PolyCE

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

Project Duration: **01/06/2017 - 31/05/2021**

Deliverable No.: **6.1**

Deliverable Title: **Map of market situation, derived barriers, drivers and information needs**

Version Number: 1.0

Due Date for Deliverable: **30/11/2018**

Actual Submission date: **30/11/2018**

Lead Beneficiary: **TU Berlin**

Lead Authors: Eduard Wagner

Contributing Authors: Nazarena Vincenti, Luca Campadello, Joe Bellott, Dr. Pouria Liravi, Andreas Hertsch, Alessia Accili

Deliverable Type: R

R = Document, report

DEM = Demonstrator, pilot, prototype, plan designs

DEC = Websites, patent filing, press & media actions, videos, etc.

Dissemination Level: PU

PU = Public

CO = Confidential, only for members of the consortium, including the Commission Services

Lead Author Contact:

Eduard Wagner

phone: +49 30 46403 7962

e-mail: eduard.wagner@tu-berlin.de

Contributing Partners:

Ecodom

University of Northampton

Kunststoffweb

MGG Polymers

Whirlpool

Disclaimer

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730308

1 Executive Summary

This report provides the analysis of the market situation by means of derived barriers, drivers and information needs of the secondary market for post-consumer plastics by date end 2017/beginning 2018. The basis for an interactive geographic map of the recycling market is provided to continue within the successive work packages. The price development for recycled plastics was analyzed to understand its underlying influences. This input will be used further in tasks 6.3 and 6.4 to develop an existing online market platform on plastics providing features and information on material exchange, stakeholder information and network possibilities for and with the input of all actors across the value chain. By this, an information and resource trading infrastructure for recycled plastics will be established.

Main challenges have been identified and mapped into 4 main categories, including technological, economic, legal and communication/social dimension. In addition, these dimensions were linked to the predefined stages in the recycling value chain, such as: collection, sorting, disassembly, pre-processing, plastic sorting, primary compounding, secondary compounding, moulding and product manufacturing (see Table 1).
With the aim to substitute virgin materials with recycled plastics while preserving same material properties, EEE manufacturers are balancing or avoiding the trade-off between the supply volatility, low material volumes whilst reducing the risk of insufficient quality related to the purity of the recovered material. Virgin plastics suppliers with steady input material quality are able to offer strong technical support throughout the application chain (selection, technical data, part design, mould design, moulding) compared to recycled material suppliers, facing fluctuation in the rate of source material and purity. Additionally, virgin plastics are multi-purpose useable, while recycled material quality attributes such as colour, clarity, mechanical property or impact strength are decreasing.

A main identified barrier for establishing a transparent market (by the setup of a trading platform in Task 6.3) including prices and material offers lies in the bilateral material sourcing, where supply and demand side negotiations are usually not public. This leads to a lack of data on average market prices, material offers and properties, including regulatory compliance as they are not transparent from data sheets as usually used for virgin plastics.
Therefore the transition from existing product development and manufacturing processes based on virgin material to recycled material requires cost intensive material acquisition and testing regarding safety, restricted substances, etc. as well as product attribute testing (durability, reliability, etc.).
Recycled plastic content in EEE products can pose challenges regarding potentially unknown substances that fall under the EU substance regulations (e.g. REACH, RoHS, etc.). Additionally, higher material requirements as required by favourable voluntary labels are even harder to fulfil.

Consumer perception towards recycled material needs to be tackled. Recycled material is seen as a critical requirement for products, this must be considered within design as well as the methods via which preconceptions of uncleanliness of using reused material can be eased.

Primary benefits of the map in its current version are the ability to visualize vast sets of data in an intuitive way and gain useful information on any points of interest. Within data gathering, the information on stakeholder business types was classified into the stages that were used to categorize the challenges previously mentioned. Furthermore, this data availability facilitates an information exchange between businesses which can in turn enable more efficient workflow either between their organisations or when cooperating. Finally, for larger companies, it can provide greater insight into the stages of their operation, the inputs and outputs of each and thus it is possible to streamline their processes.

The analysis had been carried out through quantitative and qualitative research by means of desk research (literature and price data analysis), expert interviews, online surveys and site visits. Primary data (interviews, surveys, etc.) was mainly examined from fall 2017 (beginning task 6.2) and is still ongoing, since task 6.2 finishes in month 24. The development of the interactive stakeholder map was accomplished using QGIS and its 'qgis2web' plugin.

Finally, the results are applicable and will be used within other work packages:
The derived challenges as well as the interactive map will be utilized to identify potentials for circular business plans (Task 1.5). For the examination of needs, financial and technical possibilities of each actor (Task 2.3) findings will be exchanged and aligned to derive policy recommendation. For the ongoing task of Task 6.2, the initial insight will be refined within the currently online available survey that aims specifically on the users of a trading platform.

Table 1: Mapping of challenges present on the plastic recycling market

	WEEE Management		End-processing		Production	
	Collection, Sorting, Disassembly	Pre-processing	Plastic (and Metal) Sorting	Primary Compounding	Secondary Compounder	Moulder / Product Manufacturer
Technological	Improved WEEE management: Enhancing the development of new and more cost-effective technologies for collecting, sorting and recycling plastics from WEEE to rise scrap purity.		Application specific quality: Enable high quality plastic with specific industry requirements towards: good surface finishing, flexible colouring and transparency, good olfactory performance and food contact grades		Grading System: Set up a system that indicates and guarantees the adequate quality of post-consumer recycled plastics.	
Economic - Value chain	Anticipation: Provision of a stakeholder map to visualize cooperation potential, enable industry anticipation and increase geographically diverse EU recycling infrastructure.		Vertical business integration: Establish close vertical business integration to align volumes and quality from scrap supply to production demand.		Design for recycling: Link manufactures and designers to recycling stages to exchange recycling technology information and best practices eg. by trainings to boost recycling friendly product design.	
Legal	Funded buffer stock: Market shifts due to political events leading to oversupply and therefore price fluctuations are buffered with proper funding mechanisms to ensure competitiveness of recycled plastics.		Enforcement actions to reduce the illegal shipment of plastics in low and middle income countries		Mandatory requirement: For recycled content in new products (from PCR, not only from industrial scraps) to create the demand of recycled plastics	
Communication	Information provision: Supporting the commercially available technologies for processing plastics.		Efficient collaboration: Working with the recycling supply chain to ensure the continued exchange of strong recycling practices as designs evolve.		Consumer demand: Providing information to consumers to increase their awareness, to encourage them to drive the demand and the purchase of products using recycled contents.	

2 Introduction

The European strategy on plastics in the circular economy emphasizes that: 'preparing a plan for addressing the challenges posed by plastics throughout the value chain and taking into account their entire lifecycle' should be prioritized. To derive and implement solutions that meet current challenges in the recycling market, it is necessary to carry out an analysis that can depict a clear picture of the state-of-the-art.

Waste of electrical and electronic equipment (WEEE) is one the fastest growing waste streams in the EU, growing at 3-5% per year, with a generation above 12 million tonnes estimated for 2020. New collection targets as of 2019 are raised within the recast Directive (2012/19EU) to 85% of WEEE generated (regarding each Member State). Recovery targets are raised by about 5% (comparing 2012 to 2018, depending on the category). Despite the continuous growth of WEEE streams today plastic as secondary raw material still accounts for only 5% of the materials used in the EU.

To support the WEEE recycling value chain from collection to recycling, the overall goal of Task 6 is the further development of an online market platform on plastics, establishing a trading and information infrastructure for actors that are involved in the secondary market for recycled plastics. For this purpose, the objective of this deliverable was to establish a picture on the status quo of the market. The scope of market determinants for PCR plastic material and its interacting stakeholders was set to three areas: PCR plastic price development, specific needs by means of drivers and barriers faced by the actors involved in the recycling market as well as establishing the foundation for stakeholder information visualization within an interactive geographical map. In further work (Task 6.3) the identified needs of recycling actors will be translated into technical requirements on information and functionality within the online platform to enable convenient use and engage stakeholder within material exchange, network building and to gather specific information, e.g. for recycled plastic price comparison or latest recycling technologies.

Primarily due to data limitations, the scope is narrowed down to an analysis of effects resulting from virgin competing against recycled plastic material in terms of price development. All identified challenges have been clustered and merged into four categories, such as technological, economic, legal and social/communication. Especially data limitations required to broaden the analysis, since price data and challenges do not always relate to focused materials ABS, HIPS, PP, PS. Data quantity and variety limited the initial stakeholder map data set to UK, France, Italy, Germany.

This report is structured into the underlying methodology (chapter 3), the results within each field of work (chapter 4-6) and finally concluding the work (chapter 7).

Drivers and barriers: A picture of various perspectives from the recycling actors on the current challenges is collected, structured and possible solutions where derived. Three strong challenges emerged that are integrated into this project research: standard quality of recycled materials, missing supply and demand as well as missing end user and material customer perception.

Price development: The PCR plastic price analysis is based on qualitative results from interviews and surveys as well as quantitatively by means of price development. The possible scope for a quantitative analysis is limited by the available data. A detailed methodological description shows availability from different sources and indicates comparability.

Map on recycling market: Within an interactive geographical information system (GIS), actors along the recycling value chain were mapped. The initial data collection focuses on Italy, France, Germany, UK and Ireland.

3 Methodology

3.1 Drivers and barriers of the secondary market for post-consumer recycled plastic

Currently, the small scale of use of recycled plastics from WEEE in new EEE is a clear sign that the post-consumer recycled plastics value chain in its current condition cannot meet the requirements of a circular economy model.

This section aims to analyse the current post-consumer recycled plastic market challenges, investigating barriers that are currently preventing or making the use of post-consumer recycled plastics unfavourable and drivers that are pushing its application in industrial sectors; the analysis includes also an evaluation of key factors that influence the price of plastics (both virgin and post-consumer recycled plastics).

The investigation of current drivers and barriers has been essentially investigated through expert interviews with stakeholders of the plastic value chain, both internal stakeholders of the project (consortium partners) and external ones (identified through dedicated activities along the PolyCE's project), and supported by literature available or on-line surveys.

As explained above the research has been supported by the development of two online surveys. The findings from the surveys were used to complement the information gathered from the expert interviews.

Moreover international studies, articles, reports have been reviewed; most of these researches are focused on plastics recovered from the municipal solid waste (MSW) stream with fewer articles dealing with recyclates from WEEE streams.

The first PolyCE's workshop has been organized in Essen (Germany) to discuss the preliminary findings; furthermore, additional information has been gathered during the attendance in several European events dedicated to plastic recycling industry such as *Plastics Recycling Show Europe* (Amsterdam) and *Plastics Recycling World Exhibition* (Essen).

With regard to the price development and its influencing factors the investigation has been essentially carried out through online trading websites and specialist journals on plastics market;

lastly the information collected during the investigation on drivers and barriers were used to support the results obtained.

In the following sections a deeper description of the methodology applied is shown.

3.1.1 Literature review

The literature review included peer-reviewed journals, quantitative and qualitative research studies, project and technical reports, case studies, article reports, good practice guidance, information and advice.

The literature review has taken place in 4 steps:

- identification of keywords to identify relevant materials
- internal review of literature already available
- finding and filtering literature to identify relevant sources for the scope
- reviewing each document to identify key themes and topics

An initial filtering process was carried out following a peremptory scan. This was effectively a negative sort, simply seeking to eliminate those studies which were too old, too inconclusive or too irrelevant. Finally, the filtering resulted in 50 documents that were possibly relevant. A significant number of additional items were discarded as irrelevant.

3.1.2 Expert interviews

The expert interviews have taken place in several steps:

- definition of survey, respectively interview questions
- internal discussion with relevant partners
- identification of external stakeholders of the plastic value chain in collaboration with project's partners
- filtering the external stakeholders to identify relevant ones for the scope of …?
- sending a general email about the project with a request to participate in the interview
- scheduling of the interviews
- execution of the interview
- processing and analysis of the obtained information

The questions were agreed by task partners in collaboration with the task leader. External stakeholders were identified with the support of other project's partners and contacted via email asking them if they were willing to undertake an interview, and if so date and time were arranged.

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 geographical coverage of these interviewees was Europe wide and the different nodes of the WEEE value chain was almost covered.

3.1.3 Surveys and workshop

As explained above to validate the results of expert interviews and literature review two surveys and a workshop have been conducted; a detailed description is provided below.

3.1.4 Stakeholder surveys

The first survey was developed in collaboration with other partners and launched in March 2018. The survey was available online in English and it was originally decided to limit the amount of time that the survey was available, but due to the limited number and quality of responses received, the partners involved in the task have agreed to keep the link open: results are periodically reviewed to ensure that the most level of detail is obtained.

The structure of the survey was agreed by all consortium members to ensure that the results were of maximum value to all relevant tasks and to reduce the need for duplication of surveys (the same approach was adopted in the interviews).

The survey was open to all European companies working in the plastic industry and it was designed to take 10-15 minutes, at the end of the survey participants were invited to join the expert network created by the consortium and also to provide case studies.

Questions were agreed during the second project meeting (February 2018) by a sub group of the consortium, reflecting the needs of partners that are undertaking surveys and interviews. This approach was agreed to ensure that partners involved did not need to interview the same stakeholders.

The first survey was developed using “SurveyMonkey” as it was thought that most participants would be familiar with this tool and it would be easy for them to use; moreover results are shown in a format that supports analysis.

The survey was divided in four parts that aim at different aspects:

- general information about the organization (“Your Organization”)
- general questions on Circular Economy (“Opportunities and Barriers”)
- CE Business Models and general questions on post-consumer recycling market (“Circular Economy Business Models”)
- general feedback on each company’s needs (“Support”)

The dissemination of the survey has been ensured by several channels: a link to the survey was put on PolyCE’s website, a tweet, agreed by consortium members, was shared on social media and, furthermore, an agreed email, containing the link to the survey and a brief explanation of the project, was circulated by consortium members asking them to forward the email to their stakeholders.

The questions developed by task 6 partners aimed to get a deeper insight into the challenges the European plastics industry is facing when it comes to the usage of post-consumer recycled plastics. As of the 27h September 2018, 62 responses had been received. In total 31 participants submitted their responses to the whole questions; the results of the survey, presented jointly for all

participants, are described in the chapter 4.3 to give an appropriate picture of the use of the post-consumer recycled plastics by European companies.

Based on the results of this first survey a set of questions have been set up in July 2018; the second survey was uploaded (only available in English) on the Plastic Information Europe website (https://pieweb.plasteurope.com/survey) at the beginning of September 2018. The survey was available online from the early September to the beginning of November 2018.

The second edition of the survey will enable PolyCE's partners to further identify and specify the quality and supply issues plastics industry is facing and help partners to find appropriate solutions for the future. The survey was distributed thought PIE'S network and it was designed to take 10 minutes; at the end of the survey participants were asked to join a short interview to further deepen the survey's topics.

As of the 05th November 2018, 12 responses had been received: the electrical and electronic equipment (EEE) sector forms the biggest part, with 66,7% of the participants active in the field; in the second place lie the building and construction sector and the automotive one, followed by the packaging.

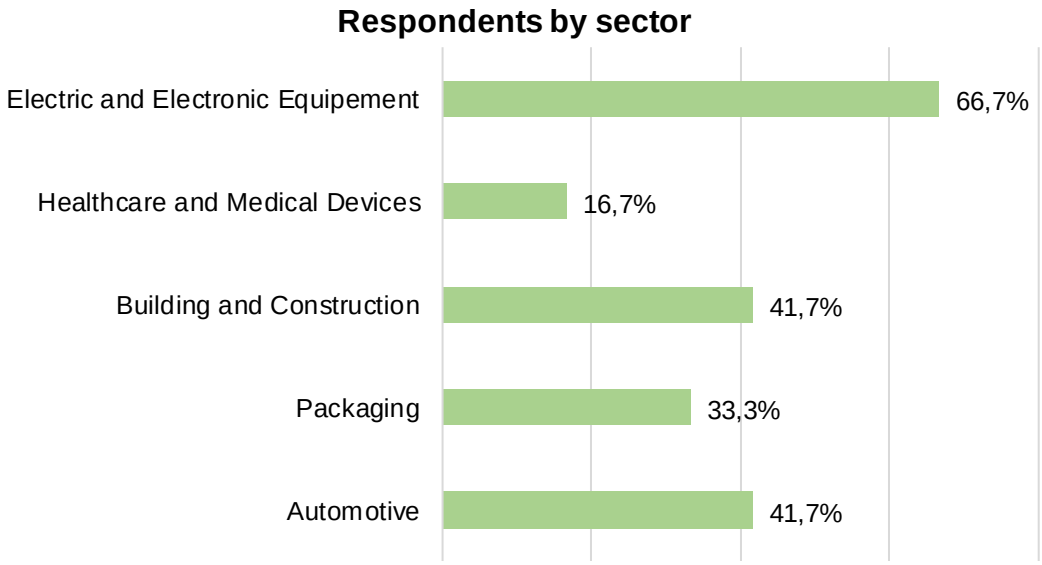


Figure 1: Survey participation by sector

Amongst the 12 participants, the "Brand company/Manufacturer" category had the biggest share of respondents, strong participation came as well from "plastic processor" category.

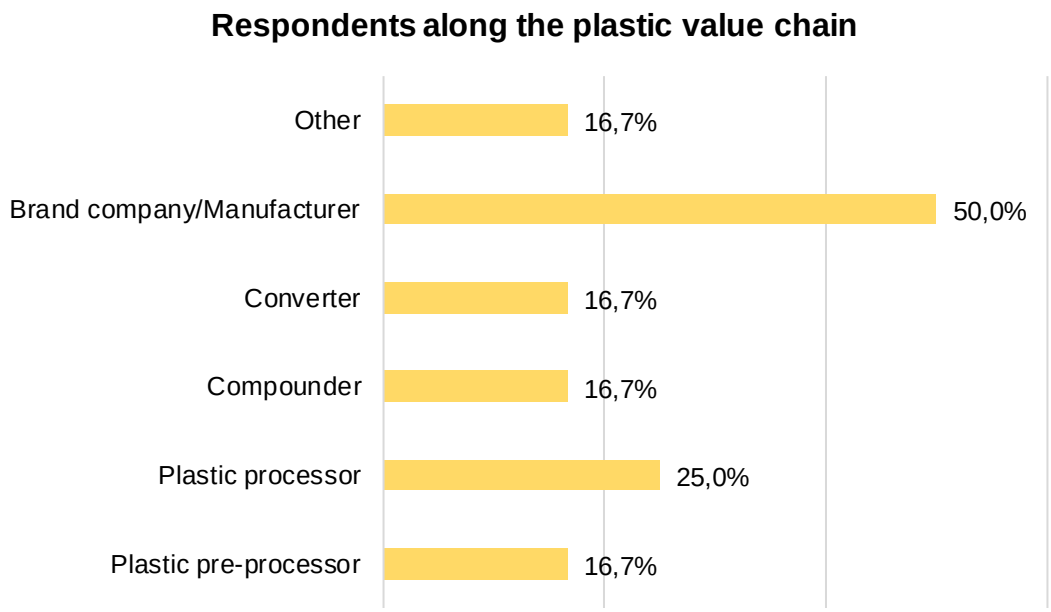


Figure 2: Survey participation by stage in the plastic value chain

The question on polymers types currently used mirrored the general state of the plastic industry: polypropylene and polyethylene (HDPE, LD/LLDPE) are the most widely used polymers, followed by acrylonitrile butadiene styrene (ABS), polycarbonate/acrylonitrile butadiene styrene (PC/ABS) as well as polycarbonate (PC) and polystyrene (PS).

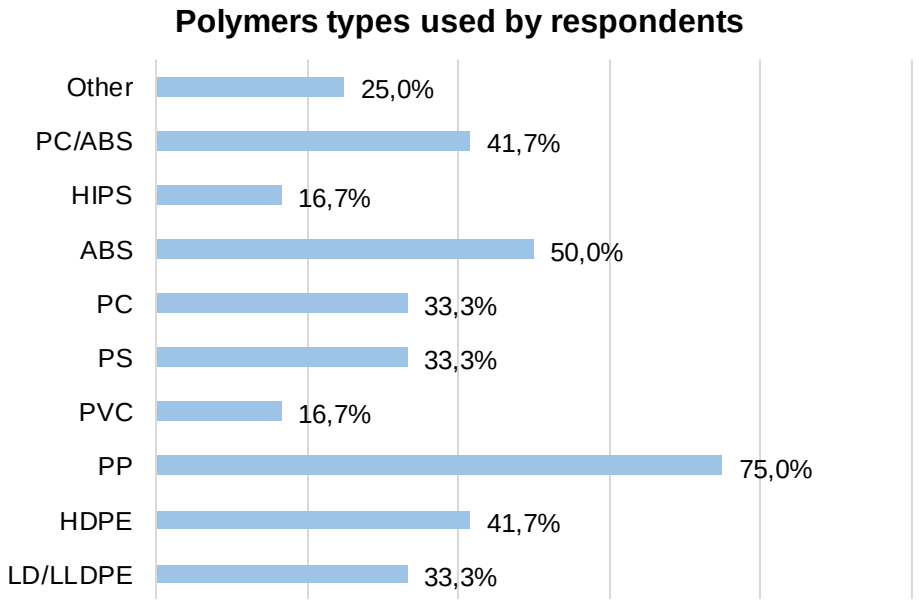


Figure 3: Currently used polymer types in manufacturing

The results of the survey, presented jointly for all participants, are described in the Section 4.3 to give an appropriate picture of the use of the post-consumer recycled plastics by European companies.

3.1.5 First PolyCE's workshop (Essen – Germany)

On 26th of June 2018, the first workshop of the project focusing on WEEE plastic value was held in Essen.

In total, 15 stakeholders (internal – project's partners and external) have been involved in the workshop.

The 7 external stakeholders invited to join the workshop were identified/categorized as follows:

- 3 research institute
- 1 public authority
- 1 plastic recycling association
- 1 WEEE recycler
- 1 plastics recycler

The workshop was divided into two parts: presentation of current project results and group discussion on topics presented.

The first moment (presentation of current project results) was articulated around two main topics: the post-consumer WEEE plastic quality and market; the results of the project researches carried out in these areas were presented and several points were brought to the table for discussion.

In the second part of the workshop the participants were invited to provide their feedback and opinions on results presented.

3.2 Polymer price development analysis

There are various online trading platforms and specialist journals for monitoring the plastic material prices: these tools generally provide a number of services including pricing data and analysis, forecasts on demand and supply, analysis of commercial transactions concluded and of key factors in price determination, such as market evolution, fluctuation of raw materials, as well as an analysis of the short and medium term price trend.

Access to such information is subject to subscription, nevertheless commonly it's possible to request a free trial and/or benchmark information; the latter option purpose is to give an overview about the platform features, for this reason it isn't allowed to access to all information available.

The great majority of these tools provide information about virgin and/or post-industrial market instead it's extremely difficult to find information about post-consumer recycled plastics and it's even harder find information about post-consumer recycled plastics obtained from WEEE stream.

Within PolyCE's project the partners have agreed to focus on the following polymers:

- polypropylene (PP)
- polystyrene (PS)
- polycarbonate (PC)
- high impact polystyrene (HIPS)
- acrylonitrile butadiene styrene (ABS)
- polycarbonate/acrylonitrile butadiene styrene (PC/ABS)

To investigate the price evolution of polymers **several online on-line trading platforms, specialist journals and other relevant sources such as recyclers associations were identified**, following as well the partners' suggestions; in the table below a list of potential sources identified is provided.

Name	Website
Anarpla	http://anarpla.com/
ChemOrbis	https://www.chemorbis.com/
Euwid	https://www.euwid-recycling.com/
Federec	http://federec.com/
ICIS	https://www.icis.com/
Kiweb	https://www.kiweb.de/
Papargus	https://www.pap-argus.com/
PiùPrezzi	http://www.piuprezzi.it/
Plastic Information Europe (PIE)	https://pieweb.plasteurope.com/
Plasticosycaucho	https://www.plasticosycaucho.com/
Plastics news	http://www.plasticsnews.com/
Plastiques & Caoutchoucs	http://www.plastiques-caoutchoucs.com/
Recycling markets	http://www.recyclingmarkets.net/
S&P Global Platts	https://www.platts.com/
Ucaplast	http://www.ucaplast.fr/
UsineNouvelle	http://indices.usinenouvelle.com/

An additional screening of the sources available has been carried out to eliminate those ones which were too too irrelevant or containing redundant information. As concerns the sources selected a description of the information available (data on virgin market, on post-industrial recycled and on post-consumer recycled) is resumed in the table below.

	Description of market price available		
	Virgin	**Post-Industrial Recycled (PIR)**	**Post-Consumer Recycled (PCR)**
ChemOrbis	X		X
Euwid			X
Federec			X
ICIS	X		
Plastic Information Europe (PIE)	X	X	
PiùPrezzi	X	X	
Platts	X		

As regards the on-line trading platform "Plastic Information Europe (PIE)", thanks to the access details provided by the project partner Kunststoffweb, it has been possible to display and download the whole website content, as described below:

- selection of virgin and recycled polymers
- online graphical visualization of the prices trends
- download of prices data time series
- report with the methodology for pricing and data evaluation ("Methodology for pricing and data evaluation")

In addition to Plastic Information Europe, another source from which a relevant number of information were downloaded has been PiùPrezzi, the gathering of the information has been possible thanks to the site's subscription.

As explained above, limited information about post-consumer recycled plastics are available and it's even harder find information about post-consumer recycled plastics obtained from WEEE stream; nevertheless, thanks to the support of other project's partners, the association of French recyclers (FEDEREC) has been got in touch to gather relevant information on post-consumer recycled WEEE plastic prices. The association provided free of charge the data time series (for the years 2016-2017) about the evolution of WEEE plastic indexes (the association provided the monthly variation recorded): the information are related to three WEEE streams (C&F appliances, screens and finally small household appliances-SHA).

Instead, as far as the other sources used to carry on the market investigation are not user-free, a brief description of the free functionality available are shown in the table below:

The results of the investigation described in detail in the Chapter 5 have been validated by the consortium partners.

Name	Description of user-free functionalities
ChemOrbis	• download graphics about polymers price evolution (no excel files with polymers prices) • download a report about European Recycled Grades Update • download a resume about the methodology for pricing and data evaluation ("Price Index Methodology")
Euwid	• necessary to subscribe to the website to gather information • free report samples sent by email to provide a general overview of the website commercial offer
ICIS	download a free sample report to have an overview about information available on the platform
Platts	• weekly report • monthly supplement about polymers supply and demand outlook • download graphics about polymers price evolution (no excel files with polymers prices)

3.3 Interactive map of stakeholders in the recycling market

The limitation of transparency regarding actors in the recycling market is tackled by a stakeholder mapping using a geographic information system (GIS)[1]. A main driver for creating and enhancing the market for recycled plastic materials is a sufficient supply and demand in conjunction with their visibility and transparent use of recycled materials[3]. To do this, Europe-wide information on actors in the recycling chain, from collection over sorting, reprocessing and compounding are collected. The graphical and interactive online map shows regional networks and possible recycling partners, enabling strategic partnerships and industrial symbiosis across the value chain. Heterogeneous European collection schemes and data availability are a major challenge towards the collection of a compressive and consistent European wide data set. Therefore, at this point the geographical focus is on Italy, Germany, France, and UK with functionality for users to add information as well as linking material offers from the trading platform is considered.

3.3.1 Data sources on stakeholder information

Data for countries within the UK was obtained from the government website (Environment Agency, 2018) and complemented manually where necessary. This provided a comprehensive breakdown of all collection points and recyclers of WEEE waste, however information on the same for plastics is currently unavailable. This data was split across 4 similarly structured documents. In some of these the location postcode information was not directly available and required filtering from the

[1] A Geographic Information System (GIS) is designed to store, retrieve, manage, display, and analyze all types of geographic and spatial data. Similar to the Raw Materials Information System, the envisioned stakeholder map will support EU-wide research on recycling actor specific information.

whole address. The postcode was always the last 7 or 8 digits of an address, therefore the last 8 digits of all were kept and any superfluous characters replaced with nothing.

Germany data was obtained in cooperation with German project partner KunststoffWeb GmbH complemented by manual google research. The raw data contained 4 fields, 2 of which constituted the name of the organisation and the remaining 2 being postcode and region. Region was deemed superfluous as postcode would be descriptive enough to determine location.
Italy data was obtained from Italian project partner ECODOM and is the most comprehensive set, detailing flows from collection point through to recycling plant including the transport operator responsible and the ZIP code for all 3. The dataset was the easiest to process, the entire list of ZIP codes for each Collection Point, Treatment Plant, and Transport Operator was separated and duplicates removed.

Data processing was more involved for the Germany data set due to no indication as to a company's function, i.e. for a company it was not clear which function they performed, recycling WEEE, plastics or both. These ~1000 entries were manually investigated to determine the functionality of each company and if they were relevant to the task at hand, as some companies – such as a chain of gyms – would not be.
The compiled French dataset currently comprises over 120 recycling actors extracted from different websites:

- ADEME (Report from 2017 including information on the French facilities):
- Eco-systèmes: (Map of French WEEE recycler from 2016 - 75% market share)
- Ecologic (Maps and lists including eg. collection points - collecte)
- Recylum (Lamps and B2B WEEE)
- PV Cycle (Solar panels)

Due to the language barrier and variety of data structures the research and collection for France is ongoing.

The information on stakeholder businesses types were classified into different dimensions: collection, sorting, disassembly, pre-processing, plastic sorting, primary compounding, secondary compounding, moulder and product manufacturer. The graphical visualization underlies a data table with columns based on the predefined dimensions. Data clustering towards the recycling value chain stages was set centrally within the project (Table 2). Data from different sources mostly did not show or provide the necessary category. While merging, manual research has been carried out for all companies with unclear stage relation.

Table 2: Predefined clustering for categorization of information on stakeholder in the recycling value chain

Stage	1	2	3	4	5	6

	WEEE Management		End-processing		Production	
Facility/Stage label	Collection, Sorting, Disassembly	Preprocessing	Plastic (and Metal) Sorting	Primary Compounding	Secondary Compounder	Molder / Product Manufacture
Product	Source separation for product type which contains certain grade material.	Bags of mixed plastics fractions	Big Bags of plastic flakes / ground plastic types	Manufacture of recycled plastic pellets	Manufacture of plastic pellets for products	Plastic components for end product

3.3.2 Front/Backend visualisation

The technical basis for the development of the interactive map detailing the various WEEE respectively plastic collection points and recycling plants across multiple countries within the EU is described in the following section.

Having extracted the Post/ZIP codes for each collection point/recycling centre the next step was to Geocode to these values such that latitude/longitude information was available (Figure 4). The Germany and Italy data sets were both of size such that an online batch geocoder could be used(www.doogal.co.uk/BatchGeocoding). Whereas the UK data set was considerably larger. A script was written to geocode this data where a HashMap has postcode keys and latitude/longitude tuple values, the postcodes were iterated through and the coordinates allocated.

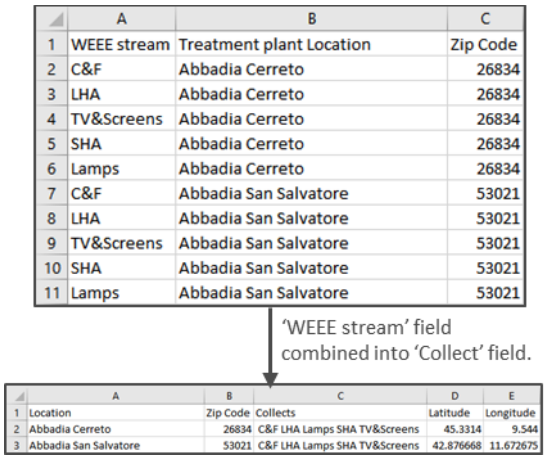
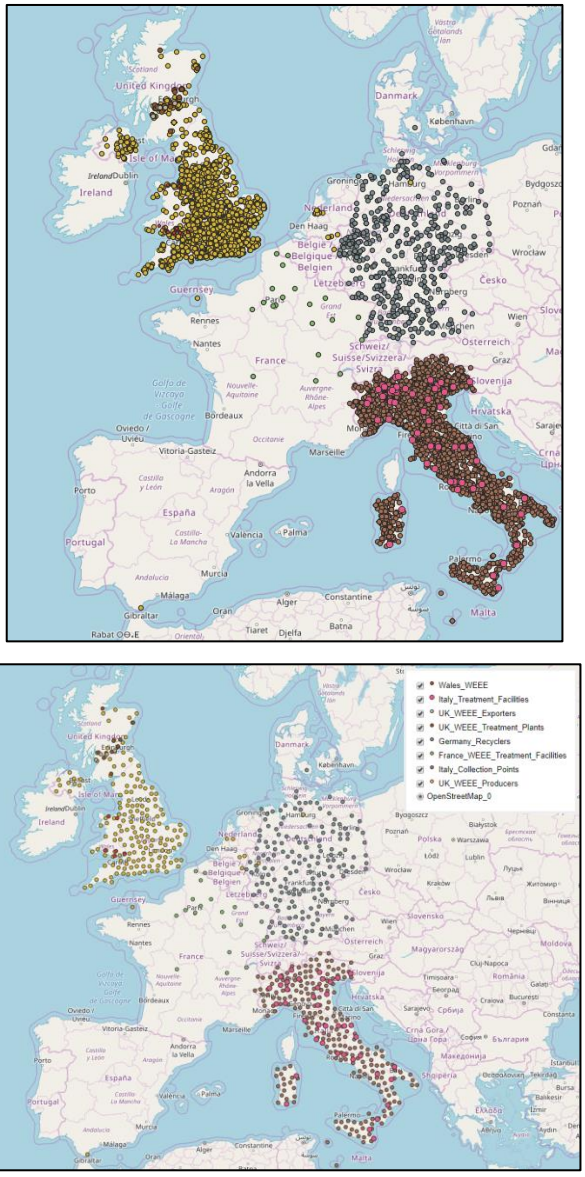


Figure 4: Data geocoded via vlookup between Postcode and Latitude/Longitude

Within a first step of mapping a non-interactive map within QGIS was created, a Geographical Information System, which allows a project to be configured in a user-specified coordinate system, in this case WGS84 was used. An OpenStreetMap layer was used to provide a background, and each of the now geocoded postcodes were added as individual layers.

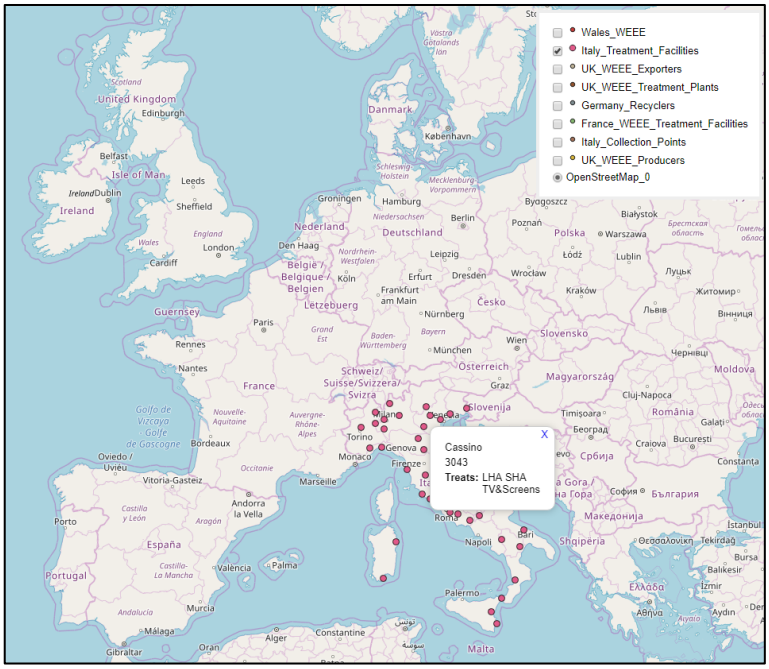
To move to an interactive map, a QGIS plug in, qgis2web, was obtained via the QGIS in-application installer. This plugin generates a html file alongside 5 directories. The html file displays the map itself and the directories contain necessary functions to achieve this. To host the map online you can either imbed the html file within an iframe or just copy the contents of the html file into the source code of the particular page you wish to display the map on. The other directories must be moved into the same location as to preserve the dependencies on them.



Figures 2 & 3: Data displayed on non-interactive map vs Interactive map

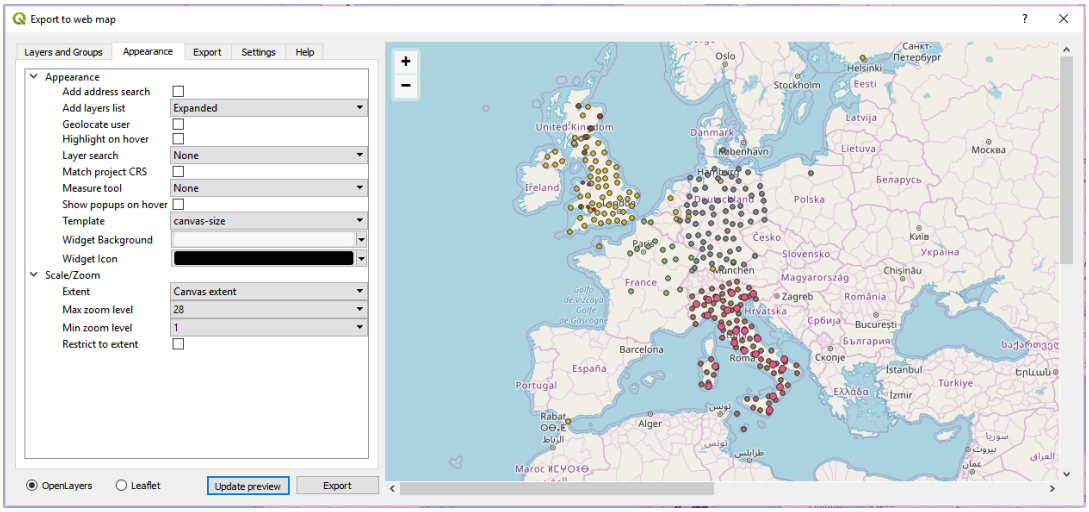
One observation between the two implementations is the seeming sparsity of data in the interactive variant. This is due to user-friendliness measures where as a user zooms into the interactive map, these points will split into the clearer picture as in the non-interactive version. Furthermore, as the resultant interactive map has been implemented using JavaScript it has been possible to develop

some extensions to the map. Namely the ability to filter by layer, such that a user can see a specific dataset of interest, as well as a measurement function which enables rudimentary analysis in-browser via providing accurate distances between user-defined locations.



Figures 4: Interactive map filtered to show a single dataset showing interactivity

There are some limitations on functionality depending on the intended use of the map past browsing. Firstly, only if the raw output of the plugin can be provided to users without any conflict of interest arising, then the map can be recreated within QGIS via a sister plugin, web2qgis. Furthermore, data will be stored in a JSON format whereas a more useful format to distribute data – should there be need to – would be via CSV, requiring a JSON to CSV parser acting as an intermediary.



Figures 5: Plugin interface used to implement interactivity

4 Drivers and barriers analysis on post-consumer recycled plastic

4.1 Literature review

Due to the focus on drivers and barriers of PCR recycled plastics coming from WEEE and barely available literature the scope was broadened to literature on challenges within the European plastic recycling market. In following, results from studies are summarized showing the challenges from different stages and actors in the recycling chain. Where possible, challenges are categorized into technical/technological and economic dimension.

Hopewell et al. (Jefferson Hopewell, 2009) stated some challenges on plastic recycling that are also mentioned in newer literature. Fundamental technical challenges arise from the chemical nature of different polymers that are not compatible with each other on molecular level and have different process requirements at macro scale. He concluded, that it is often technically not feasible to establish a material out of recycled PCR compound (with additional virgin and additives) comparable to virgin material quality. When combining recycled with virgin plastics, material quality attributes such as colour, clarity, mechanical property or impact strength are decreasing. Improving one attribute mostly results in degrading another one, leading to application specific trade-off materials. This leads to the conclusion of improving purity within the WEEE treatment process of collecting, sorting, cleaning, size reduction, separation, compatibilisation. Therefore, polymers should be effectively separated from contamination sources and stabilized against degradation during reprocessing and subsequent use. In general, a narrow range of polymer grades would reduce the difficulty of gaining high quality material out of plastic waste streams. As an economic issue it is mentioned, that the lack of information about the availability of recycled plastics, its quality and suitability for specific applications, can also act as a disincentive for manufacturers to use recycled plastics.

From an industry perspective, Setayesh stated in 2018 (Setayesh, 2018) main drivers and barriers for the usage of virgin and (PCR + PIR) recycled plastics. The arguments are categorized into technical and economic dimensions as seen in Table 3.

Table 3 Characteristics of virgin plastic vs. recycled plastics, adapted from (Setayesh, 2018)

	Attribute	Virgin plastic	Recycled plastic
Technical	Quality	Constant	Quality variation based on used source
	Availability	Good polymers availability with different fillers	Limited PCR (PP, PE, HIPS, ABS, PET) and PIR plastics (PP, PE, HIPS, ABS, PA, PBT)
	Surface	Good surface finishing quality	High gloss surfaces difficult to reach

	Colour	Flexibility in colouring	Transparent natural colour and food contact grades are barely available, mainly black and grey colour
	Olfactory performance	Good	Dependent on source the compounds can be very smelly
Economic	Supply chain	Limited number of suppliers, Availability of second source, Long standing collaboration with suppliers with proven track record	Complex supply chain PCR plastic market is dominated by upcycling companies, PIR plastic market is dominated by compounders Limited availability of PIR plastics (2-3 years)
	Support	Strong technical support through out the application chain (selection, technical data, part design, mould design, moulding)	Low level of technical support
	Applicability	One compound can be used in many application areas	Compound is application specific
	Price	highly vulnerable to oil price	Price is less vulnerable to changes in oil price, High quality recycled grades are priced as virgin material

New insights like surface quality and olfactory performance were identified as critical material attributes for the customer. Furthermore, on the technical side, the use of recycled plastics over virgin necessitates overcoming the diversity of the market via establishment of full mechanical testing and evaluation of many compounds.

On the economic side, the recycling process underlies various stages from collection to granulate, leading to complexity in the supply chain with different companies. The overall goal should be to gain a better understanding of the entire recycling supply chain in order to assure high quality material.

From the perspective of the European plastic converting industry, a study by EuPC (European Plastic Converters) shows insights on their challenges when using recycled plastic material (EuPC, 2017). The study is based on a survey between May and September 2017, specifically answered by plastic converters. Main barriers are the material quality coming from pre-processing (74%), constant supply (39%), price (15%) followed by negative consumer perception, legal issues, legacy additives and food contact application. A closer collaboration within the recycling value chain is seen as critical to overcome the mentioned challenges.

The usage of recycled plastics is mainly driven by price advantage (78%). The ambiguity of plastic price being a barrier and a driver at the same time is analysed within the chapter price development. Another incentive is seen in the positive environmental image (52%) and less environmental impact (25%). However, only 28% of the respondents claim to gain a visible market share, whilst 35% do not gain any market share at all, even when communicating with their customers.

The study concludes that it will be possible to generate demand from the customer side via changing customer attitude and risk acceptance by means of an awareness campaign.

Furthermore, 41% of the respondents agree that a higher use of recycled plastics within their companies could be influenced by unified, high-quality standards set at the European level.

4.2 Expert interviews analysis

In this section the results of the expert interviews and literature review are presented: the barriers and drivers identified by the stakeholders involved were clustered in macro-categories (economic, technological, legal and communication infrastructure), internally identified and discussed, the results of the interviews were categorized in accordance with the corresponding features.

Economic barriers

A common critical issue is related to the lack of **reliable supply** that brings to the absence of long-term commercial agreements for the use of PCR plastics, essential to guarantee the creation of a stable secondary market [1]; to manage to guarantee a stable supply of determined quality is the trigger to develop stable relationships between actors of the plastic value chain and to guarantee a reduction in the volatility of post-consumer recycled plastic **prices**.

Moreover stakeholders have pointed out that there are **missing supporting instruments** 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.

As an example, the weakness of economic incentives to use recycled plastic materials in products was also underlined by the European Commission in 2017 [2].

Moreover, the existence of the other barriers affects the absence of a stable and sound economic outlook as explained below.

Technological barriers

Plastics can be challenging to recycle because of the polymers, additives, and blends that are used in a multitude of products, as well as the fact that there are material properties that can limit the number of times that products can be recycled: as a consequence one main technological barrier mentioned in all interviews is the excessive number of polymers resulting from the treatment of a single stream of WEEE. Some members of the recycling market indicate a huge variation in material properties and insufficient quality of the PCR plastics; 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 to be competitive on plastic market (for post-consumer recycled plastics this means competing with virgin plastic), stakeholders agree that advances should be done along the entire plastic value chain; in particular improvements in the collection and sorting system are required together with clear rules for the design phase. Post-consumer recycled plastics often contain non target and non-recyclable plastics: the removal of these contaminants affects the cost of the recycling process. For lowering the cost of the recycling process and for ensuring a high quality sorting it is necessary not only to improve sorting technologies, but, above all, to enhance the quality of the collection in first place. In this respect, the collection and sorting activities are

having a high effect on the quality and supply reliability of recycled plastics. Due to concerns of plastic miscibility and content of hazardous substances, mixed plastics require careful separation before their reprocessing. (Berward, et al., 2018).

Another relevant technical issue is related to additives, e.g. some additives used in the production of primary plastics affect the physical properties of recycled plastics: for example the durability. Furthermore, a relevant factor influencing the post-consumer recycled quality is related to the low integration of design approaches such as Design For Recycling, aiming to ensure the material recyclability at end of life. Design facilitating recycling seems crucial, especially for single-use plastics: 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 [2] (Boudewijn A. , et al., 2018) [5].

Legal barriers

One relevant issue is the uncertainty, and lack of, information about the presence of chemicals of concern in recycled plastic, it has been agreed that there is a need to establish a **Quality Standard System for PCR plastic 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 a single EU Member State 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 [6]; 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**; if 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: the EEE industry accounts for the greatest consumption of Brominated Flame Retardants (BFRs) [7]: in WEEE plastics the flame-retardants content is estimated to be around 30% [8]. Plastics with BFRs are generally used in EEE products that generate heat such as televisions and monitors, printed circuit boards (PCBs) IT equipment, printers, cables and connectors [9].

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) [9].

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 due to the recovery of certain substances contained in plastics being banned.

Another practical example of this issue concerns plastics with DecaBDE flame retardants. These flame retardants are present in old flat screen casings, in small, old appliances, and in the cathode ray tube screen casing in a concentration from 17 to 5,000 ppm [10]. 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 [11].

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.

With regard to the design for recycling approach, within the legal framework 2009/125/EC Energy-related Products Directive (ErP) there currently are not any significant considerations on the re-use of recycled polymers in the manufacturing of new products [12]. The directive has a greater impact on design affecting energy consumption: as matter of fact it aims to reduce the environmental impact caused during the manufacturing, use and disposal of products and it contains general requirements centered around power consumption.

In December 2015 the European Commission presented an action plan for the circular economy; in the action plan proposed, the Commission indicated it would promote the reparability, upgradability, durability, and recyclability of products by extending the scope of eco-design requirements beyond energy efficiency. At the end of May 2018 the European Parliament noted that the Ecodesign Directive provides significant potential for improving resource efficiency that is still untapped and stressed the need to set up minimum resource efficiency criteria covering, inter alia, durability, robustness, reparability and upgradability, but also sharing potential, reuse, scalability, recyclability, possibility of remanufacturing, content of recycled or secondary raw materials, and the use of critical raw materials [13].

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 [14] 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) [14]. A relevant environmental challenge related to the illegal WEEE flows concerns

the mismanaged plastics, those that are managed and disposed outside legal systems; furthermore the illegal management can undermine the recycled market.

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. Finally, materials that are legally classified as wastes are subject to additional regulatory requirements (waste management regulation); this often produces additional costs and mostly important a material defined as waste may be perceived as less valuable; according to interviewees, the introduction of the WEEELABEX/CENELEC Standards as mandatory regulation can be an effective instrument to address the issue.

In Europe, recycling industries have raised concerns as regard as complexity of the regulation applied specifically to food contact applications. A clearly regulation of the use of recycled plastics in food application is essential.

Communication barriers

A relevant barrier is identified in the complexity of the value chain (from WEEE collectors to EEE manufacturers): the lack of communication and collaboration between buyers (manufacturers) and sellers (plastic recyclers) as well as between WEEE treatment operators and plastic recyclers is hampering the success of the post-consumer recycled market.

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.

Social barriers

The lack of knowledge on the part of consumers is a relevant barrier to post-consumer plastic market: end-user perception with regard to products containing recycled plastic is generally negative; consumers tend to perceive manufactured recycled products as inferior from the point of view of durability and reliability; moreover there are few incentives for consumers to keep plastic wastes in controlled circuits.

Legal drivers

The publication of the **first strategy "European Strategy for Plastics in a Circular Economy"** in January 2018 by the European Commission is an important first step on the road towards the development of an European circular economy; the strategy will support more sustainable and safer consumption and production patterns for plastics, protecting environment, reducing marine litter, greenhouse gas emissions and the European dependence on imported fossil fuels.

Moreover at the end of December 2017 China has put a halt to a lot of the plastic waste that was imported by foreign countries. The introduction of the **China Ban** has finally made Europe responsible for plastic wastes it has created; a research recently published states the China's import restriction may lead to a relevant increase of the pressure on waste management systems in

countries that have less stringent environmental regulations. The impact of the China's import restriction on global waste markets remains uncertain but potentially significant: a study has estimated the impact generated on global plastic waste trade by the Chinese restriction. In 2016, China imported more than 7 million tons of trash, without taking into account the nearly 61 million tons produced by its own, based on these trends, it's estimated that as results of the trash ban, 111 million tons of plastic waste will be stranded by 2030.

Social drivers

According to the results of the investigation consumers are both a barrier and a driver of the post-consumer recycled plastic market: respondents have stated that end-users play a key role in the reduction and in the recycling of WEEE stream; without them improving the sustainability of plastic would not be possible.

The awareness raising and educational programmes as well as of extended producer responsibility schemes are important factors: better information should enable consumers to take purchasing decisions for more sustainable plastic products, including for disposable ones; moreover consumers should be encouraged to adopt good disposal practices by the introduction of an efficient collection service such as ad hoc smart bins all over cities.

4.3 Surveys analysis

4.3.1 First survey results

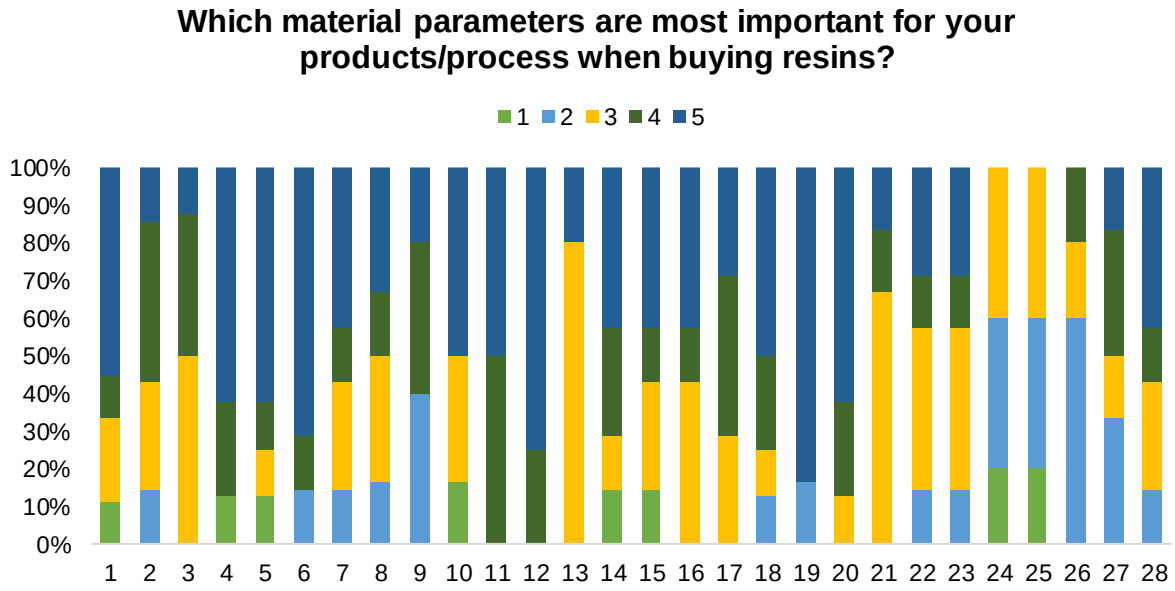
According with the survey results, more than 45% of the respondents (Q17) are operating within the EEE/WEEE sector, don't use post-consumer recycled plastics in their products; the main barriers, according with the results of the survey (Q18), that are preventing the use of post-consumer recycled plastics are:

- the quality of the final product (more than 70% of the respondents declare that this is an important/very important issue)
- the compliance with the regulation (more than 80% of the respondents declare that this barrier is important/very important)

The main approach to procure post-consumer recycled plastics, according with the results of the survey, it's the direct selling (company to company), the use of an online trading platform is not a service commonly used (less than 3% of the respondents declare they use this purchasing methodology); moreover, the majority of respondents that buy post-consumer recycled plastics through direct selling, have affirmed that they don't use a specific plastic index (Q 20); however a "quality indicator" (that classifies every bale of post-consumer recycled polymers offered on the marketplace and specifies the origin of the waste stream and the processes performed on it) is strongly required (by 51% of the respondents (Q21)).

4.3.2 Second survey results

The first part of the survey was designed to get general information about the stakeholders: identification along the plastic value chain, size of the belonging company and industrial sector.
In the first step, the respondents were asked to indicate on a scale between 1 and 5 (1 being not relevant and 5 being very relevant) the importance of 28 material parameters identified in collaboration with other relevant project partners.



1	Main polymer
2	RAL Colour
3	Darkness (for coloring during injection molding to the correct gray or other darker colors)
4	Charpy impact strength
5	Tensile Modulus
6	Tensile strength/stress
7	Density
8	Vicat Softening Point
9	Heat Deflection Temperature
10	RTI temperature
11	Flexural Modulus
12	Melt flow rate
13	Gloss
14	Post-industrial recycled content
15	Post-consumer recycled content
16	Virgin material content including virgin additives
17	Filler content
18	Filler type (glass, carbon, talk, …)
19	Compliance RoHS
20	Compliance REACH

21	Shrinkage at production
22	Flammability Rating according to UL94
23	Flammability Rating according to glow wire test
24	Granulates shape (maximum size)
25	Granulates shape (minimum size)
26	Mass fraction of different size categories
27	Dust content (mass fraction with belwo 1mm size)
28	Humidity

The current use of the post-consumer recycled plastics by the stakeholders involved in the survey was investigated, and 50% of the respondents (10 in 12) answered that they are already using PCR plastics in their company.

To provide a comprehensive overview of the barriers for the use of PCR plastics, the participants were asked to choose on a scale between 1 and 5 (1 being no barrier and 5 being high barrier) the importance of 10 barriers previously identified (expert interviews and literature review).

Another relevant information investigated was the influential factors that are affecting the selling price of PCR plastics: concerning this point the participants were asked to provide a feedback about the importance of 4 potential influential factors (they had to choose on a scale between 1 and 5 – 1 being no influence and 5 being high influence). As result, from among those who have responded "No" at question on the use of PCR plastics in their company, the majority of them consider the "price of virgin polymer" quite influential, while the "relationship between actors involved" and "the quality and/or quantity of the plastic sold" are considered important and very influential.

In the last step the respondents were asked to evaluate the requirements that a "quality indicator" for PCR plastics should have to be useful; 33,3% of the participants consider that a "Quality Indicator" to be successful should include information on legal compliance with framework on hazardous and critical substances (e.g. "RoHS" or "REACH" or POP); moreover the respondents consider also relevant the fact that the quality indicator should represent minimum mechanical requirements.

4.4 PolyCE's workshop (Essen – Germany)

In the second part of the workshop the participants were invited to provide their feedback and opinions on the results presented; the discussion has focused on the following main themes:

- **WEEE composition (in terms of polymers) and design for recycling**

The key point introduced during the discussion were the reduction of the amount of plastic used in the EEE production and moreover, according to stakeholders, limiting the use of polymers (e.g. using only one main polymer) in products manufacturing wouldn't be a feasible solution, the efforts required would be a lot and the heterogeneity would remain.

- **Stability of the post-consumer recycled market**

The stability of post-consumer recycled plastics price is affected not only by the quality level of plastic but the there are other relevant factors that should be taken in consideration: the demand and supply and the creation of long-term trade relationship

- **Collection and pre-treatment standards**

The introduction of standards as WEEELABEX/CENELEC Standards helps the recycling but it's not enough; to push the secondary market should be introduced a mandatory regulation on post-consumer recycled plastic content in new products

- **Communication along the value chain**

Stakeholders have stressed the need of establishing and in some case strengthen the relationships along the whole plastic value chain, trust is a key element that should be considered; moreover stakeholders have claimed that online platforms are not a promising tool to strengthen the recycled plastics market, it's more important to focus the effort on building strong long-term business relationships

- **Quality standard**

To establish a functioning quality standard it's necessary to identify which characteristics are required by costumers, indeed are already available technical datasheet containing information about recycled granulates. Moreover some concerns were raise in relation of having an unique quality standard, specific applications should be taken into account to reach the market

- **Food-grade**

Some trials shows that the effort required to produce a specific high-quality white food-grade polystyrene it's not enhanced by the market and moreover, as result of the sorting before the shredding of food-grade plastic sections (the quality of which is higher), the value (the purchase price) of remaining non-food grade plastics decreases given that the quality is lower

5 Price development and its influencing factors

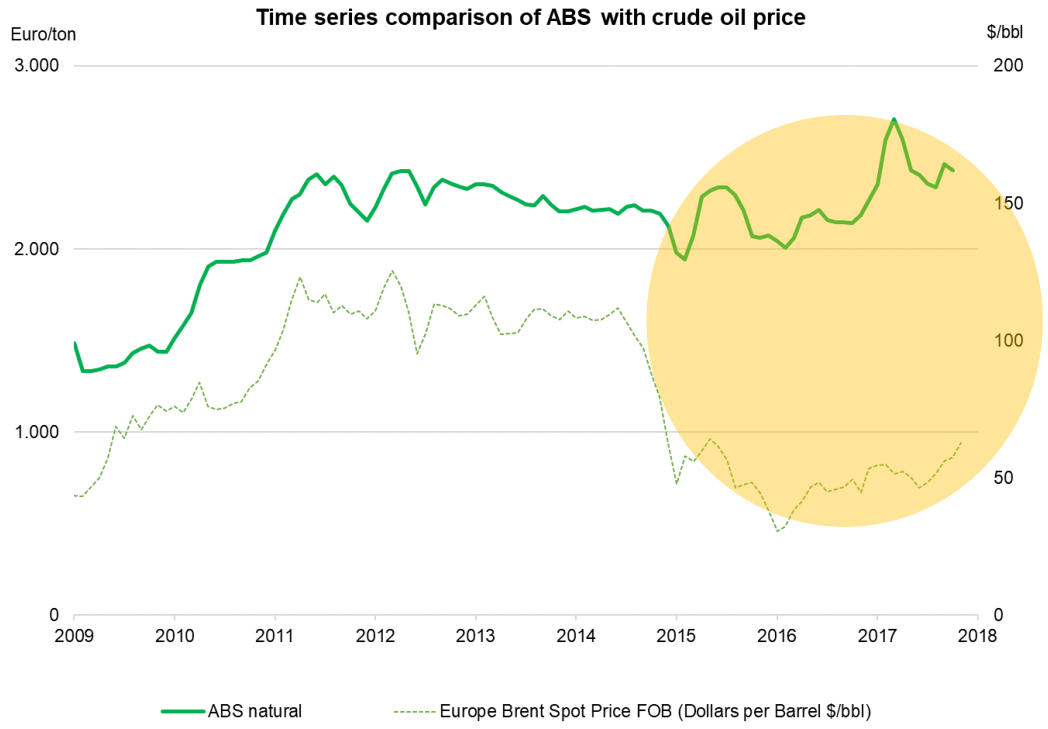
Virgin plastic

The price of virgin polymers is volatile and it reflects the changes (daily, weekly, monthly) in economic developments; virgin plastics prices are closed related with their raw materials (e.g. for virgin ABS the fluctuation of **styrene**, acrylonitrile and butadiene should be kept in check) and while the relationship between virgin plastic price and the oil one is well known being one of the strongest influential factor, there are other factors that are relevant too: grid energy price, cost of additives, supply and demand of virgin plastics.

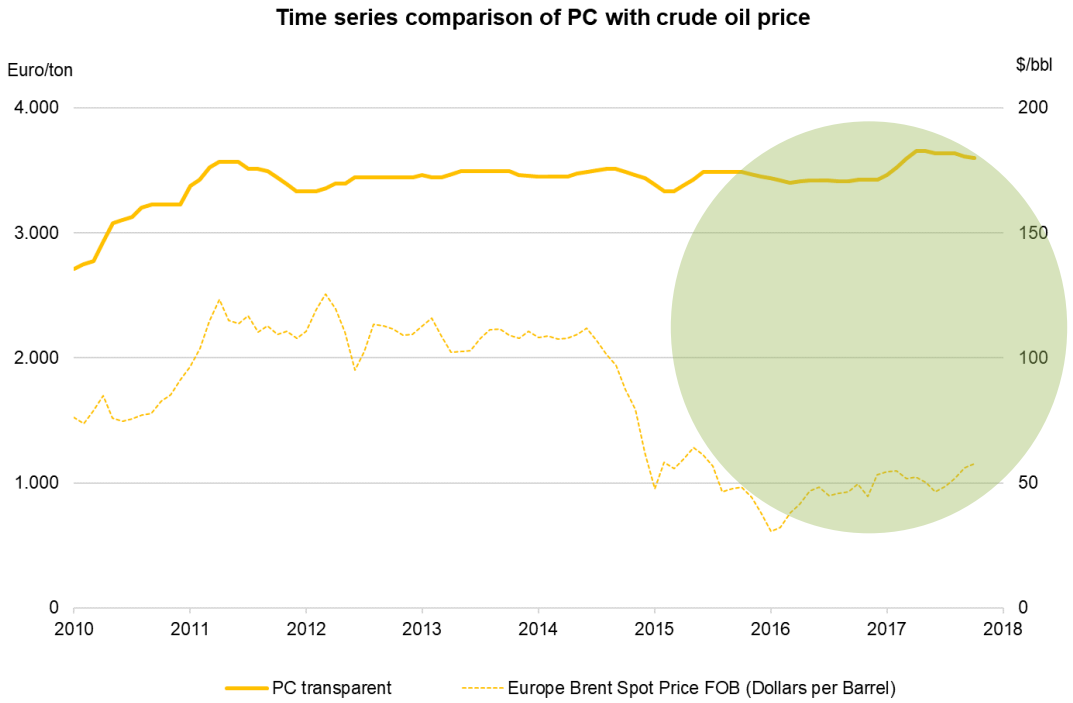
The virgin plastics prices are mainly determined by their production costs, for example the production of thermoplastics is largely based on raw materials derived from crude oil; consequentially the price of oil is therefore an essential factor in the determination of virgin plastic price.

In general, the variations in the prices of virgin resins are reflected in the prices of recycled resins: recycled plastics are exchanged at prices that include a discount compared to virgin plastics.

Figure 5, Figure 6 and Figure 7 show how the price of virgin ABS, PC and HIPS follows the price of crude oil and importantly it shows the impacts of other factors: in the period highlighted the price of oil dropped considerably but the price of virgin resins remained high, effectively decoupling from the oil price; this shows that other factors can influence significantly the trend of virgin plastic price. In addition to the factors listed above the price is also determined by commercial agreements between seller and buyer; important factors in commercial agreements between stakeholders are volumes commissioned and modification required by buyers compared with the supplier's portfolio: the demand for high volumes lead to a decrease of polymer price, while the requests for modification compared to supplier portfolio offer could increase significantly the prices.



FigFigure 6: Time series comparison of PC with crude oil price (Source: Ecodom elaboration)



Further sudden price fluctuations can arise with unstable trading relationships for example with high

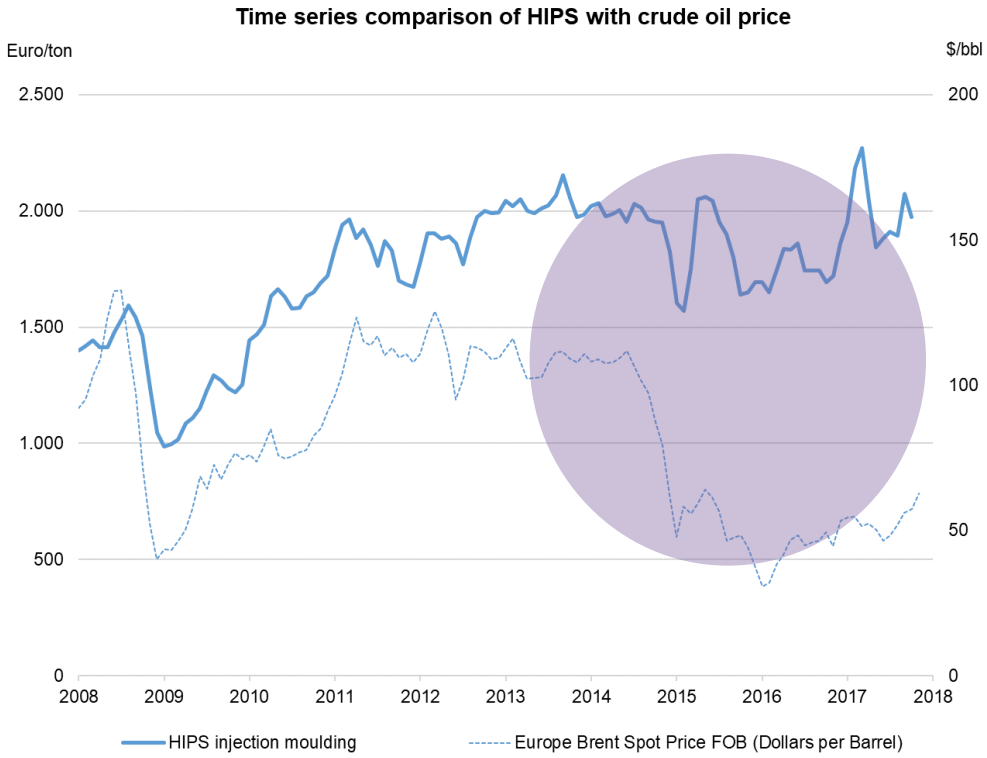


Figure 7: Time series comparison of HIPS with crude oil price (Source: Ecodom elaboration)

trade volume interdependencies or trading partners with politically critical structures. Figure 8 visualises further EU trading relationships for country specific import and export flows.

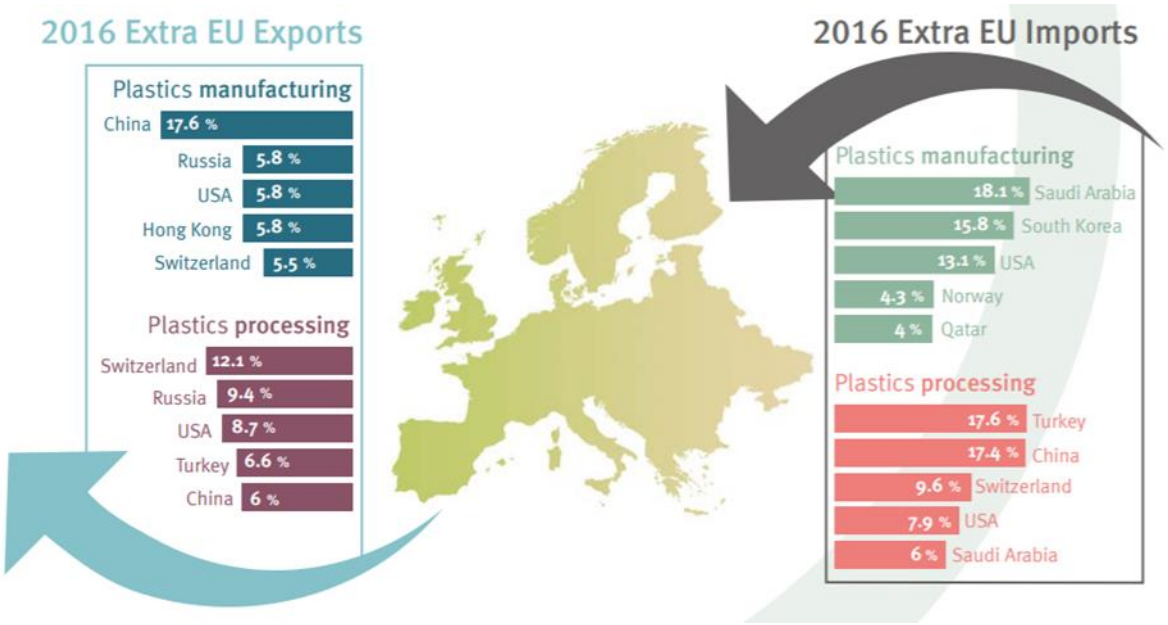


Figure 8: EU imports and exports indicating relationships and dependencies with many countries (PlasticsEurope, 2018)

Post-consumer recycled plastic

The post-consumer recycled plastic market is smaller and more fragmented in comparison with the primary plastic sector, this puts the post-consumer market and a comparative disadvantage; moreover the global market for plastics waste is concentrated in few countries: China as counted for two third of waste plastics imports during the last decade and the new Chinese policy on plastic waste importation is the evidence of a vulnerable market.

Therefore, the market for recycled plastics, despite constant development, remain fragmented and small in size compared to the virgin one. As a result, the prices of recycled plastics are not determined by the marginal costs of production, as is the case in an efficient market: the prices of recycled plastic pellets are primarily determined by the competing alternatives of virgin resins.

According to the analysis carried out, the demand of post-consumer recycled plastic is related to the unsatisfied demand of virgin plastics as consequence it seems that there isn't a parallel stable market for recycled plastics.

The price of post-consumer recycled plastic is mainly driven by the price of virgin material: therefore the price of recycled plastics is, nowadays, not connected with the costs of producing them (cost of collection and sorting, cost of treatment etc.); this is an important factor in the success of plastic recycling: it means that whatever are the management costs (collection, sorting, treatment) incurred by the recycling industry, the cost of the post-consumer recycled plastics is stickily related to the demand of recycled plastic, mainly related to the cost of the virgin plastics that is influenced by several influencing factors.

As with the prices of virgin polymers also for recycled plastics there are different influencing factors: consumer demand, environmental policy, availability of technology.

Thanks to several sources used such as expert interviews, literature review and interviews with experts from recyclers associations (e.g. FEDEREC) … information on.. was collected. Figure 9 shows the information on monthly index variation related to three WEEE streams: fridges, small household appliances (SHA) and screens; the indexes time series (for the years 2016-2017) were used to drawn up the Figure 11.

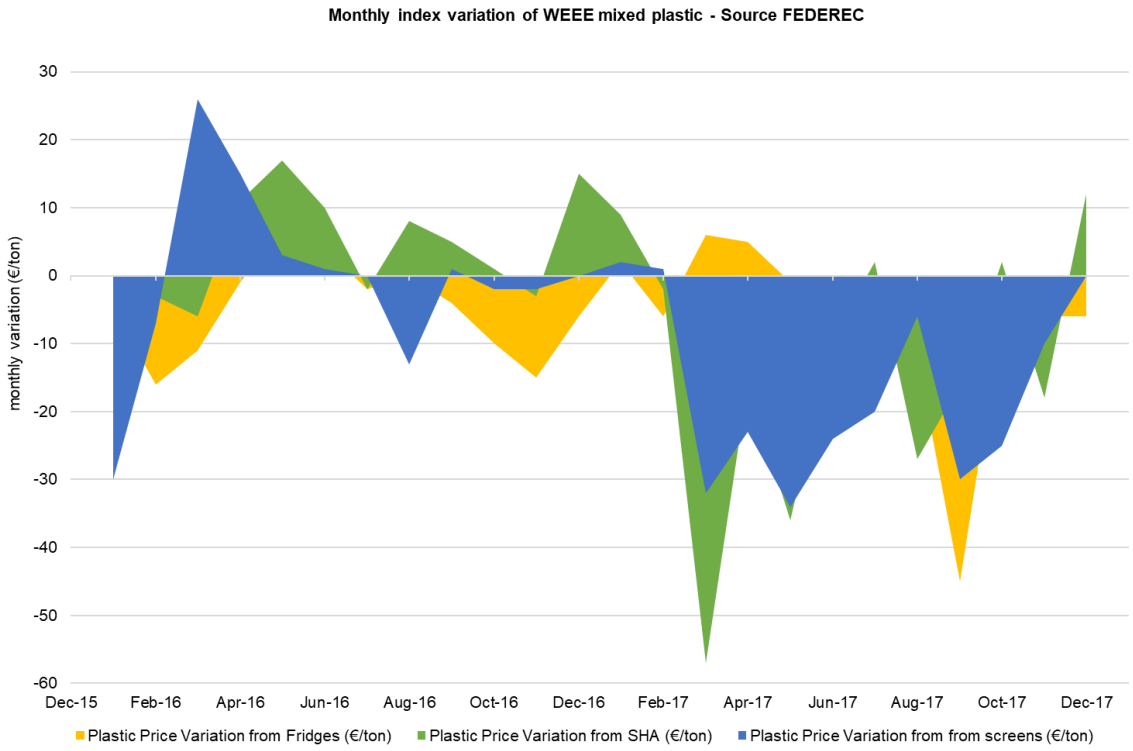


Figure 9: Monthly index variation of WEEE mixed plastic (Source: Ecodom elaboration)

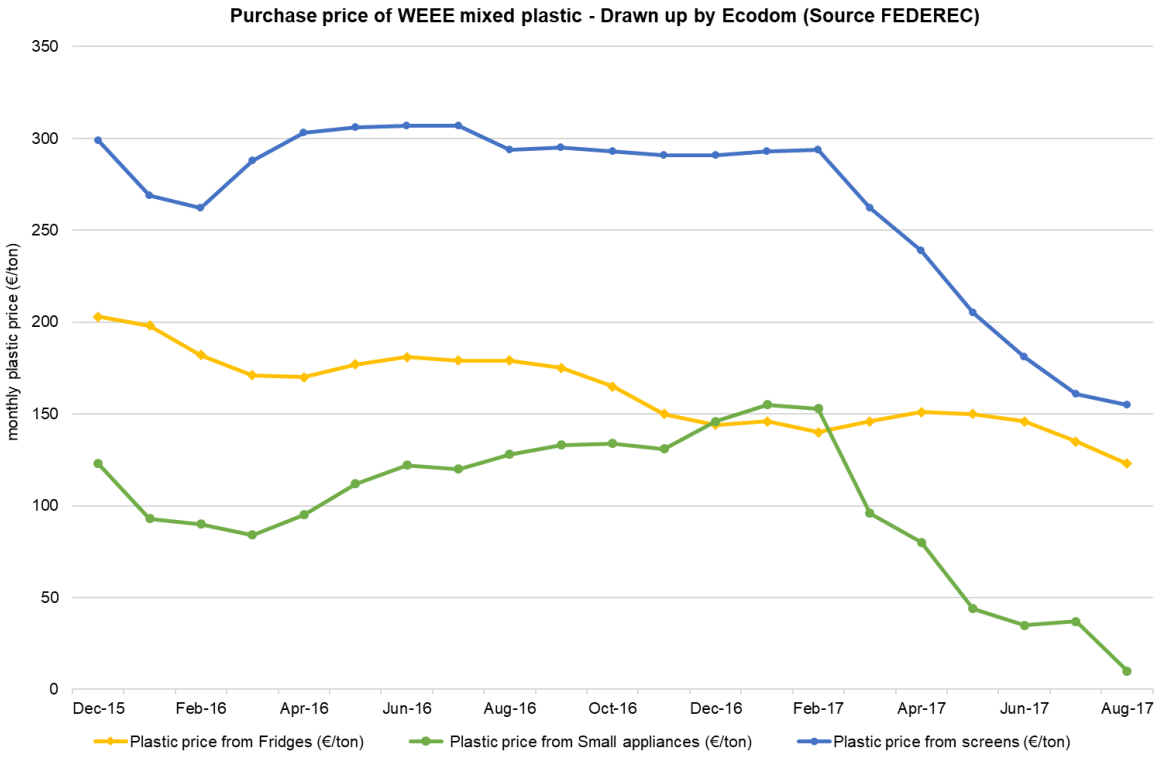


Figure 10: Purchase price of WEEE mixed plastic (Source: Ecodom elaboration)

6 Interactive geographical stakeholder map for online presentation

The main outcome is the development is the technical basis of an interactive map that visualizes stakeholders in the recycling market including their regional distribution. The map features the linkage between stakeholder and their materials offered. Within the scope of this work, most comprehensive data for initial visualization was passible to be gathered for UK, Italy, Germany and France. The map will be used within the envisioned platform for stakeholder engagement and convenient graphical visualization of stakeholder information and material availability.

6.1 Data sourcing

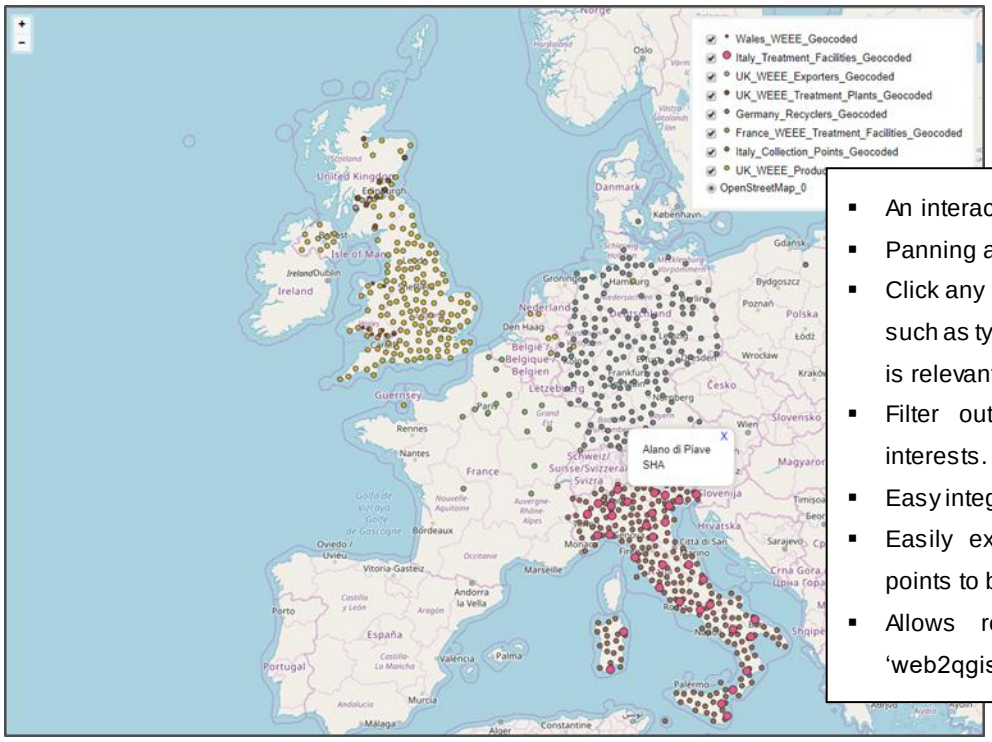
The data sets used were provided from various sources from each county in question. Due to varying sources this data was not homogeneous and therefore required a lot of cleansing. In order to establish a unified set of attributes amongst all data sets for mapping, a lot of information initially was ignored, for instance, the relevant recycling stream of a location within the regional Italy data set. However, these informative pieces were eventually reintroduced to improve usability of the final map. Additionally, the sources used to attain this data, other than those from Government bodies, run the risk of being incomplete. This means the current picture of the recycling chain potentially

has many pieces missing. This boundary is met by integrating added functionality to allow a user to provide their own information, then this issue can be circumvented.

Some data sets were missing information, such as the role a particular location played within the supply chain. This was particularly apparent in the German data, where each location was verified via Google to determine what functionality that location was responsible for. Consequences of this being that there is a reduction in the scope of companies possible functionalities, as many of them were smaller locations with either no, or more ambiguously worded websites. For the case where no information could be found on a recyclers exact functionality we decide to list them as 'processing'. Some of these German companies for instance were performing all sub-tasks of the processing stage, and more, but have still been clustered into the 'processing' category to ensure homogeneous output.

Some issues may arise in future should functionality for a user to download the data presented in the interactive map. Firstly, the mass availability of data which has been aggregated from different sources. Without a unified format across such data any analyses performed by a third-party would have to accommodate each individual formatting. Furthermore, due to recent changes in data protection, retention, and distribution laws there will have to be great care placed in the method in which data can be accessed by the general public.

6.2 Technical realization and integrated functionality



- An interactive, JavaScript-backed map.
- Panning and zoom functionality.
- Click any point for additional information, such as types of material a collection point is relevant for.
- Filter out counties irrelevant to your interests.
- Easy integration into an existing site.
- Easily extended functionality to allow points to be added at user's discretion.
- Allows reimportation into QGIS via 'web2qgis' plugin.

Figure 11: Screenshot of the graphical information system (GIS) visualizing stakeholder information

Technically, full webpage integrability is ensured. As previously stated, interactive-mapping development was undertaken using QGIS and its 'qgis2web' plugin. Despite the considerable size of the provided datasets, there were no notable affects to performance. This indicates that expansion of the information base is feasible. This is a likely side effect of the map being pre-rendered by the plugin and exported in more concise and efficient data storage methods. Furthermore, due to its use of XML within JavaScript it follows a commonly used format meaning that additions are feasible as well as alterations to the overarching style at a designer's discretion.

The primary intended use case of the interactive map was to ember it within a webpage, either via use of iframes or direct copying of the plugin-generated source code. The interactivity involves panning over a world map, as provided by OpenStreetMaps, and imposed over it are points representing various participants of the recycling supply chain of each considered country. Once clicked a small window is opened which details brief information about said participant and, if available, the stream(s) of recycling they are involved in.

Whilst generating the map, one issue encountered was an unexpected update of QGIS. Consequently, all plugins had to be reconfigured by their respective developers. This was ultimately insignificant as a prior version of the map had been generated. As this exported format was understood, being a combination of HTML, JavaScript and XML, it was possible to continue adding data to the XMLs or create entirely new ones to accommodate new data streams. This helped form ideas as to how data could be added at an observer's discretion.

The first additional piece of functionality involves the users being able to input their own data for publication into the map. This will then account for any participants of supply chains which automated data collection methods may have missed, as well as those that were stablished after the initial data collection period. Data can be added by a user via a form, and then appended to the relevant XML file for the country in question. One issue this may give rise to however is an increased requirement on the amount of storage necessary to host the map. Should users be able to add points completely at their own discretion then it will be imperative to include safeguards to prevent malicious users from flooding the map with erroneous data, which in turn may have knock on effects to any tertiary services developed. There are some solutions to these issues, such as limiting the number of entries a user can make within a given timeframe, or alternatively including a secondary step after entry where points are not submitted for publication until first checked by a human intermediary to determine they are valid. This however may prove infeasible depending on the intended scale.

Another extension to functionality implementable utilises the counterpart plugin to 'qgis2web', 'web2qgis'. This resolves a large limitation of our chosen implementation, namely that it is currently impossible for a user to perform analyses over the map. Due to being entirely visual there is no provision of analytical tools. The plugin 'web2qgis' allows a user to take the source data of the map

and import it into QGIS and view it as if it was any other project. One issue with this approach however means providing source code of the hosted map to users meaning should any vulnerabilities exist within it that they can in turn be exploited. A possible solution to this is to provide just the XML files which can then be either parsed back to CSV and imported, or a plugin can be written within in QGIS's in-built development environment to allow direct XML importing.

A further limitation of QGIS itself is its high requirements to run efficiently. Although the map may run smoothly, performing analysis over the data will require system with high specifications to complete in a reasonable amount of time.

The main limitation of this approach however arises when considering the first discussed additional functionality, users being able to add their own data points. Take for instance a situation where the map has been hosted for some time, and users have provided additional data throughout this time. If a new data set is provided for a new country to consider it will not be possible to add it to the original, reexport the map and embed it again as all the user data will be lost. Instead it will be necessary to export the map, use either an XML to CSV parser or the 'web2qgis' plug in to retrieve the data current on the map, add the newly acquired data, and finally reexport and upload. Although possible to do, it still requires a manual process which requires knowledge of several facets of the implementation.

7 Conclusions

This report summarizes the work from task 6.1 and task 6.2 comprising the programmed technical basis for the interactive stakeholder GIS as well as the analysis on barriers and drivers with special focus on information needs of supply and demand side within the secondary market for post-consumer plastics. As the third market element, the price development for recycled plastics was analysed to understand its underlying influences.

Primary data (interviews, surveys, etc.) was mainly examined from fall 2017 (beginning task 6.2) and is still ongoing, since task 6.2 finishes in month 24.

All ascertained results form the basis to achieving the overall goal of task 6 - to provide a convenient trading and information infrastructure that overcomes current market barriers. In successive work packages (task 6.3, etc.), the basis described in this report will be translated in technical requirements and functions.

The analysis had been carried out through quantitative and qualitative research by means of desk research (literature and price data analysis), expert interviews, online surveys and site visits. The development of the interactive stakeholder map was accomplished using QGIS and its 'qgis2web' plugin.

Finally, the result are applicable and will be used within other work packages:

The derived challenges as well as the interactive map will be utilized to identify potentials for circular business plans (task 1.5). For the examination of needs, financial and technical possibilities of each actor (task 2.3) findings will be exchanged and aligned to derive policy recommendation.

For the ongoing task of task 6.2, the initial insight will be refined within the currently online available survey that aims specifically on the users of a trading platform.

In the conducted interviews and talks, ideas were proposed which extend beyond the initial scope of task 6.3 but would provide large benefits to any users of the envisioned online platform. Some of these have been deemed suitable to act upon and include in future work, such as visualising links between offers across the market platform within the interactive map.

7.1 Provision of geographical stakeholder map for industry anticipation

Although the stakeholder map comprises initial data sets, diverse data sources and missing waste stream at regional level doesn't allow for conclusions at this point. Primary benefits of the map in its current iteration are the ability to visualize vast sets of data in an intuitive way and gain useful information on any points of interest. Furthermore, this data availability facilitates an information exchange between businesses which can in turn enable more efficient workflow either between their organisations or when cooperating. Finally, for larger companies, it can provide greater insight into the stages of their operation, the inputs and outputs of each and thus it is possible to streamline their processes.

Despite the challenges and limitations to the current implementation the interactive map is functional. Most of those points do not limit its usefulness nor mean it is not extensible, rather just that there must be consideration made when making further developments to ensure it remains operational, convenient to use, and useful.

7.2 Challenges, potential intervention to improve the post-consumer recycled plastic market

Given the results of the investigation on drivers and barriers of the secondary market for post-consumer recycled plastic a number of challenges have been identified:

- quality of waste and level of contamination
- design specification causing difficulties in recycling
- lack of demand for recyclates
- fragmented regulation on hazardous substances
- lack of communication and long-term relationship along the plastic value chain

Due to the scale and variety of the challenges listed above a range of possible measures and interventions are recommended; a precondition to foster the market for recycled plastics close collaboration and relationships amongst all relevant stakeholders, including policy-makers, industries, consumers are required; indeed the engagement of part of the value chain stakeholders could endanger the effectiveness of any intervention proposed.

To address the barriers that are preventing the market for recycled plastics a range of potential regulatory, technology, infrastructural interventions could be deployed.

The interventions proposed have been clustered in three groups. Challenges are highlighted that prospectively can be translated into technical features or information provision and thereby be tackled by the online platform in forthcoming task 6.3 (Table 4).

Table 4: Proposed interventions derived from concluded results on challenges for the recycled plastic market

Intervention Category	Intervention Proposed
REGULATORY	Enforcement actions to reduce the illegal shipment of plastics in low and middle income countries
	Mandatory requirements of including recycled content (from PCR, not only from industrial scraps) in new products to create the demand of recycled plastics
TECHNOLOGY	Enhancing the development of new and more cost-effective technologies for collecting, sorting, recycling plastics from WEEE
	Supporting the commercially available technologies for processing plastics
	Enable high quality plastic with specific industry requirements towards: • High gloss surface finishing • Flexible colouring and transparency • Good olfactory performance • Food contact grades
	Sharing the best recycling practices along the whole value chain

ECONOMIC – VALUE CHAIN	Providing manufactures and designers with information and training to boost the use of recycled plastics
	Providing information to consumers to increase their awareness, to encourage them to drive the demand and the purchase of products using recycled contents
	Establish the infrastructure for good collaboration and relationships of relevant stakeholder along the plastic value chain
	Set up a quality indicator system to guarantee the adequate quality of post-consumer recycled plastics

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