to the spread of the answers.

For "Higher raw material costs", more companies strongly disagree or strongly agree, meaning that this barrier is very important for some and much less so for others. This might indicate that for specific applications, where quality of the recycled material can be lower, there is a financial benefit to be gained from using recyclates, while for highly demanding applications, high-quality recyclates are needed, which are typically more expensive.

"High continuous costs" (e.g. extra quality control, more complicated material sourcing) has a much smaller spread with less extreme answers. This means that most of the companies experience this as a (limited) barrier, and not as the main barrier.

The barrier **"financial risk"** has a negative score **(-0.3)** and is not very much perceived as big issue. This means that most companies have the feeling that fluctuating prices or unforeseeable pricing in the near or far future are manageable.

4.2.2 LEGAL BARRIERS

This section focusses on barriers related to legal aspects, such as a varying legislative environment over time or different countries, or the presence of legal standards and material standards. The questions and answers given are summarised in Table 6 and Figure 14

Table 6: Questions and answers regarding legal barriers

	STRONGLY DISAGREE, NO BARRIER	RATHER DISAGREE, LIMITED BARRIER	RATHER AGREE, SIGNIFICANT BARRIER	STRONGLY AGREE, ONE OF OUR MAIN BARRIERS	AVERAGE SCORE
L1. Rapidly evolving or unclear legislation, makes us hesitant to use plastic recyclates	5	22	13	10	**0.06**
L2. Non-uniform regulation across the EU complicates the use of recyclates in our products (e.g. end-of-waste status, product regulation, transboundary shipments)	4	18	14	12	**0.21**
L3. Legal standards limit the use of recyclates in our products	6	14	18	12	**0.22**
L4. Lack of quality standards for plastic recyclates complicates our search for well suited material	1	14	20	14	**0.46**

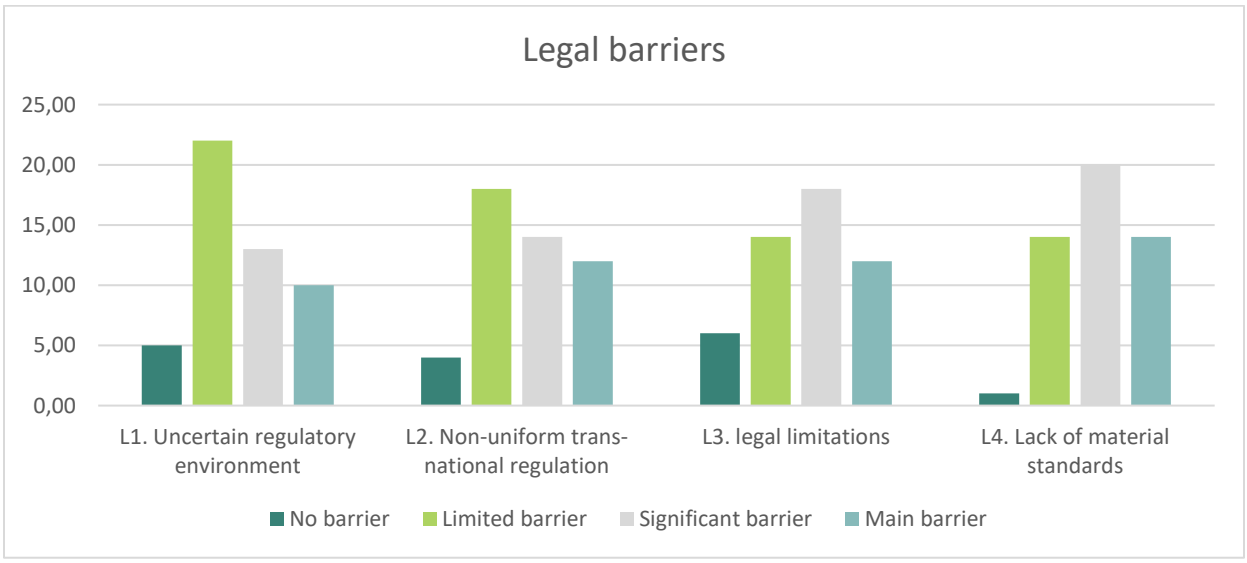


Figure 14: Answers related to legal barriers

The most important barrier, with a score of **0.46** and almost no strong disagreement, is the **"lack of quality standards"**. This is consistent with the results from the in-depth interviews. The absence of such standards complicates the search for well suited material because the quality and the properties of recycled material vary significantly over different suppliers, and even within different batches. Extensive tests are therefore

needed on the incoming material, and constant monitoring and adjustments to the production process are required.

"**Legal limitations"** is a second important barrier for using plastic recyclates, and has a positive score of **0.22**. Often the use is restricted by a strict product regulation such as the food-contact regulation or toys regulation. Although in most cases this strict regulation is justified, in some specific cases the use of plastic recyclates could be safe and adjustments of these regulations can stimulate the use of plastic recyclates.

Also **"Non-uniform transnational regulation"** has a positive score **(0.21)** and is experienced as a barrier. Different interpretations of end-of-waste status or regulations on transboundary movements complicate shipments of waste or recyclates in between EU member states. Also, different collection schemes result in different recycling streams.

"Uncertain regulatory environment" has a small positive score **(0.06)** and many companies don't experience this as a significant barrier. However, looking at Figure 14, we can see that the spread is rather large and that a significant part of the respondents indicate that this is one of their main concerns. For these companies, a clear and stable legislative environment will help them decide to invest in using more recycled material.

4.2.3 MARKET BARRIERS

Next, we will examine barriers related to the EU market, ranging from availability of recyclates on the market, to consumer demand for and perception of products made (partially) out of recycled plastics. An overview of the answers and calculated scores is given in Table 7 and Figure 15 .

Table 7: Questions and answers regarding market barriers

	STRONGLY DISAGREE, NO BARRIER	RATHER DISAGREE, LIMITED BARRIER	RATHER AGREE, SIGNIFICANT BARRIER	STRONGLY AGREE, ONE OF OUR MAIN BARRIERS	AVERAGE SCORE
M1. Availability of recyclates that fit our requirements is too low or too unstable	4	11	18	17	**0.46**
M2. Our customers lack interest in buying products with recycled content	10	14	16	8	**-0.04**
M3. We do not trust in the quality of available recyclates	4	14	20	11	**0.28**
M4. Our customers have negative associations with recycled plastics	13	23	9	5	**-0.38**
M5. Using recyclates leads to an unacceptable change in the appearance of our product	4	21	17	8	**0.08**
M6. Our customers are not willing to pay more for products with recyclates	3	4	18	18	**0.69**

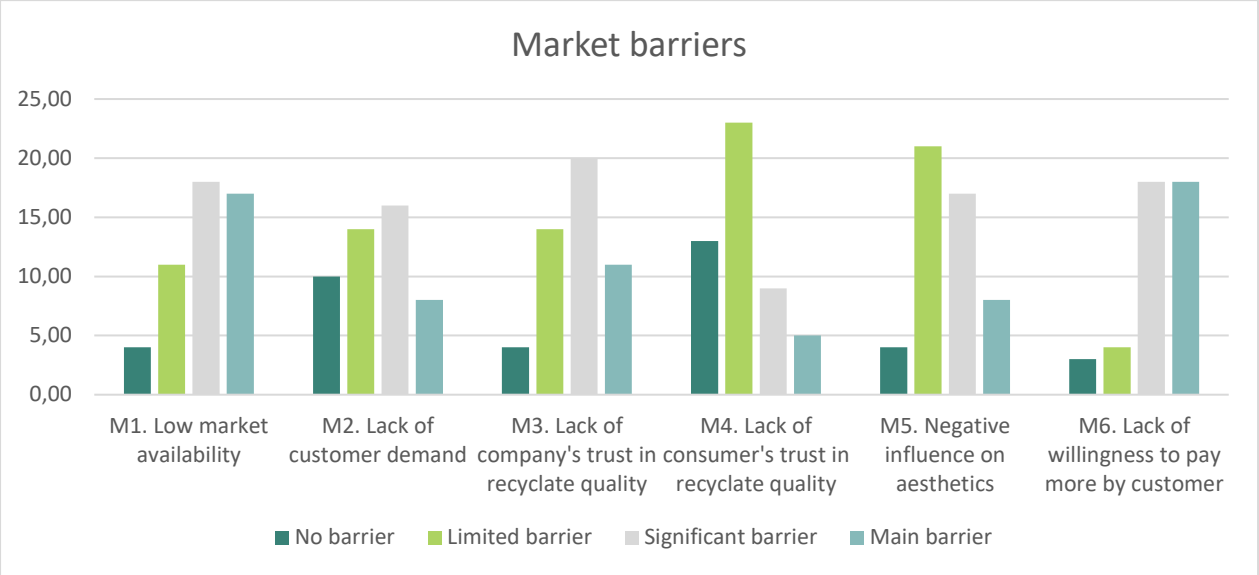


Figure 15: Answers related to market barriers

With a score of **0.69** and very few disagreements, "**Lack of willingness to pay more by customer"** is a major barrier. Although many companies experience a clear increased consumer awareness (see section 3.4.3) and increasing demand for plastic recyclates, the same consumer is not yet willing to pay more for products containing plastic recyclates. This is consistent with what is mentioned in the in-depth interviews.

A second significant barrier is the **"Low market availability"** of plastic recyclates that meet the demands of the plastic convertor **(0.46)**. Although increasingly more plastic waste is being collected, because of high quality demands it does not find its way back to plastic convertors.

The fact that high-quality recycling is crucial is also reflected in the rather high score for the barrier **"Lack of company's trust in recyclate quality" (0.28)**. Companies are not confident enough that the plastic recyclates on the market are of sufficient quality for the production process or final product. This makes them reluctant to use more recyclates.

"Negative influence on aesthetics" has a small positive score **(0.08)**. A significant set of companies sees the negative effect of recyclates on the appearance of the final product (e.g. undesired colour variance or surface impurities) as a barrier for using them in their products. However, a large group mentions this as only a limited barrier, meaning they can somehow cope with this effect (e.g. by using recyclates in invisible parts or in products where appearance is of less importance).

"Lack of customer demand" has a small negative score **(-0.04)** and is, on average, not really seen as a barrier. However, Figure 15 shows that the spread in the answers is rather large, which indicates that some companies do not see this as a barrier at all, while others do see this as one of their main barriers. This is consistent with information from the in-depth interviews (section 3.4.3,) where indeed a shift in demand is noted in some but not all sectors.

Finally, there seems to be only a limited "**Lack of consumer trust in recyclate quality"**, so in general this is not a barrier. This might indicate that consumers trust plastic convertors to safeguard the quality of the final product, or are not aware that using plastic recyclates in plastic products is not always straightforward.

4.2.4 SUSTAINABILITY BARRIERS

In this section we investigate the extent to which sustainability is seen as an important target by companies or their customers, and whether or not the use of plastic recyclates contributes to sustainability targets. An overview of the questions and answers is given in Table 8 and Figure 16.

Table 8: Questions and answers regarding sustainability barriers

	STRONGLY DISAGREE, NO BARRIER	RATHER DISAGREE, LIMITED BARRIER	RATHER AGREE, SIGNIFICANT BARRIER	STRONGLY AGREE, ONE OF OUR MAIN BARRIERS	AVERAGE SCORE
S1. Using plastic recyclates conflicts with other priorities within the company (e.g. marketing, efficiency of production, quality)	10	20	6	1	**-0.55**
S2. Customers are not willing to adapt their product to enable the use of recyclates (e.g. through product redesign, allowing small imperfections,…)	2	12	13	10	**0.34**
S3. Using plastic recyclates does not make our products more sustainable	19	22	4	1	**-0.6**
S4. We are not using plastic recyclates because there are better options to make our products more sustainable (e.g. bio-based plastic, bio-degradable plastic)	20	13	4	14	**-0.93**

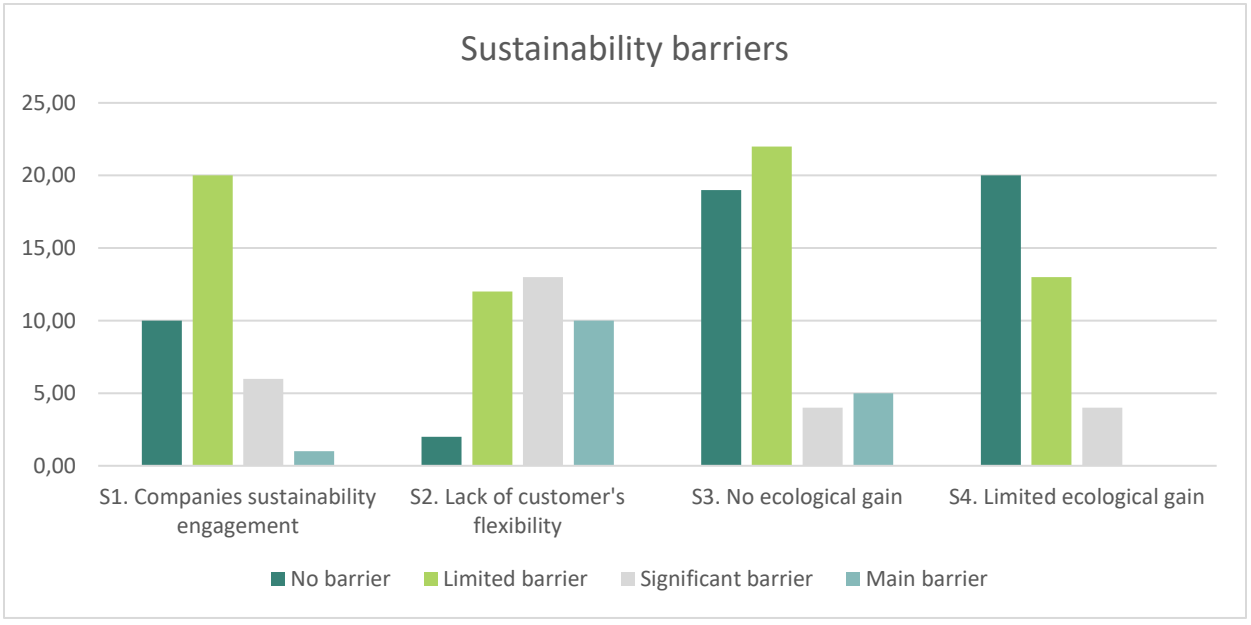


Figure 16: Answers related to sustainability barriers

The main barrier related to sustainability targets, and the only one with a positive score, is **"Lack of customer flexibility" (0.34)**. Many companies experience a certain unwillingness of customers to change the product design or allow small imperfections to their products (e.g. colour, surface impurities) that would allow more use of recyclates.

The arguments **"Companies' sustainability engagement"**, **"No ecological gain"** and **"Limited ecological gain** of using plastic recyclates, all have a high negative score **(-0.55, -0.6, -0.93** resp.**)**. This indicates that companies clearly believe plastic recyclates can make their products more sustainable, and that this does not necessarily conflict with other priorities of the company. Recyclates do not conflict with other technologies (e.g. biodegradable or biobased material) for making the companies' products more sustainable.

4.2.5 TECHNICAL BARRIERS

The final type of barrier that was questioned is related to technical issues, such as quality of input material and final products, or knowledge and adaption of the production process to cope with recycled material. The questions and answers are presented in Table 9 and Figure 17.

Table 9: Questions and answers regarding technical barriers

	STRONGLY DISAGREE, NO BARRIER	RATHER DISAGREE, LIMITED BARRIER	RATHER AGREE, SIGNIFICANT BARRIER	STRONGLY AGREE, ONE OF OUR MAIN BARRIERS	AVERAGE SCORE
T1. Using recyclates requires additional quality control of input material	0	6	23	20	**0.79**
T2. Using recyclates has a negative impact on the functionality of our product (e.g. impact strength, weight)	2	14	22	7	**0.26**
T3. We do not have enough expertise within our company to use plastic recyclates	13	12	9	3	**-0.45**
T4. Our production process is not suited for the use of recycled materials	14	15	7	1	**-0.64**

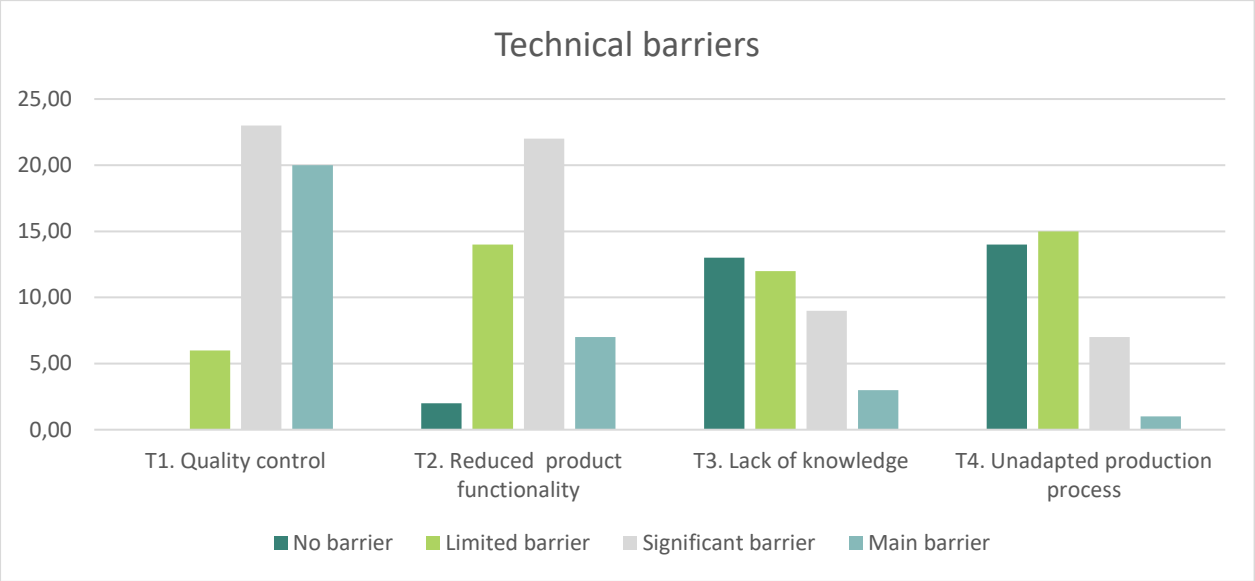


Figure 17: Answers related to technical barriers

Almost all companies indicate that using plastic recyclates requires extra **"Quality control"** of the incoming material **(0.79)**. The fact that virgin material cannot be replaced one to one with plastic recyclates clearly is a major barrier for companies to make the switch to more recycled material. It is an extra step that complicates the production process and makes it more costly.

Also, a **"Reduced product functionality" (0.26)** is regarded to be a problem for using plastic recyclates. Even with quality control of the incoming material, negative effects on the quality of the final product (e.g. impact strength, colour, functional properties) cannot always be avoided.

"Lack of knowledge" (-0.45) or an **"unadapted production process" (-0.64)** are not regarded as significant barriers. Companies feel they have the knowhow inhouse, and they are equipped for using plastic recyclates.

4.2.6 General overview

Figure 18 provides an overview of the barriers questioned in the survey, ranked according to their average score. It gives a clear overview of which of the barriers are experienced as the most significant and which are of less importance.

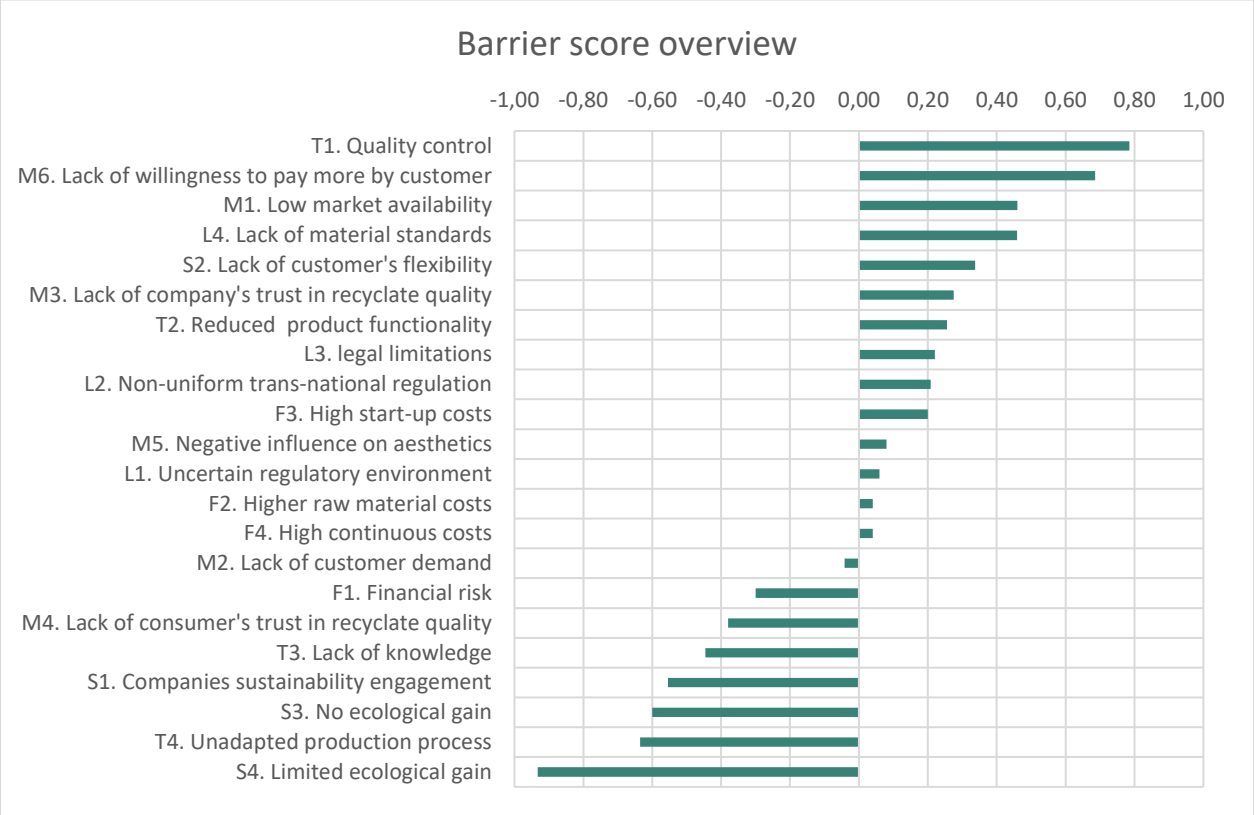


Figure 18: Overview of barriers ranked according to importance

The group of most important barriers is led by the necessity for thorough **quality control**, followed closely by a **"lack of willingness to pay more by customer"**. Other significant barriers are the **"low market availability"** of plastic recyclates that meet the standards of plastic convertors and the **"lack of material standards"** for plastic recyclates. This indicates that companies mostly are reluctant to make the switch to circular material because it comes with a lot of extra effort to ensure that the quality of the final product is sufficient, and to ensure that the production process keeps on running smoothly. Moreover, extra effort is needed to find enough high-quality material on the market. The latter is complicated by the lack of material standards to ensure purchased material can be used in the production process. Moreover, the customer is not willing to pay extra for this effort.

The group of less important barriers includes **"limited or no ecological gain"**, **"unadapted production process"** or **"lack of knowledge"** and **"companies' sustainability engagement"**. This means that companies in general believe plastic recyclates can make their products more sustainable, they are willing to look into this option and the have the technological means to do so.

In general, financial concerns score only average**. Financial risks** are manageable, and high **continuous costs** or **higher material prices** are not that often noted as an important barrier. One exemption lies in **the high start-up costs** associated with modification of the production process, installing a new production protocol or building up of inhouse knowledge. It may be expected that giving direct financial stimuli for using plastic recyclates, such as tax reduction for recyclates and a virgin tax, will stimulate a circular economy for plastics, but also that subsidies for investments may be more effective.

4.3 MATERIAL PARAMETERS

In the second part of the survey, 13 material parameters that are relevant for plastic recyclates were presented to the respondents with the question of how important these are for the production process or the

quality of the final product. The question was formulated as "To what extent do the following technical parameters pose a risk to your production process and final product quality when using plastic recyclates". For each of the parameters, respondents had to indicate one of four possibilities

- No risk - parameter does not affect production process or quality of product
- Low risk - can be controlled with limited adaptations to production process or statistical control of input material
- High risk - can only be controlled with significant investments in production process or quality control of input material
- Very high risk - main barrier for using (more) plastic recyclates

Based on the distribution of the answers, an average score was calculated as before.

Since we are mostly interested in the experience of plastic convertors, we filtered out answers from plastic recyclers and sector federations. Results presented thus are given by plastic convertors, research institutions and plastic compounders, representing 44 out of 51 answers. An overview of the answers is given in Table 10 and Figure 19. An overview of the average score is given in Figure 20.

Table 10: Answers related to risk of technical parameters

	NO RISK	LOW RISK	HIGH RISK	VERY HIGH RISK	AVERAGE SCORE
Physical impurities	0	4	19	15	**0.79**
Hazardous (restricted) substances	2	8	12	16	**0.61**
Legacy additives (unwanted functionality)	0	13	15	10	**0.42**
Melt flow rate	1	16	15	5	**0.15**
Colour	3	14	15	6	**0.13**
Izod/Charpy impact strength	3	15	12	7	**0.12**
Tensile strain at break	0	16	19	2	**0.12**
Flexural strength	1	17	15	2	**0.01**
Flexural modulus	2	20	13	2	**-0.09**
Tensile modulus	2	20	14	1	**-0.12**
Moisture content	5	19	11	2	**-0.23**
Vicat softening temperature	5	18	10	2	**-0.24**
Ash content	6	20	10	1	**-0.34**

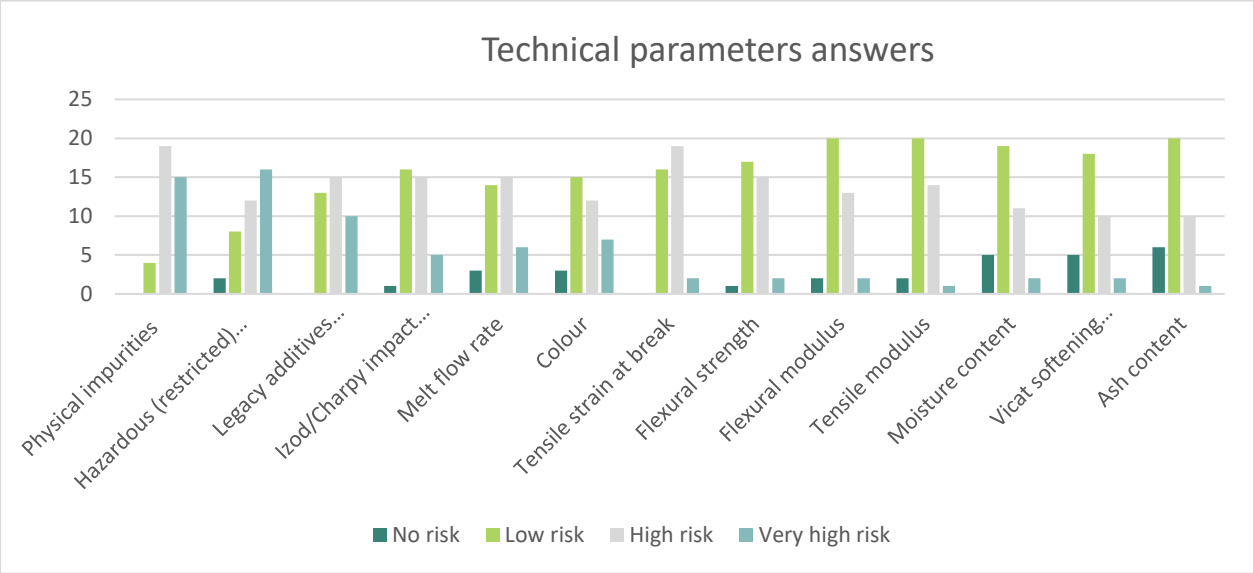


Figure 19: Answers related to risk of technical parameters

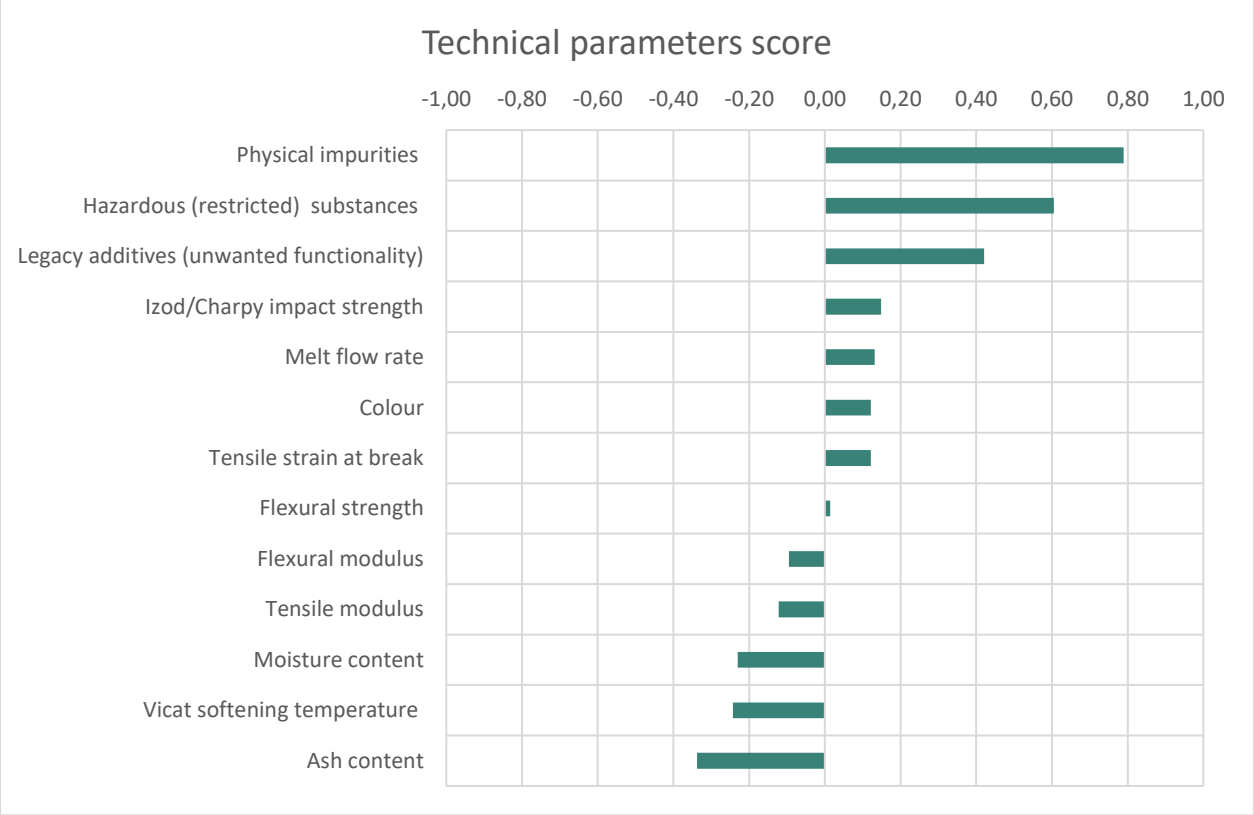


Figure 20: Overview of technical risks ranked according to importance

Looking at the average scores, the number one concern for plastic convertors when using plastic recyclates is the presence of **"physical impurities"** that can lead to failed parts or even the shutdown of the entire

production process. None of the respondents indicates this to be of no risk, and this property is thus important for all plastic convertors.

Other parameters with a very high score are **"Hazardous substances"** that are restricted by regulation and **"Legacy additives"** that give unwanted functionality to the material or final product. This definitely indicates that the scope of the CREAToR project, removal of legacy substances from plastic waste, is very relevant in a circular economy for plastics. Although the project focusses on the removal of hazardous substances, it is worthwhile to investige how other legacy additives behave in the purifying process and whether or not the CREAToR process also removes other unwanted additives.

Two parameters that strongly influence the mechanical properties of a final product are the **"Impact strength"** and the **"Tensile strain at break"**, which both score relatively highly.

Also, the **"Melt flow rate"**, indicated by the melt flow index (MFI) and **"Colour"** of the material have a high score. However, Figure 19, shows a relatively large spread in the answers concerning the importance of these two parameters. This indicates that, while for some the MFI is very important to keep the production process running, for others this is of less importance. The same goes for colour. This matters a lot more for producers making visible products than for those who make semi-finished products that are not visible in the final product.

It is expected that the technical parameters that are relevant depend heavily on the production process that is used. The importance of MFI, for instance, can be very different for an injection moulding process than for a foam extrusion process. In Table 11 the average score for each technical parameter is therefore listed according to the conversion process that the respondent was familiar with.

By comparing the average score for each processing technology, it is clear that not all have the same quality requirements. (Blow) film extrusion and foam extrusion have relatively high scores, indicating that these processes are very demanding on the quality of the material. Injection moulding, on the other hand, has less strict requirements. This is due to the nature of the product. For thin films and thin cell walls in the foam, impurities are lot more disruptive than in a thicker injection moulded part.

Table 11 can also be used to compare individual parameters and find the right customers for certain batches that have very high or very low quality for a specific parameter. Based on the gathered data, a sheet film extruder or foam extruder is most likely willing to pay more for a batch with highly stable MFI, with low variance in one single batch, than an injection moulder.

However, care must be taken in interpreting the table below, since for some of the converting technologies, the number of respondents is rather low. More research, reaching more companies, is needed to make final conclusions (Table 11).

Table 11: Technical scores by converting technology; care must be taken in analysing the later columns, which correspond to converting technologies that lack sufficient numbers of respondents.

	Injection moulding	Sheet film extrusion	Film extrusion	Blow moulding	Foam extrusion	Blow film extrusion	Tubing extrusion	Coating	3D-printing
Colour	1,45	1,63	1,83	1,57	1,67	1,80	1,33	2,00	1,00
Physical impurities	2,05	2,25	2,67	2,14	2,67	2,40	2,00	2,75	2,33
Moisture content	1,05	1,29	1,50	1,14	1,00	1,60	1,25	2,00	1,33
Ash content	0,90	1,29	1,33	1,29	1,00	1,60	0,75	2,00	1,00
Legacy additives)	1,90	1,63	2,00	2,00	2,67	1,80	2,00	2,00	2,00
Hazardous substances	2,00	2,13	2,33	2,29	2,67	2,00	1,25	2,25	2,33

Melt flow rate	1,57	2,13	1,50	1,71	2,00	1,80	1,75	0,75	1,67
Impact strength	1,71	1,50	1,60	1,71	1,67	1,60	1,25	1,00	1,33
Tensile modulus	1,35	1,29	1,50	1,50	1,33	1,60	1,00	1,25	1,67
Tensile strain at break	1,60	1,43	1,67	1,67	1,33	1,80	1,00	1,50	1,67
Flexural modulus	1,35	1,43	1,50	1,50	2,00	1,40	1,25	1,00	1,67
Flexural strength	1,58	1,17	1,67	1,60	1,67	1,60	1,00	1,00	1,67
Vicat softening temperature	1,15	1,29	1,60	1,80	1,33	1,40	1,00	1,00	1,33
Number of respondents	22,00	10,00	8,00	7,00	5,00	5,00	4,00	4,00	3,00
Average score	1,51	1,57	1,75	1,69	1,77	1,72	1,29	1,58	1,62

5 GENERAL RECOMMENDATIONS AND POSSIBLE PRE-TREATMENT STEPS FOR THE CREAToR PROCESS

The previous chapters of this report examined technical parameters that are relevant for plastic recyclates. Both the in-depth interviews and the survey provided information on which are the most relevant of these, and made it possible to rank them according to importance or risk. The in-depth interviews also provided the opportunity to receive input from plastic convertors on what they see as possible solutions to improve the quality of recyclates.

In this chapter we suggest some possible pre-treatment steps that can be added to the CREAToR process that can help to match the output material properties with the demands of the market. Suggestions for extra services are also made to help improve the economic viability of the CREAToR's business model.

5.1 FILTERING WITH FINER MESH FILTERS

According to both the in-depth interviews and the results of the survey, physical impurities are the leading technical parameter that determines the quality of the recyclates. Installing a fine mesh filter in the extrusion process seems like an obvious step to increase recyclate quality. Often recyclers choose a coarse grid because this enables higher material throughputs and reduced costs. For the CREAToR process, however, the impact of a fine mesh filter on the total costs is reduced because:

- The process requires the solvent to interact for a certain amount of time with the polymer. This is most likely to determine the total throughput of the material. A finer mesh grid is then no longer the bottleneck.
- The sc-CO_2 lowers the viscosity of the melted polymer. When the mesh filter is installed somewhere in the purifying phase, filtering can become easier.
- The increased cost of extra filtering might be small compared to the overall extra costs of the purifying process.

The necessary mesh size can depend on the customer's needs. While for an injection moulder a grid of 400µm can suffice, a thin film producer needs a mesh filter down to 20µm.

5.2 CONTINUOUS MFI MEASUREMENT DURING EXTRACTION, COMBINED WITH AN EXTRA SORTING STEP

The melt flow rate of the recyclate is seen by the in-depth interviewees as the second most important technical parameter, and is highly relevant according to the survey as well. Ensuring high quality on this parameter, meaning a well-defined MFI with low spread in a single batch, is a very effective way to increase the overall quality of the recyclate.

One way of achieving this is to install a measuring device that constantly monitors the MFI of the material flowing through the extraction process. Since the residence time in the extrusion line is quite short, it is possible to calculate quite precisely when the material exits the nozzle and redirect the material to another lot depending on the MFI measured.

More research is needed on the feasibility of such a technique in combination with the CREAToR purifying process, and on the effect of the spread of the MFI. However, a small increase in the quality of the MFI can drastically increase the acceptance of the recyclates in high-demanding processes where the MFI has to be very stable.

5.3 SELECTIVE SOURCING AND MAXIMAL SEPARATION OF DIFFERENT WASTE STREAMS

Selective sourcing of the incoming material may also help to improve recyclate quality by reducing physical impurities coming from wrongly sorted polymers or reducing variance on other physical parameters such as the MFI. Good examples are the sourcing of demolition waste directly from large demolition sites, or waste coming from large companies that replace a lot of material with the same properties at the same time.

Maintaining separate recycling streams for more product categories, as is currently already done by separating fridges from other WEEE, can also be a good method to create more uniform recycling batches.

5.4 QUALITY CONTROL AS A SERVICE

According to the study, the need for extensive quality control is seen as a major barrier to the use of plastic recyclates. By taking this out of the customer's hands and integrating it into the CREAToR process, companies could be persuaded to switch to using recycled plastic.

Specifically, products from the CREAToR process could be subject to a number of additional tests that currently must be performed by customers of plastic recyclates themselves in order to keep their process running smoothly and guarantee constant quality of their end products. A "Quality control as a service" in close cooperation with the customer is a way to save the end user additional efforts and lower the threshold to plastic recycling. Moreover, this can increase companies' confidence in the CREAToR material, and plastic recyclate in general.

Of course there is an initial cost involved in getting to know each new customer's production methods and material requirements, but it has the advantage of creating a close relationship between end user and recycler. Also, when using well defined own standards, or standards developed in collaboration with other partners from industry, as described in section 5.8, it will be easier to translate lessons learned at one customer's situation to that of another.

5.5 MATCH THE OBTAINED MATERIAL WITH THE CUSTOMER WHOSE SPECIFICATIONS BEST CORRESPOND

Table 11 clearly shows that not all types of conversion technologies have the same requirements on plastic recyclates. Extensive measurements of technical parameters, combined with a thorough knowledge of the requirements of customers, can be used to couple customers with material that meets their specific demands. This way recycled plastics with different properties are used in the highest-quality products possible, and there is a greater economic return from the material.

Note that this approach again strongly benefits from well-defined material standards, as described in section 5.8.

5.6 SMART HOMOGENISATION ACCORDING TO CUSTOMER'S SPECIFICATION

Homogenisation is a double-edged sword. On the one hand, by mixing multiple batches of material, a larger amount of material is obtained for which the average material parameter of interest lies somewhere in between that of the original batches. This allows the end-user to work longer with the same production settings. However, it also increases the variability of each parameter, or the deviation from the new average within the batch. In general this decreases the overall quality of the recyclate and lowers the technical quality

of the material. In some applications, this limits the amount of recycled content that can be used in the production process.

Smart homogenisation of different batches can be an effective compromise. Here, a set of batches of which a series of relevant technical specifications are known, are kept apart for as long as possible. Based on specific demands of a customer that has strict requirements on one parameter, but lower requirements on others, batches that meet the most strict parameters are mixed with each other. In the mixing process, less important parameters, or parameters with larger allowed deviation, can then be ignored without loss of quality for that specific customer.

Again, this approach strongly benefits from well-defined material standards, as described in section 5.8.

5.7 EXTEND PURIFYING PROCESS TO TARGET OTHER LEGACY SUBSTANCES

The presence of hazardous substances is seen in the survey as the second most important risk. However, the importance of legacy substances that have unwanted functional properties (and are not necessarily hazardous or restricted) cannot be underestimated either.

The removal of hazardous substances is of course the main scope of this project and probably also that of the industrial follow-up. However, extending the scope of the CREAToR process from removing hazardous substances to removing all kinds of additives, thereby improving the general quality of the recyclates, can generate extra added value to the process. The process is already developed for the removal of odours, and might be applicable to even more substances. Although more research is needed about the extent to which the CREAToR process can also remove other legacy additives, and how it can be optimised for this, marketing the product with this extra benefit can increase economic value of the output material.

5.8 DEVELOP UNIFORM MATERIAL STANDARDS IN COLLABORATION WITH OTHER PARTNERS IN RECYCLING INDUSTRY

The lack of material standards for plastics makes it hard for end-users to source the materials that meet their requirements, and is seen as the fourth most important problem in the survey. Consistent and thorough inhouse methods for measuring material properties guaranteeing constant material quality are of course a minimal requirement for good functioning of an industrial scaled plant. However, extensive collaboration with other partners within the recycling industry, to develop uniform material standards, will increase trust in - and market uptake of - plastic recyclates even more. By participating in the development of such standards, CREAToR partners can build up a high degree of expertise and become frontrunners in high-quality recycling.

Moreover, the approaches to obtain more economical value from plastic recyclate suggested in sections 5.4, 5.5 and 5.6, strongly benefit from the existence of clear and well-defined material standards.

6 POLICY RECOMMENDATIONS

Many of the companies we spoke to in the in-depth interviews presented possible solutions that can be enforced by new legislation or market incentives. In this chapter we summarise the recommendations that were presented by the companies themselves and are supported by information from the survey. Suggestions where ideas differed and are not broadly supported, are not included here.

6.1 MAKE THE USE OF RECYCLATES THE MOST ECONOMIC OPTION

Price remains the main factor in the decision of whether or not to use plastic recyclates. Many companies do wish to lower the ecological footprint of their products by using recycled plastics, and consumers are increasingly interested in buying these products. However, as indicated in the interviews and clearly confirmed by the digital survey, most people are not willing to pay more for products made from recycled materials. Also, with few exceptions, companies remain reluctant to increase recycled content at the cost of profit.

We therefore conclude that financial incentives that promote the use of plastic recyclates will definitely drive a circular economy for plastics.

Respondents to the survey indicate that high start-up costs are the most significant financial barrier, and are more important than high raw material prices. This indicates that financial instruments to help companies with initial investments might be more effective than lowering recycled material prices or increasing virgin prices.

6.2 STIMULATE HIGH-QUALITY RECYCLING

Low market availability of high-quality recyclates is a big obstacle that prevents producers from using more plastic recyclates. Although plenty of waste is generated, much of it is recycled into low-quality products or even shipped abroad. Best available techniques (BATs) must be facilitated to enable recyclers to treat certain waste streams, and research must be stimulated to develop new techniques. A possible way to achieve this is to include quality of recycling into the development of new recycling targets.

However, high-quality recycling is expensive, and methods must be developed to overcome this.

6.3 INSTALL UNIFORM COLLECTION SCHEMES THROUGHOUT THE EU

The installation of uniform collection schemes throughout the EU would stimulate a circular economy for plastics in multiple ways. By creating more uniform waste streams, recyclers can anticipate these more easily on and adjust their recycling accordingly. This will result in higher recycling rates and more high-quality recycling. The increased scale of the waste streams will also make it more profitable to invest in the best available techniques (BATs) that can handle specific waste types. Finally, when products are recycled in a similar way across the EU, it will be easier for producers to design their products for recycling.

It remains important that these collection schemes differentiate sufficiently between different material types or product categories. EU-wide EPR schemes for more product categories can also be helpful in achieving this.

6.4 INSTALL TRACK AND TRACE SYSTEMS TO FACILITATE CLOSED LOOP RECYCLING

Unwanted legacy additives or substances of concern in certain waste streams pose a significant challenge to the use of plastic recyclates, particularly in post-consumer waste where the material source is often unknown.

One solution to overcome this is to implement legislation that promotes traceability of products and materials. This can be achieved by requiring producers to label their plastic products with a QR code or watermark to identify and sort out products that are suitable for recycling with specific purposes, such as food contact materials, toys, or less demanding applications. Such labeling can also enable producers to identify and recover their own material and reuse it in their products while still conforming to the relevant legislation. Additionally, the implementation of extended producer responsibility (EPR) schemes for more product categories can help to increase the volume of recycled materials, making the overall process more efficient and economically viable.

6.5 ALLOW RECYCLED CONTENT IN PRODUCTS WHERE SAFE USE IS GUARANTEED

According to interviewed companies and confirmed by the digital survey, legal and voluntary standards often directly or indirectly limit the use of recycled plastics in certain products.

However, new recycling and conversion technologies are constantly being developed that can allow safe use of recycled plastics in specific products. When this can be guaranteed on a scientific basis, exemptions for responsible use of recycled materials should be allowed. More specifically, adjusting voluntary standards to focus on functional requirements and not on material-specific standards can increase the uptake of recycled material.

6.6 CREATE PUBLIC AWARENESS ABOUT CHALLENGES IN RECYCLING PLASTICS

While a growing number of consumers are aware of the ecological benefits of using plastic recyclates, and are increasingly willing to purchase such products, they tend to have limited knowledge about the challenges involved in plastic recycling. Educating people about these challenges can stimulate them to sort better and think of their own material usage. It also will clarify why using recycled plastics is not always cheaper, and potentially foster support for paying more for sustainable products.

Finally, if customers could be convinced to reduce certain requirements, such as highly specific RAL colours or surface textures, it would be possible to incorporate a greater amount of recycled material.

6.7 STIMULATE THE DEVELOPMENT OF MATERIAL STANDARDS FOR PLASTIC RECYCLATES

The search for recycled material to meet a producer's demand is hampered by the absence of clear material standards. Quality of material varies greatly among different recyclers, and even within different batches. This makes extensive quality control in the plastic conversion process necessary, which is seen as the main barrier for using more recyclates.

The development of clear material standards for plastic recyclates will ensure more stable output streams and facilitate the search for specific grades of recyclates on the market. These standards must be developed in a close collaboration between recyclers and plastic convertors, in order to guarantee a match between offer and demand.

7 CONCLUSIONS

This study investigated limits and barriers experienced by plastic converters when using plastic recyclate. Through in-depth interviews with industry members, an initial picture could be obtained of the possible technical, legal, economic and societal problems. The identified barriers were then summarised and presented in a digital survey to a broader group of stakeholders, asking to what extent companies experience these barriers sector-wide. This resulted in a broad list of problems ranked by priority.

The main barriers experienced by industry were found to be (ranked by priority)

- The need for thorough quality control in the deployment of plastic recyclate
- Low availability of high-quality material on the market
- Lack of material standards, which makes it difficult to find correct material on the market
- Price-related problems such as high investment cost, high price for high-quality recyclate and customers unwilling to pay more for more sustainable products
- The negative impact of recyclate on the final quality of their products in combination with high customer demands
- The possible presence of harmful substances prohibited by general and product-specific regulations

Information was also sought concerning technical requirements, and on this basis the following list of parameters affecting recyclate quality was compiled (ranked by priority)

- The presence of physical impurities
- The presence of legacy additives, prohibited or not
- Melt flow rate (especially important during the production process)
- Homogeneity of the material
- Mechanical parameters of impact strength and tensile strain
- Colour

Based on these conclusions, and using further information from the in-depth interviews, a series of recommendations were drawn up to optimise the CREAToR process and its business model. Further recommendations were aimed at policy makers to facilitate a circular economy for plastics.

To improve the CREAToR process and its business model, we made following the recommendations to those who will upscale the process and take it to an industrial level:

- Apply a fine mesh filter before/during or after the extraction/purification step, depending on the material purified
- Continuous MFI measurement combined with an extra sorting step during the extraction phase on the basis of this measurement
- Selective sourcing of waste to ensure pure waste streams
- Offer quality control as a service tailored to the customer
- Match the obtained material with the customer whose specifications best correspond
- Smart homogenisation according to customer's specification
- Extend purifying process to target other legacy substances
- Develop uniform material standards in collaboration with other partners in the recycling industry

For EU and local policy makers, we compiled the following list of recommendations that can assist the transition towards a circular economy for plastics:

- Make the use of recyclates the most economical option
- Stimulate high-quality recycling
- Install track and trace systems to facilitate closed loop recycling
- Install uniform collection schemes throughout the EU
- Allow recycled content in products where safe use is guaranteed
- Create public awareness about challenges in recycling plastics
- Develop material standards for plastic recyclates

These recommendations will be included in CREAToR's policy brief, together with more general input from the CREAToR consortium and lessons learned during the CREAToR project. This document will be published as a public deliverable in May 2023.

8 APPENDICES

8.1 APPENDIX 1: INTERVIEW GUIDE

General info	Company name		
	Contact person		
	Date of Interview		
Before the interview	Give a short presentation of the project		
	Ask permission to record the interview for processing only		
	Data governance: proofreading of report is possible, information is only stored for duration of project		
Guiding question	**Checklist (Address if not mentioned on its own)**	**Notes (Please start new line within same cell for multiple answers under same topic (using ALT+ENTER))**	**Possible specific questions (at appropriate point, if necessary when checklist topics are not mentioned on its own)**
What is the main activity of your	products		What is the main activity of your company?

company and what is the role of your company in the plastic production chain?	materials		What materials are used in the production process and what are the required volumes (ton) on a yearly basis?
	production process		
	Sales area		In how many companies are the products distributed inside Europe and outside Europe? Is the product distributed for a specific number of customers or is it broadly distributed?
	Customers		
	Suppliers		Who are your suppliers? Do you have a fixed long-term relationship with your suppliers, or are suppliers regularly changed? Do you depend on a single supplier for one type of resource, or do you have multiple resources? (*) What are your main criteria to choose a certain supplier?
	Stock		What is the time-period that resources are buffered or planned for? Is this influenced by current market price of material?
	Other		
What is your company's strategy with respect to the use of virgin and recycled material? What are the main problems you	Motivation for (not) using recyclates		What is or could be the most important driver for the company to use recycled materials?
	Origin of recyclates		**What type(s) of recycled materials are used in the production process (Production scraps, post-industrial waste or post-consumer waste)**

encounter when using plastic recyclates?	Recycled materials used		What are the key technical parameters you are the most interested in to switch from virgin to recycled materials
	Problems in demand and supply		Is the demand and supply of material constant or predictable? Have you ever encountered problems with delivery?
	Quality problems		Do you receive a quality assessment report from your supplier? Is the quality of the input material measured? What is the routine procedure for this (short)? (*) How often are incoming materials rejected? What is the impact of the rejection? (*) Do you have to deal with customer requirements that cannot be reached by using recycled materials? If so, what kind of requirements are this?
	Technical problems		What are the main technical difficulties when using plastic recyclates, how do you overcome them? Has the production process been designed or adjusted for the use of recycled materials?
	Running or discontinued projects		Can you share some practical examples (collaborations, best practices, partnerships, …) that could inspire stakeholders of the circular plastics economy?
	other		Have you heard of chemical recycling? What do you think will be the importance of this technology in your sector?
In your opinion, what could or should be done to stimulate the transition towards a	EU-regulation		What are the challenges on an EU market to enable the use of recycled materials? Do you encounter legislative issues that prevent (further) use of recycled materials in your products?

more circular economy for plastics?	Local regulation		Is there binding regulation specific for your country to promote the use of recycled polymers for your products? Do you know the public procurement policy in your country? Is there a specific approach for recycled materials? What can your government do more to enable the circular use of materials?
	Customer's awareness		Do you feel that customers are positive, negative or neutral to the use of recycled materials in their products? Do you notice a shift in awareness for this?
	Design for recycling		Do you already take recyclability/reparability into account in designing your products? If so, How?
	Other		
Conclusion	Do you have anything you would like to add?		
	Do you have any further question concerning the next steps?		
	Would it be okay if we contact you again if we have some follow-up questions that arise during the analysis of the interview?		

	We are still looking for interview partners. Do you maybe know someone who has insights on the topic and might be willing to talk to us?		

8.2 APPENDIX 2: DIGITAL SURVEY

Survey on plastic convertors' barriers for using plastic recyclates

*Vereist

Thank you for participating in our survey. The survey is part of the EU-financed research project CREAToR. Completing the survey will take about 10-15 minutes.

This online survey is a follow-up study on a first round of in-depth interviews with members of the plastic converter industry. In these conversations, we have identified several barriers that we now wish to present to a broader set of stakeholders of the plastic converter industry to verify its general applicability.

- *Goal 1:* identify end-user **technical requirements** for plastic recyclate and process limitations so that future pre-treatment steps can be defined and the CREAToR process optimized. This information will be shared in a public report so interested parties can learn from our findings.
- *Goal 2:* learn from **your experience** (good and bad) with recycled material and what you experience as the most significant barriers. This information will be used as input for a **policy brief** addressed to the European Commission and for a scientific publication to be submitted in 2023.

About the CREAToR project
Problem statement

Some complex plastic waste streams (e.g. e-waste or construction waste) that contain hazardous (legacy) brominated flame retardants can not be recycled because of human health and environmental risks and regulation on the restriction of certain hazardous substances in new products.

Goal

The CREAToR process will produce REACH- and POP-regulation-compliant recycled polymers free of hazardous legacy brominated flame retardants from waste streams containing brominated flame retardants.

The partners aim to create an economically viable business model, taking into account the entire value chain, from collecting the waste, recycling with advanced purification methods, to deploying the recyclates into new products.

More information on the CREAToR project can be found here.

Responsible editor survey: Roeland Juchtmans

Contact details: roeland.juchtmans@ovam.be

Data-governance

• **Full transparency and ownership of the information** for you and your company is guaranteed. You can withdraw from the survey or ask for the removal, or modification of the data at any time.

• The results of the survey, will be used as input for a public report on the end-user requirements of plastic recyclates and for the CREAToR's policy brief. Furthermore, this information can be used for a scientific publication that will be submitted in 2023. These public reports will only share anonymized aggregated data and basic information (Country/industry/number of employees/...).

• For review purposes of the financing agency (EU's Horizon 2020 program), the raw data will be stored for 5 years after the end of the project and will be deleted afterwards (31/04/2028).

Company information

In this section, we ask for general information about your company. This information will not be shared with third-parties and will only be used to analyze the result and communicate the draft report.

1. Company name (optional)

_____

2. Country

Markeer slechts één ovaal.

- ◯ Austria
- ◯ Belgium
- ◯ Bulgaria
- ◯ Croatia
- ◯ Cyprus
- ◯ Czech Republic
- ◯ Denmark
- ◯ Estonia
- ◯ Finland
- ◯ France
- ◯ Germany
- ◯ Greece
- ◯ Hungary
- ◯ Ireland
- ◯ Italy
- ◯ Latvia
- ◯ Lithuania
- ◯ Luxembourg
- ◯ Malta
- ◯ Netherlands
- ◯ Poland
- ◯ Portugal
- ◯ Romania
- ◯ Slovakia
- ◯ Slovenia
- ◯ Spain
- ◯ Sweden
- ◯ Africa
- ◯ Asia
- ◯ Europe (outside EU)

- North America
- Oceania
- South America

3. Industry *

Vink alle toepasselijke opties aan.

- [ ] Packaging
- [ ] Electronics
- [ ] Automotive and transportation
- [ ] Building and construction
- [ ] Textiles
- [ ] Anders: _____

4. Company size (staff) *

Markeer slechts één ovaal.

- 1-10
- 11-50
- 51-250
- >250

5. What is your position within the company

_____

6. Please indicate what applies most *

Markeer slechts één ovaal.

- My company produces plastic products ready to be sold on the market
- My company produces semi-finished plastic parts for other companies
- I'm a plastic recycler
- I'm a representative of a sector federation *Ga naar vraag 14*
- Anders: _____

7. To what extend is sustainability being addressed within your company? *

Markeer slechts één ovaal.

- We are not yet addressing sustainability as point of attention
- We are starting to look into ways of making our products and production process more sustainable (e.g. taking measures against wastage, increasing process efficiency)
- We have taken certain measures to make part of our production process and products more sustainable (e.g. pay attention when buying raw material, installing sustainability manager, offering certain green products in our portfolio)
- Sustainability is in the heart of everything we do, it is an important point of attention in every department (e.g. company-wide establishment of sustainability targets, striving to make all our products sustainable)

Ga naar vraag 8

Technical information

In this section, we ask you for general information about your company to analyze the answers according to different parameters.

Multiple answers are sometimes possible, like when your company converts different types of plastics or uses different converting technologies. In case the usage of plastic recyclates or problems you encounter in it differ significantly among the different options, we suggest selecting only one and filling in the rest of the survey concerning this option.
You are free to fill in the survey multiple times for different materials, polymer types or, production processes.

8. What are the main types of polymers used in the production process or the ones you would like to address in this survey *

Vink alle toepasselijke opties aan.

- [ ] PET or PETE (Polyethylene terephthalate)
- [ ] HDPE (High density polyethylene)
- [ ] PVC (Polyvinyl chloride)
- [ ] LDPE (Low density polyethylene)
- [ ] PP (Polypropylene)
- [ ] PS (Polystyrene)
- [ ] ABS (Acrylonitrile Butadiene Styrene)
- [ ] PMMA (Polymethyl Methacrylate)
- [ ] PU (Poly Urethane)
- [ ] Anders: _____

9. What are the main production processes used in your company or the ones you would like to address in this survey *

Vink alle toepasselijke opties aan.

- [ ] Injection Moulding
- [ ] Blow Moulding
- [ ] Rotation Moulding
- [ ] Vacuum Moulding
- [ ] Foam extrusion
- [ ] Film extrusion
- [ ] Sheet film extrusion
- [ ] Blow film extrusion
- [ ] Tubing extrusion
- [ ] 3D-printing
- [ ] Slabstock foaming
- [ ] Anders: _____

10. What is the average amount of plastic converted by your company on an annual basis (in tonnes/year)

_____

11. Whate type of recyclates do you use in your products *

Vink alle toepasselijke opties aan.

- [ ] None
- [ ] Own production scrabs
- [ ] Post-industrial recyclates
- [ ] Post-consumer recyclates

12. What is the share of recycled plastics compared to the total amount of plastics used in your products (Post-industrial and post-consumer only) *

Markeer slechts één ovaal.

- ◯ None
- ◯ >0%-5%
- ◯ 5%-10%
- ◯ 10%-25%
- ◯ 25%-50%
- ◯ >50%

13. If known, how many years have you been using recycled plastic in your products (Post-industrial and post-consumer only)

_____

Barriers for a circular economy for plastics

In this section we present 21 barriers we have identified in previous in-depth conversations with members of the plastic convertor industry. By presenting these to a broader set of companies, we want to verify their general applicability and order them according to the impact they have.

14. To what extend do you agree with following statements related to possible **financial barriers** for using more plastic recyclates in your products

Markeer slechts één ovaal per rij.

	Stongly disagree, no barrier	Rather disagree, limited barrier	Rather agree, significant barrier	Strongly agree, one of our main barriers
F1. Using recyclates poses unpredictable financial risks for us (e.g. due to possible increased production time and material loss, insecure delivery, volatile prizes)	⬭	⬭	⬭	⬭
F2. Using plastic recyclates in our products is more expensive than using virgin plastics	⬭	⬭	⬭	⬭
F3. Using plastic recyclates requires significant financial investments (e.g. research, modification of the existing production process, product redesign)	⬭	⬭	⬭	⬭
F4. Using recyclates requires a lot of continuous effort for our company (e.g. higher production costs, handling of additional materials)	⬭	⬭	⬭	⬭

15. To what extend do you agree with following statements related to possible **legal barriers** for using more plastic recyclates in your products

Markeer slechts één ovaal per rij.

	Stongly disagree, no barrier	Rather disagree, limited barrier	Rather agree, significant barrier	Strongly agree, one of our main barriers
L1. Rapidly evolving or unclear legislation, makes us hesitant to use plastic recyclates	◯	◯	◯	◯
L2. Non-uniform regulation across the EU complicate the use of recyclates in our products (e.g. End-of-Waste status, product regulation, transboundary shipments)	◯	◯	◯	◯
L3. Legal standards limit the use of recyclates in our products	◯	◯	◯	◯
L4. Lack of quality standards for plastic recyclates complicates our search for well suited material	◯	◯	◯	◯

16. To what extend do you agree with following statements related to possible market related barriers for using more plastic recyclates in your products

Markeer slechts één ovaal per rij.

	Stongly disagree, no barrier	Rather disagree, limited barrier	Rather agree, significant barrier	Strongly agree, one of our main barriers
M1. Availability of recyclates that fit our requirements is too low or too unstable				
M2. Our customers lack interest in buying products with recycled content				
M3. We do not trust in the quality of available recyclates				
M4. Our customers have negative associations with recycled plastics				
M5. Using recyclates leads to an unacceptable reduction of the appearance of our product				

M6. Our costumers are not willing to pay more for products with recyclates				

17. To what extend do you agree with following statements related to possible **sustainability barriers** for using more plastic recyclates in your products

Markeer slechts één ovaal per rij.

	Stongly disagree, no barrier	Rather disagree, limited barrier	Rather agree, significant barrier	Strongly agree, one of our main barriers
S1. Using plastic recyclates conflicts with other priorities within the company (e.g. marketing, efficiency of production, quality)	◯	◯	◯	◯
S2. Customers are not willing to adapt their product to enable the use of recyclates (e.g. through product redesign, allowing small imperfections,...)	◯	◯	◯	◯
S3. Using plastic recyclates does not make our products more sustainable	◯	◯	◯	◯
S4. We are not using plastic recyclates because there are better options to make our products more sustainable (e.g. bio-based plastic, bio-degradable plastic)	◯	◯	◯	◯

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18. To what extend do you agree with following statements related to possible **technical barriers** for using more plastic recyclates in your products

Markeer slechts één ovaal per rij.

	Stongly disagree, no barrier	Rather disagree, limited barrier	Rather agree, significant barrier	Strongly agree, one of our main barriers
T1. Using recyclates requires additional quality control of input material	◯	◯	◯	◯
T2. Using recyclates has a negative impact on the functionality of our product (e.g. impact strength, weight)	◯	◯	◯	◯
T3. We don't have enough expertise within our company to use plastic recyclates	◯	◯	◯	◯
T4. Our production process is not suited for the use of recycled materials	◯	◯	◯	◯

19. What do you consider to be the most important barrier for increasing the use of plastic recyclates in your products *

Markeer slechts één ovaal.

- ◯ F1. Financial risk
- ◯ F2. Higher raw material costs
- ◯ F3. High start-up costs
- ◯ F4. High continious costs
- ◯ L1. Uncertain regulatory environment
- ◯ L2. Non-uniform trans-national regulation
- ◯ L3. legal limitations
- ◯ L4. Lack of material standards
- ◯ M1. Low market availability
- ◯ M2. Lack of customer demand
- ◯ M3. Lack of trust in recyclate quality [Company]
- ◯ M4. Lack of trust in recyclate quality [Customer]
- ◯ M5. Negative influence on esthetics
- ◯ M6. Lack of willingness to pay more by customer
- ◯ S1. Companies sustainability engagement
- ◯ S2. Resistance to change
- ◯ S3. No ecological gain
- ◯ S4. Limited ecological gain
- ◯ T1. Quality raw material
- ◯ T2. Reduced product functionality
- ◯ T3. Lack of knowledge
- ◯ T4. Unadapted production process

20. (Optional) What do you consider to be the second most important barrier for increasing the use of plastic recyclates in your products

Markeer slechts één ovaal.

- F1. Financial risk
- F2. Higher raw material costs
- F3. High start-up costs
- F4. High continious costs
- L1. Uncertain regulatory environment
- L2. Non-uniform trans-national regulation
- L3. legal limitations
- L4. Lack of material standards
- M1. Low market availability
- M2. Lack of customer demand
- M3. Lack of trust in recyclate quality [Company]
- M4. Lack of trust in recyclate quality [Customer]
- M5. Negative influence on esthetics
- M6. Lack of willingness to pay more by customer
- S1. Companies sustainability engagement
- S2. Resistance to change
- S3. No ecological gain
- S4. Limited ecological gain
- T1. Quality raw material
- T2. Reduced product functionality
- T3. Lack of knowledge
- T4. Unadapted production process

21. (Optional) What do you consider to be the third most important barrier for increasing the use of plastic recyclates in your products

Markeer slechts één ovaal.

- F1. Financial risk
- F2. Higher raw material costs
- F3. High start-up costs
- F4. High continious costs
- L1. Uncertain regulatory environment
- L2. Non-uniform trans-national regulation
- L3. legal limitations
- L4. Lack of material standards
- M1. Low market availability
- M2. Lack of customer demand
- M3. Lack of trust in recyclate quality [Company]
- M4. Lack of trust in recyclate quality [Customer]
- M5. Negative influence on esthetics
- M6. Lack of willingness to pay more by customer
- S1. Companies sustainability engagement
- S2. Resistance to change
- S3. No ecological gain
- S4. Limited ecological gain
- T1. Quality raw material
- T2. Reduced product functionality
- T3. Lack of knowledge
- T4. Unadapted production process

22. (Optional) Comments or nuances on answser above, can be made here

(Optional) Technological parameters that determine the quality plastic recyclates

In this section, we would like to learn from you, as a plastic converter, what are the most critical technical parameters that determine the quality of plastic recyclate?
If you do not represent a converter company, or you don't feel to have the technical knowledge to answer these questions, you may skip this section.

23. To what extent do following technical parameters pose a risk to your production process, and final product quality when using plastic recyclate.

Markeer slechts één ovaal per rij.

	No risk, property does not affect production process or quality of product	Low risk, can be controlled with limited adaptations to production process or statistical control on input material	High risk, can only be controlled with significant investments in production process or quality control of input material	Very high risk, main barrier for using (more) plastic recyclate
Color				
Physical impurities (e.g. grain of sand, missorted types of polymer)				
Moisture content				
Ash content				
Legacy additives with unwanted functional properties				
Hazardous substances (legacy additives restricted by product or chemical legislation)				
Melt flow rate				

Izod/Charpy impact strength				
Tensile modulus				
Tensile strain at break				
Flexural modulus				
Flexural strength				
Vicat Softening Temperature (VST)				

24. (Optional) Please indicate other technical parameters that pose a risk to your production process or final product quality when using plastic recyclates

Contact details (optional)

Thank you for completing the survey!

Please fill in your email address below if you want to be informed about the results of this survey. This information will not be used for other communication or shared with third parties.

25. email address contact person (optional)