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Where the shoe pinches – tackling current market challenges for recycling plastics from WEEE

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Abstract: As one the fastest growing waste streams in the EU, waste of electrical and electronic equipment (WEEE) growing at 3-5% per year, with an estimated generation above 12 million tonnes for 2020, has emerging and urgent potential for recycling. This paper gathers information on the current recycling market challenges, takes a look on weaknesses and needs of the secondary market for post-consumer recycled (PCR) plastics. On one side, barriers currently preventing or making the use of PCR plastics unfavourable and on the other side drivers pushing the application of post-consumer plastics in industrial sectors are investigated. The outcomes of the investigations, were categorized to underline technical/technological, economic and legal.

1. INTRODUCTION

According to Plastics Europe, the Association of Plastic Manufactures, in 2016 the total demand of plastic by European plastic converter is almost 50 Mt (2016) of which 6.2 % (~3.1 Mt) is in Electrical and Electronics Equipment (EEE) sector [1].

In the same year the world generated 44.7 million metric tonnes (Mt) of e-waste; by 2021 this figure is expected to increase to 52.2 million metric tonnes [2].

At EU level, WEEE is currently considered to be one of the fastest growing waste streams, growing at 3-5% per year in European Union or approximately three times faster than the other individual waste streams [3].

The total volume of plastic waste collected for recycling increased by 79% from 2006 to 2016 in the EU [1]. About 25 million tonnes of post-consumer plastic waste were generated in the European Union, of which only 30% were recycled [4]; in many countries, landfill is still the first or second option of treatment for plastic post-consumer waste.

This recycling rate is too modest taking into consideration EU recycling targets set for 2020 by the European Commission.

According to WEEE Directive (Directive 2012/19/EU) the Member State shall meet a recycling target between 55% and 80%, depending on the WEEE category. The implementation of the WEEE Directive has a huge potential for increasing the rate of recycling in the EU. Currently, only for a very minor share of post-consumer plastics from Waste Electrical and Electronic Equipment (WEEE) there is a reuse in new products in place.

While the systems for collection, sorting and recycling of scrap metals from WEEE are already well established, there is great potential for plastic. The WEEE stream differs from other waste streams by containing a variety of products with electronic content, including complex and integrated material composition; according to Philips [4] WEEE is the main components are ferrous and nonferrous metals (48% by weight), and of plastics (21% by weight). Depending on the product or application considered the composition of plastic type varies, resulting in a corresponding mixed recycling fracture with several types of WEEE plastics as shown by [5]. The average composition of WEEE plastics for recycling consists of 24% ABS, 27% HIPS, 29% other plastics

(including BFR's plastics), 7% polyolefins, 7% PC and PC-ABS, 6% other (metals, wood, etc.) [5].
Most of these plastics end up in incineration plants and at landfills, or at best are downcycled and used for low-end thick walled applications, such as outdoor furniture replacing biodegradable wood. In consequence, the overall recycling rate of plastics in WEEE and reapplication similar to the original applications is to date still very low.
Despite several initiatives, currently the small scale use of recycled plastics from WEEE in new EEE [4] is a clear sign that the post-consumer recycled (PCR) plastics value chain in its current condition cannot meet the requirements of a circular economy model.
This paper aims to analyze the current post-consumer recycled plastic market challenges, investigating barriers that are currently preventing or making the use of PCR plastics unfavourable. First potential ideas to tackle those barriers within ongoing and further research but also an online platform are proposed, as it has great potential to overcome trading and communication infrastructure barriers.

2. INVESTIGATION ON BARRIERS OF THE RECYCLING PLASTIC VALUE CHAIN

In this chapter, the examination on the current challenges within and from the perspective of the plastic recycling value chain is described. The Section 2.1 will present the material and methodology applied to carry out the investigation.
Section 2.2 describes the challenges as mentioned by the interviewees. Similar statements or barriers are aggregated. Where applicable, potential platform solutions are proposed as initial ideas that will be further investigated

2.1. METHODOLOGY

This research was carried out within the EU H2020 project "PolyCE" (High Quality Post Consumer Recycled Plastic for the Circular Economy) between December 2017 and April 2018.
The analysis of the current PCR plastic market situation was essentially investigated thought focus and expert interviews with stakeholders of the plastic value chain, both internal stakeholders of the project (consortium partners) and external ones.
Relevant external stakeholders were identified through dedicated activities along the PolyCE project. In total, 12 stakeholders have been involved in the investigation:

- 1 WEEE pre-processor
- 7 plastic recyclers
- 2 EEE manufactures
- 1 plastic converter
- 1 online trader

The research was also supported by the review of all the available literature, by information gathered during the attendance in several events dedicated to plastic recycling such as *Plastics Recycling Show Europe* (Amsterdam) and *Plastics Recycling World Exhibition* (Essen) and by the review of existing legislation.
In particular, the European Commission has adopted two pieces of revised legislation:

- Directive 2012/19/EU on EEE producers' responsibilities for the collection and recycling of their products at the end of their lifecycle (WEEE Directive)
- Directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS Directive)

Furthermore, a survey was conducted to validate the barriers as mentioned by the interviewee.

2.2. IDENTIFIED CHALLENGES

The determined barriers are clustered in four macro-categories: economic, technological, legal and communication infrastructure in accordance with the corresponding features and a possible platform solution that is envisioned.

2.2.1. ECONOMIC BARRIERS

Under the *economic perspective*, the common critical issue is related to the lack of **reliable supply** by means of long-term commercial agreements, essential to guarantee the creation of a stable secondary market [6]; stable relationships between actors of the plastic value chain would guarantee a reduction in the volatility of post-consumer recycled plastic **price**.
Moreover stakeholders have pointed out that the **inadequate funding** allocation by legislators to integrate recycled material in the production process and in general to promote products with post-consumer recycled plastic content is missing, hindering the creation of a secondary market.
The weakness of economic incentives to use recycled plastic materials in products was also underlined by the European Commission in 2017 [7].
The absence of a stable and sound economic outlook is affected by the existence of the other barriers.

2.2.2. TECHNOLOGICAL BARRIERS

One main technological barrier mentioned in all interviews is the **uncertain availability** of high quality recycled plastic. The recycling market shows a huge variation in material properties and insufficient quality. Therefore, many interviewees think that using recycled plastics in products is not feasible or requires a steady adaption of materials with the incorporation of additives.

In order for the PCR plastic to be competitive on plastic market, stakeholders agree that advances should be done along the entire plastic value chain; in particular improvements in the collection and sorting system are required.
For ensuring a high quality sorting it is necessary not only to improve on **sorting technologies**, but, above all, to improve the quality of the **collection** in first place. In this matter, the collection and sorting activities are having a high effect on the quality and supply reliability of recycled plastics. Mixed plastics required to be properly separated before being reprocessed due to the immiscibility between certain polymers or due to prohibition of hazardous substances, as also stated in [8, 9, 10].
Furthermore, a relevant factor influencing the post-consumer recycled quality is related to the **poor design for recycling approach.** Many plastic materials and products are designed for a linear lifecycle, not taking into account resource efficiency aspects, such as durability, recyclability, reusability or reparability. Design facilitating recycling seems crucial, especially for single-use plastics on top of prevention. Design facilitating recycling seems crucial: the absence of a strategy in the product design generates during the treatment process impurities and requires labour-intensive processes to achieve a reliable quality of the recycled plastics [7]. Recommendations on design-for-recycling were published in the frame of the PolyCE project [11, 9].

2.2.3. LEGAL BARRIERS

Under the *legal perspective*, a stated relevant issue is the uncertainty and the lack of information about the possible presence of chemicals of concern is a relevant issue for the creation of post-consumer recycled plastic market; a significant point of agreement is the need for the establishment of a **Quality Standard System at EU level**. A common system would minimize barriers that are currently hampering the use of post-consumer recycled plastic by stimulating the secondary market. Another reason for the mentioned importance to set plastic recycling standards is to ensure the reliability of the plastic recycling industry and the production of higher quality of plastics. At the same time it was criticized, a mandatory decision by EU Member States on the compliance with recycling standard could result in a unbalanced WEEE supply and demand, creating a distortion in the recycling market. In order to create a fair competition in the EU, the compliance with recycling standards should be mandatory for all WEEE treatment facilities in the EU and a proper enforcement is required [12]; this measure will increase the quality level of plastics by having a positive impact on the EU goals set in the EU Strategy for Plastics in the Circular Economy.
Using post-consumer recycled plastics in electrical and electronical appliances requires the compliance with several regulations: in addition to the RoHS Directive other chemical substance regulations such as REACH and POPs Regulation must be fulfilled.
A mentioned challenge to the recycling plastic value chain is the content of legacy **hazardous substances**; not properly managed, contaminated recycling fractions from WEEE do not reach quality requirements and are unusable on specific applications due to environmental and health risks.
The **complex EU legal framework** on hazardous substances let the WEEE recycling industry and EEE manufactures often face difficulties to comply with all requirements.
In this manner, the EEE industry accounts for the greatest consumption of Brominated Flame Retardants (BFRs) [13]: in WEEE plastics the flame-retardants content is estimated to be around 30% [14]. Plastics with BFRs are generally used in EEE products that generate heat such as CRT televisions and monitors [11], printed circuit boards (PCBs) IT equipment, printers, cables and connectors [15].
Some BFRs contained in EEE products are classified, according to the legal framework, as hazardous substances (8% of plastic fraction that contains BFRs is not recyclable and undergo incineration due to the restricted BFRs content) [15].
To properly separate BFRs classified as hazardous substances, a recycling standard for WEEE mixed plastics has been developed by the European Electrotechnical Commission (EN Standard 50625-1:2014 and its Technical Specification TC 50625-3-1). Clear limit value (Br < 2,000 ppm), protocols and analysis to identify and separate BFRs plastics have been set.
Whilst there are targets set by the WEEE Directive (Directive 2012/19/EU) to achieve a certain recovery rate, other legislations such as POPs Regulation may prevent the achievement of such targets being banned the recovery of certain substances contained in plastics.
Another practical example of this issue concerns plastics with DecaBDE flame retardants. This flame retardants is available in old flat screen casing, in small old appliances and in the cathode ray tube screen casing in concentration from 17 to 5,000 ppm [16]. DecaBDE is banned in accordance with RoHS legislation and is included in REACH and POPs regulation; in the same time the WEEE Directive requires a challenging recycling target, in accordance to the category, of 80% of the whole appliances that contains also plastics with DecaBDE that cannot be recycled [17].
To promote the Circular Economy Strategy a **harmonization of European regulations** on hazardous substances is required. A legal clarity in the

definition of thresholds for legacy substances must be in place. Furthermore, the industry needs a transition period to adapt to the legislations adopted by European Commission.
Another challenge to foster the post-consumer recycled market is related to the significant part of WEEE stream generated in Europe that is still treated in sub-optimal manner within Europe or outside of it. According to [18] annually 1.5 million tons leave EU: 200,000 tons are documented as export of used electrical and electronic equipment (UEEE), since it is legal to export functioning UEEE and the remaining 1.3 million tons are also predominantly UEEE (without a documented export), but are frequently mixed with WEEE before being exported. Based on literature resources and inspection observations is estimated that 30% of the remaining 1.3 million tons are WEEE (400,000 tons) [18].
To address the **illegal WEEE flows** is necessary to set a clear, harmonized and comprehensive legal framework. A harmonization will limit the shift of illegal activities among countries and discrepancies between the Member States facilitate investigations and ensure penalties.
From a consumer perspective there are few incentives to keep plastic wastes in controlled circuits. Better information should enable consumers to take purchasing decisions for more sustainable plastic products. The awareness raising and educational programs as well as of extended producer responsibility schemes are also mentioned as important factors.
Under the **communication perspective** a big barrier is identified in the complexity of the value chain (from WEEE collectors to EEE manufacturers). Consequently the lack communication and collaboration between buyers (manufacturers) and sellers (plastic recyclers) as well as between WEEE treatment operators and plastic recyclers. For instance, the relationship between plastic recyclers and WEEE treatment operators are driven by commercial relation without having the possibility to discuss together possible improvements in the recycling activities.

3. TACKLING CHALLENGES

The main challenges identified during the investigation will be tackled by following potential options.
To rise the overall quality of the PCR plastic in the plastic market, following instruments are envisioned for buyers and sellers to provide for sufficient trust on quality of the recyclates:

- A standardized quality test methods or reference test
- Information on minimum requirements for compounded plastics
- Selection, definition and of relevant quality indicators including the ones usually indicated on technical datasheets as well as the indication within the material exchange platform.
- Contacts to test institutes for quality /contamination testing [6]

Stability in supply of recycled plastics needs the consideration of various potential influences like the quantities depending on the WEEE collected and the WEEE collected depending on many factors such as price of the metals, legislative framework.
Within the platform, traceability and long term availability will be indicated. The dialog and contact over a communication or trading platform will be enhanced by a convenient website. Within the trading platform, functionality as grouping and filtering of plastics with same or similar material properties and qualities will show Europe wide offers of same quality materials, reducing the overall risk of only one material source.
To tackle the lack of collaboration between actors opportunities are foreseen in extending an online platform that can provide details and structure collaboration between buyers and sellers, facilitating the communication and standardizing the offers and the demands. Search functionality and easy website handling has the potential to attract stakeholders without online affinity.

4. DISCUSSION AND OUTLOOK

The results across economic, legal and technical dimensions show the complexity and variety of challenges in the PCR market. Systemic problems as complexity in supply chain or unstable supply and quality are making specific and tangible measures more difficult to derive. Depending on the perspective in the recycling value chain, some contrary barriers are stated. E.g. the supply of plastics with a constant quality was mentioned while on from another perspective the demand was seen as missing.
Tackling challenges related to missing communication infrastructure is therefore a general challenge that is within the scope of this paper. In detail, three challenges that where stated by all interviewees and that are seen as critical are focused by proposing instruments, functions and actions that will be realised within an online platform. Possibilities for material exchange, b2b communication as well as possibilities for the dissemination of information and project results are provided. It is aimed to use a platform that will persist and be supported beyond project duration.

Besides the specific actions, all barriers are systemized and potential solutions where identified that constitute great potential for future work.

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