Action 4.1: Market conditions for plastic recycling

2 January 2013

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<td><strong>Done by</strong></td>
<td>David Snällfot, Ida Leisner, Mette Skovgaard, Anna Warberg Larsen</td>
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<tr>
<td><strong>Quality assured by</strong></td>
<td>Mette Skovgaard</td>
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<tr>
<td><strong>Approved by</strong></td>
<td>Merete Kristoffersen</td>
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Introduction

Objective of study
The Plastic Zero Project’s survey on market conditions for plastic recycling (Action 4.1) is reported in this document. The purpose of the survey was 1) to investigate and evaluate the current market conditions for plastic recycling with focus on identification of barriers and opportunities and 2) investigate the main markets trends and the new technological possibilities for increasing the recycling level in Europe.

The consumption of plastic in Europe is increasing. According to one prognosis the total amount of waste plastic in Europe is expected to increase from 24.9 Mtonnes in 2008 to 30.6 Mtonnes in 2015 (Bio Intelligence Service 2011). Treatment by mechanical recycling is expected to increase from 21.3% to 22.8% in the same period. This means that the amount of waste plastic in the European waste sector and recycling industry will increase from 5.3 Mtonnes to 7.0 Mtonnes in just seven years. In addition, a minor amount will be recovered by feedstock recycling, but the majority of waste plastics will still be disposed of, either by energy recovery or landfilling. This development in waste amounts calls for a better understanding of how the waste management sector can promote recycling and make the resources in waste plastic available for European manufacturers in a steady or reliable flow.

The applications of recycled plastics are increasing due to the development of more advanced recycling technologies, but at the same time, the complexity of waste plastic is expected to increase as well. Furthermore, current recycling technologies are mostly applicable for relatively well-defined waste streams such as packaging waste. There is a need for looking ahead and taking the recycling technologies a step further.

A thorough understanding of the market conditions is needed in order to identify barriers and propose new initiatives which can stimulate the European recycling industry. Aspects of the European and global markets as well as the national markets in the partner countries were analysed in the survey. The aspects included here were among others the amounts of waste plastic, export and import, quality criteria set for waste plastic, technological developments, price structures and job growth in the recycling industry.

Approach
Information for the survey was gathered in several ways:
- Interviews with national and international stakeholders
- Review of literature: research publications, statistics and legal documents
- Survey on waste plastic amounts (action 1.2)
- Survey on best practices in Europe (action 1.3)
- Survey on collection and sorting technologies (action 3.1)

Four country reports on national market conditions (for Finland, Latvia, Denmark and Sweden) were made based on stakeholders interviews, which are listed in the tables below. Following types of stakeholders were suggested in the beginning of project: national environment protection agency, the plastics industry association, a broker in waste materials, and a national/regional waste organisation. To complement these national market perspectives, additional interviews were conducted on the German and the European market conditions for plastic recycling. In total 22 interviews were executed during the period August to October 2012. Finally, supporting literature was sought out for all markets to validate circulated claims as well as to generally enhance the quality of the data gathered.

The survey did mainly include the market conditions for the most common plastic types (PE, PP, PS, PET). The more specialised polymer types constitute a minor share of the plastic production in Europe, but information about recycling and market conditions is sparse.

Finland

<table>
<thead>
<tr>
<th>Name of stakeholder</th>
<th>Type of stakeholder</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finnish Plastics Industries Federation</td>
<td>The central organization for plastic industries in Finland</td>
<td>29.08.2012</td>
</tr>
<tr>
<td>The Finnish Plastics Recycling Ltd</td>
<td>Founded to promote recycling of used plastic products in Finland</td>
<td>29.08.2012</td>
</tr>
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</table>
### Latvia

<table>
<thead>
<tr>
<th>Name of stakeholder</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Zala Josta Ltd</td>
<td>Waste packaging manager</td>
<td>22.10.2012</td>
</tr>
</tbody>
</table>

### Denmark

<table>
<thead>
<tr>
<th>Name of stakeholder</th>
<th>Type of stakeholder</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Danbørs</td>
<td>Waste broker</td>
<td>01.08.2012</td>
</tr>
<tr>
<td>Dakofa</td>
<td>National waste management association</td>
<td>02.08.2012</td>
</tr>
<tr>
<td>Plastindustrien</td>
<td>National association of the plastics industry</td>
<td>08.08.2012</td>
</tr>
</tbody>
</table>

### Sweden

<table>
<thead>
<tr>
<th>Name of stakeholder</th>
<th>Type of stakeholder</th>
<th>Date</th>
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<tbody>
<tr>
<td>Swedish Waste Management</td>
<td>National waste management association</td>
<td>14.08.2012</td>
</tr>
<tr>
<td>Swedish Environmental Protection Agency</td>
<td>Governmental agency</td>
<td>24.08.2012</td>
</tr>
<tr>
<td>FTI AB</td>
<td>Waste collector</td>
<td>30.08.2012</td>
</tr>
<tr>
<td>The Swedish Plastics and Chemicals Federation</td>
<td>National trade organization of the manufacturers and suppliers of chemicals and plastic products</td>
<td>31.08.2012</td>
</tr>
<tr>
<td>Stena recycling</td>
<td>Waste reprocessing and recycling company</td>
<td>04.09.2012</td>
</tr>
<tr>
<td>Plastic recycling in Strömsbruk AB</td>
<td>Sorting and recycling company for plastic products</td>
<td>07.09.2012</td>
</tr>
<tr>
<td>SWEREC</td>
<td>Plastic sorting and recycling company</td>
<td>11.09.2012</td>
</tr>
<tr>
<td>Polyplank</td>
<td>Manufacturer, which is using recyclable composite material composed of recycled thermoplastic resins and organic fibers</td>
<td>11.09.2012</td>
</tr>
<tr>
<td>Rondoplast</td>
<td>Plastics manufacturer</td>
<td>11.09.2012</td>
</tr>
<tr>
<td>Axjo Plastic AB</td>
<td>Develops, produces and markets packaging solutions and customized systems in polymer materials.</td>
<td>17.09.2012</td>
</tr>
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### Germany

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<tr>
<th>Name of stakeholder</th>
<th>Type of stakeholder</th>
<th>Date</th>
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### Europe

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<tr>
<th>Name of stakeholder</th>
<th>Type of stakeholder</th>
<th>Date</th>
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<tbody>
<tr>
<td>Plastics Europe</td>
<td>European association of plastics manufactures</td>
<td>23.08.2012</td>
</tr>
<tr>
<td>EPRO</td>
<td>European association of plastics recycling and recovery organisations</td>
<td>13.09.2012</td>
</tr>
</tbody>
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The four country reports are enclosed as annex A to D:

Market conditions for plastic recycling

An overview of the market conditions for plastic recycling in Denmark, Finland, Latvia and Sweden as well as characteristics of the European market in general are presented in this section. The information presented here was compiled from the country-specific background reports in Annex A-D, if no other source has been stated. The aspects describing the markets included waste quantities, qualities, domestic demand and export. Main barriers and market trends were also identified. Common for all investigated markets is that there is a potential to increase waste plastic recycling from domestically generated waste plastic. Barriers preventing this development are seen as: low or fluctuating volumes of waste plastic collected combined with poor quality/homogeneity of sorted and collected material. As a consequence of unstable domestic supply of waste plastic much waste plastic is being exported.

Overview of waste plastic generation and recycling

Generated waste plastic ends up in disparate treatment facilities and/or management options depending on the country concerned. The most commonly applied options are: material recycling, incineration (includes energy recovery) and landfills. In accordance with the overarching goals of Plastic Zero, the primary focus in this report has been placed on material recycling. Table 1 below gives an overview of estimated waste plastic generation in the respective participating country as well as the amounts being recycled based on background data from the survey of plastic waste in the participating cities (action 1.2 in the project).

Table 1: Generated waste plastic and material recycling 2009 (based on data from action 1.2).

<table>
<thead>
<tr>
<th>Country</th>
<th>Waste plastic/tonnes</th>
<th>Material recycling/tonnes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>309,000</td>
<td>76,000</td>
</tr>
<tr>
<td>Finland</td>
<td>208,000</td>
<td>38,000</td>
</tr>
<tr>
<td>Latvia</td>
<td>63,000</td>
<td>14,000</td>
</tr>
<tr>
<td>Sweden</td>
<td>364,000</td>
<td>129,000</td>
</tr>
<tr>
<td>EU27+N+CH (2010)</td>
<td>24,700,000</td>
<td>6,000,000</td>
</tr>
<tr>
<td>(Plastics Europe 2011)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1 indicates that the material recycling rates are in the region of 20-35 % of the total generated waste plastic in the participating countries as well as in the EU. Since plastic packaging waste accounts for the largest fraction of total generated waste plastic, it does remain appropriate to infer from Table 1 that meeting the goals, as stipulated in EU Directive 2008/98/EC, will require further progress in material recycling rates.

Exports

The flood of waste plastics out of the European Union continues unabated. According to the most recent figures from Eurostat, the European statistics office, the 27 EU Member States exported around 3.36 million tonnes of "waste, parings and scrap of plastic" to destinations outside the EU in 2011 (EUWID 2012). The export shipments were nearly all destined for Asia, with the largest part of those being sent to East Asia. The development in amounts exported to the main destinations in Asia is shown in Figure 1. Nearly 87 % of the waste plastics exported from the EU were imported by China and the Chinese special administrative region of Hong Kong. The data appears to show a shift in recent years to favour direct exports to China. Exports to India and Malaysia have also risen sharply. As in the past, the lion's share of European waste plastics exports in 2011 consisted of PE. Waste PE shipments from the EU to China and Hong Kong alone reached 1.6 million tonnes last year (EUWID 2012).
Figure 1: Extra-EU27 trade: Export to five Asian countries (Eurostat 2012a)

In September 2012, the Chinese Ministry of Environmental Protection put forward proposals to implement a ban on unwashed post-consumer plastic material from entering Chinese facilities, as well as banning the sale of imported waste plastic to a company other than those approved to import the material (LetsRecycle 2012a).

Since early September 2012, the Malaysian government has banned imports of solid waste plastic from the EU (LetsRecycle 2012b). The reason for the ban is not known, but according to letsrecycle.com, it is thought to be connected to the quality of waste plastic coming from the EU.

China already has a considerable domestic market for recycling its own waste plastic. In 2011 around 15 million tonnes of waste plastic of Chinese origin was recycled which is much higher than the 8 million tonnes the country imports (Plasticker 2012a). A total of 23 million tonnes of secondary materials were available at the Chinese market.

Reliable statistics on export quantities from the respective markets in the participating countries are scarce and often fragmentary in their availability. Therefore it is advised to consider the numbers stated hereafter lightly and instead consider the underlying causes claimed to exacerbate or improve exportation.

**Denmark**
More than 80% of collected waste plastic is being exported, primarily to Sweden and Germany. A lack of advanced sorting facilities in Denmark is stated as being the primary cause for the export of mixed and contaminated waste plastic, in particular. Most of the waste plastic is assumingly exported to Germany or Sweden, however, this was not verified by statistics due to insufficient data available. Additionally, China and Hong Kong are the two main destinations outside Europe for Danish waste plastic and they collectively accommodated 8,198 tonnes in 2011.

**Finland**
Approximately 50% of the annually recycled waste plastic is estimated to be exported. Exports are due to a low domestic demand for recycled plastic. Exporting is considered a profitable solution.

**Latvia**
Latvia does not export waste plastic for recycling as is the case for most other countries. Instead, the country imports waste plastic for the reprocessing (recycling) industry. The reprocessed material (pellets, granulate or other) is then exported to plastic producers. Most reprocessors are specialised in particular waste plastic types and it is reflected in the types of waste plastic that is being imported.
Sweden
Exports of recycled plastic in Sweden tend to go to Germany and more broadly the EU market. Price is claimed to be the driver of exports of recycled material. Two of the interviewed stakeholders stated an estimated 50-55% of their recycled output as being exported to Germany.

Costs and capacity
Common for Denmark, Finland and Sweden is the supply of waste plastic to be volatile and fluctuating. This situation has given rise to significant uncertainties when evaluating the economical viability of existing and/or planned future recycling facilities. In Denmark there are examples of recycling facilities being closed down as a consequence. Further, Denmark does not have a producer responsibility scheme which has stimulated plastic recycling in other member states.

Latvia has taken a different approach as significant imports from EU supply domestic recycling facilities and as such eradicates the risks associated with domestic volatility of available input material.

Quality and demand
Common for recyclers and consumer in all markets is a demand for high quality input/output material. An additional point shared in all markets is specialization undertaken by recyclers toward particular waste plastic types and/or streams which in turn aims to match the demand for output material quality.

Denmark
Currently Danish domestic demand for recycled plastic is estimated as being low as plastic manufacturers in Denmark mainly produce technical plastic products or advanced products, e.g., used in the medical industry. Recycled plastic does not meet the quality criteria of these producers/products.

Finland
Finnish domestic demand for recycled plastic is estimated as being low. It is further claimed that only certain kinds of products can be made from recycled plastic which impedes its potential usage in certain applications.

Latvia
Demand for Latvian recycled plastic is driven by plastic producers to which the recyclers sell their output. An average contamination level of 10-12% is estimated to be present in the total input material; while around 1% is considered to be non-recyclable. The price of output material is determined by its quality.

Sweden
Stakeholders interviewed for the Swedish market stated that demand is driven by the lower price of recycled plastic relative to the price of virgin plastic. Contemporary market demand tends to be on higher quality output material relative to prior years. In this context recyclers stressed the importance of matching the quality of input material to the demand for output material quality.

Main barriers to plastic recycling
In Denmark, Finland and Sweden barriers are manifested as low volumes and/or fluctuating supply of input material as well as low quality of the received material. Latvian concerns are on price of input material, its contamination level and general recyclability.

The European perspective echoes the national markets: small volumes are problematic, especially so in small countries (Interview: EPRO 2012). Exports to Asia in that context are particularly attractive. Furthermore, it is noted that infrastructure/technology is not sufficiently developed and in need of further investments (Interview: Plastics Europe 2012). Citizens need to be more participatory in the recycling schemes and the choice of collection systems is an important consideration with great impact on plastic recycling. Standards on plastic in contact with food, as set by the European Food Safety Agency, are stringent and disfavours the use of recycled plastic.

Denmark
Danish interviewees identified two main barriers to increasing plastic recycling. The first concern is associated with economical risks related to establishment of plastic recycling facilities in a small country with relatively small volumes of waste plastic. With unstable and
low domestic supply it might be difficult to get sufficient amounts of waste plastic for the facility to become economically viable. The incentive for establishing recycling facilities in other countries has been the producer responsibility scheme on packaging, which does not exist in Denmark. The second concern raised involves high production costs coupled with a low domestic demand for the resulting output material. Yet another barrier concerned the high costs of labour associated with sorting facilities as manual labour is to some extent still needed and the wage level is regulated.

**Finland**
Key barriers identified in Finland concerned low volume and quality of input material available for recyclers. Similar to Denmark domestic demand for recycled plastic was also considered to be low. Several barriers were examined concerning the whole chain of waste plastic generation to the end-use of the recycled material. Here, paraphrased for brevity: Disparate materials combined and used in the production process complicate recycling. Recycling has a subordinate position to for example functionality. Sorting of waste plastic is insufficiently conducted at a myriad of generating sources. Logistic issues and costs associated with being geographically a large country with low population density. There is a lack of reliable statistics on potentially recyclable material. Recycled material needs to meet quality standards of virgin plastics while keeping a competitive pricing. Recycled plastics cannot fill all applications that virgin plastic occupies today. Quality assurances and clarifications on recycled material are needed for food packaging and additives included in the REACH directive, respectively.

**Latvia**
Latvian concerns as a net-importer of waste plastic has to do with the price of input material, contamination level of the received material (averaging at 10-12 %) and the fraction received that is unsuitable for recycling (averaging around 1 %).

**Sweden**
Identified Swedish barriers closely resemble the Finnish concerns. Further, there seems to be a brewing bifurcation in waste management strategies where interests in material recycling and in waste incineration with energy recovery collide.

**Market trends**
Various stakeholders expressed rather optimistic views on the future for plastic recycling in Europe. However, none expressed expectations of radical changes in the current business.

**High quality**
Swedish stakeholders see a robust and growing international and EU27 market with emphasis on a demand for high quality output material. Consequently, the view of market trend is one expecting a wider integration of recycled plastics into more applications. Demand for high quality output materials is expected to increase. EU support for the end-of-waste criteria was met with ambivalence, as it is seen as potentially facilitating some procedures while potentially complicating others. The end-of-waste criteria are further discussed in the section about Quality criteria and the use of standards.

**Legislation**
Legislation is seen as one of the drivers for encouraging recycling of waste plastics. The new recycling targets set in the Waste Directive are currently being implemented in the member states. In the case of Denmark, this is assessed to be an important driver, because there has not been a producer responsibility scheme in place to encourage collection of waste plastic. The municipal waste management plans are under current revision and are likely to include and establish collection of mixed waste plastic from households which will boost further input material volumes potentially made available for recyclers. In the case of Finland, legislation on the future direction of producer responsibilities are currently under negotiation and once finalized will have a great impact on plastic recycling.

**Environmental concerns**
From the European perspective, plastic producers are seeking to address environmental concerns associated with waste plastic (Interview: EPRO 2012). This is done by reducing the amount of material used in products, improving and increasing efforts on recyclability and/or substituting plastics for bio-plastics. Various tools and audit schemes can be applied in order to reduce the environmental burden of production and consumption and create a ‘greener’ imager of a product. This also applies to plastic products, which for example are attacked for not being carbon-neutral and are visible signs of the consequences of littering (Interview: EPRO 2012). However, the trends within product design, in relation to environmental aspects
and demand for ‘green’ products, were not further investigated in this survey. Some of the environmental accepts are covered in the project's Action 2.1 about waste prevention. Expectations to developments of new plastic materials are further elaborated on in section about Technologies.

**Expanding markets**

Market trends identify a potential for increasing recycling of residual waste from households and commerce as well as from the construction and demolition industry. One example is the introduction of the 'Gelbe Tonne Plus' which includes non-packaging products in the existing packaging collection schemes (Interview: Interseroh 2012).

It is further claimed that the EU recycling infrastructure is changing towards more effective recycling of other plastics types than PET (Interview: Plastics Europe 2012). This development can be seen as a logical expansion, since the demand for PET is virtually satisfied in the contemporary market. However, more investments are needed to concretize this vision of expansion. Additionally critical mass for alternative waste plastic streams does remain a precondition for economic viability of recycling facilities and its materialization may prove to be another barrier.

Take-back schemes exist for certain products such as carpets and furniture and could be a possibility for a broader range of products. If take-back schemes will play an important role in the future is uncertain, and no clear trend this regard was identified. However, this could be a future opportunity for creation of local treatment facilities as the pre-treatment of waste could be performed locally which in turn would lower transport costs.
Quality criteria and the use of standards and specifications in the plastic recycling sector

Sorting and quality

The options for use of recycled plastic depend on the quality and polymer homogeneity of the material. The material properties are the dominant market concerns. A clean, contaminant-free source of a single polymer recycled waste plastic has more end-use options and higher value than a mixed or contaminated source of waste plastic. The use of recyclates is heavily dependent on demand, which is influenced by the price of virgin material, as well as the quality of the recycled polymer. The aim of the recycling industry is generally to keep the same application for a plastic material as the one it had, as in this way it is easier to make use of the properties of the polymer and its additives and meet the requirements needed for technical or legislative reasons. However, it is not easy to obtain homogenous waste plastic streams. Mixed plastic systems are less expensive but are dependent on still imperfect but continuously evolving separation technologies (JRC 2012).

The scope of ‘waste plastic recycling sector’ and what quality criteria are used in the sector is in this overview mainly focused on post-consumer waste plastic. Post-consumer waste is considered to correspond with the plastic content of Municipal Solid Waste collected from households and commerce together.

The transformation of waste plastic into recyclates takes place in several steps of handling the waste plastic: Collection, sorting, baling, crushing, reprocessing, conversion and manufacturing of new plastic products.

In this description the focus is on the interface between pre-treatment and reprocessing. Pre-treatment refers mainly to collection and presorting, while the reprocessing activity is the production of recyclates like pellets, regrind and flakes taking waste plastic as an input, but it can also involve melting and extrusion with regranulates and profiles as output (JRC 2012). In Germany, as an example, recyclates are often defined as: Regrind, agglomerates, granulate and compounds (DKR 2004, Interview: BVSE 2012, Interview: Interseroh 2012). These categories are defined with reference to the way of reprocessing the waste plastic material, see Table 2.

<table>
<thead>
<tr>
<th>Table 2: Definition of recyclates categories (DKR 2004, Interview: BVSE 2012, Interview Interseroh 2012)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Regrind</strong></td>
</tr>
<tr>
<td><strong>Agglomerate</strong></td>
</tr>
<tr>
<td><strong>Granulate</strong></td>
</tr>
<tr>
<td><strong>Compound material</strong></td>
</tr>
</tbody>
</table>

Sorting categories

A basic distinction of waste plastics is often:
- Flexible plastic/film
- Rigid plastic
- PVC
- Other plastics

It is important to keep flexible material separate from rigidis. Flexible packaging (for example films and single use carrier bags) is difficult to separate mechanically and commonly results
in lower-grade bales being produced; the earlier in the process it can be separated the better (WRAP 2012a).

Different regional or national collection schemes of municipal waste define their own categories, which could as well be product definitions such as bottles, pots, cups and trays, toys, hollow bodys etc. In Germany, the sorting categories used are suited for line floating sorting technology: Hollow bodies, foils, PET bottles, mixed plastics (Interview: BVSE 2012).

For each category a further sorting will be by:
- Polymer type
- Colour (transparent or jazz)
- Purity

For polymer type the most common grades are: PP, PE (HD-PE, LD-PE), PET, PS and PVC. 75% of the demand on plastic recyclates in Europe is covered by these five polymers (JRC 2012). Technical polymers such as ABS used for toys (e.g. LEGO), car parts and CDs and PBT and POMS used for construction materials are also recyclable. They are very valuable, but it requires special qualifications to sort and recycle the technical plastics (Interview: BVSE 2012). Recycled technical polymers gives a much higher price than standard polymers, and granulates are more valuable than regrinds. The price structure is elaborated on in the section about Prices.

Which target polymer a plastic recovery facility (PRF) will sort out depends on the technology of the plant, the costs of sorting to higher grades, the demand of the target polymer and the price that can be obtained. For example in the United Kingdom, PRFs tend to exclude PVC, multi-layer plastics and engineering plastics such as ABS, which is found, for example, in waste electrical and electronic equipment (WEEE) and toys. (WRAP 2012a)

Waste plastic must be sorted in specific polymers, because the different types of plastics tend to phase-separate, like oil and water, when they are melted together. The phase boundaries cause structural weakness in the resulting material, meaning that polymer blends are useful in only limited applications.

Colour is also an important criterion. If the end use requires transparent resins, the recycled resin should be produced from transparent plastic. Transparent recycled resins are difficult to obtain from a mixed colour input. Therefore, recycling of transparent plastic is often set up in closed loops (JRC 2012). Colour determines value as well – transparent polymers like LDPE will pay the highest price (see section on Prices). Black rigid packaging, for example food trays, continues to be a challenge to identify and positively sort in MRFs and PRFs as the carbon black colorants prevent the plastic from being detected by the optical sorting equipment. The result is that black plastic often ends up in the residual waste stream (WRAP 2012a).

Purity refers to what content of other polymers and non-plastics/impurities that are accepted. In the first step of collecting and sorting it is important to obtain a pure stream of one or two polymers for recycling. Inefficient sorting leads to mixed plastic material not being recycled – or downcycled. Some polymers are unfortunate to mix, as an example there is a risk of cross-contamination between PVC and PET (JRC 2012). In addition, the waste plastic should be clean. Non-plastics should be removed. Contamination from food and other substances should be washed off.

Quality and price

Basically, it is the world market demand of recycled plastics that defines the price and quality of waste plastics, which was confirmed by the stakeholder interviews. The preceding collection and sorting will set the limits for how well the quality requirements of purchasers can be met. The economics of any recycling process depends on the yield of useful material that can be achieved from the feed material; for instance the proportion of the higher-value polymer types (such as PET, HDPE, LDPE) that a bale contains. Contaminations with non-targeted polymer (e.g. film in a rigid plastic stream) or paper can lower a value of a mixed plastic bale from 5% to 35%. Top end prices are only achieved for mixed bales if PET and HDPE bottles have not been extracted from the mixed plastic stream for separate sale (WRAP 2012a). Processing costs are determined by quality of the material, the type of polymer, the facility for reprocessing and technologies used (JRC 2012). Furthermore, quality analyses add to the costs of reprocessing, possibly decreasing the competitiveness of recycled polymers.
**Quality criteria and standards**

When waste plastic is traded between supplier (collection and presorting activity) and reprocessor there are several ways of specifying the quality of the product, ranging from business-to-business specification of batch characteristics to a detailed contract based on standardized specifications of national standards and/or common European or international standards. The basic categories of polymer, purity and colour will mostly be included in specifications.

Below, an overview of European and international standards and examples of national standards and of the actual practices of trading waste plastic between supplier and reprocessor will be presented. The overview and the examples should be considered non-exhaustive.

**European quality standards and specifications**

**The European Standards**

Technical specifications and standards can be used in the industry to create references for price-setting, for classification and for quality control. There exist a wide number of quality standards and technical requirements for waste plastic, recyclates and recycled plastic end-uses. Standards provide the test specifications and test methods (interoperability, safety, quality, etc.) They are voluntary, consensus-based and as such do not impose any regulations. However, laws and regulations may refer to standards and even make compliance with them compulsory. In the European Union, Directives, Regulations and other EU legislation may refer to European Standards.

EN standards are provided by CEN, the European Standards organization. CEN cooperates with ISO, the international counterpart in standards, adopting the same text for mutual ISO and EN standards. CEN has 33 national members. In the member states, an EN standard is issued via national standard bodies. EN standards replace national standards for the product in question. It is – as said above – not mandatory for a product or material to be in conformity with a relevant standard (CEN 2012). To meet the requirements of a given EN standard is solely to be decided by the manufacturer.

A list of EN Standards and specifications relevant for waste plastic is shown in Table 3. Two main groups of technical specifications and standards can be applied for waste plastic for recycling (JRC 2012):

- Specifications and standards on waste plastic; i.e. input material to reprocessing, and to some types of converting.
- Specifications and standards on waste – plastic-based intermediates (e.g. regranulates) - which are output materials from reprocessing and are used as input for the converting industry.

**Table 3: Common standards used for recyclates in EU (JRC 2012, table 2.37)**

| EN 15342 | Plastics. Recycled plastics. Characterization of polystyrene (PS) recyclates |
| EN 15343 | Plastics. Recycled plastics. Plastics recycling traceability and assessment of conformity and recycled content |
| EN 15344 | Plastics. Recycled plastics. Characterization of polyethylene (PE) recyclates |
| EN 15345 | Plastics. Recycled plastics. Characterization of polypropylene (PP) recyclates |
| EN 15346 | Plastics. Recycled plastics. Characterization of poly(vinyl chloride) (PVC) recyclates |
| EN 15347 | Plastics. Recycled Plastics. Characterization of plastics waste |
| EN 15348 | Plastics. Recycled plastics. Characterization of poly(ethylene terephthalate) (PET) recyclates |
| prCEN/ TR 15353 | Guidelines for the development of standards relating to recycled plastics |
| EN 13430 | Packaging. Requirements for packaging recoverable by material recycling |
| EN 13437 | Packaging and material recycling. Criteria for recycling methods. Description of recycling processes and flow chart |
| ISO 16103 | Packaging. Transport packages for dangerous goods. Recycled plastics material |
| ISO 15270 | Plastics – Guidelines for recovery and recycling of waste plastic |

For the Plastic Zero project the first category is the most relevant as it addresses the interface between collection and reprocessing of waste plastic. EN 15347 of the first category provides “the characterization of waste plastics laying out those properties for which the
supplier of the waste shall make information available to the purchaser”. The characteristics of a batch of waste plastic are either required or optional, see Table 4. Specification and standard deviation or range of values within and between batches of material are agreed between supplier and purchaser.

The second category of standards is mainly for recycled plastics and end-uses. They characterize plastic material at a secondary raw material stage, for example for regranules, flakes or pellets, after reprocessing. EN standards for specific recyclates, as shown in Table 3, define quality parameters for a specific recyclate, which can be mandatory or optional, and the relevant test procedures, the limit values for each parameter must be agreed between the supplier and the purchaser. Thus, in practice more specific requirements may be added to these standards. Purchaser’s specifications often involve higher quality requirements, and the burden of testing is usually placed on the reprocessor, sometimes with the quality insurance provided by third party organization/external audit. Each standard includes cross-references to other relevant ISO and EN standards. The EN 15347 refers to all other EN 15342-48 standards, which are all listed and described briefly in Annex E.

<table>
<thead>
<tr>
<th>Property</th>
<th>Status (test method)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batch size</td>
<td>Required (weight or volume)</td>
</tr>
<tr>
<td>Colour</td>
<td>Required (visual assessment)</td>
</tr>
<tr>
<td>Form of waste</td>
<td>Required (e.g. flake, film or bottle)</td>
</tr>
<tr>
<td>History of waste</td>
<td>Required (EN 15343)</td>
</tr>
<tr>
<td>Main polymer present</td>
<td>Required (percentage by weight if known)</td>
</tr>
<tr>
<td>Other polymers present</td>
<td>Required (percentage by weight if known)</td>
</tr>
<tr>
<td>Type of packaging in which the waste is present</td>
<td>Required</td>
</tr>
<tr>
<td>Impact Strength</td>
<td>Optional (EN ISO 179-1 and EN 179-2 or EN ISO 180)</td>
</tr>
<tr>
<td>Melt mass flow rate</td>
<td>Optional (EN ISO 1133)</td>
</tr>
<tr>
<td>Vicat softening temperature</td>
<td>Optional (EN ISO 306 method A)</td>
</tr>
<tr>
<td>Additives, contaminants, moisture, volatile</td>
<td>Optional</td>
</tr>
<tr>
<td>Ash content</td>
<td>Optional (EN ISO 3451-1)</td>
</tr>
<tr>
<td>Moisture</td>
<td>Optional (EN 12099)</td>
</tr>
<tr>
<td>Tensile strain at break</td>
<td>Optional (EN ISO 527, parts 1 to 3)</td>
</tr>
<tr>
<td>Tensile strain at yield</td>
<td>Optional (EN ISO 527, parts 1 to 3)</td>
</tr>
<tr>
<td>Volatiles</td>
<td>Optional (Weight loss at a process temperature)</td>
</tr>
</tbody>
</table>

The EN standards for recycled plastic, EN 15342-48 and CEN/TR 15353, should be used by auditors for assessing recyclers for EuCertPlast certification (see below). The CEN/TR 15353 is a Technical Report that provides a format for the drafting of standards for recycled plastics. It is intended for use by all those who are preparing drafts for consideration by the Technical Committee. The guide provides information for the development of standards (guides, practices, test methods, and specifications) relating to the proper use of recycled plastics. All standards should incorporate considerations of environmental aspects in accordance with the guidance issued by CEN and ISO. Those general environmental aspects that are common to all recycled plastics are included in these guidelines and may be referenced in other documents.

The European Food safety Agency sets the standards for plastic in contact with food which are rather strict. Food contact for recycled plastic has to comply with specific EU regulation (Regulation 282/2008/EC and Regulation 1935/2004). As waste plastic may be contaminated by substances from the previous use or by substances originating from non-food grade plastic, there are very specific input characterization and required cleaning processes. At national level it is seen that the use of recycled plastic (regranulates) for food is prohibited, even if the material has exactly the same technical qualities as virgin material (Interview: Interseroh 2012). Hence, it is not likely, that waste plastic originating from MSW will be used for food grade plastic.

_EuCertPlast - new EU certificate_

EuCertPlast is a European Certification for post-consumer plastics recyclers who are recognized for operating in compliance with high quality standards (EuCertPlast 2012a).
The certificate should serve as a harmonized auditing scheme for Europe and thus overcoming difficulties in gaining access to waste plastics from the different and often complex national systems. Further it should increase customers’ confidence that recycled products are environmentally friendly and in compliance with national legislation. The certificate is supposed to be requested by purchasers of post-consumer plastic recyclates from their suppliers.

The certification is based on existing European Standards and audited according to best available German auditor scheme (EuCertPlast 2012b). Standards that will be used by auditors in assessing the recycling process include EN standards no. EN 15342-48, guideline CEN 15353 and vocabulary EN-ISO 472. Content of the certificate will include the input polymer(s) for the recycling process and whether it is for flexible or rigid input waste plastic, and the recycled output produced, showing the polymer and physical nature of the material (flake, pellet, agglomerate, micronized powder etc). Further, means of traceability should be established. This requirement caused some discussions, due to the storing of input waste plastic often being mixed with regards to supplier (for same polymer). The solution to this was to ensure traceability to batches of input waste in same storage bay (EuCertPlast 2012a).

The EuCertPlast certificate was launched in July 2012. There remains yet to build competences and organisations to actually carry out the certification. A Blue Angel scheme will implement the certificate from 2013.

**European PET Bottle Platform**

The European PET Bottle Platform (EPBP) is a voluntary initiative, aimed at the packaging industry, which has established test procedures to assess the recycling profile of new packaging technologies such as barriers, additives, closures, labels, etc. Products passing these tests will be given approval for recycling. The platform has also developed PET recycling guidelines, describing the different materials allowed or not in the bottle components (body, label, cap) (JRC 2012).

**End-of-waste criteria**

The European Commission is establishing end-of-waste criteria for a number of specific recyclable materials including metal scrap of copper, aluminium and iron, waste paper, waste glass, compost, and plastics. End-of-waste criteria specify when certain waste ceases to be waste and obtain a status of a product (or a secondary raw material). A consignment of waste plastic ceases to be waste when the producer of the waste plastic certifies that all of the end-of-waste criteria has been met. According to Article 6 (1) and (2) of the Waste Framework Directive 2008/98/EC, certain specified waste shall cease to be waste when it has undergone a recovery (including recycling) operation and complies with specific criteria to be developed in line with certain legal conditions.

A final report with the technical proposals for end-of-waste criteria for plastics is expected for the end of 2012. The following presentation of end-of-waste criteria is based on the second draft of criteria from the JRC technical working group. According to the proposal waste plastic should cease to be waste when (JRC 2012):

- “Waste plastic complies with industry specifications for a waste plastic grade for which there is a market or demand for plastic conversion;
- Waste plastic includes precise information about the type(s) of polymer(s) contained, the additives contained (as these are required by REACH, RoHS or the food contact legislation once the plastic becomes a product), and has a known maximum content of non-plastic components and unusable plastic types. Other properties of interest to the buyer such as moisture, density or melt mass flow rate may be added as non-compulsory information;
- Waste plastic has not hazardous properties;
- Waste plastic is during processing not in contact with certain waste types that can cause cross-contamination, e.g. biowaste, oil waste, waste solvents, health care waste or mixed municipal solid waste;
- The producer of waste plastic provides documentation of the fulfilment of all conditions above, and supplementary information concerning the limitation of use to plastic manufacturing.”

**Expected benefits**

The following main benefits can be expected when EU-wide end-of-waste criteria for waste plastic are introduced (JRC 2012):
• Clearer differentiation of the high-quality waste plastic, and recognisable distinction to lower-quality waste plastic. Certainty that only high-quality waste plastic will cease to be waste. This confirms additionally the waste status for low-quality waste plastic, and the reasons for keeping it;
• Improved functioning of the internal and external markets to the EU (simplified and harmonised rules across countries, increased legal certainty, increased transparency and reliability on quality assured shipments);
• Reduction of administrative burdens related to shipment, transport and trade that are redundant for environmentally safe materials.

Finally, end-of-waste criteria are expected to contribute to a higher share of material led to recycling instead of landfiling or incineration.

Proposed criteria
The proposal for the End-of-waste criteria as of April 2012 is shown in the box below (JRC 2012):

1. Quality of waste plastic resulting from the recovery operation

1.1 The waste plastic shall comply with a customer specification, or an industry specification for direct use in the production of plastic substances or objects by remelting in plastic manufacturing facilities.

The following standards on characterisation of plastic recyclates shall be used:
• For polystyrene: EN 15342 Plastics. Recycled plastics. Characterization of polystyrene (PS) recyclates
• For polyethylene: EN 15344 Plastics. Recycled plastics. Characterization of polyethylene (PE) recyclates
• For polypropylene: EN 15345 Plastics. Recycled plastics. Characterization of polypropylene (PP) recyclates
• For poly(vinyl chloride): EN 15346 Plastics. Recycled plastics. Characterization of poly(vinyl chloride) (PVC) recyclates
• For poly(ethylene terephthalate): EN 15348 Plastics. Recycled plastics. Characterization of poly(ethylene terephthalate) (PET) recyclates

1.2 The non-plastic component content shall be ≤ 1 % of air dried weight. (1 % is set as a fictive value that has to be discussed in the JRC Technical Working Group). A non-plastic component is any material different from plastic, which is present in waste plastic. Examples of non-plastic components are metals, paper, glass, natural textiles, earth, sand, ash, dust, wax, bitumen, ceramics, rubber, and wood, except when these materials are integral constituents of the plastic structure in fillers and reinforcements such as minerals, glass fibres or wood fibres.

1.3 The waste plastic, including its constituents, shall not display any of the hazardous properties listed in Annex III to Directive 2008/98/EC. The waste plastic shall comply with the concentration limits laid down in Commission Decision 2000/532/EC207, and not exceed the concentration limits laid down in Annex IV of Regulation 850/2004/EC

1.4 Waste plastic shall not contain oil, solvents, glues, paint, aqueous and/or fatty foodstuffs, that can be detected by visual inspection.

2. Waste used as input for the recovery operation

2.1 Health care waste, and used products of personal hygiene shall not be used as input.

3. Treatment processes and techniques

3.1 Waste plastic streams used as input shall, once received by the producer or importer, be kept permanently separate from the contact with any other waste, including other waste plastic grades.

3.2 All treatments needed to prepare the waste plastic for direct input to manufacturing of plastic products, such as debaling, sorting, separating, size-reducing, cleaning, melting, filtering, regranulating, or grading, shall have been completed.
REACH and end-of-waste criteria
If risk substances are present in plastic products, REACH is to ensure the provision and environment and health information throughout the supply chain. Once the plastic products are used and become waste, this information chain is broken. Reprocessors and especially converters have to reestablish the information chain, in the first place by characterizing thoroughly the recycled plastic output. If the plastic should cease to be waste certain information is necessary in order to prepare safety data sheets to accompany recycled material (JRC 2012).

Other international quality standards and specifications

ISO standards
ISO is an international standards organisation that since 1947 has published more than 19,000 International Standards covering almost all aspects of technology and business (ISO, 2012). ISO is a network of national standards bodies. These national standards bodies make up the ISO membership and they represent ISO in their country. ISO standards are in some cases equal to European standards, thus the EN is an ISO-EN standard (see Annex E, the EN 15347 standard with reference to other EN and EN-ISO standards).

ISRI specifications (USA)
The US Institute of Scrap Recycling Industries (ISRI) issues yearly the so-called “Scrap Specifications Circular” which provides standard specifications intended to assist in the international buying and selling of reclaimed materials such as plastics. The specifications are constructed to represent the quality or composition of the materials bought and sold in the industry. The standards define different grades of plastics, using a grade code and a brief verbal description. They also define contamination thresholds. The ISRI standards categorise contamination in plastics as (WRAP 2009):
- allowable contamination (easily removed materials such as cans, cardboard etc); and
- prohibited material, which refers to hazardous wastes, highly flammable materials, all free-flowing liquids and plastics detrimental to the production process.

ISRI specifications are not used in general in Europe, nor in trade between Europe and Asian countries (JRC 2012).

ASTM standards (USA)
ASTM International (former American Society for Testing and Materials) provides a global forum for the development and publication of international voluntary consensus standards for materials, products, systems and services. 30,000 technical experts from 135 countries around the world serve on one or more of ASTM’s 145 technical committees, developing standards for a broad range of areas, including metals, paints, plastics, textiles, petroleum, construction, aviation, energy, the environment, consumer products, electronics, medical services and devices, computerized systems, homeland security and much more (ASTM, 2012). ASTM has published 248 standards for products with a content of recycled plastic.

ASTM is, like ISRI, one of several standardization organisations of USA. These organisations are often specialized and thus it is very likely that they have developed standards that are not available in Europe. According to Danish Standards, if no European standard exists, it can be advisable to check the US standards for inspiration.

Chinese standards
Some waste plastic is shipped abroad, mainly to China and especially Hong Kong, mostly after the collection and grinding stage, and not after reprocessing. A Chinese standard GB 16487.12-2005 has been developed to specify the forbidden and allowed importation of waste plastic (JRC 2012).

National Quality Specifications
EN ISO standards are often recognized European wide or even worldwide in all parts of recycling, e.g. sorting, processing, storage, shipping. EN ISO standard 15347, characterization of waste plastic, is a very general formulation of how to handle waste plastic and leaves a high degree of freedom between buyer and seller to detail the quality. Many European member states have made additional specifications of limits and categories of waste plastic in order to facilitate trade between collectors/brokers and reprocessors. Mostly, purchasers and sellers of waste plastic materials prefer to do their own bilateral
specifications, based often on standards and adapted to the specific trade. Hence, the existing common European standards are not widely used in the plastic recycling sector, according to interviews and country reports carried out in the Plastic Zero project and according to WRAP (WRAP 2012a).

In the following national examples there is no explicit reference made to EN standards. However, the basic structure and content of EN standards could be mirrored both in business-to-business agreements and in national standards and guidelines.

Germany
In Germany, Der Grüne Punkt - Duales System Deutschland GMBH, was founded in 1990 as the first dual system providing take-back systems (Der Grüner Punkt 2012). Der Grüner Punkt has become a trade mark of the producer responsibility for commercially organized systems. These systems organize the collection, sorting and recycling of packaging waste, and ‘the Green Dot’ signals that the circulators of the sales packaging contribute to the financing of the recycling. Der Grüner Punkt operates in 31 European countries and Canada. Where Green Dot operates, it carries out quality controls of the waste, and if the material is not in accordance with regulations, the financial incentive for the collector is reduced. Der Grüner Punkt provides product specifications for waste plastic through DKR (Deutsche Gesellschaft für Kreislaufwirtschaft und Rohstoffe mbH). DKR has made specifications for 12 different polymers, in total 16 specifications including different purities (DKR 2012). DKR specifications are valid for packaging materials and should be used by sorters that supply plastics recyclers. The specifications are basic for the recyclers to accept waste plastic for further processing. Details of DKR specifications and examples of business-to-business specifications are given in Annex F.

United Kingdom
In contrast to Germany, the United Kingdom has no long tradition for sorting waste and recycling of waste plastics. As for Germany and other European countries, the EN standards have been implemented by the British Standards Institute, but are not widely used.

Recently, the national PAS-103 specification has been developed by WRAP together with the British Plastics Federation Recycling Council and the British Standards Institute (WRAP 2012b). PAS-103 outlines some of the main contaminants and also the clarification and grading process for plastics. It applies at the stage between the plastics trader/collector and the reprocessor. It is not to be considered as a British Standard. PAS 103 applies to unprocessed waste plastic packaging for mechanical recycling. It is built around a visual inspection methodology and an inspection sheet that lists original use of material, contamination etc. The PAS states that visual inspection is to be preferred on cost grounds, but that sorting may be required in the case of disputes (Details in Annex G).

According to WRAP (WRAP 2009), the PAS 103 has some flaws that make it difficult to use. It is counter-intuitive, which could be the reason for most reprocessors saying that they did not make much use of PAS 103, and did not use the labelling system it advocated. The WRAP report concludes that MRFs and reprocessors are carrying out materials quality analysis that, while perhaps useful for internal monitoring or decision making, is not standardised enough to be comparable with data from other MRFs or reprocessors. This lack of a level playing field where material quality might be assessed and compared is a potential impediment to smooth functioning of materials markets.

Some stakeholders have called for consistently applied grading system for baled material, starting from clearly defined end market requirements. Standardised bale characteristics can raise quality and increase yields, so that the United Kingdom reprocessors would have improved certainty around what they are buying and the value they can add (WRAP 2012a).

Details of PAS-103 and examples of other types of specifications used in the United Kingdom are given in Annex G.

Denmark
The market for recycling waste plastic is very limited in Denmark, as described above in the section about market conditions. Only a few industrial enterprises are engaged in sorting recycling of waste plastics. Examples of business-to-business quality specifications used in Denmark are given in Appendix H.
**Latvia**
The recyclers accept waste plastic according to their own criteria. The recyclable plastics must be sorted by polymer types and colours. The reprocessors/recyclers postulate strong quality criteria by which the delivered waste plastics must comply, in order to force suppliers to put more efforts into delivering good quality (sorted and uncontaminated) if they want a higher price.

**Finland**
Quality requirements for recyclable materials are very high. Certain polymer flows can be recycled only as pure material flows. Sorting pure polymer fractions from mixed waste plastic is practically impossible with available technologies in Finland. Plastic used in recycled plastic products does mainly originate from industrial rejetms. A new Waste Act with full producer responsibilities for packages will increase the push for recycling; however, recycling plastic packaging from households will remain a challenging issue.

**Can standards prevent deterioration and downcycling of waste plastics?**

**A need for standards?**

Though most EU member states have established standards institutes that are members of CEN and thus (should) have implemented all common EN standards, the most likely situation is the use of business-to-business specifications. For instance in Germany, at the stage of recyclates, the only valid criteria are qualities fixed to bilateral agreed quality parameters, i.e. chemical and physical parameters (Interview: BVSE 2012). In the United Kingdom, Denmark, Finland and Latvia business-to-business agreements on qualities are dominating as well. Whether this is a satisfactory situation – or the opposite - is however not very well documented. A few sources discuss this. In the United Kingdom, WRAP initiated an investigation of MRF output material quality thresholds (WRAP 2009). The report points to the disjunction of what quality is required as input from sorting facilities/suppliers and what quality the reprocessors claim that they actually get. A recently opened sorting facility in Denmark anticipates a year of operation before the aimed for input qualities can be achieved, because it takes time and experience to learn how to sort input material (DKRaastoffer 2012). If the quality of input material (i.e. waste plastic collected from households or enterprises), is of poor quality, there is a risk is that the quality of the reprocessed plastic is then deteriorated or not upgraded insufficiently.

The use of and need for common standards vary greatly from nation to nation in Europe. Whereas Germany has developed and established well-functioning sorting and recycling schemes and practices, the United Kingdom is only about to start this process. Thus, in the United Kingdom, enterprises tend to focus more on the need for standards than in Germany. And as concluded by WRAP (WRAP 2009), this would be a highly recommended initiative.

The EuCertPlast certificate and the End-of-waste criteria may have an impact in this respect, which some of the interviews point to. The idea behind the EuCertPlast is to facilitate trade of waste plastics across nations in Europe by applying common standards of CEN. The EuCertPlast certificate may help to overcome the lack of comprehensive information of existing standards.

Implementation of national standards may be a barrier in relation to the use of common European standards (Interview: EPRO 2012). Such standards are operated in the United Kingdom, Italy and Germany to support the national markets. Another barrier is that certificates given are for the sorting facility, reprocessor or manufacturer, but not for the product, as for EuCertPlast or ISO quality and environment certificates.

Another important question to be raised is how market rules and regulation will meet/correspond in the future. The End-of-waste criteria and the EuCertPlast certificate are attempts to simplify regulation and facilitate cross-national trade of waste plastic for recycling – and increase shares of recycled high quality waste plastics. On the other hand, a well-structured private enterprise such as the Green Dot, operating in most European countries could potentially also be an important player in setting requirements for future recycling of waste plastics. Some stakeholders pointed to both market competition and high (national) recycling targets as important drivers for increased recycling of waste plastics.

Quality standards are also needed as assurance for the safety of recycled plastics. In some cases, consumers will most likely be reluctant to buy products with a content of recycled
polymers, e.g. for appliances where health safety is a crucial property. Certification of the quality could then be used for marketing of the safety of the products.

**Need for better sorting**
The risk of mixing colours and polymer types and/or contaminating the plastic with non-targeted materials in the collection phase increases with the diversity of the mixed waste. Thus, there is a need for more accurate sorting. This is why source separation will produce the best quality waste for recycling, according to several stakeholders interviewed. If the cost of sufficient sorting in different polymers gets too high, the waste plastic will most likely be exported to countries with lower treatment costs or the waste will be downcycled because of low quality. The varying quality of the input material was mentioned by several stakeholders as a barrier for the demand of recycled plastics.

It is in the interest of recyclers to encourage and promote sorting at source, as it increases the waste plastic’s value and reduces the cost of reprocessing. To make source separation efficient, however, it is important to continuously provide citizens with information on how to sort their household waste for recycling. This is one important barrier for improved recycling that is stressed by several European stakeholders in the waste plastics industry. It has been a lesson learned in Germany that, with the liberalization of Der Grüner Punkt, the responsibility and financial means of information of citizens has not been in place, with the result that the quality of collecting secondary raw material is deteriorating year by year (Interview: BVSE 2012, Interseroh 2012).

**Cascading principles for recycling**
Plastic recycling can be seen as a cascade with several levels of quality. It is possible to use recycled plastics several times depending on the sort of material/polymer. However, contamination and the breaking and crosslinking of polymer structures will become limiting factors.

The recycling system is covering the whole range of waste plastics, from high value pure polymers to low value mixed qualities, as it is not possible to sort all waste plastic into pure qualities. It is necessary for comprehensive recycling to treat it as a cascade process, where high quality plastics eventually are graded down to lower qualities. When agglomerates are used for building material or the likes, it will typically be incinerated after use (Interview: BVSE 2012).

There are many qualities of recyclates on the market. This main reason is that some sources are capable of providing more pure and homogeneous waste plastics than other, e.g. single polymer industrial scrap vs. comingled collected packaging waste.

It is well-known that the costs of waste sorting will reach a break-even point, where it is not economically viable to improve the quality by further sorting. However, such break-even points were not identified in this study, as this point will vary according to national regulation and implementation of waste plastic treatment as well as fluctuation of raw material prices. This could be differences in regulation and taxation of landfill or incineration of waste, whether a producer responsibility scheme is implemented and how it is financed etc. Further, the politically determined recycling targets set quantitative rather than qualitative goals for waste management. With no clear targets for the quality of recycling there seems to be lacking incentives for increasing the quality of plastic recycling and preventing downcycling.

**Impact of the End-of-waste criteria**
To prevent downcycling of plastics is one of the expected main benefits of the End-of-waste criteria; i.e. to be able to more clearly differentiate the high-quality waste plastic and make sure that only high quality waste plastic should cease to be waste, while low quality plastics should be considered as waste and treated as such. According to the draft report on End-of-waste criteria for waste plastic (JRC 2012), it is very difficult to obtain homogeneous waste plastic streams, as closed-loop systems are effective but expensive. The variety of the plastics industry makes it very hard to build a map of precise waste plastic streams going through one type of recycling process and resulting in a specific application. Thus, the options for marketing materials of mixed origin will often involve downcycling.

An important issue that has been discussed in the Technical Working Group of formulating the criteria, which is also a focus of stakeholders in the plastics recycling industry, is the threshold of impurity/non-plastic material content of the recycled plastic. The threshold of criterion 1.2 is ≤ 1 % of air dried weight. This has caused some reactions.
Though discriminating waste plastic with content of non-plastics slightly over the threshold, it will be a driver for improvement; it is said in the report on End-of-waste criteria (JRC 2012). That 1% would be a suitable numeric value for a threshold of non-plastic content in waste plastic for recycling (post-consumer) could be justified by the fact that in many cases, the intermediates for recycling are already below this threshold. This goes for most dry regrind material and flakes of high purity, for washed regrind material, and definitely for further processed material (pellets, melt filtration). Pre-consumer originating waste plastic would in general meet the threshold as well, without need for further sorting and reprocessing. Only agglomerates and similar intermediates would not meet the threshold, and thus not qualify for end-of-waste. For some articles made of recycled plastic, such as outdoor furniture, which contain non-plastic materials in amounts above 1%, a mechanism for exception could be devised, if the non-plastic materials are encapsulated in the plastic matrix of the product (JRC 2012).

The European Plastics Recycler Organisation, EPRO, and others, have suggested raising the threshold to 3% to include a larger share of waste plastic (Interview: EPRO 2012). BVSE agree that a threshold of 1% of contaminants is acceptable, but for agglomerates it should be 3% contaminants (Interview: BVSE 2012). The aim is to ensure that more recycled plastic is within the End-of-waste criteria.

In general, the waste plastic sector does not expect that the End-of-waste criteria will change the world of recycling waste plastics or prevent downcycling. Many stakeholders point to the fact that it can be easier to deal with plastic as waste rather than as a product made from recycled plastic, due to the REACH requirements. For plastic converters to re-establish the information chain on health and environment information for recycled plastic could be a heavy administrative burden. This was a point made in several interviews conducted in the Plastic Zero Project.
Technologies
Purpose of this section is to give an overview of available and promising recycling technologies and their market positions. The main focus is put on mechanical recycling as this is the most common method for recycling of plastics. Chemical recycling, or tertiary recycling, will only be described as a future technology.

Available recycling technologies
The definition of mechanical recycling technologies, as applied in this report, covers techniques by which the quality of the recyclable plastic is being upgraded and techniques for manufacturing of plastic products. The entire process is composed of three main steps:

- Upgrading, involving sorting, cleaning and size reduction of waste plastics
- Intermediate products, involving grinding, extrusion and pelletizing
- Manufacturing new products, e.g. extrusion, moulding or blowing

It is chosen here to include the first upgrading step and the intermediate products in the definition of recycling, because high-quality sorting is a precondition for the application of recycled plastic in new production, and because the process is not divided into three separate steps in reality. The sketched production chain is somewhat simplified. Sub-processes might be skipped or repeated, depending on the quality of the input material and the requested quality of the output material.

There are basically two types of mechanical recycling: the material can be used for the same purpose for which it was made originally (this is called direct recycling or closed-loop recycling), or it can be used in new types of products (this is often called downcycling).

Direct recycling (closed-loop)
Closed-loop recycling is obtained, if the polymers can used for the original purpose again. Examples of closed-loops are beverage crates, soft drink bottles made of PET, milk bottles made of HDPE, and pipes made of PVC.

Establishment of closed material loops most often requires a separate collection system in order to avoid mixing the target products with other products. In the case of bottles, it is possible to sort out the bottles from a mixed waste streams, because they are relatively easy to recognise and are found in large quantities. A deposit-and-return system is another common way of collecting bottles.

Recycled for new purposes (downcycling)
One reason why waste plastics often are downcycled is that the colour of the output material becomes darker due to impurities in the input material (JRC 2012). The final product might also get specks on the surface due to these impurities. It is difficult to obtain pure white or other colours, if the input material consists of mixed colours. Therefore, the output material is used in gray or black products. Examples of applications are:

- Opaque films and bags
- Transport materials, building and construction materials and outdoor furniture (pallets, pipes, grids, fences, planks, benches, flower pots). The colour is of no or minor importance for many of these applications.
- Utility items and furniture (boxes, lamps, fibres). Imperfect colours are acceptable or part of the desired look for many of these applications

Most of the applications are as direct substitutes for virgin plastics, while others substitute other materials, e.g. a plastic bench substitutes a bench made of wood, or synthetic fibres substitutes natural fibres like wool or down. Even though such applications are considered to be downcycling, the products are often long-lived. This extra life given to the material postpones the final disposal of the material. In many cases, the material can even be recycled several times. However, the collection schemes needed for collection of plastics from bulky waste and construction and demolition waste might not always be established, which is an obstacle for multiple recycling cycles.

Another reason why plastic is not kept in a closed loop is stringent requirements in terms of material quality for certain applications, e.g. food contact packaging (JRC 2012). Food packaging can be used as food packaging again, but process includes separation of the target food packaging from the mixed waste plastic stream, followed by a decontamination process. This is an expensive recycling process, and recyclable mixed plastic packaging is therefore often used in other types of products. Mainly PET bottles and HDPE bottles are currently being recycled into new bottles (Cowi, 2012). Other applications with stringent requirements are electrical and electronic products, children’s toys, and medical equipment.
Developments
There is not a clear of picture how much plastics is being recycled and how is being downcycled today.

More effective sorting will prevent downcycling of plastics. State-of-the-art sorting of mixed plastics involves a series of sorting technologies including NIR detection of polymer types and colours. NIR detection has certain limitations (e.g. recognition of black items, wet items and multilayer films), but the technology is constantly being improved. Following ongoing developments have been identified (Cowi 2012):

- Further development of the software enabling separation of new type of materials, e.g. composite materials, different shapes of the same polymer, separation of polymers close to each other at the spectrum etc.
- Possible separation of smaller size material (smaller flake sizes), which will reduce the reject fraction and thereby increase the sorting efficiency.
- Development of the technology so the sensors and software can work on the whole NIR scale. This will enable a more effective utilization of each NIR detector, since it will be easier to use it for detection of more materials (plastic and other materials).
- Reduction of electricity consumption (only marginal reductions), e.g. through use of LED light instead of other light sources.
- Improvement of the separation of wet materials.

There are several ways of improving the existing sorting technologies and eliminating the current barriers. The stakeholders interviewed believed that sorting of mixed plastics will become more efficient with the ongoing developments, increasing the recycling options of the outputs. In addition, more mixed plastics being collected in the European member states will create a larger market for plastic sorting and push forward the developments.

Technical development is also seen for other optical sorting technologies, such as camera line (detection of colour and shape) and X-ray technology (detection on molecular level). The different optical sorting technologies have potential in different areas and can thus supplement each other. However, the NIR technology seems to have the largest potential (more details in Cowi (2012)).

Technologies without market penetration

Recycling of food grade plastic
Production of food grade plastic from a source of mixed plastics containing non-food packaging is technically possible. As described above, mainly PET and HDPE is being recycled as food grade plastic today, but PP can potentially also be recycled (see details in Cowi (2012)). When this technology will become commercially feasible has not been investigated here.

Removable colour systems
Removable colour systems have been investigated by WRAP (2010a). Different kinds of removable labels or inking techniques can be applied to non-coloured packaging bodies. This will reduce the variety of colours range needed for packaging, and thereby increase the recyclability of plastic packaging. The label or ink can easily be removed as a part of the sorting/upgrading process. Economical rather technical considerations limit the implementation of these techniques.

Feedstock recycling
Feedstock recycling is a common term for chemical or thermal processes by which plastic is depolymerised, i.e. the polymers are broken down to smaller molecules. Monomers produced by depolymerisation can be used for production of new polymers or other chemical substances. They can also be used for energy purposes. Feedstock recycling is only feasible for high value materials such as PET. It has not yet had a commercial breakthrough as a technology for removal of impurities and additives, but there seems to an increasing interest in the plastic industries for feedstock recycling (Cowi 2012).

Recycling of WEEE plastics
Plastics in WEEE (and also End-of-life vehicles (ELV) and building materials) are highly specialised materials containing various additives. The most common plastic types in WEEE are ABS, PP, HIPS and PC (IVL 2012), and often applied additives are bromated flame retardants and heavy metals. Plastics with hazardous substances can be separated from non-hazardous plastics by different sorting technologies: NIR detection (but limited by the high
share of black plastic in WEEE), XRF-scanner (X-Ray Fluorescence), density sorting, e.g. sink/float sorting, and manual sorting of the problematic components (IVL 2012). However, the risk of spreading hazardous substances, high costs associated with thorough sorting and low traceability of plastic components are barriers for sorting and recycling of WEEE today. There is a market for non-hazardous WEEE plastics, e.g. a sorting facility in Sweden sorts out recyclable, non-hazardous plastics from WEEE, amounting to 50% the plastic fraction (see more details in Cowi (2012)). Chemical removal of hazardous substances like bromated flame retardants has been tested on pilot plants, but the technology is as far as known not commercialised (see more details in Cowi (2012)).

**Trends in technological development**

There was a general belief among the interviewed stakeholders that the commercialised sorting technologies will be further developed and become cheaper and more advanced, which in return will increase the quality of the output material and lead to new applications for recycled plastics. At least, this is a likely future for the plastic types already being recycled in wide extent, such single-polymer packaging. The sorting facilities will refine sorting by polymer types, colours as well as shapes. Robotics will most likely also be seen at advance sorting facilities. However, several of the interviewed stakeholders clearly stated that it is not possible to say if and when these expected developments will take place, and as such, it would not be reasonable to wait passively for them.

Increased focus on resource efficiency, e.g. motivated by the strategy for a resource-efficient Europe and recycling targets set by the Waste Directive, will be a driver for increased material recycling. This could be important for developing the market for recycled plastics, for which the potential is far from being utilised today.

Recyclability of packaging is not highly prioritised and not a consumer demand today. The question is if the awareness among consumers will cause a demand for recyclable products in the future. Several of the interviewed stakeholders believed so, but the statements were not substantiated by evidence. It seems more likely that manufacturers will push this development, by profiting from creation of ‘green’ profiles. This is already seen in certain sectors, for example manufacturers of carpets and furniture who have created closed materials loops by taking back their products for recycling. Manufacturers might be motivated by a need for improving the image of plastic (avoid littering and increase sustainability) and appreciating the material’s good qualities (superior functionalities when compared to other materials).

There seems to be a technical and political basis for further development of plastic recycling. However, the question is how this development will be affected by changes in the composition and application of plastic in products. Examples of such changes are given below.

**Packaging: specialised properties and new designs**

The stakeholders pointed out that plastic can be designed to possess a large range of material properties, and most likely we will see more ‘intelligent’ plastics in the near future. This could be design for optimised protection of the content or packaging designed for different consumer segments. Another trend is weight reduction of plastic products, e.g. by making packaging thinner or lighter, as a natural response to increasing raw material prices.

**New materials**

A special case of new materials is the emergence of nanomaterials, which are highly debated because the potential risks to human health and environment are largely unknown. It is also not known if such materials will pose a risk for the current waste management practices.

RFID tags implemented in products will also cause new challenges for the waste management practices if widely applied to products.

Composite materials like multi-layer packaging may have many benefits in the use phase, but they become a problem as waste, because they are not suitable for mechanical recycling and do not fit into the existing recycling systems. In general, if the complexity of materials will increase and thereby reduces the feasibility of mechanical recycling, feedstock recycling could potentially be applied as a recycling method.

**Bioplastics**

The production of bioplastics is still marginal, but it has found its own market niches. However, it is not possible to say which level the application of bioplastics will reach in the
future. It depends among other things on the availability of biomass resources and the production costs, and also to which extent the bioplastics can substitute for the conventional polymer types.

When talking about bioplastics it is important to distinguish between different terms:

**Bioplastics**, like PLA and PHA, are different from other types of polymer and are therefore recognisable by NIR detection. Even though some stakeholders expressed their concerns about mixing bioplastic with conventional polymer types, it is possible to sort it out like other types of polymers. Bioplastics cannot be mechanically recycled, but chemical recycling technologies are emerging (Cowi 2012). Furthermore, some bioplastics possess the functionality of being biodegradable. However, this property can only be utilised, if the waste management system is designed to handle biological waste in a special way, which often is not the case. Therefore it is still to be assessed for which purposes bioplastics will have an advantage over conventional plastic, when considering both the material functionalities and the resource mass flow.

**Biobased plastics** are produced from biomass sources such as sugar cane and corn and are similar to polymers produced from fossil fuels, e.g. a PE with same properties as its fossil-based counterpart (Force Technology 2012). The demand for biobased plastics is increasing, and it will most likely be possible to see a mix of bio-based and fossil-based plastics in the future.

**Biodegradability** is as mentioned above a functionality of bioplastics as well as conventional polymers, which may be wanted for specific purposes or be suitable for special types of waste treatment. A special case is the so-called oxo-degradable plastic, which breaks down when exposed to UV light and heat in process that is catalyzed by additives (Cowi 2012). This chemical process speeds up the actual degradation process, but the material cannot be considered to be compostable. Biodegradability or oxo-degradability can potentially corrupt the functionality of recyclable plastics. Plastics with these functionalities should therefore be avoided in mechanical recycling processes.

**New waste fractions**
The interviewed stakeholders commonly agreed on the fact that there will be more waste plastic in the future and that a number of new waste fractions will appear. One reason is the increasing amount of ‘historical’ waste – waste of long-lived products such as leisure boats and building materials (Interview: EPRO 2012). That is products which have been used for a long time, but now is being disposed off. Another reason is that plastic is appreciated for a large number of good qualities and can be designed with much different functionality, which makes it a good substitute for other materials. More specialised applications will increase the diversity of waste plastics, and perhaps result in increasing numbers of waste fractions.
**Prices**

In a study to better understand the factors that influence the future prices for secondary plastics in the United Kingdom WRAP has presented a diagram (see Figure 2) that shows the elements in the production chain that influence prices for virgin plastics and recycled plastics (WRAP 2008).

Oil is the major raw material used to produce plastics, and along with the price of oil and other raw materials (such as plasticisers, flame retardants, fillers etc.) and labour costs, it determines the supply of virgin plastics. Demand for plastics is dependent on the production and the plastic content in domestic production, and thus the general economic activity. The price reflects the equilibrium between demand and supply.

Prices for recycled or secondary plastics largely depends on the demand for recycled plastics at the international market (China/Asia), which again depends on the economic activity level in the import country; global prices for recycled plastics; and domestic or EU regulation.

![Diagram](image)

**Figure 2: Determinants of virgin and recycled plastic prices - an analytical framework (WRAP 2008)**

Most of the prices referred to in this section relate to prices of standard waste plastics which accounts for around 80 percent of the plastics on the market. Prices for technical plastics are much higher. The average price for technical plastics is at least twice as high as for standard plastics (see for example Plasticker (2012a)).

**Prices for virgin plastics**

Virgin plastics are commodities traded at the global and competitive market, and prices are determined by production costs. According to economic theory, the long-term price should equal the marginal production costs. The past development in prices is briefly described here.

Figure 3 shows the development in virgin plastic prices in 2008-2012. In 2008-2010 prices fluctuated around GBP 1,000 per tonne (app. 830 euro). In April 2011 they rose to GBP 1,300-1,500 per tonne (1,100-1,250 euro) and then declined to around GBP 1,100-1,300 (920-1,100 euro). Another example of virgin standard plastic prices is presented in Table 5.
Figure 3: Virgin standard plastic prices, the UK market, left side (WRAP 2010b), right side (http://www.wrap.org.uk/content/virgin-plastics-prices-europe).

Table 5: Comparison of EUWID quotes for standard plastics (Plasticker 2012b)

<table>
<thead>
<tr>
<th>Prices in €/t</th>
<th>Dec 11</th>
<th>Apr 11</th>
<th>Dec 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDPE film grade</td>
<td>1270 - 1310</td>
<td>1570 - 1630</td>
<td>1570 - 1630</td>
</tr>
<tr>
<td>LLDPE film grade</td>
<td>1180 - 1230</td>
<td>1490 - 1550</td>
<td>1390 - 1390</td>
</tr>
<tr>
<td>HDPE injection moulding</td>
<td>1220 - 1280</td>
<td>1420 - 1470</td>
<td>1170 - 1220</td>
</tr>
<tr>
<td>HDPE blow moulding/injection moulding</td>
<td>1230 - 1280</td>
<td>1420 - 1470</td>
<td>1170 - 1230</td>
</tr>
<tr>
<td>PS crystal clear</td>
<td>1250 - 1290</td>
<td>1530 - 1560</td>
<td>1370 - 1420</td>
</tr>
<tr>
<td>PS high impact</td>
<td>1370 - 1420</td>
<td>1620 - 1680</td>
<td>1450 - 1520</td>
</tr>
<tr>
<td>PP homopolymer</td>
<td>1210 - 1260</td>
<td>1520 - 1630</td>
<td>1320 - 1390</td>
</tr>
<tr>
<td>PP copolymer</td>
<td>1250 - 1310</td>
<td>1600 - 1700</td>
<td>1370 - 1430</td>
</tr>
<tr>
<td>PVC tube grade</td>
<td>1100 - 1140</td>
<td>1220 - 1270</td>
<td>1120 - 1180</td>
</tr>
<tr>
<td>PVC film/cables</td>
<td>1200 - 1240</td>
<td>1310 - 1360</td>
<td>1190 - 1250</td>
</tr>
<tr>
<td>Average:</td>
<td>1253 ± 72</td>
<td>1501 ± 133</td>
<td>1308 ± 110</td>
</tr>
</tbody>
</table>

Correlation with oil prices
Over summer 2008 when the financial crisis became apparent to everyone, the oil price dropped from 133 dollars per barrel to just above 40 dollars per barrel in December 2008 (shown in Figure 4). Since then it rose gradually, and in April 2011 it peaked at 123 dollars per barrel. After another minor decline in price, it peaked again in March 2012 at 124 dollars per barrel, just to fall to 96 dollars per barrel in June. In August it was on the rise again and was 113 dollars per barrel in August 2012. So, although the oil price is volatile, it has been increasing steadily since the financial crisis.
Figure 4: Brent, Monthly prices, dollars per barrel (Energistyrelsen 2012)

To illustrate the link between the oil price and the price for recycled plastics, the LDPE regrind price has been added to chart. Even though the plastic price is in euro, and the oil price is in dollars, it is clear that peaks in oil prices often are followed shortly after by a rise in recycled plastic price. The LDPE regrind price peaked in May 2011, about a month after the oil price peak. One year later, in April 2012 it peak again one month after the oil price.

Figure 5: Brent, monthly prices, dollars per barrel, and secondary LDPE, euro per tonne (Energistyrelsen 2012, Plasticker 2012c)

Prices for recycled plastics
Past development in prices
The Eurostat price indicator for waste plastic shows the same trend as for virgin plastic and crude oil: when the effect of the economic crisis hit the global economy in the last half of 2008, the price fell sharply (see Figure 6, purple line). Four years later, the prices are almost back at the pre-crisis level. By early 2012 the price indicator showed an average, annual
price level of 350 EUR/tonne. The indicator also shows monthly prices and they fluctuate a great deal.

The traded volume of waste plastic has risen gradually since 2000, despite the downturn in economic activity. The traded volume was around 2 million tonnes in 2000 and this reached 7.2 million tonnes in 2011. The low prices in 2008 even increased the demand and since 2009 the annual, traded volume has been higher than it was prior to the crisis (see Figure 6, green line).

![Figure 6: Price indicator and trade volume for waste plastic in EU-27 till May 2012 (Eurostat 2012b).](image)

The general picture is supported by the price development for HDPE and PET during the period 1997-2012, which is illustrated in Figure 7 and 8 (Postplus 2012a, 2012b). Since 2004 prices have been rising and peaked in late 2008. In 2009 prices dropped and reached the 2004-level (HDPE) and 2005-level (PET). The price drop for PET was only 150 euro per tonne for PET whereas it was 320 euro per tonne for HDPE. This reflects a PET market which is much more established than it is for HDPE. Prices are shown after the plastic has been sorted, i.e. ex sorting plant, and include charges only up to the seller's factory or premises. All charges from there on, such delivery, distribution, and commissions, are to be borne by the buyer.

Since late 2009/early 2010 prices have been on the rise again. For HDPE they are almost back at the high 2008-level, for PET they are around 200 euro higher per tonne than the 2008-level.

The last half of 2012, prices have started to decline a little. One reason for this is the receding demand at the Chinese market due to a more strict enforcement of import regulations. Exports to China are subject to strict border controls - both in the export harbours and at the import checkpoints in Hong Kong. Imports to Hong Kong via the People’s Republic of China have been made considerably more difficult. China has put in place new requirements for the quality grades, which are now checked accordingly.

Moreover, the Chinese have an extensive domestic infrastructure for collection and recycling of waste plastic, whereby the domestic market is also supplying waste plastics to reprocessors.
**Polymers and output qualities**

The market reports from the United Kingdom Waste Resources and Action Programme (WRAP) show prices for coloured PET grades (clear and coloured bottles) and LDPE (film – natural), in Figure 9. In 2012 the plastic bottle prices declined in May and have remained at the lower level since then. According to WRAP (2012c), PET bottle grades are linked to the price of cotton as cotton is a substitute for the manufacturing of textiles. Over the last year the price of PET bottles has been 25-40% lower as the cotton price has decreased by 45%.

Some polymer types are more valuable than others. The prices for PET are generally higher than the prices for HDPE, followed by LDPE and mixed polymers (Figure 7, 8 and 9). Food-grade PET and HDPE are the most valuable polymers with prices around 900-1,100 GBP (1,100-1,350 euro) per tonne for pelletized polymers (WRAP 2012a). The prices of polymers like PP and PS are considerably lower, for example 0-200 GBP (0-250 euro) per tonne of baled materials. Thus the composition of a mixed waste plastic stream is of great importance of the overall value of the recyclates obtained after sorting.
Furthermore, clear and natural polymers are more valuable than coloured polymers (jazz). The degree of reprocessing also affects the price of the recyclate. For example, regranulates yields a higher price than regrinds and bales, as seen in Figure D and E. Finally, the purity of the recyclate is also determining the price.

![Graph showing recovered plastic packaging prices](image)

**Figure 9: Recycled plastic packaging prices, GBP per tonne 2008-2012 (WRAP 2012c).**

*Costs of collection, sorting and transport*

Waste plastic is a costly stream to collect due to its low weight-volume ratio. Waste plastic takes up a good deal of space in a bin, but does not weigh much, so to get a tonne of waste plastic quite a few bins need to be emptied.

In the City of Copenhagen, total costs of introducing the scheme for rigid plastics has been estimated at 7,300 DKK per tonne (970 euro). The costs include procurement of bins, distribution of bins to households, collection, sorting and project management (City of Copenhagen 2011). All bins are collected not at kerbside but from on the property. The calculation is based on an expected amount of collected rigid plastics.

In Germany, a total of 1.2 million tonnes of packaging waste plastic is collected and sorted via the producer responsibility scheme, and the fees paid in the scheme add up to EUR 700 million. Based on this, the average cost of collection, sorting, recycling and trading is 583 euro per tonne (Interview: Interseroh 2012).

The development in collection and sorting cost of plastic bottles and flasks, metal packaging and drinks cartons fraction (PMD) in Belgium has been illustrated by Fostplus (2012c), see Figure 10 and 11. Where the collection cost has increased by 12 percent to 210.2 euro per tonne between 2002 and 2011, the sorting cost has decreased by 13 percent to 167.6 euro per tonne. Total cost of collection and sorting of the PMD fraction was 377.8 euro per tonne in 2011. From the figures, it is difficult to say if and how much the revenue from the sale of metals subsidise the collection and sorting of plastics (and drink cartons). The collected amount of PMD was 15.2 kg per inhabitant in 2011 and it has risen very little since 2002 where it was 14.1 kg per inhabitant. Plastics comprises just less than half of the PMD fraction, metals around one third, drinks cartons around one tenth and residues are around 15 percent. Fostplus notices that the residue amount is larger in cities such as Antwerp, Brussels, and Liège than in the Belgian average. The cities are dominated by multi-storey buildings where inhabitants are more anonymous and thereby less inclined to participate in sorting. Thus, Fostplus has taken specific action in cities and results now show a decrease in the residue from 25 to 18 percent in Liège and a drop from 55 to 30 percent in Brussels.
Figure 10: PMD collection cost, EUR per tonne 2002-2011 (Fostplus 2012c).

Figure 11: PMD sorting cost, EUR per tonne 2002-2011 (Fostplus 2012c)

In the United Kingdom, the cost of sorting the mixed plastic waste at a MRF may range from 40 to 180 GBP (50-220 euro) per tonne, dependent on the annual capacity of the plant and whether the plant is operating at full or half capacity (WRAP 2011). This is illustrated in Figure 12.
Figure 12: The MRF Cost Model provides representative capital and operating costs for range of MRF sizes (WRAP 2011).

The transport costs are decisive for demand for recycled plastics. Often it will be cheaper to send the materials to Asia by ship than to drive it 200 km by lorry. Further, the transport prices fluctuate considerably: if a ship is about to sail and needs to be loaded with goods, the prices go up; when a ship has just sailed, the prices go down. The prices can vary from day-to-day (Veolia 2012).

In general, the transport costs for export to Asia have increased from app. 20 to 60 GBP (25-75 euro) per tonne during the last five years as shown in Figure 13 (WRAP 2010b).

Baling is only used for long transport distances. It costs around 12-14 EUR per tonne to bale (Veolia 2012).

Figure 13: Container freight rates, WRAP (2010b).

It is evident that the costs of collection, sorting and transport of waste plastics can be considerably high, but they are very dependent on local conditions such as transport distances, labour costs, MRF capacities and availability of freight centres.

The income from sale of recyclables cannot fully cover these costs. Figure 14 below shows the Belgian producer responsibility organisation Fostplus’ revenues from green dot fees and
the sale of all materials. Until 2007, material revenues were rising at a steady rate, then came the crisis and revenues dropped. Since 2009, the revenues have increased drastically as a result of increased material prices.

However, in the case of mixed waste plastic especially from households, the revenue from the sale is far from being able to cover the costs of collection and sorting.

![Evolution of revenues chart](image)

**Figure 14: Revenues from green dot fees and materials (Fostplus 2012c)**

**Outlook**

WRAP (2008) finds that the outlook for recovered plastics prices in the United Kingdom is determined by:

1. The outlook for crude oil prices, and their impact on virgin plastics prices.
2. The outlook for the global economy and its impact on the global demand for both virgin and recovered plastics.
3. The outlook for the Chinese economy and the growth of its industries which make intensive use of plastics in the goods they manufacture.
4. The outlook for the regulation of the waste plastic industry in the United Kingdom.

Other determinants of prices for recycled plastic in the EU are for example:

- Quality of secondary material.
- Costs of collection, sorting and recycling.
- Administration or transaction costs of registering shipments of waste (intra and extra EU).

The World Bank has estimated the development in several material prices since 1960 (see Figure 15). The trend is clear: over a 40-year period until 2000 the prices for most materials or commodities, except energy, has fallen, but since 2000 the prices for all commodities has increased (World Bank 2012). In fact, for most commodities the real price in 2010 is just as high – or higher – than it was in 1960. This observation must lead to expect rising prices in the future.

So far, the Asian demand for resources for their expanding economies has been a major reason why prices have been driven up over the last ten years. As more countries in the developing world have high growth rates, they too will demand resources and contribute to a
likely increase in prices. Figure 16 show that several developing economies such as BRIC\(^1\) and Next-11\(^2\) have higher growth rates than the EU-27.

Figure 15: Revenues from green dot fees and materials (World Bank 2012)

Figure 16: Gross domestic products (GDP), index 2006 = 100, (OECD 2012)

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\(^1\) The BRIC countries are: Brazil, Russia, India and China.
\(^2\) The N-11 countries include Bangladesh, Egypt, Indonesia, Iran, Korea, Mexico, Nigeria, Pakistan, Philippines, Turkey and Vietnam.
Job creation and green growth

Economic activity in the waste management sector

Data on the economic activity in the waste management sector has been obtained from the NACE Rev. 2 database in Eurostat. The European waste management sector employed 735,000 persons in 2009. More than half of the persons were collecting waste, while around 21 percent were in waste treatment & disposal and in materials recovery.

The sector comprises 36,400 enterprises, where the majority is in materials recovery closely followed by waste collection. See Table 6. On average, the materials recovery enterprises have fewer employees per company compared with waste collection and treatment & disposal.

The treatment & disposal enterprises generated the highest value added per employee with 72,000 euro per person. Materials recovery generated 46,000 euro per person, and waste collection 41,000 euro per person.

Table 6: Sectoral breakdown of key indicators, waste collection, treatment and disposal activities; materials recovery (NACE Division 38), EU-27, 2009 (Eurostat 2012c).

<table>
<thead>
<tr>
<th></th>
<th>Number of enterprises</th>
<th>Number of persons employed</th>
<th>Turnover</th>
<th>Value added</th>
<th>Personnel costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste collection, treatment and disposal activities; materials recovery</td>
<td>36.4</td>
<td>735.0</td>
<td>108,000</td>
<td>35,771</td>
<td>21,700</td>
</tr>
<tr>
<td>Waste collection</td>
<td>14.9</td>
<td>410.0</td>
<td>41,000</td>
<td>16,691</td>
<td>12,000</td>
</tr>
<tr>
<td>Waste treatment and disposal</td>
<td>5.2</td>
<td>160.0</td>
<td>30,000</td>
<td>11,503</td>
<td>6,000</td>
</tr>
<tr>
<td>Materials recovery</td>
<td>16.4</td>
<td>157.0</td>
<td>37,600</td>
<td>7,277</td>
<td>4,220</td>
</tr>
</tbody>
</table>

*Source: Eurostat 2012d (online data code: sbs_na_ind_r2)*

The statistical classification of economic activities in the European Community has been revised and as of 1 January 2008, the NACE Rev. 2 is to be used for statistics referring to economic activities performed (see Annex I for further definition of the statistical classification). The change has the unfortunate effect that time series break in 2008. Prior to 2008 the statistics included only part of current division 38, namely 38.3 materials recovery. Thus, data are not directly comparable.

Still, in the next section we present data on the employment in the materials recovery section for 1999-2008 to see the development over a longer period than just the NACE Rev. 2 data set for 2008-2010. Since 2008 and 2009 are the years where the economic crisis hit the economy and thereby employment, these years do not show the overall trend in the waste management sector.

Employment in the waste management sector

**Employment in the materials recovery sector 1999-2008 and 2008-2010**

The graphs below in Figure 17 show the employment in materials recovery (recycling) in the six largest member states as well as Sweden, Finland Latvia and Denmark for 1999-2008.

All the six most populated countries experienced an increase in employment over the period. France has the highest number of employees with 30,000 in 2007 which fell to 25,000 in 2008. In relative terms, Spain increased the employment by 400 percent over the eight years to 7,500. Germany doubled the employment in the materials recovery sector up till 2007. If we compare with other large member states, it is interesting to see that for many years France had around twice as many employees in the sector than Germany.
In Sweden and Finland the number of employees in the materials recovery has also risen considerably between 1999 and 2008. In Finland the number of jobs has increased by around 400 percent and in Sweden by 150 percent. In Latvia employment in the sector fell in the period up to the accession to the EU and after it slowly increased up to its 1999-level.

The employment data corresponds with the development in the recycling level. In 1999 the average European recycled 77 kg municipal waste and in 2008 it had increased to 123 kg, or by 60 percent. These figures cover large differences among member states. Where Germany collected 277 kg municipal waste per capita in 2008, Latvia collected 17 kg (Eurostat 2012d).

![Number of employees, Materials recovery, 1999-2008 (Eurostat 2012d).](image)

Figure 17: Number of employees, Materials recovery, 1999-2008 (Eurostat 2012d).

Figure 18 shows the employment per 10,000 inhabitants for the 27 member states for 2008-2010 according to the NACE Rev 2 classification (but no data available for Greece and Malta). Slovenia, Luxembourg, Romania, Czech Republic and France all employ more than 5 persons per 10,000 inhabitants. All partner countries, except Sweden with 4.3, employ less than 2.6 persons per 10,000 inhabitants.

![Number of employees per 10,000 inhabitants, Materials recovery, 2008-2010 (Eurostat 2012c).](image)

Figure 18: Number of employees per 10,000 inhabitants, Materials recovery, 2008-2010 (Eurostat 2012c).

**Key employment figures for countries relevant for Plastic Zero**

Looking at the number of people working in the waste management sector – not just materials recovery – in the five countries of the Plastic Zero partner cities, Germany clearly
has the highest employment as more than 106,000 persons work in the waste sector. In Sweden around 13,500 people work in waste management and just around 6,000 in Denmark and Finland. In Latvia 3,500 persons work in the sector. See details in Table 7.

In relative terms there are some significant differences between the countries. Waste collection accounts for only 40 % in Finland and 76 % in Latvia. Treatment and disposal account for only 8 % in Latvia and Sweden, and 30-35 % in Denmark, Germany and Finland. In materials recovery, Latvia, Denmark and Germany employ 16-19 % of the persons in the sector, while Finland employs 24 % and Sweden 30 %.

Table 7: Number of persons employed, NACE 38, 2010 (Eurostat 2012c).

<table>
<thead>
<tr>
<th></th>
<th>Denmark</th>
<th>Germany</th>
<th>Finland</th>
<th>Latvia</th>
<th>Sweden</th>
</tr>
</thead>
<tbody>
<tr>
<td>38</td>
<td>Waste collection, treatment and disposal activities; materials recovery</td>
<td>6,198</td>
<td>106,459</td>
<td>5,668</td>
<td>3,553</td>
</tr>
<tr>
<td>38.1</td>
<td>Waste collection</td>
<td>3,179</td>
<td>50,809</td>
<td>2,293</td>
<td>2,683</td>
</tr>
<tr>
<td>38.2</td>
<td>Waste treatment and disposal</td>
<td>1,850</td>
<td>35,436</td>
<td>2,002</td>
<td>290</td>
</tr>
<tr>
<td>38.3</td>
<td>Materials recovery</td>
<td>1,169</td>
<td>20,214</td>
<td>1,373</td>
<td>581</td>
</tr>
<tr>
<td>38.3.2</td>
<td>Recovery of sorted materials</td>
<td>971</td>
<td>n/a</td>
<td>1,246</td>
<td>565</td>
</tr>
</tbody>
</table>

The highest turnover per person employed is in the materials recovery and in recovery of sorted materials with EUR 160,000 (Latvia) – 627,000 (Finland). In comparison, the turnover in waste treatment and disposal is EUR 60,000 (Latvia) - 366,000 (Denmark), and in waste collection it is EUR 30,000 (Latvia) – 221,000 (Denmark).

Table 8: Turnover per person employed, 1,000 euro, NACE 38, 2010 (Eurostat 2012c).

<table>
<thead>
<tr>
<th></th>
<th>Denmark</th>
<th>Germany</th>
<th>Finland</th>
<th>Latvia</th>
<th>Sweden</th>
</tr>
</thead>
<tbody>
<tr>
<td>38</td>
<td>Waste collection, treatment and disposal activities; materials recovery</td>
<td>325</td>
<td>229</td>
<td>283</td>
<td>53</td>
</tr>
<tr>
<td>38.1</td>
<td>Waste collection</td>
<td>221</td>
<td>158</td>
<td>127</td>
<td>30</td>
</tr>
<tr>
<td>38.2</td>
<td>Waste treatment and disposal</td>
<td>366</td>
<td>225</td>
<td>259</td>
<td>60</td>
</tr>
<tr>
<td>38.3</td>
<td>Materials recovery</td>
<td>543</td>
<td>416</td>
<td>580</td>
<td>160</td>
</tr>
<tr>
<td>38.3.2</td>
<td>Recovery of sorted materials</td>
<td>598</td>
<td>n/a</td>
<td>627</td>
<td>163</td>
</tr>
</tbody>
</table>

The development during the three years 2008-2010 for waste collection, treatment and disposal and materials recovery are shown in Figure 19. Data for the sub-sector, recovery of sorted materials, is also included. The development is different in each of the five countries: employment in waste collection is largely unchanged in Sweden and Germany, it has decreased in Denmark and Latvia and it has increased in Finland. The drop in waste collection in Denmark from 2008 to 2009 is most likely explained by erroneous registration in 2008.
Figure 19: Employment in the waste management sector in Denmark, Sweden, Latvia, Finland and Germany, 2008-2010 (Eurostat 2012c).

Note: Recovery of sorted materials is a sub-category of materials recovery.

Key figures on employment, 2010
In order to estimate the potential for job creation later in the Plastic Zero project, we present key figures on the employment in the sub-sections of the waste management sector, such as data per 10,000 inhabitants and per 1,000 tonnes of waste generated.

When the Eurostat data in Table 8 are presented per 10,000 inhabitants, Latvia has the highest employment with 15.8 persons per 10,000 inhabitants, closely followed by Sweden with 14.5 persons. The lowest employment rate is in Finland with 10.6 persons per 10,000 inhabitants.

In Latvia 11.9 persons are employed in the waste collection whereas Finland only employs 4.3. The reason for the latter may be that in Finland not all waste streams are collected separately in rural areas due to the large distances.

For materials recovery, Sweden employs 4.3 persons while the four other countries employs between 2.1 and 2.6 persons. Sweden, together with Latvia, also has the lowest rate of employment in treatment & disposal with 1.2 and 1.3 persons.

Table 9 includes a rough figure on the employment per 1,000 tonnes of total waste generated in the country. Excluding waste from the mining and quarrying sector from the waste generation, 2.4 persons are employed per 1,000 tonnes of waste generated in Latvia. This is considerably more than in the four other countries where 0.1-0.5 persons are employed per 1,000 tonnes of waste generated. In this respect it is important to notice that the results depend heavily on the waste statistics and the structure of economic sectors in
countries. For example the Finnish construction sector produces much more waste than in Sweden and Denmark.

Table 9: Number of persons employed per 10,000 inhabitants and per 1,000 tonnes of waste generated, 2010 (Eurostat 2012c).

<table>
<thead>
<tr>
<th></th>
<th>Denmark</th>
<th>Germany</th>
<th>Latvia</th>
<th>Finland</th>
<th>Sweden</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Per 10,000 inhabitants:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waste collection, treatment and disposal activities; materials recovery</td>
<td>11.2</td>
<td>13.0</td>
<td>15.8</td>
<td>10.6</td>
<td>14.5</td>
</tr>
<tr>
<td>Waste collection</td>
<td>5.7</td>
<td>6.2</td>
<td>11.9</td>
<td>4.3</td>
<td>9.0</td>
</tr>
<tr>
<td>Waste treatment and disposal</td>
<td>3.3</td>
<td>4.3</td>
<td>1.3</td>
<td>3.7</td>
<td>1.2</td>
</tr>
<tr>
<td>Materials recovery</td>
<td>2.1</td>
<td>2.5</td>
<td>2.6</td>
<td>2.6</td>
<td>4.3</td>
</tr>
<tr>
<td>Recovery of sorted materials</td>
<td>1.8</td>
<td>n/a</td>
<td>2.5</td>
<td>2.3</td>
<td>3.8</td>
</tr>
<tr>
<td><strong>Per 1,000 tonnes waste generated (excl. mining and quarrying):</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waste collection, treatment and disposal activities; materials recovery</td>
<td>0.4</td>
<td>0.3</td>
<td>2.4</td>
<td>0.1*</td>
<td>0.5</td>
</tr>
</tbody>
</table>

* Waste generation (excl. mining and quarrying) in Finland is 49.5 million tonnes, mainly due to large amounts of waste from the construction sector. In comparison, the generation is 28.6 million in Sweden and 14.0 million in Denmark. If the Danish waste amount is used, the ratio increases to 0.4.

Knappé and Blażejczak (2007) present employment data for the collection, treatment and sorting of specific waste streams in Germany. See Table 10. The total employment per 10,000 inhabitants for the selected waste streams is 5.3 persons while the total employment based on Eurostat data is 6.2.

An interesting conclusion from the data is that collection and incineration of residual waste produces 1.1 jobs per 1,000 tonnes whereas collection and sorting of the lightweight packaging fraction produces 2.4 jobs.

Table 10: Germany: Employment for the management of specific waste streams, 2006 (Knappé and Blażejczak 2007, Fischer 2012).

<table>
<thead>
<tr>
<th></th>
<th>Waste collection from households</th>
<th>Treatment, sorting and materials recovery*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Per 10,000 inhabitants</td>
<td>Per 1,000 tonnes waste*</td>
</tr>
<tr>
<td>Residual waste</td>
<td>1.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Bulky waste</td>
<td>0.7</td>
<td>2.5</td>
</tr>
<tr>
<td>Biowaste</td>
<td>1.3</td>
<td>1.5</td>
</tr>
<tr>
<td>Waste paper</td>
<td>0.8</td>
<td>0.9</td>
</tr>
<tr>
<td>Lightweight packaging</td>
<td>0.7</td>
<td>1.3</td>
</tr>
<tr>
<td>Glass</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Incineration</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>5.3</td>
<td></td>
</tr>
</tbody>
</table>

*Fischer (2012) based on Knappé and Blażejczak (2007)

Data for Copenhagen on waste collection (City of Copenhagen 2012) show a higher employment rate for the collection of residual waste with 3.3 persons per 10,000 inhabitants compared with 1.8 persons in Germany. The data are for collection of municipal waste, i.e. they include collection of waste from commerce and administration. See Table 11.

The job-ratio for garden waste is much lower in Copenhagen which may be due the fact that more than 90 percent of the dwellings in Copenhagen are in multi-storey buildings and they typically generate much less garden waste than one-family houses.

The figures for waste paper and cardboard are also lower than the Germany average. In this respect it is relevant to remember that the recycling rate for household waste in Copenhagen is just around 28 percent while it is 45 percent in Germany (Eurostat 2012e). One reason for the lower recycling rate may be found in the difficulty in placing waste bins for recyclable waste streams at all properties, in particularly the medieval city centre.
Table 11: Copenhagen: Waste collection from households, 2012, employment (City of Copenhagen 2012)

<table>
<thead>
<tr>
<th>Waste Type</th>
<th>Jobs per 10,000 inhabitants</th>
<th>Jobs per 1,000 tonnes of waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residual waste*</td>
<td>3.3</td>
<td>1.1</td>
</tr>
<tr>
<td>Bulky waste</td>
<td>0.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Garden waste</td>
<td>0.1</td>
<td>0.6</td>
</tr>
<tr>
<td>Waste paper</td>
<td>0.4</td>
<td>1.1</td>
</tr>
<tr>
<td>Cardboard</td>
<td>0.2</td>
<td>2.7</td>
</tr>
<tr>
<td>Glass</td>
<td>0.1</td>
<td>0.4</td>
</tr>
<tr>
<td>Total</td>
<td>4.5</td>
<td>6.9</td>
</tr>
</tbody>
</table>

Note: * Includes waste from commerce and administration, i.e. municipal waste. Data are based on the waste amount in 2011.

Competitiveness of the waste management sector

Investment in recycling facilities (plants, land and technology) is high, and operational cost largely consists of labour and energy costs. Thus, labour productivity plays an important role in deciding where to establish a recycling/reprocessing facility and whether to invest in more or less labour intensive technology.

Apparent labour productivity is measured in gross valued added in thousand euros per person employed. Figure 20 illustrates how the 12 new EU member states in general have a much lower labour productivity than the old member states. However, when the labour productivity is adjusted for differences in salary, the picture reverses and several of the new member states are in the high-end of the productivity scale (see Figure 21). The graph only deals with materials recovery, not the entire waste management i.e. waste collection, treatment and disposal.

Some countries also show rather significant changes between 2009 and 2010. Most dramatically is the increase in the Danish apparent labour productivity which doubles from 2009 to 2010. Other relative increases occur in Romania, Slovenia, Czech Republic, Latvia, Hungary, Poland, Finland and Sweden.

![Figure 20: Materials recovery: Apparent labour productivity (Gross value added per person employed), 1,000 euro (Eurostat 2012c).](image-url)
Figure 21: Materials recovery: Wage adjusted labour productivity (Apparent labour productivity by average personnel costs) (%) (Eurostat 2012c).
Conclusions

The main findings of the survey are:

- The recycling market for plastics is relatively robust, and the interest in plastic recycling is growing. This interest is in part driven by the relatively lower price of recycled plastic for the customer (the plastic manufacturer) with possible additional benefits such as green profiling etc. The purity of the recycleate is determining price and application of the recycate. The market demand is highest for pure recyclates like industrial scrap that fit into existing plastic manufacturing practices and/or work as diluting material in the production of virgin plastics.

- Export to Asia has for long been the most feasible solution for the less valuable waste plastic fractions. On one hand, export for recycling is often the most feasible way of utilising (low quality) plastic collected for recycling; on the other hand, export is sensitive towards the economic situation and changes in regulations in the importing countries. Lack of treatment capacity for mixed waste plastic and high costs associated with reprocessing are some of the causes for the low demand on the domestic markets.

- The interest in recycled plastics is also a consequence of regulation and waste management policies, where recycling is placed high in the hierarchy of waste management options. Part of the market for recycled plastic has been stimulated by legislative drivers such as producer responsibilities, recycling targets and incineration taxes. National practices and regulations are therefore determining the amount and quality obtained in a given country. So far, recycling targets have only been specified for the quantity to be recycled, not the quality of the recycled material.

- Recycling of postconsumer waste plastics, mainly packaging waste, is faced with challenges related to the costs of collection and sorting and to the quality of collected waste. Collection and sorting of this fraction is expensive and in many cases subsidised by producer responsibility schemes or waste collection fees. Furthermore, a low-quality residual fraction of waste plastic remains, when the most valuable polymer types have been sorted out. Issues that need to be addressed in order to make new collection schemes and sorting facilities economically viable are for examples long transport distances and fluctuating volumes.

- The market may benefit from application of common standards and certifications, but less formal bilateral (business-to-business) agreements seem to be the prevailing practice, because such agreements allow more precise specifications and less demanding documentation than formalised standards.

- End-of-waste criteria are primarily aimed at increasing the level of high quality material that is available to market demand. However, it is an open question whether trade of recycled plastics actually will become smoother because of the criteria, as plastic as a product must comply with other regulation such as REACH.

- The quality of waste plastic received at sorting facilities is a key factor, especially for waste streams of mixed plastics. Efficient source separation of the waste plastics is crucial, but not always easily obtained. Further, many facilities sort a dry recyclables stream (e.g. cardboard, metal and plastic) whereas others sort only (source separated) plastics. It requires experience and knowledge about the local conditions to motivate people to do the intended source separation correctly. The citizens’ and enterprises’ ways of managing the waste plastics should be adjusted regularly, e.g. by continuously providing them with information.

- Another key factor is the security for a stable supply of waste plastics as companies will not prepare sorting and production of recycled plastic, if they have no security for a stable supply. It takes time to establish collection schemes, which can provide a stable supply of material. In many cases, the success is dependent on subsidies in order to reach a critical mass and eventually become economically viable. The market opportunities for recycled plastic are in general dependent on the political will to initiate and support the development, as the demand for recycled plastics is limited to applications in certain sectors.
• The prices of recyclates are expected to rise. The price of crude oil, but also the demand of plastic on the global market (mainly from China), are determining for the price of recycled plastic.

• The number of employees in the waste sector (collection, treatment and material recovery) is increasing, because more waste plastic is being recycled.

• Sorting and recycling technologies are mature for some qualities of waste plastic, but there are big potentials for further development of recycling technologies and applications of recycled plastics for a range of plastic types. Especially, the inevitably problem of downcycling of the materials calls for new technological solutions.

New initiatives will be needed in order to develop the market and increase recycling of waste plastics within a short time horizon. Even though the prices on raw materials are rising, it seems unlikely that plastic recycling will increase by market demands alone. The core question is:

*How can the framework conditions in terms of regulations be changed in order to improve the market conditions for plastic recycling?*

• The obligations in producer responsibility schemes should be extended with instruments that motivate producers to use recycled plastic in their products and/or increase the recyclability of products. More focus on the links between product design and recycling will enhance the recyclability of waste plastics and enable creation of closed material loops. Possible answers to the question could be to differentiate fees in collective producer responsibility schemes according the recyclability of the products, e.g. imposing higher fees on virgin materials or on products containing multiple materials. That might motivate manufacturers to rethink product design, e.g. by using recycled/recyclable materials and ease disassembly of the product.

• Quantitative recycling targets should be supplemented with qualitative targets in order to reach a quality of the recylcate which can substitute virgin plastic and thereby prevent downcycling of plastics. Acknowledging the diversity of plastics, differentiated targets should be set for plastic types/products. Such targets could more specifically assist local authorities in defining which waste plastic fractions to collect and how to treat them.

• More recycling will create more jobs in the waste management sector, e.g. workers employed for collection and sorting of waste plastics and workers in the manufacturing industry. Furthermore, innovative solutions for residual waste plastics from sorting processes as well as for new plastic types and composite materials, currently not recyclable, are needed. Recycling of these materials constitutes a new market opportunity for plastics manufacturers and recycling industry in Europe. Research and development in the business could be motivated by setting higher quantitative as well as qualitative recycling targets in the waste management sector.

The work of the Plastic Zero project will aim at finding new solutions for recycling of waste plastics in Europe. In this report, the current state of market for recycled plastic has been analysed and market barriers and opportunities have been identified. Outcome of other parts of the project, like further analyses of the application of recycled plastic, assessment of economic and environmental impact and knowledge gained from forums and tests, will supplement findings reported here and lead to suggestions for new initiatives that will help achieve the overall objective of the project. This includes suggested solutions for:

• Creation of domestic markets for recycled plastic and job creation
• Ensuring materials’ applicability in manufacturing processes
• Substitution of virgin plastics and prevention of downcycling
• Transnational cooperation on waste plastic recycling
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Fischer, C. Calculation of jobs per 1,000 tonnes of waste. Personal communication with C. Fischer, Copenhagen Resource Institute, Copenhagen, Denmark. 2012.


WRAP. Recovering value from MRFs. A review of key studies relating to the specification, operation and costs of Materials Recovery Facilities. Waste & Resources Action Programme, Banbury, the UK. 2011

WRAP. Collection and sorting of rigid household plastic waste. Waste & Resources Action Programme, Banbury, the UK. 2012a.


**Annexes**


E: EN 15342-48 standards

F: German specifications

G: UK standards and specifications

H: Danish specifications

I: Definition of the statistical classification: Comparison between NACE Rev. 2 and NACE Rev. 1.1