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Inventory of barriers and enablers for the uptake of recycled plastic

Outcomes of seven workshops in North West Europe

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As part of the TRANSFORM-CE project, several (online) workshops were organised to identify industry and business needs to use recycled materials in production processes. Seven in-depth workshops are done to achieve an inventory of the various barriers and enablers organisations face with the uptake of recycled plastic feedstock. This document combines the outputs of workshops held in the Netherlands, the United Kingdom, Germany and Belgium.

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1. Introduction and method

1.1 Introduction

Plastic is a widely used material and millions of plastic products and packaging are manufactured each year. Since plastic products are often only used once and then disposed of when no longer needed, the total amount of plastic waste is increasing each year. Further to this, only 30% of total plastic waste is collected for recycling. With the growing demand for plastic expected to continue, leading to yet further depletion of resources, it is important to utilise plastic waste in a resourceful way.

Subsequently, issues with plastic waste have prompted both European and national targets to further increase recycling rates, including goals to increase the use of recycled content in products[1]. To reach these objectives, it will be beneficial to identify and compare the various factors that influence uptake of recyclate in industry.

This research focusses on the barriers and enablers that various actors along the value chain face with the uptake of recycled feedstock. Several organisations from different positions in the value chain participated in the workshops, representing businesses, consultancies, academics, governmental organisations and waste management companies. Focus was placed on the North West Europe region, with workshops being held in the Netherlands (2), the United Kingdom (2), Germany (2) and Belgium (1), leading to a total of seven in-depth workshops. In total 85 persons from 78 different organisations participated in the workshops. Next to the workshops, on online survey was also done to research the barriers for the use of recycled feedstock. These results can be found in a separate document.

1.2 Goal of the workshops

The main goal of the workshops was to map the problems businesses encounter when implementing recycled materials (barriers), the factors enabling them to use recycled materials (enablers) and the conditions and instruments needed to accelerate this (needs). During the workshops, companies actively participated in mapping the barriers, enablers and needs in relation to the uptake of recycled feedstock.

In addition to sharing experiences, know-how and knowledge about the use of recycled feedstock, participants were presented with an opportunity to connect with and learn from each other. The workshops therefore also provided a means by which businesses were able to establish and deepen networks on circular economy (CE).

The results of the workshops are shared in this document, which serves as a first step to accelerating the uptake of recycled single-use plastics from household waste into new products. The report lays important groundwork for developing the approach TRANSFORM-CE will take to provide in-depth support to 20 exemplary businesses, helping them to take up single used plastics and to develop products and business models aligned with a CE.

1.3 Workshop set up

The in-depth workshops took place between June 2020 and April 2021. The workshops were organised online via MS Teams, with a length of two hours each. Each workshop started with an

[1] See also Velzing et al. (2020). *Policy for a Circular Plastic Economy in the Northwest European (NEW) Region*

introduction (45 min), explaining the TRANSFORM-CE project and the need for transitioning towards a CE, as well as an example of a best practice CE business model.
For the next step (60 min), participants were divided into separate breakout rooms, in order to have smaller groups (3 to 8 participants). During these focus-group sessions, the different barriers, enablers and needs associated with the uptake of recycled content were discussed in more detail. The focus-group sessions were split into five activities:

1. Introductions/icebreaker: participants shared details of a circular product they manufacture;
2. Outlining & exploring the value chain for the manufacturing/recycling of plastic products (production, selling, use, collection, recycling etc.) (light yellow sticky notes);
3. Making an inventory of drivers (orange) and enablers (dark yellow) by using sticky notes, and placing them at the right step in the value chain;
4. Specifying the needs (pink sticky notes);
5. Identifying the most important barriers, enablers and needs.

In each session, an online board was used to map these factors at different parts of the value chain (see figure 1 for an example). By visualising and dividing these aspects based on their positioning in the value chain, an overarching image of the current situation can be created. The workshop ends with a plenary wrap up (15 min), presenting the highlights of each group.

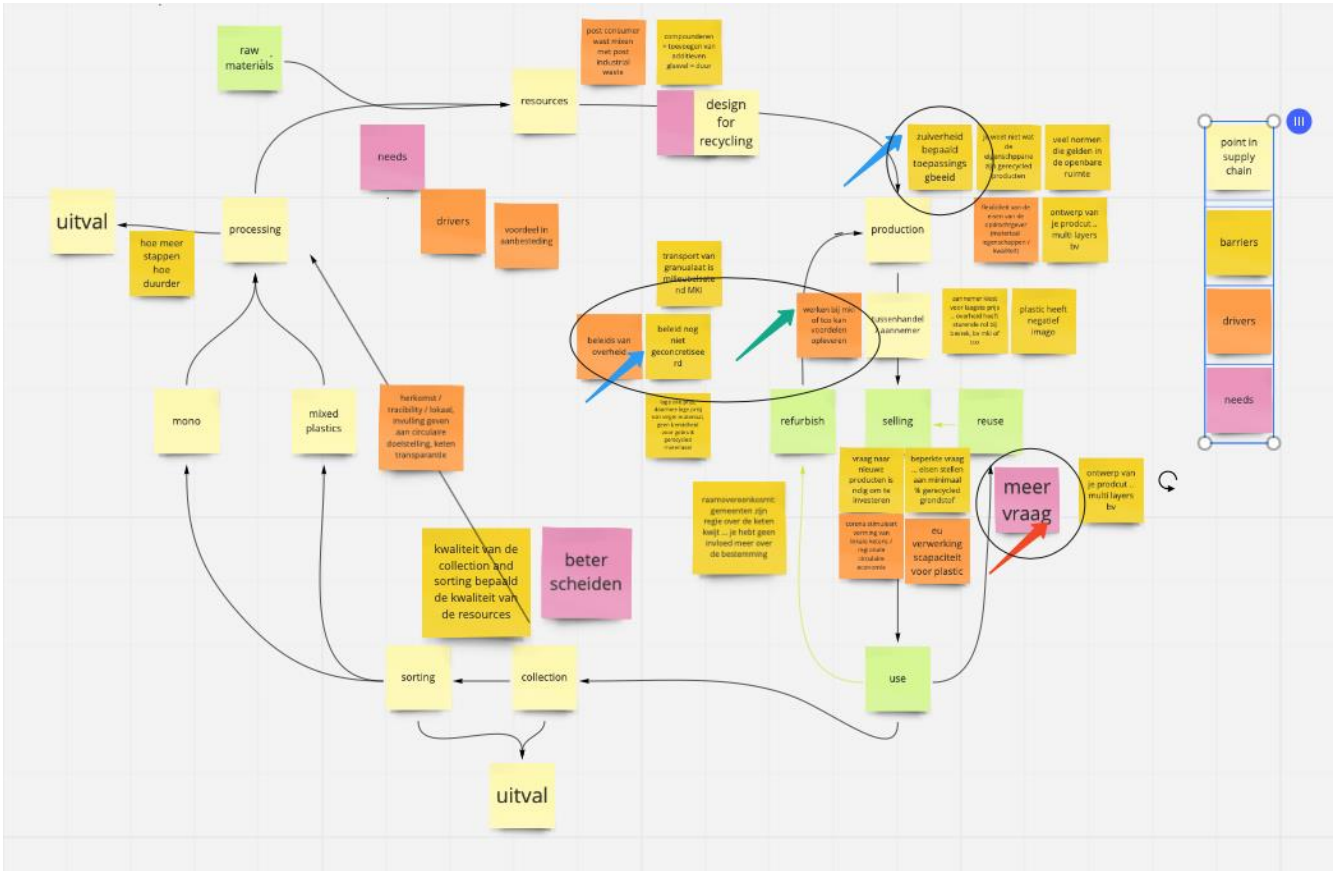

Figure 1: *Output from one of the breakout rooms – visualisation of barriers, enablers & needs along the value chain*

2. Results

Several barriers and enablers to the uptake of recycled materials have been identified during the workshops. The main focus of the workshops was the uptake of recycled plastic feedstock. For this reason, barriers and enablers in terms of recycling have been highlighted in this report. Other factors that are important for transitioning towards a CE, such as improving durability of products and designing products for disassembly, were also mentioned but will not be further elaborated on.

The distinction between barriers and enablers is made based on the current situation and results of the workshops. If a factor is not applied in industry (yet), is hindering (optimal) recycled applications or is not correctly applied at this moment, it is classified as a barrier. If a factor is perceived to stimulate recycled applications or is already applied to some extent, but may further stimulate the uptake of recycled materials, it is classified as an enabler. Hence, the absence of an enabler does not necessarily imply that recycled plastic cannot be used. As an example, *optimised waste separation and sorting* is classified as an enabler, because, with the current system, recycled plastic can still be used in products. Yet, the situation may be improved by *optimised waste separation and sorting*, which will lead to higher quality outputs and, in turn, an increased uptake of recycled materials. In contrast, *contamination of waste streams* is classified as a barrier, since contamination will prevent a certain batch to be applied as recycled material.

The outputs of the workshops are combined and presented in table 1, and a synthesis of the views of the participants about each factor is further elaborated on below. A distinction is made between regulatory and policy, economic, technical, systemic, organisational and cultural factors[2]. The table also gives an overview of which steps in the value chain are directly affected.

Table 1: *Overview of barriers and enablers and their position in the value chain*

Category	Barrier/enabler			Position in value chain						
		barrier	enabler	material sourcing	production	sale	usage	collection	sorting	reprocessing
Regulatory & policy factors	Misalignment of regulations	x								
	Financial stimulation		x							
	Minimum recycled content requirement		x							
	Public awareness		x							
	Lack of enforcement of waste legislation	x								
Economic factors	High cost of recycling	x								
	Price competitiveness of recycle	x	x							

[2] See for a similar approach Hart et al., 2019, Kirchherr et al., 2018 and Tura et. al, 2019.

Table 1 (continued): *Overview of barriers and enablers and their position in the value chain*

Category	Barrier/enabler			Position in value chain						
		barrier	enabler	material sourcing	production	sale	usage	collection	sorting	reprocessing
Economic factors	High cost of recycling	x								
	Price competitiveness of recyclate	x	x							
	Fluctuating costs	x								
	New markets and applications		x							
	Increased prices for consumers	x								
	Cost for research and investments	x								
	Reluctance to invest in more expensive recycling methods	x								
	Lack of economies of scale for new investments	x								
	Investment costs for capital and infrastructure	x								
	Supplier transaction costs	x								
	Long-term contracts for more security of investments		x							
	Growing demand from existing markets		x							
Technical factors	Contamination of waste streams	x								
	Optimised waste separation and sorting		x							
	New material innovation	x								
	New technologies for recycling		x							
	Design for recyclability		x							
	Material quality issues	x								
	Inconsistent material quality	x								
	Unknown material quality	x								
	Availability of material data/information		x							
	Combination of polymer type and used production process	x								
	Use of materials with better properties than required	x								
	Application possibilities	x								
	Lack of colour options	x								
	Lack of design freedom	x								
	Quality assurance	x								
	Slower production process	x								
	Additional testing	x								

Table 1 (continued): *Overview of barriers and enablers and their position in the value chain*

Category	Barrier/enabler			Position in value chain						
		barrier	enabler	material sourcing	production	sale	usage	collection	sorting	reprocessing
Systemic factors	Systems perspective		x							
	Closed loop recycling		x							
	Matchmaking platform		x							
	Lack of infrastructure	x								
	Standardisation of recycling processes		x							
	Increased recycling capacity		x							
	Lack of a reliable stream of material	x								
	Standardisation for (quality of) recyclate		x							
	Standardisation of product designs		x							
	Technology, data and traceability		x							
Organisational factors	Internal organisation and decision making	x								
	Lack of innovation culture	x								
	Business tendency towards short-termism	x								
	Circularity reporting		x							
	Existing manufacturing infrastructure	x								
Cultural factors	Consumer demand and acceptance	x	x							
	Unwillingness to pay	x								
	Difficulty in gaining market share	x								
	Lack of customer requests	x								
	Limited visual appearance of recycled products	x								
	Lack of experience from product designers	x								
	Recycled material as a basic requirement		x							
	Setting unnecessary high standards for products of recycled materials	x								
	Resistance to change	x								
	Perception of (recycled) plastic	x								
	Lack of knowledge, information and education	x								
	Awareness creation		x							
	Information about possibilities		x							

2.1 Regulatory and policy factors

Misalignment of regulations (b)
Certain policies and support programs for CE have already been introduced on European and national level. However, policy measures are mostly abstract goals for the near and distant future. It was noted that current regulations are not cooperating, nor in line with the current situation in industry. Design requirements in terms of quality, food safety etc. play an important role in determining application possibilities for products. The use of recyclate for food contact, for example, is limited to rPET (recycled polyethylene-terephthalate), whereas the use of rPE (recycled polyethylene) and rPP (recycled polypropylene) is largely limited to application in non-food products. Recycled feedstock may only be used for food contact if it can be shown that at least 95% has been previously used for food purposes only and has been separately collected. These requirements are currently restricting the use of recycled feedstock in certain products or the possibility of certain materials to be recycled, whereas the technical possibilities to recycle materials may already be there. Regulations for food contact and medical applications are considered to be too strict by some participants. In contrast, restrictions for fire safety are regarded to be strict but adequate.

Financial stimulation (e)
Governmental stimulation is seen as a key driver for businesses to use recycled feedstock. Businesses are asking for financial stimulation by means of financial incentives for the use of recycled materials or an introduction of taxes for using virgin materials. Moreover, it was noted that governments generally budget less money for sustainable goals than for the fulfilment of economic goals. Financial stimulation could also be sought in the form of state-subsidised product analyses. An example in Germany includes Product-integrated environmental protection (PUIS). This analysis includes the sustainable use of resources and energy in production plants, combined with the avoidance of waste, waste water and emissions.

Minimum recycled content requirement (e)
Next to financial incentives, governmental stimulation could also be obtained by setting requirements for a minimum percentage of recycled materials to be used in products.

Public awareness (e)
Legislative amendments and changes rarely reach consumers. Consumers will not develop an interest in sustainability and recycling if governments do not actively communicate the relevance of the topic in an understandable way. Additionally, the public is often not included in decisions and debates on waste policy.

Lack of enforcement of waste legislation (b)
A lack of governmental intervention in recycling practices is highlighted as a potential limitation to successfully recycle materials. The enforcement of the legal framework in waste legislation is not controlled strictly enough or is regarded to be too lax. In industry, action is not consistent enough, and in the private sector it is often difficult to trace who caused the waste. There is a lack of political consequences if not followed strictly. Additionally, the regulatory framework in relation to waste

management can change rapidly. This may stimulate the market, but may also bring along uncertainties.

2.2 Economic factors

High costs of recycling (b)
For plastic waste to be used in new products, it first needs to be processed. Due to additional steps, transportation and time, the recycling process of plastic waste (collection, sorting and reprocessing) has many additional costs. It is usually the case that a higher quality of recyclate requires more sorting/processing steps to take out any residuals or contamination. Therefore, higher quality recyclate is often more costly than lower quality recyclate. If colour sorting is desired, this will require some extra steps and thus additional costs. More efficiently closing the loop and optimising recycling can take away costs concerns.

Price competitiveness of recyclate (b, e)
Businesses seem to have different experiences concerning the price of recycled materials in comparison to virgin materials. Price used to be the initiator for use of recycled materials. But in certain periods virgin material has been cheaper than recycled materials. Prices of virgin materials dropped due to low oil prices, while material processing costs were still there. With recycled materials being more expensive compared to virgin materials, there is little incentive for the use of recycled feedstock. If this is the case, options have been noted to make recycled materials cheaper or to increase prices of virgin materials. Optimising the recycling process will also help with decreasing the prices of recycled materials and making them more competitive to virgin variants. Moreover, growth of businesses could help to make investments easier and will present options for agreements with suppliers to ensure lower prices of recycled materials. However, it was also mentioned that additional costs should not be a barrier when the characteristics of the material represent a value and businesses are already making profit on the product.
On the other hand, price does not always seem to be a problem. Where some businesses seem to be experiencing recycled materials to be more expensive, some other businesses experience this the other way around, with prices of recycled materials being equal or cheaper compared to virgin materials. This is especially the case for lower quality (mix) recycled plastics, because recyclers also have to pay for incinerating them.

Fluctuating costs (b)
The difference in prices of recycled materials, especially in relation to the price of virgin materials, leads to uncertainties about costs. Fluctuating costs and uncertainties about costs over the long term make the implementation of recycled feedstock more difficult. Agreements made with suppliers could help to take such uncertainties away

New markets and applications (e)
The use of recyclate may open up opportunities for businesses to explore new markets and product applications.

Increased prices for consumers (b)
Products made of recycled materials are often more expensive than virgin versions. Prices are not only higher due to the use of more expensive resources, but also because of additional costs, steps and testing. The lack of consumer demand for products of recycled materials is seen as one of the key economic barriers for businesses to use recycled materials. Cost increases for products of recycled materials make it unfavourable for consumers to choose them over products from virgin materials, simply because they are not willing to pay for it. The willingness to pay more for circular products is increasing, but still remains low. In contrast, it is often assumed that recycled materials are cheaper, which is not always the case.

Costs for research and development (b)
To optimise the supply chain, recycling process, material quality and allow for testing, additional research is needed. Additional costs are also the result of requirements for product testing and certificates. Grants and funding could be a driver for this.

Reluctance to invest in more expensive recycling methods (b)
Waste management usually favours recycling methods of the least costs (e.g. thermal recycling) over those with smaller loops (e.g. mechanical recycling). Thermal recycling is the cheapest way of disposing waste because it is fast and involves fewer steps. Additionally, there is uncertainty regarding the market for recyclate.

Lack of economies of scale for new investments (b)
For some plastics there are low volumes of waste. This makes it not economically viable to have a separate waste stream during sorting. Such materials then end up in the leftover stream, which are often incinerated. A similar thing applies to companies willing to manage their own disposal routes. This requires a permanent flow of resources, from high volumes. Without security of supply, it will not be economically viable to set up closed-loop systems.

Investment costs for capital and infrastructure (b)
For businesses to switch to the use of recyclate, investments are needed. These could be investments in capital (e.g. purchase of new equipment) or investments needed for changing infrastructure of the manufacturing site.

Supplier transaction costs (b)
Switching to recycled materials may also lead to additional costs related to finding new suppliers. Current supplier contracts may present barriers for businesses to switch to recycled materials. In contrast, it was also noted that previously established relationships with suppliers of recycled feedstock may be enough reason to stay with recycled materials and limit businesses to switch to (cheaper) virgin materials.

Long-term contracts for more security of investments (e)
In order to improve the ability to plan investments in the future, multi-year contracts should be concluded with recyclate producers. Since the market for recyclate is growing and recycling plants will have to be optimised and maintained in the future, longer contracts serve the recyclers' security.

Growing demand from existing markets (e)
In order to make any decisions or investments, demand is needed. It is said that the demand for recyclate within existing markets is growing, making it economically interesting for businesses to switch to the use of recycled plastic feedstock and/or to make investments. Growing demand for recyclate by businesses also stimulate waste management companies to make the necessary investments.

2.3 Technical factors

Contamination of waste streams (b)
Contamination of material streams largely affects the quality of recyclate, which in turn influences the uptake of recycled content in products. Contamination may be caused by a lack of circular product designs, but can also come from residuals or incorrect waste separation by consumers. Contamination highly influences the quality and thus the amount of usable recyclate. The more contaminated a batch is, the higher the sorting effort and the higher the costs. Contamination of individual products can make an entire batch unusable. Mixing of material flows negatively influences contamination (e.g. plastic mixed with organic waste).
Next to the quality of collection, the quality of sorting and reprocessing is also key to sufficient material quality. There are currently many problems that cause certain products or packaging to hinder or disturb sorting and recycling, such as the use of certain materials (e.g. PVC), a combination of materials (e.g. multilayers), certain colours (e.g. carbon black) or the use of certain inks or adhesives. Such issues will cause a lower quality of material output. The use of composites and additives may also cause problems with sorting or lead to impure recyclate.
Moreover, only three polymer types are currently recycled in the Netherlands from household waste (PET, PE and PP), which limits possibilities for polymer types that are not recycled at this moment. Some materials cannot be mechanically recycled, such as polyamide mixtures, with material properties being lost when shredded. For other materials there is a lack of volume for recycling to be economically viable.

Optimised waste separation and sorting (e)
In line with contamination, it is suggested that more separate collection methods (e.g. separate collection of mattresses, to have a similar material) can help with increasing recycling rates. It could also generate a fraction that can be reused immediately without having to go through a re-sorting process. Nonetheless, additional sorting steps may help to further limit contamination. This way, usable parts of a batch can be sorted out and the proportion of unusable plastics is reduced. Although more collection streams and additional steps for sorting are seen as an enabler for higher quality recycled plastics, it also brings along additional costs, which could make it unfavourable from an economic point of view.

New material innovation (b)
New materials are constantly entering the market and their properties often differ from existing plastics. The variability in plastic materials creates new challenges during sorting and reprocessing of materials. There is a difficulty in distinguishing between materials, such as recyclables or

biodegradable plastics. Moreover, composite materials are difficult to recycle in industry, because used materials first have to be separated.

New technologies for recycling (e)
Recycling installations are starting to use more advanced techniques for better sorting. Near-infrared (NIR) already allows to sort waste more precisely. Newer recycling technologies may present opportunities for better sorting of materials. Barcode scanning uses invisible digital watermarks for more efficient sorting, for example allowing food products to be sorted separately. Other techniques may involve colour sorting of products for further dividing material streams by colour.

Design for recyclability (e)
Currently, there are many products and packaging that can either not be recycled or cannot be correctly sorted. Such non-recyclable products hinder or disturb the recycling process. The design of products and packaging is key in this, particularly in reference to the use of multilayers, carbon black or adhesives, inks and labels, as these can be difficult to separate at end-of-life or give problems with properly sorting products. Designing products fit for recycling could help to limit such problems and will subsequently lead to higher material quality. Since many businesses are still unfamiliar with the recycling process and lack knowledge to design products fit for recycling, it will be essential to provide information about 'bad' product designs and show solutions to design for recyclability. Other circular economy principles such as design for disassembly were also identified as important drivers for the recycling of plastic waste and the uptake of recyclate.

Material quality issues (b)
A significant barrier in the successful commercialisation of recycled plastic feedstocks and their uptake by businesses is a (real or perceived) reduction in the quality and performance of recycled materials compared to virgin alternatives, particularly over long periods of time and through multiple reprocessing cycles. Plastics were never designed for recycling and are not suitable for endless recycling. Contamination of waste streams and problems with material sorting will lead to downgrading of the material. With each recycling cycle, the material will become a bit harder to process. Therefore, it is hard to maintain material quality when materials are recycled a few times and full circularity seems (yet) impossible. Degrading of material quality presents a challenge for maintaining (control about) material quality over time.

Inconsistent material quality (b)
Due to the unsteady composition of plastic waste, properties of recycled materials can vary greatly over batches. The lack of a homogeneous flow makes it harder to understand the quality that is being used. Solutions seem to present itself by creating a mix of different batches, to better control material quality. A constant quality of materials is seen as an important driver, because production processes and machine settings could be adjusted accordingly. Nonetheless, there remain to be uncertainties concerning (long-term) agreements about consistent quality.

Unknown material quality (b)
Due to the unknown quality of the used materials, it is not sure what the quality of the end product will be like. This uncertainty was identified as a bigger barrier than lower quality of materials itself.

Quality uncertainties are even bigger for mix-plastics in comparison to mono-material from recyclate. For this reason, mono-material from plastic waste is regarded to have a higher viability then mix-plastics. Trust in material quality needs to be obtained by increasing knowledge of materials and quality. This requires more testing of materials, but also showing information about possibilities.

Availability of material data/information (e)
Knowledge about material properties is seen as a key driver for determining material quality and possibilities are seen for creating for instance a 'material passport'. Such a passport may be more relevant for bigger products that are separately collected, while technologies such as 'barcode scanning' may help with determining properties during sorting of packaging and smaller plastic products.

Combination of polymer type and used production process (b)
Technical possibilities for the use of recycled materials also depend on the type of material being used, the production process and combination of both. Some production processes are not suited for certain polymer types due to material characteristics (e.g. melt flow or viscosity), which differ for recycled materials. The used production process by manufacturers may limit possibilities for the use of recycled materials to only a specific polymer type. Therefore, many manufacturers are not looking for a standard plastic, but want more possibilities in terms of polymer choice (a specific material for extrusion, another material specifically designed for injection moulding, etc.). This significantly limits the use of recycled plastic, as different polymer types are mixed, even if a 'mono-material' of recyclate is used (e.g. different grades of PP exist, with one more suited for a certain process of application, these are mixed with recycling). Other production processes, such as IEM (intrusion extrusion moulding), have a wider range of options in terms of material type and can process mix-plastics with high contaminations. However, such production processes are often used for products with lower design requirements (e.g. benches or roadside posts). Possibilities are seen to use another production process, specifically designed to process a specific type of recyclate.

Use of materials with better properties than required (b)
In some cases, the chosen plastic material is of higher quality than required by the customer's demands. For example, using high quality rPET with a food grade, for non-food applications. This then leads to a shortage of food grade materials to be used for food applications, and ultimately downgrading of materials (when not used for food, it may not be used for food afterwards). Additionally, some participants stated that current quality standards for food products, toys and cosmetics are more strict than necessary. An example was given of shampoo bottles made of food grade recycled materials, simply because this material is regarded to have higher quality and does not smell.

Application possibilities (b)
Due to mixing of different polymer types and (high) contamination of recyclate, quality of used materials is often lower compared to virgin materials. Lower material quality will determine possible application areas. Regulations limit the use of recycled material for food products, products used for skin contact (e.g. cosmetics) and medical applications. There are also many

norms for products in public spaces where products may need to be UV-resistant or require flame retardants.
Higher quality products require specific material characteristics that are difficult to be met when using recycled materials. It is therefore regarded to be easier to use recyclate in products with less stricter quality requirements. Other problems are seen when safety of the product is important, such as in the automotive industry. Hence, for certain (parts of) products, no deductions should be made, as quality, safety and durability are decisive. Opportunities are seen to strengthen critical parts by using extra materials, providing extra support for that part or, as a last option, using virgin materials only for the critical parts of products. Other options are seen for chemical recycling (in which polymers are brought back to monomers, fuels or chemicals for more virgin-like plastic), which will broaden application possibilities.

Lack of colour options (b)
Due to contamination of materials and mixing of different colours during recycling, recycled plastic will receive a 'greyish' appearance. This 'greyish' look significantly limits the diversity of colour possibilities, where specific colours used for marketing purposes are difficult to make or deviate from current colours. Recycled materials are therefore rarely used for completely transparent products. A possibility is seen to colour products with light grey as a starting point (instead of transparent or white) or for other colours to become standard in industry (e.g. 'greyish look' becomes more accepted or a less variety in colours on shelves). Options for colour sorting of materials may present options to limit this barrier. However, it was also mentioned that the current situation is contradicting: colour is desired for sale, but when recycled materials are used by the business, it is expected that colour is removed. The less colour is used in products, the higher the quality output of materials at end-of-life.

Lack of design freedom (b)
In line with lower material quality, certain material characteristics (e.g. melt flow) may differ for recycled materials, which could lead to limitations in product designs. However, it was also suggested that product designs could be adjusted. Examples include to make certain points thicker or with less sharper edges. This solution, however, will cause a lack of design freedom.

Quality assurance (b)
Due to the unknown quality of recycled feedstock, difficulties with quality assurance arise. During purchasing of materials, there are doubts about how quality of materials will impact the end product. There is a lack of certifications and documentation to guarantee quality. There are also customer concerns about warranty. Lower quality of products may have the disadvantage of a shorter lifespan. This conflicts with durability, which is desired from a sustainability point of view.

Slower production process (b)
Recycled materials may lead to a slower production process. First of all, mechanical properties of recycled materials (e.g. melt flow) can lead to a slower production process. Second, differentiating mechanical properties of materials requires changes in machine settings, which causes delays in production. Both issues lead to a higher lead time, in line with additional costs.

Additional testing (b)
Lower and unknown material quality leads to the need for additional testing procedures. Recycled materials have a different viscosity or melt flow, which influences settings for production processes. Testing is therefore required for each batch, which requires additional time and investments. Moreover, testing may also be needed to determine material quality. To allow for recycled materials to be used for food contact, more testing of material streams is required.

2.4 Systemic factors

Systems perspective (e)
In order for any individual business to take up recycled plastic feedstock, all stages of the supply chain need to be established and functioning effectively. Any disconnect or breakdown in communication between key stakeholders could disrupt the entire system, requiring a joined-up systems perspective and a collaborative approach. An example provided was products technically designed for disassembly and recyclability, which then are not disassembled or recycled by waste collectors due to a lack of awareness, facilities or due to the process not being economically and practically feasible.
Additionally, industry does not take responsibility for more thoroughly integrating recycling. Examples of the paper and glass industry were mentioned, where industry successfully introduced recycling. Although it is noted that with plastic certain issues for recycling seem to be more complex, the industry is regarded to take responsibility for increasing the uptake of recycled plastic. Some participants noted that this should be a shared responsibility of all stakeholders. Moreover, it is important to find the right partners to work with. Concern for the switch to recycled materials was expressed regarding the need to create entirely new partnerships in favour of those established over a long period of time.

Closed loop recycling (e)
It was noted that manufacturers have limited influence where waste ends up. Possibilities are highlighted to locally implement a CE and create separate loops to collect and recycle a specific material or product (e.g. waste of mattresses used for new mattresses). Opportunities are found to source materials directly from companies (before it goes to waste processors). Buy-back options could be offered for products that have reached end-of-life, to ensure recycling possibilities. However, sufficient quantities are needed for this to be economically viable.

Matchmaking platform (e)
To successfully implement recycled materials, it is important to find the right partners to work with. Therefore, it was suggested that it could be useful to establish a platform where businesses and recyclers can find each other. On this platform, recyclers could offer recyclate at their own set prices. Manufacturers could also offer the waste of their production processes. In addition, companies can compare prices and/or properties and choose recyclate that is best suited for their product.

Lack of infrastructure (b)
A further challenge identified was a lack of infrastructure necessary to support waste collection and sorting, with one participant in the UK expressing their frustration at the fact that not all plastics were accepted for household recycling in their area, with only plastic bottles collected. The expansion and improvement in waste collection and sorting infrastructure and services were highlighted as important driver for the uptake of recycled plastics. This was also considered essential for the achievement of a further driver in terms of securing a supply of plastic waste that is consistent in terms of composition and quantity.

Standardisation of recycling process (e)
The lack of standards in industry leads to many different ways to collect waste, sort it and reprocess it into recyclate. This then leads to many confusions about how to dispose waste (as this differs per country and also per municipality) and whether materials or products can be recycled or not. It is regarded to be beneficial for industry to aim for standardisation and for actors in the recycling process to be more in line with one and another. More collaboration amongst actors is therefore required for setting such standards.

Increased recycling capacity (e)
Due to the recent export ban of plastic waste to China, there is currently more waste material than before. To process all these materials, the recycling capacity within the EU, and consequently within individual countries needs to be increased. This will ensure more plastic waste material to be available for the production of new products.

Lack of a reliable stream of material (b)
The lack of a reliable stream of recyclate is seen as a key barrier to the uptake of recycled materials in new products. Because quantity of waste varies, there is no continuous flow of recycled plastic. Due to many external influences there is a lower delivery reliability and longer delivery times for recycled materials. There are also some issues with (uncertainty of) availability in general. Some manufacturers experience that availability of (high quality) recyclate is very low, others suggest that there is a large amount of recycled materials available. For PET, a lot of supply goes to the clothing industry. It is also suggested that the plastic market is too big to make everything out of recycled materials and that it will always be necessary to use some share of virgin materials.
The high uncertainty of availability and lack of a reliable stream may lead to virgin materials being favoured over recycled versions. Such issues could be solved when a better and more efficient system is set up. Agreements made with suppliers could help to take (part of) this barrier away for manufacturers. Moreover, since businesses often have no idea what to do with their waste, possibilities present themselves to design products based on the availability of materials.

Standardisation for (quality of) recyclate (e)
Standardisation is not only required for the recycling process, but also for the recyclate that will be used as input for new products. To facilitate this, it is essential to determine (quality) requirements for recycled materials. It is suggested to define standard grades for recycled feedstock and options are noted to establish requirements that the material must meet. However, it is also noted that a specific quality standard is not desired by all manufacturers (because of different production processes and different requirements).

Standardisation of product designs (e)
More neutral product designs would improve and simplify the recyclability of plastics. This may include less material options, less colour variety or the use of lighter colours, but also includes standardisation for used inks, adhesives, labels and additives. Moreover, there is a multitude of labels on packaging that are not comprehensible from the consumer's point of view. The more labels there are on the market, the more confusing waste disposal becomes for the consumer, hence, standardisation of waste disposal labels is required.

Technology, data and traceability (e)
An interesting idea that emerged from discussions was the potential for new technologies to record data relating to materials as they progress through the product lifecycle and subsequent recycling processes. As a driving force for plastics recycling, technologies including blockchain, big data and connected products (e.g. smart packaging) may help to achieve material traceability, supporting extended producer responsibility enforcement. Insights generated may also help to keep track of the supply, volume and location of plastic wastes, helping businesses to plan and allocate resources accordingly. It was also suggested that the real-time visibility provided by material traceability data may also help to ensure waste collectors, sorters and recyclers are suitably rewarded for the services provided, incentivising increased take-up throughout the supply chain.

2.5 Organisational factors

Internal organisation and decision making (b)
On a business level, the internal organisation of a company plays an important role in deciding whether recycled materials should be used or not. Since often many different departments have to agree for such a decision to be made, this could lead to obstacles and time delays. For high quality products, this issue seems to be bigger. Moreover, resistance of one department could lead to rejection of the decision to implement recycled materials at all.

Lack of innovation culture (b)
Another identified barrier preventing businesses from transitioning from traditional, linear material inputs to recycled plastic feedstocks and adopting circular practices is the lack of an 'innovation culture', contributing to 'linear economy lock-in'. This is coupled with a risk-averse approach to doing business. Top-down direction and a clear vision from senior leadership individuals who support and cultivate an innovative company culture together with circular economy leaders throughout the workforce may help to stimulate innovation and the use of recycled materials.

Business tendency towards short-termism (b)
It was noted that businesses are willing to increase the use of recycled materials, however, goals that businesses have set are lying far away in the future. For instance, it was mentioned that governments should focus on short-term circular procurement, instead of setting goals to be reached in 5-10 years.

Circularity reporting (e)
It is noted that actively showing what is saved in terms of sustainability, will help to increase demand of more circular products. Therefore, conducting Life Cycle Analyses (LCA's), mapping environmental cost indicator and total cost of ownership (TCO) are seen as key drivers to the uptake of recycled materials. Showing such numbers will help to understand the consequences, need for recycling and use of recycled materials. A suggestion was made to create a quality mark that could be placed on products or packaging, similar to that of energy labels. Moreover, increasing supply chain transparency, increasing traceability and showing the origin of products are also proposed to help with consumer willingness.

Existing manufacturing structure (b)
A company's production is usually set up in such a way that the production process and the upstream chains are optimised. It may be the case that the infrastructure and layout of the factory needs to undergo changes in order to switch to recycled feedstock. However, it was also mentioned that if recyclate is already used by manufactures, changes in infrastructure will be needed again to switch back to virgin materials.

2.6 Cultural factors

Consumer demand and acceptance (b, e)
Acceptance for the use of recycled materials in products is growing amongst the population, but is yet not strong enough. The uptake of recycled materials by businesses is largely influenced by demand and acceptance of consumers. The emergence of sustainability and circular economy as a trend, particularly with younger generations, is highlighted as an important driver for consumer interest in recycled products. As a result, it is suggested that growing consumer demand, built on trust, may be an important driver for business uptake of recycled plastic feedstocks.

Unwillingness to pay (b)
Most consumers are still not willing to buy circular products due to higher prices. However, it is also noted that consumers are looking for circular products, which could be a potential driver for the use of recycled materials. Willingness to pay additional costs for recycled materials not only comes from consumers, but this is also the case for (larger) influential companies that may have the power to move an entire industry.
Additionally, participants noted that businesses, especially contractors, look mostly at costs, not at possibilities in terms of circularity. This presents opportunities for governments to take circularity (such as environmental cost indicator ('mileukosten indicator', MKI) and total cost of ownership (TCO)) into account with tenders to push for more sustainable alternatives. This way, governments could have a more stimulating role with tenders of contractors.

Difficulty in gaining market share (b)
In terms of value proposition and gaining market share, businesses identified challenges in effectively communicating the benefits of recycled products to consumers and in gaining their confidence when introducing new products. A further barrier identified in gaining market share is the advantage of established companies that have a marketing advantage in terms of resources

and brand awareness. Moreover, there is competition with other sustainable product options from other businesses.

Lack of customer requests (b)
Although the demand is growing, there is still little demand for sustainable products in some sectors. Hence, sustainability is not always explicitly requested by customers, with thus little incentive for manufacturers to explore possibilities for the use of recycled materials. Moreover, there is also a lack of customer requests because of higher costs for products.

Limited visual appearance of recycled products (b)
Customers and/or consumers often have a certain idea of the visual design of a product in mind. If these expectations are not met, there is a risk of losing customers to competitors that make products with virgin materials, which are still able to meet the required appearance.
Another issue with acceptance of recycled materials could be the lower diversity of colours. Completely white or transparent packaging is for this reason not possible and is believed to lead to customer rejection. It is therefore key to create more willingness for the use of recycled materials and increase wider acceptance. An example was given to, for instance, raise more awareness for lower colour diversity of plastics. If this is better understood, consumer acceptance to recycled materials and deviating colours will become more accepted. In addition, it was also said that companies should reassess their priorities. Perhaps the company's usual colour scheme should undergo some changes.

Lack of experience from product designers (b)
Product designers who design packaging, for example, have customer specifications to which they must adhere. However, they lack the required know-how about the use of recycled materials and/or the recyclability of plastics. During the design process, the main focus is on the sale and use phase of products. What happens to products or packaging at end-of-use is usually not taken into account.

Recycled material as a basic requirement (e)
Virgin materials are often still seen as a standard for production and purchasing. Current decisions are based on existing options. Instead, recycled materials should be considered as a first option and if that is not possible, virgin materials may be used. Examples include material decisions made by governmental organisations, where virgin materials are still considered as a first option.

Setting unnecessary high requirements for products of recycled materials (b)
Businesses and consumers have set high demands for the use of recyclate and have high standards for products. It is often the case that higher requirements for quality and material characteristics are asked than needed, which leads to over qualification of products. More flexibility is needed for characteristics of products in terms of material properties, appearance (e.g. the use of black or dark black) and quality, from manufacturers, customers and consumers. Recycled materials should therefore be treated as a completely new material, not as a replacement that will be completely the same as virgin plastic.

Resistance to change (b)

Transitioning to a CE requires changes in industry, society and policy making. This comes along with resistance to change, at customer, company and industry level. For businesses throughout the value chain, a reluctance to change or 'linear economy lock-in', a lack of commitment to solving the problems associated with single use plastic and an aversion to risk taking were highlighted as key barriers. For manufacturers, it is regarded to be easy to work with virgin materials, hence, the need for switching to recycled materials is not seen here. In contrast, start-ups seem to be thinking in possibilities and see many opportunities for the use of recycled materials. For recycled materials to be actively used by manufacturers, acceptance of the sector is required.

Perception of (recycled) plastic (b)

Due to aspects such as the plastic soup, plastic litter and micro-plastics, plastic has received a bad image. Environmental disadvantages are often highlighted, whereas the positive side is neglected. Consumers are not aware of the benefits of plastics, nor of the positive impact of recycling, with cynicism about the effectiveness of recycling. Hence, many opportunities can be found for creating a new image for recycled plastics in which the positive sides could be highlighted, such as utilising residual flow. A more positive image could be created by for instance image builders, marketing or storytelling. Examples were given to use story telling as a way to communicate that products are made of recycled plastics or create products from waste plastic to be used as a marketing tool. Moreover, it was noted that current communication campaigns target consumers' disposal behaviour but are not aimed at purchasing or usage of sustainable products (made from recycled materials). In contrast to the general image of plastic, the perception of recycled materials may be associated with dirty, non-hygienic (e.g. in Asia), unsafe (e.g. PVC) or lower quality. Such issues can lead to resistance within organisations. Misperceptions about sustainability may also be caused by greenwashing, with advertising and marketing strategies of companies making consumers believe that products are sustainable when they are not.

Lack of knowledge, information and education (b)

The lack of knowledge from various stakeholders is seen as a significant barrier to circularity adoption. Lack of knowledge can be seen on various aspects.

For instance, there are different views on circularity, recycled or recyclable. Lack of knowledge also relates to the value for use of recyclate not being seen. Lack of technical knowledge relates to application possibilities, material quality and properties, safety requirements, machine settings etc. Moreover, there is limited knowledge (and varying expectations) on the consequences of plastics that are only used once, and the benefits of circularity and recycling. For consumers there is misinformation regarding collection systems. They are not sufficiently informed on how to dispose products and packaging, and they do not see the consequences of their incorrect sorting. Concludingly, lack of knowledge comprises the complete supply chain and ranges from recyclers and manufacturers to customers and consumers.

In line with a lack of knowledge, there is a lack of information and education in relation to recycled and recyclable materials, recycling processes, disposal options and manufacturing options for the use of recyclate. Because of filter functions, important information may not always reach actors further down the chain. For consumers there is not only a lack of information, but they also do not know where to find this information. Hence, educating industry and society seems necessary.

Awareness creation (e)
The general understanding of environmental issues and the importance of sustainability is growing amongst the population and in industry. Such issues have become more and more important in recent years, with attention in Media and general debate. It is important to raise awareness for the issue by showing the importance of recycling and using recycled materials. By offering sustainable product variants, companies can create an incentive for rethinking.

Information about possibilities (e)
An important driver that was often noted is to show the possibilities for use of recycled materials. Examples of pioneers such as Innocent drinks and Lush cosmetics were given and considered important for paving the way for a wider range of businesses. The successful implementation of recycled plastic by these businesses will set a good example for others. Showing that it is possible to successfully use recyclate could stimulate other businesses and may serve as inspiration for other businesses to do the same. Best practices and pilot projects should be showcased in industry and various media. The dissemination of such information is highlighted as an important driver for widespread replication and upscaling of solutions. Insights into the activities of other companies will not only show that they are doing it, but also how they do it. This could help increase business confidence and give practical tips for businesses looking to follow suit.

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About the project

The problems associated with plastic waste and in particular its adverse impacts on the environment are gaining importance and attention in politics, economics, science and the media. Although plastic is widely used and millions of plastic products are manufactured each year, only 30% of total plastic waste is collected for recycling. Since demand for plastic is expected to increase in the coming years, whilst resources are further depleted, it is important to utilise plastic waste in a resourceful way.

TRANSFORM-CE aims to convert single-use plastic waste into valuable new products. The project intends to divert an estimated 2,580 tonnes of plastic between 2020 and 2023. Two innovative technologies – intrusion-extrusion moulding (IEM) and additive manufacturing (AM) – will be used to turn plastic waste into recycled feedstock and new products. To support this, an R&D Centre (UK) and Prototyping Unit (BE) have been set up to develop and scale the production of recycled filaments for AM, whilst an Intrusion-Extrusion Moulding Facility, the Green Plastic Factory, has been established in the NL to expand the range of products manufactured using IEM.

Moreover, the project will help to increase the adoption of technology and uptake of recycled feedstock by businesses. This will be promoted through research into the current and future supply of single-use plastic waste from municipal sources, technical information on the materials and recycling processes, and circular business models. In-depth support will also be provided to a range of businesses across North-West Europe, whilst the insights generated through TRANSFORM-CE will be consolidated into an EU Plastic Circular Economy Roadmap to provide wider businesses with the 'know-how' necessary to replicate and up-scale the developed solutions.

Lead partner organisation
Manchester Metropolitan University

Partner organisations
Materia Nova
Social Environmental and Economic Solutions (SOENECS) Ltd
Gemeente Almere
Save Plastics
Technische Universiteit Delft
Hogeschool Utrecht
Hochschule Trier Umwelt-Campus Birkenfeld Institut für angewandtes Stoffstrommanagement (IfaS)
bCircular GmbH

Countries
UK | BE | NL | DE

Timeline
2019-2023

www.nweurope.eu/transform-ce