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Glossary

BREFs	Operating permits under the IPPC Directive are issued based on Best Available Techniques Reference Documents (BREFs) in order to ensure protection of the environment
Chemical recycling	*See feedstock recycling*
Disposal	Disposal encompasses a variety of definitions. In accordance with the terms the Waste Framework Directive, disposal refers to: • Deposit into or onto land (landfill) • Specially engineered landfill; for example, placement into lined discrete cells which are capped and isolated from one another and the environment • Release into a water body • Release into seas/oceans including sea-bed insertion • Biological or physico-chemical treatment which results in final compounds or mixtures which are discarded by means of other disposal methods. • Incineration on land or at sea • Permanent storage • Blending or mixing prior to any of the above operations • Repackaging prior to submission to other disposal methods • Storage, pending disposal by any of the above methods
Energy recovery	The use of waste principally as a fuel or other means to generate energy
Feedstock recycling	Also known as chemical recycling, feedstock recycling refers to techniques used to break down plastic polymers into their constituent monomers, which in turn can be used again in refineries, or petrochemical and chemical production.
Mechanical Recycling	Mechanical recycling of plastics refers to processes which involve the reprocessing of plastic was by melting, shredding or granulation.
Municipal Solid Waste	Post-consumer waste collected by local authorities and can include household waste, and waste collected from public institutions and spaces.
Pre-consumer waste	Also known as post-industrial waste, or industrial scrap, this refers to waste generated during converting or manufacturing processes.
Polymer	Polymers are large molecules made up of repeating chemical units. The term polymer is usually used to refer to plastics.
Post-consumer waste	This is waste produced by material consumers, where waste generation did not involved the production of another product.
Plastic waste	The output of consumption, which is disposed of and forms waste streams
Recovery	Recovery is a broad term that includes any useful use of a waste to

replace another material. In accordance with the Waste Framework Directive, recovery here is used to describe the following operations:

- Use of waste principally as a fuel or other means to generate energy
- Recycling/reclamation
- Oil re-refining or other reuses of oil
- Use of wastes obtained from any of the operations above
- Exchange of wastes for submission to any of the operations above
- Storage of wastes pending any of the operations above

A form of material recovery that should not be considered recycling is backfilling, where waste is used to refill excavated areas for engineering purposes (safety or slope reclamation).

Recyclate — Materials resulting from the processing of plastic waste (pellets, granules, flakes, etc).

Recycling — Although recycling is a form a material recovery, where the term ‘recycling’ has been used, it refers to material recovery involving the concept of reprocessing into products or raw materials.

Waste plastic — Plastic material that is a resource with a potential use such as an input into recycling processes.

Plastic recycling ‘cascade’ terminology[1]

ASTM D7209 – 06 standard definitions	Equivalent ISO 15270 standard definitions	Other equivalent terms
Primary recycling	Mechanical recycling	Closed-loop recycling
Secondary recycling	Mechanical recycling	Downgrading
Tertiary recycling	Chemical recycling	Feedstock recycling
Quaternary recycling	Energy recovery	Valorisation

[1] Adapted from Hopewell, J. et al. (2009) *Plastics recycling: challenges and opportunities*.
Note that quaternary “recycling” is not generally considered recycling in the EU context.

Abbreviations

ABS	Acrylonitrile butadiene styrene
amino	Any thermosetting synthetic resin formed by copolymerisation of amines or amides with aldehydes.
ANAIP	Asociacion Nacional de Industrias del Plastico
A-PET	Amorphous polyethylene terephthalate
APME	Association of Plastics Manufacturers in Europe (now PlasticsEurope)
ASA	Acrylonitrile styrene acrylate
ASR	Automotive shredder residue
B&C	Building and construction
BFR	Brominated flame retardant
BPA	Bisphenol A
BREF	Best Available Techniques reference document
C&D	Construction and demolition
CEN	European Committee for Standardization
C-PET	Crystalline polyethylene terephthalate
DEFRA	UK Department for the Environment, Food and Rural Affairs
EEA	European Environment Agency
EEE	Electrical and electronic equipment
ELV	End-of-life vehicles
EoL	End-of-life
EoW	End-of-waste
EP	Epoxy (resin)
EPBP	European PET Bottle Platform
EPRO	European Association of Plastics Recycling and Recovery Organisations
EPS	Expanded polystyrene
ETP	Engineering thermo-plastics
EuPC	European Plastics Converters
EuPR	European Plastics Recyclers
FEDEREC	Fédération des entreprises du recyclage (France)
FR	Flame retardant
HDPE	High density polyethylene
HIPS	High impact polystyrene
ISO	International Standardisation Organisation
kt	Thousand tonnes (kilotonne)
ktpa	Thousand tonnes per annum
LCA	Life-Cycle Assessment
LDPE	Low density polyethylene
LLDPE	Linear low density polyethylene
MR	Mechanical recycling
MRF	Material recovery facility
MS	Member State(s) of the European Union
MSW	Municipal solid waste
Mt	One million tonnes (Megatonne)
NAFTA	North American Free Trade Agreement

NIR	Near infrared
nm	nanometre
OECD	Organisation for Economic Co-operation and Development
OPA	Oriented polyamide
OPP	Oriented polypropylene
OPS	Oriented polystyrene
pa	Per annum
PA	Polyamide
PBB	Polybrominated biphenyls
PBDD/F	Polybrominated dibenzodioxins and dibenzofurans
PBDE	Polybrominated diphenyl ethers
PBT	Polybutylene terephtalate
PC	Polycarbonate
PCB	Polychlorinated biphenyl
PE	Polyethylene
PEN	Polyethylene naphthalate
PET	Polyethylene terephthalate
PLA	Polylactic acid
PMMA	Polymethyl methacrylate
POM	Poly-oxy-methylene
POPs	Persistent organic pollutants
PP	Polypropylene
PPE	Polyphenylene ether
PPO	Polyphenylene oxide
PS	Polystyrene
PU/PUR	Polyurethane
PVC	Polyvinyl chloride
PVDC	Polyvinylidene chloride
RoHS	Restriction of hazardous substances (in electrical and electronic equipment)
SAN	Styrene acrylonitrile copolymer
SMA	Styrene maleic anhydride
SB	Styrene-butadiene
UP	Unsaturated polyester
WEEE	Waste electrical and electronic equipment
WFD	Waste Framework Directive
WRAP	Waste & Resources Action Programme
XPS	Extruded polystyrene

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EXECUTIVE SUMMARY

HIGHLIGHTS

Plastic is a relatively cheap, durable and versatile material. Plastic products have brought benefits to society in terms of economic activity, jobs and quality of life. Plastics can even help reduce energy consumption and greenhouse gas emissions in many circumstances, even in some packaging applications when compared to the alternatives.

However, plastic waste also imposes negative environmental externalities. It is usually non-biodegradable and therefore can remain as waste in the environment for a very long time; it may pose risks to human health as well as the environment; and it can be difficult to reuse and/or recycle in practice. An issue of particular concern is that giant masses of plastic waste have been discovered in the North Atlantic and Pacific Oceans, the full environmental impacts of which are not yet fully understood but which cause severe damage to seabirds, marine mammals and fish.

This report describes trends in plastic waste generation and management, develops a baseline scenario, presents five policy options that could change that scenario and analyses the most promising three of these in more detail.

Plastic waste generation is set to continue growing and the development of new materials continues apace. Bioplastics are growing extremely rapidly but from a very small base, and further research into life-cycle environmental impacts is needed. As for recycling, it is also expected to grow in absolute terms and innovate technologically, but it will not keep up on current trends and so other solutions are needed.

Plastic waste cuts across a large number of policy fields and regulations are not usually targeted specifically at plastic waste. This makes it difficult for policy to evolve in line with trends in production, use and disposal. Policies and measures targeted specifically at plastic waste are needed, in co-ordination with broader waste policy.

A mix of policy initiatives can be recommended, targeted at key sectors, treatment options and types. Those described in this report are:

1. Sustainable packaging guidelines
2. Agricultural plastic recovery and recycling guidelines
3. WEEE and automotive plastic waste targets
4. Recycled plastics and bioplastics phasing targets
5. Research innovation on the reduction of plastic waste

Of these, the first, second and fourth policy options were judged to be the most appropriate and effective ones for further consideration. Option 1 would be likely to have the most significant effect on plastic waste reduction and recovery because it targets packaging. It will depend on the involvement of producers and retailers, which will drive the success of the instrument. Although the impact of Option 2 may be small, the option has the advantage of targeting a distinct sector and a particular type of material. Still, the difficulties of collection in rural areas must be taken into account. As for Option 4, the main effect would be to reduce the amount of petroplastics sent to disposal, the environmental benefits of which depend on those of the recycled plastics and bioplastics that would replace them. The policy options are not mutually exclusive and would complement each other well.

Whichever mix of policy options might be chosen, more complete and timely data on plastics generation and waste is also needed to help policy makers to respond effectively. Better information would also aid the design of consumer awareness campaigns regarding appropriate use and disposal of plastics and bioplastics – improved awareness is vital to the successful implementation of policy in this domain.

PLASTICS PRODUCTION AND USE

As with most materials, global plastics production is estimated to have fallen from 245 Mt in 2008 to around 230 Mt in 2009 as a result of the economic crisis. Over the past fifty years however, there has been a very steep rise in plastics production, especially in Asia. The EU accounts for around 25% of world production; China alone accounts for 15%.

Polyethylene has the highest share of production of any polymer type, while four sectors represent 72% of plastics demand: packaging, construction, automotive, and electrical and electronic equipment. The rest includes sectors such as household, furniture, agriculture and medical devices.

The plastics industry is in constant development, with technology evolving in response to ever-changing demand. Some trends that emerge clearly are continued innovation and improvements such as weight reduction of individual items, increasing use of plastics (and bioplastics) in vehicle manufacturing, a shift in primary plastic production to transition and emerging economies, and continued growth in the market share of bioplastics (despite some sorting and price barriers).

BIOPLASTICS

Bioplastics fall into either or both of two broad categories:

- **Bio-based plastics** that are derived from renewable resources;
- **Biodegradable (compostable) plastics** that meet standards for biodegradability and compostability.

Bio-based plastics can be either biodegradable or non-biodegradable. Similarly, biodegradable polymers can be petroleum-based.

In Europe, bioplastics consumption is estimated at around 0.1-0.2% of total EU plastics consumption but the global bioplastics market is growing very rapidly. Bioplastics can potentially be used for a wide range of applications but cannot yet replace all types of petroleum-based plastics for all applications, for reasons such as resistance and durability. Another barrier is compatibility with existing equipment and end-of-life management systems. In general, production costs are substantially higher than for petroleum-based plastics.

The main drivers for biodegradable polymers are landfill capacity, pressure from retailers, consumer demand, and legislation based on concern over fossil-fuel dependence and greenhouse gas emissions. However, the extent to which bioplastics can address these issues is a matter of some debate as the environmental qualities of bioplastics have not yet been documented comprehensively. Key considerations are the amount of non-renewable energy used in their manufacture and potential land-use implications.

PLASTIC WASTE MANAGEMENT

In 2008, total generation of post-consumer plastic waste in EU-27, Norway and Switzerland was 24.9 Mt. Packaging is by far the largest contributor to plastic waste at 63%. Average EU-27 per-capita generation of plastic packaging waste was 30.6 kg in 2007.

Several end-of-life options exist to deal with plastic waste, including recycling, disposal and incineration with or without energy recovery. The plastics recycling rate was 21.3% in 2008, helping to drive total recovery (energy recovery and recycling) to 51.3%. The highest rate of recycling is seen in Germany at 34% and the lowest in Greece at 8%.

As plastic packaging has the longest established system for the recovery and recycling of plastic waste, it is natural that its recycling rates are higher than those of other streams. It is followed by agricultural waste plastic, which although not under direct legislative obligation to increase recovery, is subject to economic incentives linked to the availability of homogenous materials. Although WEEE and construction plastic waste sources have relatively low rates of recycling overall, the rate of energy recovery is relatively high. Overall, total recovery is highest for plastic packaging at 59.8% and lowest for ELV plastics at 19.2%.

Plastic recycling needs to be carried out in a sustainable manner. However, it is attractive due to the potential environmental and economic benefits it can provide. There is a wide variety of recycled plastic applications and the market is growing.

However, demand depends on the price of virgin material as well as the quality of the recycled resin itself. Use of recycled plastics is marginal compared to virgin plastics across all plastic types due to a range of technological and market factors. Recycled plastics are not commonly used in food packaging (one of the biggest single markets for plastics) because of concerns about food safety and hygiene standards, though this is beginning to change.

Another constraint on the use of recycled plastics is that plastic processors require large quantities of recycled plastics, manufactured to strictly controlled specifications at a competitive price in comparison to virgin plastic. Such constraints are challenging, in particular because of the diversity sources and types of plastic waste and the high potential for contamination.

As some Member States do not have the capacity, technology or financial resources to treat plastic waste locally, a significant and growing amount is exported. The biggest net exporter of plastic packaging waste in relation to domestic generation is Luxembourg, followed by Belgium and Sweden. In Ireland and Bulgaria, more plastic is imported than is exported, resulting in negative net trade of around -8% and -2% respectively.

BASELINE SCENARIO

A baseline scenario of future plastic waste generation in the EU was projected to 2015, based on the current situation of plastic and bioplastic waste in the EU and existing policies and measures. An extrapolation was then made to 2020, to facilitate comparison with other studies on the Sustainable Management of Resources.

In summary, the projections show:

- a 23% increase in the **overall generation** of plastic waste of between 2008 and 2015, driven largely by the packaging sector;
- an overall decline in the level of **disposal** of plastic waste (from 49% to 43%), with the most significant drop seen in packaging;
- an increase in the proportion of **energy recovery** as a treatment option from 30% to 34% over the period;
- an increase in **overall recovery** of 36%;
- an increase of 30% in the overall level of **mechanical recycling** between 2008 and 2015. However, while overall levels of recycling increase, its share remains relatively stable.

It is not known exactly how the sectoral breakdown of plastic waste will change over time in line with changes in GDP, product production technologies, uptake of new materials such as biodegradable plastics or recycled PET, consumer behaviour and availability of resources. A major conclusion of the exercise is the importance and necessity of better statistics for all Member States. More reliable, timely and complete data on plastic waste would allow for more robust estimations and projections.

TRENDS IDENTIFIED

The following key trends were identified and are assumed to continue to 2015:

- the **generation** of plastic waste will increase;
- levels of **recycling**, primarily mechanical, will increase;
- levels of **energy recovery** will increase but in a more limited way than recycling levels due to the lead times associated with plant development;
- proportional use of **disposal** will decrease;
- the most substantive changes in terms of volume will be seen in the treatment of **packaging** wastes. However, proportional changes will also occur in the other sectors analysed.

Other trends likely to influence the impacts associated with generation and management of plastic wastes to 2015 are:

- a continuing upward trend in the **demand** for plastics;
- the level of **exports** of waste, in particular plastic waste for recycling and recovery, looks set to increase as overall recycling levels and volumes increase;
- the **production of plastics** will also tend to be dominated by the Asian market and particularly China;
- the **production of bioplastics**, while remaining a relatively low proportion of total plastic use, will increase rapidly;
- **waste-to-energy (incineration)** is set to increase, reducing the percentage of landfilling, and overall levels may decline.

Plastic waste generation is anticipated to rise in a proportionally significant way for all sectors. This raises questions: firstly in relation to packaging waste and whether existing targets are sufficient to continue to address what is the most significant sector for plastic waste generation in Europe; and secondly, whether action should be taken to address sectors whose waste generation is not explicitly regulated at present, e.g. agriculture.

In terms of environmental impacts the following trends are considered to be of most significance:

- **Rising use of plastics** – The primary plastics feedstock will remain fossil fuels, despite the anticipated rapid rise in the production of bioplastics.
- **Rising levels of plastic waste generation** – This implies the need for an expanded waste management system simply to remain capable of dealing with the anticipated increase waste production.
- **Increasing levels of recycling** – Recycling rates are anticipated to increase over the outlook period and end markets are developing. However, the proportion of disposal is expected to remain significant.

- **Post-2015 increase in energy recovery from plastic waste** – Many Member States will be relying heavily on biomass as a source of renewable energy to meet their targets for 2020 under Directive 2009/28/EC. There might therefore be an increase in levels of energy recovery in the run up to this deadline, particularly in light of the fact that plastics have a relatively high calorific value when burnt.
- **Increasing levels of export** – At present, rising levels of recycling in terms of volume and proportion appear to also be driving an increase in the level of export of plastic waste for reprocessing. The export trend means that while environmental impacts within Europe might be reduced, Europe's contribution in terms of global environmental impact will rise.

Overall, the level of environmental impact associated with plastic waste is anticipated to increase over the period to 2015 due to continued growth in plastic waste production (associated with continued rises in plastic waste consumption). Also, the continued expansion of plastic exports is anticipated to expand the environmental footprint of the EU associated with plastic waste globally.

More specifically, greenhouse gas emissions associated with the plastics life cycle are anticipated to increase, albeit on a lower trajectory than in the past. Negative consequences in terms of littering and plastic pollution in marine waters would also be anticipated to increase in the absence of any additional curbs.

It should be noted that the trends above assume an expansion in recycling capacity, which will require associated expansion in collection activities, use of secondary plastic materials and, associated with the latter, better methods for separating the different types of plastic to reduce contamination levels. These will allow the delivery of higher quality plastic waste streams to facilitate higher levels of recycling and to ensure quality markets for the secondary raw materials that result.

The main trends of interest in terms of economic impacts are anticipated to be the relative expansion of the recycling sector and questions regarding the economic impact of potentially lower economic growth on plastic waste treatment and secondary raw material use.

The main social impacts are anticipated to be associated with: health and in particular the epidemiological impacts associated with treatment of waste in third countries; and the social perceptions around the continued use and increasing levels of plastic consumption and waste production.

POLICY OPTIONS

An initial list of five potential policy options was drawn up, with particular emphasis placed on options that include preventive measures and options that minimise administrative burden. The policy measures also take into account the waste hierarchy described in Article 4 of the WFD: prevention; preparing for reuse; recycling; other recovery, e.g. energy recovery; and disposal.

These policy options are neither mutually exclusive nor exhaustive: there may be additional tools which would successfully contribute to more sustainable plastic use. For example, further efforts at national or local levels in the area of consumer behaviour and awareness might bear fruit.

Option 1: Sustainable packaging guidelines

The objective of this policy option is to provide plastic packaging consumers (retailers in particular) with a standardised methodology for using plastic packaging in a way that minimises the combined environmental impacts of products and their packaging and for better management of plastic packaging waste:

- **Voluntary initiative**;
- A system by which retailers may **measure the sustainability** of their plastic packaging would be developed, centring on the reduction of the overall environmental impact associated with the package and its contents, the inclusion of alternative materials and allowing recovery rates to be increased more easily;
- **Best-practice guidelines** and best-available techniques for plastic packaging producers, linked to the above system and emphasising use of plastic packaging in a way that minimises overall environmental impacts;
- An **independent labelling system** may be warranted, in order to provide feedback to consumers;
- A programme or campaign of **public awareness** and education that would cover plastics in general and differences between the main types of plastics.

Option 2: Agricultural plastic recovery and recycling guidelines

This policy would aim to introduce best-practice guidelines for the preparation, collection and recovery of agricultural waste plastics, and ultimately provide targets for the recycling and recovery of agricultural plastics:

- **Voluntary initiative**;
- Provide **guidelines for farmers** for the adequate preparation of plastics for collection as well as alternatives for the reduction of plastics use;
- Provide **best practice guidelines** for collection and recovery;
- Establish a central entity responsible for organising an **EU-wide network** of approved collectors and reprocessors that will manage recovery and recycling;
- Set **collection targets**, focusing particularly on plastics with a high rate of recyclability and which make up a large fraction of the market;

- As smaller collection schemes are already in place in some Member States, this measure should include the **identification of existing networks**, followed by the provision of support to expand collection.

Although not directly reducing the amount of plastic waste produced, this measure could result in increased recycling of agricultural plastic waste, thereby diverting this type of waste from landfill and potentially other disposal methods such as incineration.

Considering the volatile nature of the recycled plastics market, it is difficult to determine whether significant mitigation of resource depletion could be achieved.

OPTION 3: WEEE AND AUTOMOTIVE PLASTIC WASTE TARGETS

This initiative would set specific targets for the recovery of the plastic fraction of WEEE and automotive plastic wastes:

- **Mandatory initiative** in the form of an amendment to the WEEE and ELV Directives;
- Specific **guidelines** should be included to explicitly define recovery;
- In the case of WEEE waste, the specific inclusion of targets will need to be closely related to design and thus depends on the specific inclusion of plastics in the design considerations governed by the **Ecodesign Directive**.

This option has the potential to reduce the amount of plastic waste in the environment. However, a review of the language in the Directive may be required to determine whether incineration of plastic composites for use in cement production is in fact considered disposal or recovery. A main challenge would be to determine targets for what is often a small share of each respective product’s composition.

Considering the volatile nature of the recycled plastics market, it is difficult to determine whether significant mitigation of resource depletion could be achieved. Also, complications with contamination of plastic material may be a barrier to the success of this option. Plastics in automotive and EEE products often consist of composites, for which there is currently no commercially viable recycling technology, though composites may be used for the production of cement in kilns.

OPTION 4: RECYCLED PLASTICS AND BIOPLASTICS PHASED TARGETS

This initiative would set targets for the increased inclusion of recycled plastics and bioplastics in place of some types of virgin petroplastics, taking into account design viability, environmental impacts and market feasibility.

- **Mandatory policy**;
- **Targets** should be aimed at those plastic types that can:
    - be viably replaced by bioplastics,
    - suffer from low recovery and recycling targets;

- In order to maximise its effectiveness, this option could be combined with a **labelling system** and initiatives to increase public **awareness and education** about different types of plastics.

This initiative may not directly reduce the amount of plastic used, but instead replace petroleum-based plastics with either degradable plastics or recycled material.

It is assumed that increasing the market share of bioplastics and recycled plastic products can result in overall lower environmental impacts. However, it should be underlined that biodegradable plastics and recycled plastics still need to be properly disposed of. In the case of bioplastics, there may be other adverse environmental effects related to crop growth to consider.

The increased use of bioplastics may have implications for the recycled plastics industry, as it could potentially lead to the contamination of recycled plastics by bioplastics, affecting the quality and physical integrity of the resulting material. Investment may be needed in sorting technology to deal with this challenge.

The administrative burden may also be somewhat high as it will involve the creation of benchmarks (hence, further study may be necessary), drafting of new policy measures, and the monitoring of compliance in different Member States.

Option 5: Research innovation on the reduction of plastic waste

The initiative would aim to consider the most significant and viable measures for the reduction of plastic use in the design of different products:

- **Voluntary initiative**;
- Although no specific targets may be provided, guidelines of **best practices** or best-available techniques should be developed;
- The results of this initiative should go towards **informing policy makers** and perhaps the integration of some measures into existing policy instruments.

It is difficult to estimate the degree to which investment in innovation will aid the reduction of plastic waste. Research efforts will facilitate best practices and potentially lead to the introduction of novel technology that can contribute to reducing the amount of plastic waste produced.

With this initiative, there is the question of where funds may be sourced from and how they should be distributed. Investment in research innovation could lead to increased availability of academic and employment opportunities, particularly within the EU.

COMPARISON OF THE POLICY OPTIONS

A simply multi-criteria analysis was used to determine the top three options. Options 1 (packaging guidelines), 2 (agriculture sector) and 4 (targets) were found to be the most viable, mainly due to their greater environmental benefits.

These three policy options were then compared to the baseline scenario in order to determine the extent to which they can reduce the quantity of plastic waste compared to the baseline and highlight their strengths and weaknesses.

Option 1: Sustainable packaging guidelines

This option could result in positive outcomes, particularly in terms of increasing levels of recycling; reducing the overall quantities of plastic packaging, hence preventing waste and reducing use of virgin raw materials; and increasing the quality of recyclables, promoting better sorting and understanding of the different materials involved and potentially leading to better/more reliable sources of secondary materials and increased confidence in the use of such materials. The approach would offer flexibility for industry in terms of their implementation approach and potentially lead to a better environmental reputation of the retail sector and increased awareness concerning the management of this key area for packaging generation. The major challenge associated with it is that its voluntary nature means that outcomes cannot be guaranteed and the lack of binding requirements means that other instruments would need to be put in place in order to promote adoption by the industry, i.e. labelling schemes so that compliance can be recognised or some alternative form of incentives associated with adoption.

In order to provide a quantitative estimate of impacts, despite the potential high variability in the level of delivery, it is estimated that the guidelines might result in a reduction of 30% in plastic packaging material by 2015. In addition it is anticipated that plastic packaging recycling would be expected to increase by 20% over the period – in addition to existing estimates for 2015 based on business as usual.

Option 2: Agricultural plastic recovery and recycling guidelines

The key benefit of Option 2 is that it offers a flexible approach to dealing with plastic waste generated by the agriculture sector, a significant sector where there is currently no binding regulation to directly address this question. It also supports the development of collection infrastructure in rural areas, which might lead to the more effective management of waste more broadly in these regions. The guidelines should have a positive impact on levels of recycling and recovery in this sector. However, the way in which materials are treated following collection is less within the control of the agriculture sector. Drawbacks might include a lack of clarity in terms of anticipated action and potential variability in approaches adopted in different Member States.

It is estimated that guidelines in this sector would lead to both an increase in recycling of particular polymers and also an increase in the overall level of recovery. Values assigned for these changes are delivering 50% recycling of LDPE produced by agriculture and also achieving a 70% level of recovery for this sector – compared to the original BAU estimate of 49%.

OPTION 4: RECYCLED PLASTICS AND BIOPLASTICS PHASED TARGETS

The obvious benefit of such targets would be that they should lead to a reduction in the use of primary raw materials and specifically the use of petroleum-based plastics. They would also encourage innovation in the sector. However, the implementation of such targets would need to be associated with supporting measures to raise awareness regarding the potential uses of bioplastics/recycled materials and their treatment at end-of-life by consumers. Otherwise there would be a risk of imposing targets on industry that might lead to significant costs but without support in terms of delivery. Moreover, there are risks of contamination of waste streams. Some stakeholders express concern over the broad application of targets for inclusion of certain levels of materials in products.

It is assumed that the following targets would apply: that 10% of the plastics placed on the market are bioplastics; and that 15% of plastic materials placed on the market would be recycled by 2020.

SUMMARY OF POLICY OPTION ANALYSIS

Although direct comparison of the three policy options is not always feasible, the analysis has shown that due to the size of the sector involved in Option 1, if successful this option is likely to have the most significant effect on plastic waste reduction and recovery, and consequently on the environment, employment and the economy. This will largely be dependent on the involvement of producers and retailers, which will drive the success of the instrument.

In the case of Option 2, although its impact may be small, the option deals with a distinct sector and a particular type of material. Although this does facilitate the construction of a network for managing agricultural plastics, the inherent difficulty of collection in rural areas must also be taken into account.

The main effect of Option 4 is to reduce the amount of petroplastics sent to disposal with the ultimate goal of reducing the impacts tied to production and disposal. Further study is required to determine whether the impacts of increased bioplastics production outweigh the benefits of the reduction of plastics at the end-of-life phase. In the case of increasing recycled plastics consumption, although the direct reduction potential is uncertain, an increase in recycling at the expense of virgin plastics production would have a definite positive impact of the environment.

A final aspect to consider is the potential to link these three options. Considering that Options 1 and 2 address different sectors, and potentially rely on different instruments and methods of implementation, it is highly likely that these two options can be implemented in parallel at the EU level. Although plastic waste generation would still only see a modest 1.9% reduction, disposal could be reduced by as much as 41.2% and total recovery could be increased by 19.2%. However, the introduction of Option 3 would impact the feasibility of Options 1 and 2, as the replacement of materials upstream can affect the viability of product design (in the case of Option 1), and the recycling and recovery rate of certain materials (in the case of either option). It would nevertheless be possible to introduce all three policy instruments simultaneously, as for the most part they can work independently from each other, thus further increasing environmental and economic benefits.

1. INTRODUCTION

The objective of this study is to gather and analyse available data and information on plastic generation and waste, current waste management options and the related environmental and health impacts. The study addresses types of plastics and their major uses. It also aims to consider potential additional measures that can be taken at various levels to reduce plastic waste and its associated impacts.

1.1. CONTEXT

Plastic is a relatively cheap, durable and versatile material. These properties have led to the creation of many thousands of products, which have brought benefits to society in terms of economic activity, jobs and quality of life. Plastics can even in many circumstances help reduce energy consumption and greenhouse gas emissions, especially when compared with the alternatives, but sometimes independently such as in the cases of insulation and applications in wind and solar photovoltaic power generation.[2]

However, plastic waste can also impose negative externalities such as greenhouse gas emissions or ecological damage. It is usually non-biodegradable and therefore can remain as waste in the environment for a very long time; it may pose risks to human health and the environment; in some cases, it can be difficult to reuse and/or recycle.

There is a mounting body of evidence which indicates that substantial quantities of plastic waste are now polluting marine and other habitats.[3] The widespread presence of these materials has resulted in numerous accounts of wildlife becoming entangled in plastic, leading to injury or impaired movement, in some cases resulting in death. Concerns have been raised regarding the effects of plastic ingestion as there is some evidence to indicate that toxic chemicals from plastics can accumulate in living organisms and throughout nutrient chains. There are also some public health concerns arising from the use of plastics treated with chemicals.[3]

Societies are increasingly reliant on plastics, which are already a ubiquitous part of everyday life. As the development of new materials is ongoing, limiting their detrimental effects poses new challenges for policy makers. Regulatory instruments designed to mitigate the effects of plastics on human health and the environment must evolve in line with trends in production, use and disposal (Figure 1-1).

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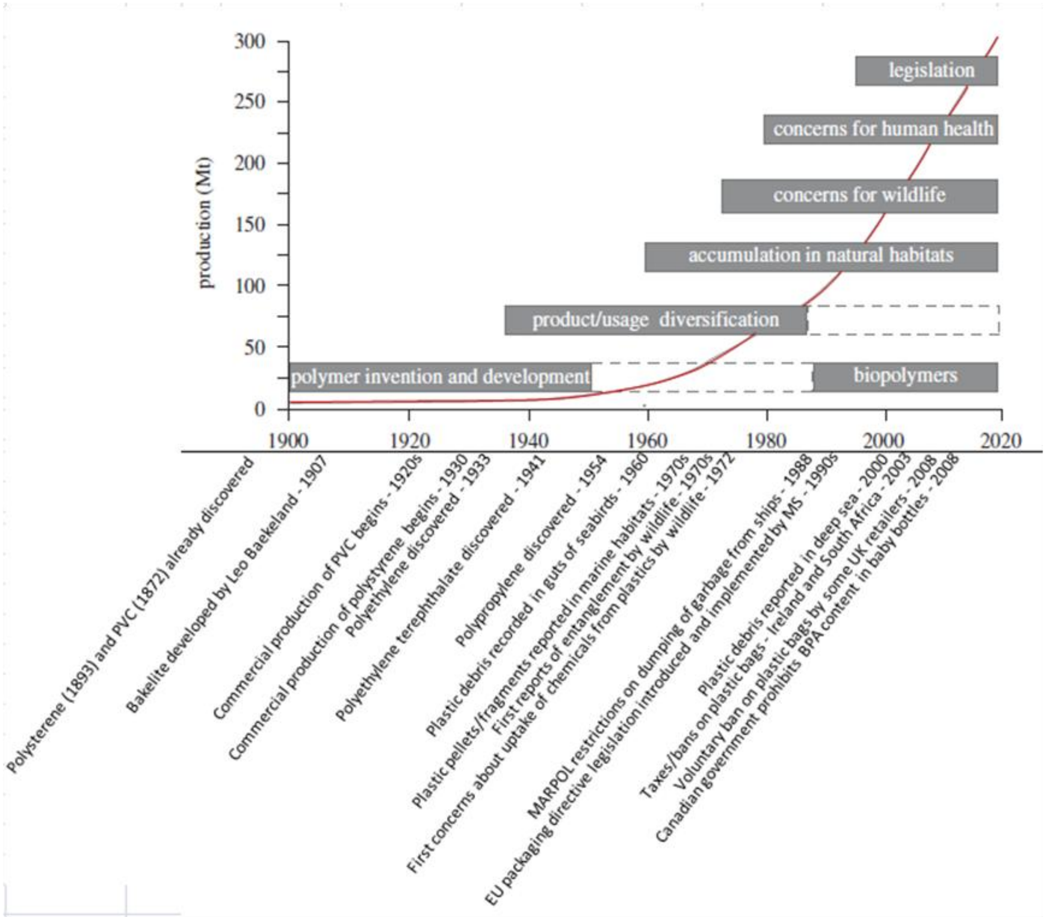
[2] Pilz, H., Brandt, B. and R. Fehringer (2010) *The impact of plastics on life cycle energy consumption and greenhouse gas emissions in Europe*, Summary report, Denkstatt.

[3] Thompson R. C., Swan S. H., Moore C. J. and vom Saal F. S. (2009) "Our plastic age" in *Philosophical Transactions of the Royal Society*.

Figure 1-1: Global plastic production (Mt) with historical stages in the development, production and use of plastics, and associated concerns and legislative measures[4]



1.1.1. Policies targeting plastic waste

The management of plastic waste cuts across a number of policy fields: not only the sustainable management of resources but also climate change, energy, biodiversity, habitat protection, agriculture and soil protection. This section provides an overview of existing EU measures to reduce the environmental impacts of plastic waste.

Note that regulations are not usually targeted specifically at plastic waste, let alone specific types of plastic. This limits the incentive to divert plastic waste when, for example, other elements of the waste stream such as paper or glass will meet weight-based targets far more easily and quickly.

1.1.1.1 Waste Framework Directive, 2008/98/EC

The Waste Framework Directive (WFD), revised in 2008, aims to protect human health and the environment against harmful effects caused by the collection, transport, treatment, storage and landfilling of waste.

[4] Adapted from Thompson R. C., Swan S. H., Moore C. J. and vom Saal F. S. (2009) "Our plastic age" in *Philosophical Transactions of the Royal Society*.

The Directive:

- sets new recycling targets to be achieved by EU Member States by 2020, including recycling rates of 50% by weight for household and similar wastes and 70% for construction and demolition waste;
- strengthens provisions on waste prevention through an obligation on Member States to develop national waste prevention programmes and a commitment from the EC to report on prevention and set waste prevention objectives;
- sets a clear, five-step "hierarchy" of waste management options; prevention is the preferred option, followed by reuse, recycling and other forms of recovery – with safe disposal as a last resort; and
- clarifies a number of important definitions, such as recycling, recovery and waste itself. In particular, it draws a line between waste and by-products. Through the concept of End-of-Waste, it also defines criteria to indicate when waste has been recovered enough – through recycling or other treatment – to become a non-waste (e.g. secondary material, by-product and product). Furthermore, the criteria will include limit values for pollutants where necessary and take into account any possible adverse environmental effects of the substance or object.

Plastics typically make up a large proportion of the waste streams covered by the Directive so the revision is likely to have a significant impact.

1.1.1.2 Landfill Directive, 1999/31/EC

Directive 1999/31/EC of 26 April 1999, the Landfill Directive, on the landfill of waste has set a combination of intermediate and long-term targets for the phased reduction of biodegradable waste going to landfill, and banned the disposal to landfill of certain materials (e.g. infectious hospital and other clinical wastes). It also requires the pre-treatment of wastes going to landfill (which can include sorting).

The Directive will therefore have an influence on the disposal of biodegradable plastics. Possible future increases in use of this material, for example in food packaging, may create difficulties in meeting the biodegradable waste to landfill targets.

The requirement for treatment or sorting of waste may boost recycling of plastics, as this can be a crucial but costly stage in the process of plastic recycling – mandating sorting of waste could therefore increase recycling levels by providing greater volumes of treated and sorted plastics.

1.1.1.3 Packaging and Packaging Waste Directive, 94/62/EC

Directive 94/62/EC on Packaging and Packaging Waste covers all packaging placed on the market in the Community and all packaging waste, and requires the return and/or collection of used packaging in order to meet targets for the recovery and recycling of this material. This includes plastic packaging and plastic packaging waste. By no later than 31 December 2008, a target of 22.5% for the return and/or collection of plastic materials contained in packaging was to be attained.[5]

Although the target dates have passed, amendment 2005/20/EC set different target deadlines until the end of 2012 for ten Member States (the Czech Republic, Estonia, Cyprus, Latvia, Lithuania, Hungary, Malta, Poland, Slovenia and Slovakia).

Commission Decision 1999/177/EC established a derogation for plastic crates and plastic pallets in relation to the heavy metal concentration levels established in the Directive on Packaging and Packaging Waste. In 2009, the Commission extended the derogation.

1.1.1.4 Registration, Evaluation, Authorisation and restriction of CHemicals (REACH), 1907/2006/E

REACH aims to lower levels of pollution and increase safety levels in relation to the use of hazardous chemicals. Recycled plastics are affected as it requires recycling firms to provide information on the types of chemicals included in their recycled plastics. Furthermore, the Regulation requires recycled plastics producers to register chemicals in the European Chemicals Agency database.

- **Waste**

The REACH Regulation does not exempt waste from its provisions but clarifies that waste is not a substance, a preparation or an article within the definition of REACH.[6] However, when a Chemical Safety Assessment is required for a substance, this must include the whole life cycle of the substance including the waste stage (cf. Annex I, 0.7 and 5.1.1). If necessary to manage risks from chemical substances, recommended waste management measures have to be communicated through the supply chain via Safety Data Sheets (heading 13). However, waste treatment is not a downstream use under REACH and waste treatment operators will not receive Safety Data Sheets on how to handle the substance during the waste phase.

It is important to note that once waste is recovered and in this recovery process another substance, preparation or article is produced, the REACH rules will in principle apply. In specific cases, where a recovered substance is the same as a substance which has already been registered, an exemption from the registration obligation may apply.

- **Recovered plastic**

According to a document published in May 2008 by the European Chemical Agency,[7] companies undertaking recovery of plastic polymer substances from waste are exempted from the obligation to register the monomer(s) or any other substance(s) meeting the provisions of Article 6(3) in the recycled polymer, provided that the

[5] See http://europa.eu/legislation_summaries/environment/waste_management/l21207_en.htm.
[6] European Chemical Agency (2009) *Guidance on registration*. Available at: http://guidance.echa.europa.eu/docs/guidance_document/registration_en.pdf.
[7] European Chemical Agency (2008) *Guidance for the implementation of REACH, Guidance for monomers and polymers*. Available at: http://guidance.echa.europa.eu/docs/guidance_document/polymers_en.pdf.

substance(s) constituting the recycled polymer have been registered.[8] It is worth noting that this exemption does not require the substance to have been registered by an actor in the same supply chain. It is sufficient that a registration was made for the substance by a company in another supply chain. The remaining uncertainty concerns the point at which waste will cease to be waste and be covered by the REACH Regulation.

Should the polymer recovery also include the recovery of other intended substances (e.g. substances added to adjust or improve the appearance and/or the physicochemical properties of polymeric material) originally present in the polymeric material that was recovered, as may be the case for selective recovery, it is recommended that the recovered material be regarded as a preparation. For example in the case of selective recycling of soft PVC, it may be necessary to register the relevant softeners, unless they have been registered before.

Whenever the presence of other chemicals derived from substances originally present in the polymeric material that was recovered is not intentional, these chemicals can be regarded as impurities of the recovered polymer substance (e.g. pigments which have no more intended function in the recovered material can be considered as impurities). If however the chemical constituent is present in quantities above 20%, the constituent should be seen as a substance in a preparation, even if its presence is non-intentional.

In determining the status of the recovered polymeric material, information on its origin may be important in order to know which constituents may be present in the material and whether they should be seen as impurities or separate substances. An analysis of the waste material will only be necessary if constituents may in normal cases occur in quantities above 20% (or are intended). Moreover, if impurities are relevant for the hazard profile of the material or might be subject to restrictions under REACH, further analysis may be necessary. Analysis of the material is not required in cases where no significant impurities are expected. In some cases it is possible to characterise the recovered polymeric product sufficiently without considering the origin.

If the recovery process directly results in articles (i.e. if the first non-waste product in the recovery chain is an article and neither a substance nor a preparation), any polymer substance present in the recovered articles is exempted from the registration requirements under REACH.

The European Plastics Converters (EuPC), the European Plastics Recyclers (EuPR), PlasticsEurope and Vinyl 2010 have launched a project on Safety Datasheets for Recyclates (SDS-R). REACH requires information exchange between producers and users of plastic materials. Due to their particular position in the supply chain, plastics recyclers may find it difficult to assemble the necessary waste composition information and may thus not be able to provide their customers with the information required to meet their REACH obligations.

[8] Article 2(7)(d)) of the Reach regulation.

The aim of the project is to create tailor-made Safety Data Sheets for recycled plastics, downloadable from a website accessible to recyclers. These Safety Data Sheets will be based on historical data for polymers and toxicological data for polymer additives. Recyclers will be prompted to input specific data related to the recycled articles in order to improve the accuracy and the quality of the SDS.

Meanwhile, the P-REACH (Polymer REACH) project is developing an e-learning platform and training materials for the European polymer industry to help it understand how to manage its obligations under REACH. The project uses a "blended learning" approach, offering both interactive on-line modules and traditional paper-based materials, focusing on the needs of small- and medium-sized enterprises (SMEs).[9]

1.1.1.5 Waste Electrical and Electronic Equipment Directive, 2002/96/EC

Electrical and electronic equipment (EEE) being an important source of waste plastic, Directive 2002/96/EC on Waste Electrical and Electronic Equipment has some important implications for plastics recycling. The Directive sets out certain design requirements, the result of which could be a gradual reduction in the variety of plastic components in EEE products. The legislation increases the emphasis on the recyclability of EEE product components, though costs and economic feasibility remain barriers to its success.

1.1.1.6 End-of-Life Vehicles Directive, 2000/53/EC

Vehicles form a small but significant part of the plastic waste stream. Directive 2000/53/EC, the End-of-Life Vehicles (ELV) Directive, sets out targets aiming to reduce the amount of waste from vehicles when they reach the end-of-life stage. One such target is that by 1 January 2015, reuse and recovery of vehicle material (including plastics) must be increased to a minimum of 85%. However, plastic parts in vehicles do not at present contribute greatly to targets in the ELV Directive, and rates of recycling for ELV plastics are relatively low.[10]

1.1.1.7 Ecodesign Directive, 2005/32/EC, 2009/125/EC

The Ecodesign Directive is one of the important building blocks of the Sustainable Consumption and Production and Sustainable Industrial Policy Action Plan of the European Commission.[11] The Ecodesign Directive is a product-based policy tool that seeks to integrate environmental aspects in the design phase of products with the aim of improving their environmental performance throughout the product's life cycle. Requirements regarding the ecodesign of products can contribute to sustainable production by substituting the worst-performing products on the market and shifting the economy towards solutions with least life-cycle costs.

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[9] This project is supported by the EC's Life Long Learning programme, Leonardo, and will run to 2011. The consortium includes the British Plastics Federation, Rapra Limited and other partners from Belgium, Italy, Portugal, Lithuania and Estonia.

[10] Brass (2006) *End of Life Vehicle Waste Management*. Available at: www.brass.cf.ac.uk/uploads/Series3elvpdf.pdf.

[11] See http://ec.europa.eu/environment/eussd/escp_en.htm.

The Ecodesign Directive covers all the environmental impacts caused by products during any phase of the life cycle. In all Ecodesign preparatory studies, a life-cycle assessment of typical products is carried out and impacts are calculated for 13 environmental indicators (emissions to air, to water, resource consumption, waste generation, etc.). The use of plastics in a product can have a significant effect on several of these indicators.

Other environmental issues with relevance to plastic waste, such as natural resource consumption, have been highlighted as key aspects in environmental policy development in the EU in recent years. For example, the 6th Environmental Action Programme introduced the concept of Thematic Strategies, covering several fields such as air, soils, natural resources, or waste prevention and recycling. The Ecodesign Directive is a horizontal tool with a wide scope that makes possible to address issues on all those subjects. For the development of the new working plan of the Ecodesign Directive, material efficiency (including in relation to plastics) and other environmental aspects will be just as important as energy efficiency.

1.1.1.8 Plastic materials and articles intended to come into contact with food Directive

Directive 2002/72/EC, relating to plastic materials and articles intended to come into contact with food, establishes a list of monomers and other substances, such as additives, that are permitted for use in the manufacture of food packaging. It also amends existing restrictions, in particular related to epoxidised soybean oil (ESBO) migration in PVC gaskets used to seal glass jars containing foods for infants and young children.

1.1.1.9 Lead Market Initiative

DG Enterprise and Industry has initiated a policy to drive six lead markets,[12] bringing together the European Commission, Member States and industry. Of particular interest from a plastics perspective are the bio-based products and recycling markets. The programme develops policy initiatives under four broad themes:

- standardisation, labelling and certification;
- legislation;
- public procurement; and
- complementary actions.

Bio-plastics are included in the bio-based products programme and this involves proposals, amongst others, to apply the EU Eco-label to products with a minimum level of bio-based content, map bio-refinery facilities and fund research through FP7 calls. The recycling programme aims to, for example, support the implementation of the

[12] "A lead market is the market of a product or service in a given geographical area, where the diffusion process of an internationally successful innovation (technological or non-technological) first took off and is sustained and expanded through a wide range of different services." See: http://ec.europa.eu/enterprise/policies/innovation/policy/lead-market-initiative.

WFD, stimulate demand for recycled products through public procurement, set up eco-innovation projects to develop new recycling techniques and support best practice networks.

1.1.1.10 Regulation on shipments of waste, (EC) 1013/2006

This Regulation aims to prevent the illegal shipment of waste. Under Article 59, checks can be carried out on waste shipments or on related recovery or disposal.

The rationale for the review of the waste shipment Regulations in 2006 was the implementation of various changes in the UNEP Basel convention on transboundary movements of waste. According to the Regulation's provisions, two types of procedures can apply in cases where transboundary shipments are allowed:[13] the so-called "green list" and the notification procedure. When waste falls within the scope of the green list, transboundary shipments are facilitated.

Plastic waste is generally on the green list,[14] except when unsorted, dirty or contaminated. Nevertheless, main destination countries such as China and India have considerably reinforced their control procedures.

National authorities contacted for the purposes of study responded that they do not possess statistics on plastics waste shipments since this material is green-listed and does not require notification to the authorities.

1.1.1.11 Thematic Strategy on the Prevention and Recycling of Waste

The European Commission Communication of 21 December 2005 describes the Thematic Strategy on the Prevention and Recycling of Waste, which sets out guidelines for EU action and describes the ways in which waste management can be improved. The aim of the strategy is to reduce the negative impact on the environment caused by waste throughout its lifespan. This overall strategy encompasses many of the legislative developments discussed above.

The main focus of the strategy for preventing waste production is on reducing the environmental impact of waste and products that will become waste. In order to be effective, this impact must be reduced at every stage of a resource's lifespan. The strategy places particular emphasis on biodegradable waste, two-thirds of which must be redirected to be disposed of using methods other than landfill as is required under the Landfill Directive, 1999/31/EC.

Remaining issues related to plastics include the potential to increase the use of plastic waste as a resource and reduce the need for virgin resources (landfilling of plastics increased by 22% between 1990 and 2002 despite increased recycling). However, there may be limited net environmental advantage to recycling some mixed/contaminated plastic waste for non-technical applications when it replaces a less polluting feedstock such as wood.

[13] Therefore excluding red listed products.
[14] Directive 2006/1013/EC on Waste Shipments.

Work is currently ongoing to review the strategy and a parallel study to this one is examining this in detail.[15] That study in particular aims to make an assessment regarding the impact to date of the Thematic Strategy towards the key objectives to increase recycling and reuse; to improve disposal; and to prevent waste.

1.1.1.12 Resource Efficient Europe

The Europe 2020 Flagship Initiative "Resource Efficient Europe" aims "to support the shift towards a resource efficient and low-carbon economy that is efficient in the way it uses all resources. The aim is to decouple our economic growth from resource and energy use, reduce CO_2 emissions, enhance competitiveness and promote greater energy security."

The strategy states that "At EU level, the Commission will work (…) to establish a vision of structural and technological changes required to move to a low carbon, resource efficient and climate resilient economy by 2050 which will allow the EU to achieve its emissions reduction and biodiversity targets; this includes disaster prevention and response, harnessing the contribution of cohesion, agricultural, rural development and maritime policies to address climate change, in particular through adaptation measures based on more efficient use of resources, which will also contribute to improving global food security."

The Commission is preparing a Communication for summer 2011 on "The Road Map towards a Resource Efficient Europe".

1.1.2. Note on plastic waste data

The EU List of Wastes (2000/532/EC) provides a framework for the collection of official statistics on plastic waste streams. The data gathered in this report has been organised according to the different waste streams set out in the table below.

Table 1: Sources of plastic waste according to official waste categories[16]

Description		Waste category - EU list of waste (200/532/EC)	Sector
Municipal wastes and similar commercial, industrial and institutional wastes including separately collected fractions	Mixed municipal waste	20 03 01	Municipal solid waste (MSW)
	Separately collected fraction - plastics	20 01 39	
Waste packaging; absorbents, wiping cloths, filter materials and protective clothing not otherwise specified	Plastic packaging	15 01 02	Plastic packaging and other plastic waste
	Mixed packaging	15 01 06	
	Composite packaging	15 01 05	

[15] See www.eu-smr.eu/tssrm.

[16] List of Wastes in Commission Decision 2000/532/EC. Available at: eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2000D0532:20020101:EN:PDF.

Description		Waste category - EU list of waste (200/532/EC)	Sector
Construction and demolition wastes (including road construction)	Plastic	17 02 03	Demolition and construction waste
	Glass, plastic and wood containing or contaminated with dangerous substances	17 02 04*[17]	
Wastes from agricultural, horticultural, hunting, fishing and aquaculture primary production, food preparation and processing	Waste plastics (except packaging)	02 01 04	Agricultural waste
Wastes from the MFSU (Manufacture Formulation Supply and Use) of plastics, synthetic rubber and man-made fibres	Waste plastic	07 02 13	Production areas (industrial sources)
Wastes from shaping (including forgoing, welding, pressing, drawing, turning, cutting and filing)	Plastic particles	12 01 05	
ELVs and their components	ELVs, drained of liquids and emptied of other hazardous components	16 01 06	ELVs
	Plastic	16 01 19	
Wastes from waste management facilities , off-site wastewater treatment plants and the preparation of water intended for human consumption and water for industrial use	Plastic and rubber	19 12 04	Wastes from the mechanical treatment of waste not otherwise specified

It is important to distinguish between pre-consumer and post-consumer plastic waste. Pre-consumer plastic waste is defined as material sent by industry for disposal, which is not fed back into the production line. This type of waste is currently recycled to a greater extent than post-consumer plastic waste, as it is relatively pure, available in high volumes, and often supplied by a small number of sources. Unless otherwise stated, the data presented in this report is based on post-consumer waste generation figures.

In most sections of this report, accurate and updated data on plastic waste have been provided. The data presented can be considered a good representation of the current situation in the EU-27. However, data is not consistently available for the same year across all sectors or at country level for all Member States. In some cases, the data that has been found dates from more than five years ago, which is unfortunate since rapid changes in the development of certain sectors of the plastics market are being observed.

[17] Any waste category of the EU Waste List marked with an asterisk (*) is considered as a hazardous waste pursuant to the Hazardous Waste Directive 91/689/EEC (Art. 1).

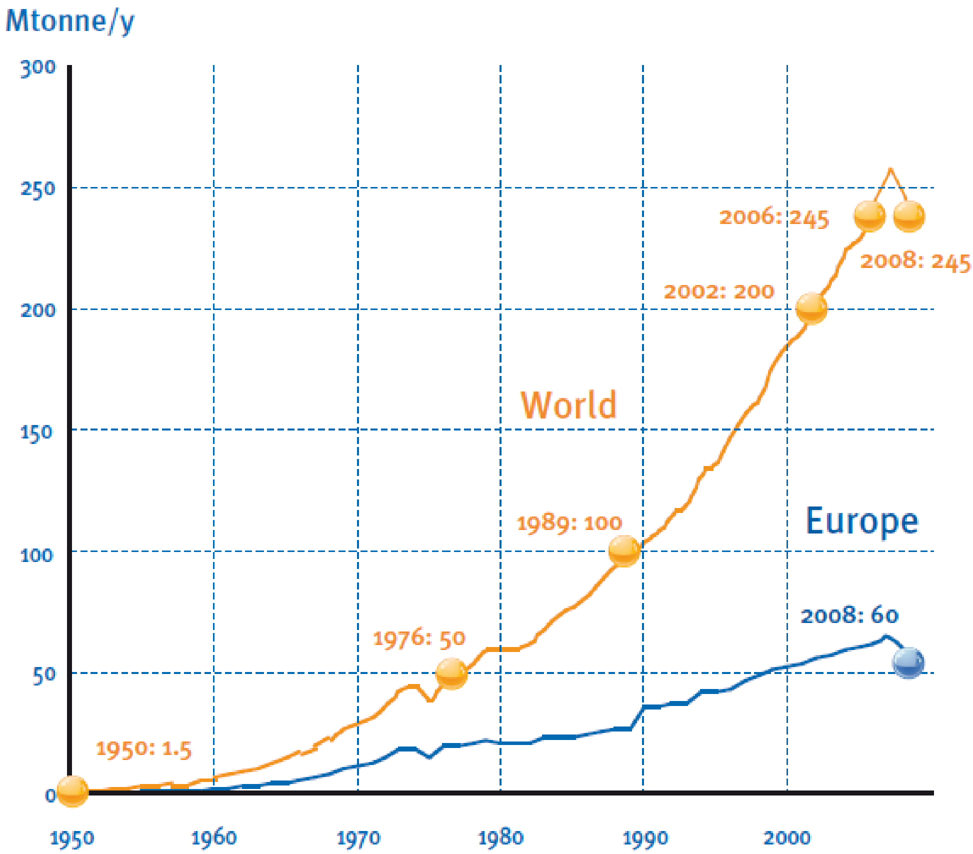
2. PLASTIC WASTE GENERATION

2.1. PLASTIC CONSUMPTION AND PRODUCTION

2.1.1. REGIONAL DISTRIBUTION

Figure 2-1 presents global and European plastics production from 1950 to 2008. Global plastics production has grown markedly faster than European production, most likely due to the growth of plastics production in Asia, which accounted for 93.1 Mt, or 38%, of world production in 2008. Global production is estimated by PlasticsEurope to have fallen from 245 Mt in 2008 to around 230 Mt in 2009.

Figure 2-1: World plastics production, 1950-2008 (Mt)[18]

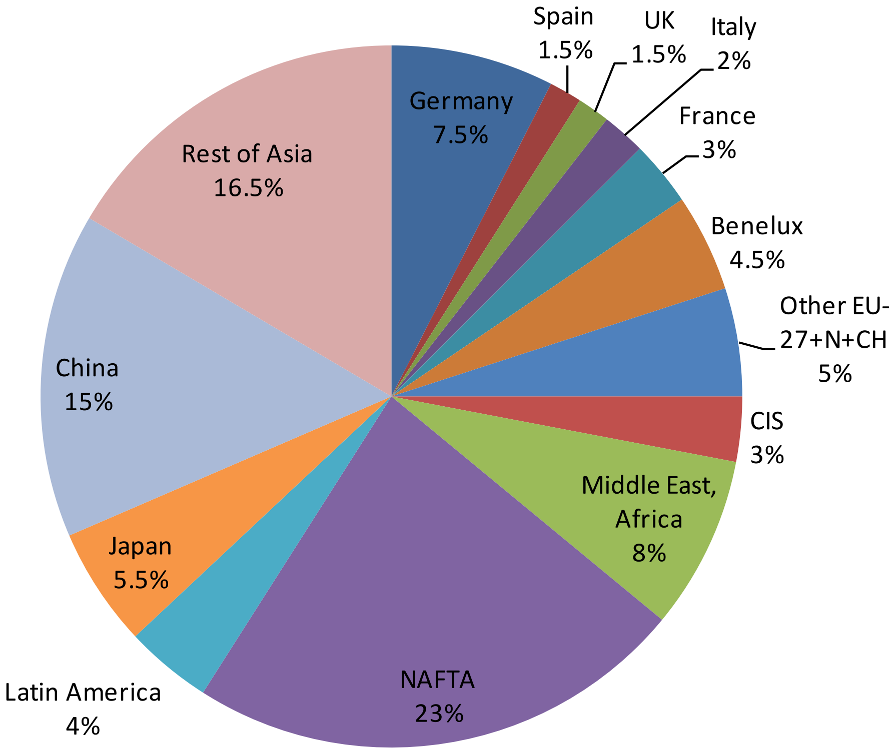


Includes Thermoplastics, Polyurethanes, Thermosets, Elastomers, Adhesives, Coatings and Sealants and PP-Fibers. Not included PET-, PA- and Polyacryl-Fibers

18 PlasticsEurope, EuPC, EuPR, EPRO and Consultic (2009) *The Compelling Facts about Plastics - An analysis of European plastics production, demand and recovery for 2008*.

The EU accounts for around 25% of world production.[19] China produces more plastic than any other country, at 15% of global production. Germany produces the greatest amount of any EU country, accounting for about 8% of global production.

Figure 2-2: Distribution of world plastics production[19]

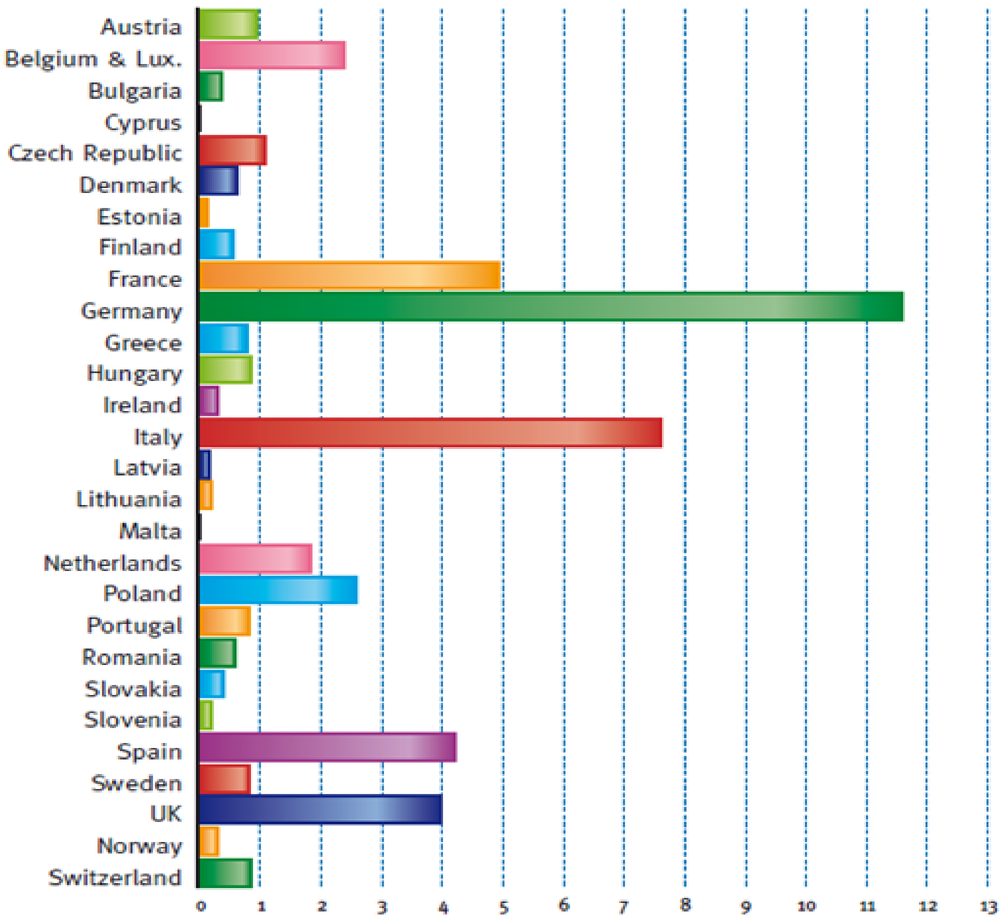


In Europe, plastics demand from converters in the EU-25, Norway and Switzerland was 48.5 Mt in 2008. Demand expressed as tonnage of virgin resin processed by European converters by country is shown in Figure 2-3.

The major plastic-consuming countries are Germany and Italy, which together account for around 40% of the EU market of converters to plastic products. Of the new Member States, Poland has the largest amount of plastic conversion, currently at around 2.5 Mt. The Czech Republic and Hungary are each at about half this level.

[19] Ibid.

Figure 2-3: Plastic demand from converters by country (tonnes of virgin resin), 2008[19]

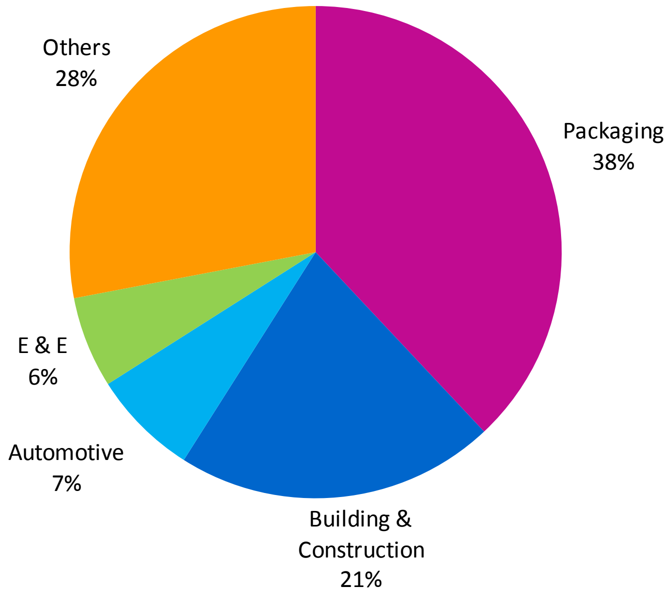


2.1.2. SECTORAL DEMAND

Various end uses of plastic in EU-27, Norway and Switzerland are shown in Figure 2-4. It is clear that packaging is the largest single sector for plastics, at about 38% (18.5 Mt). Other data suggests that around 73% is used by households while the remaining 27% is used as distribution packaging in industry.[20] Household packaging applications are usually quite short-lived but distribution packaging items that are designed to be reused, such as pallets, crates and drums, generally have much longer lifespans (10-15 years).[21]

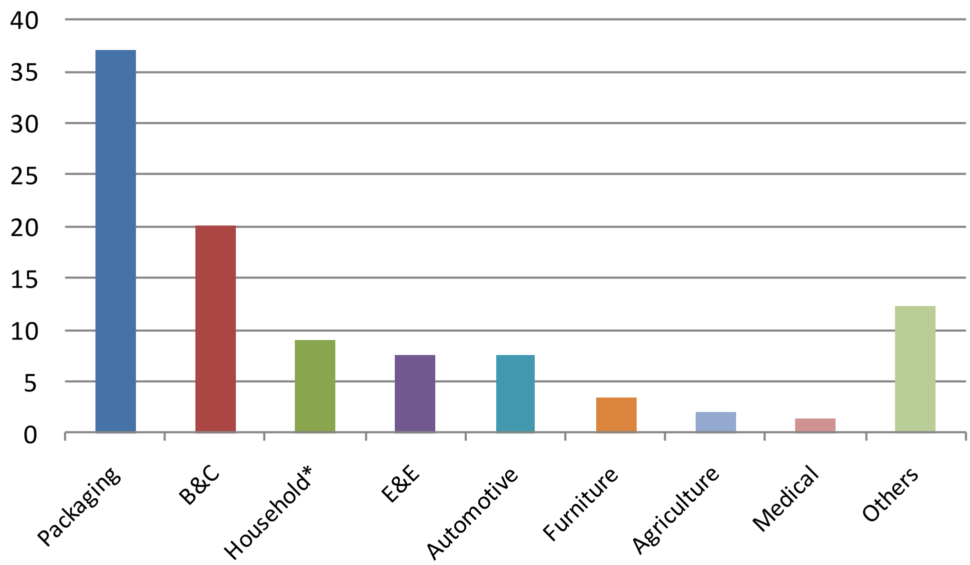
[20] Association of Plastic Manufacturers in Europe (APME) (1999) *A material of choice for packaging*.
[21] Bio Intelligence Service (2008) *Study to analyse the derogation request on the use of heavy metals in plastic crates and plastic pallets*, European Commission DG Environment.

Figure 2-4: Plastics demand by end-use in EU-27, Norway and Switzerland, 2008[19]



Four sectors represent 72% of plastics demand: packaging, building & construction (B&C, 21%), automotive (7%) and electrical and electronic equipment (EEE, 6%). The category "Others" include sectors such as household (toys, leisure and sports goods), furniture, agriculture and medical devices. Older data (see Figure 2-5) enables a more precise breakdown by category of plastics demand in 2004 (EU-15, Norway and Switzerland). Household goods represented a substantial share of demand at 9%. The other sectors' shares were similar to the more recent data: 37% for packaging, 20% for B&C and 7.5% for automotive and EEE.

Figure 2-5: Plastics demand in EU-15, Norway and Switzerland by end-use application, 2004 (%)[22]



*Includes sports and leisure

[22] PlasticsEurope (2006) *An analysis of plastics production, demand and recovery in Europe 2004*. Available at: www.plasticseurope.org.

2.1.3. Polymer types

At world level, polyethylene (PE) has the highest share of total production of any polymer type (Figure 2-6). It is followed by polyethylene terepthalate (PET), which accounts for 20% of thermoplastic resin capacity. Polypropylene (PP) accounts for 18%, followed by polyvinyl chloride (PVC) and polystyrene/expanded polystyrene (PS/EPS).

Figure 2-6: World thermoplastic resin capacity, 2008[23]

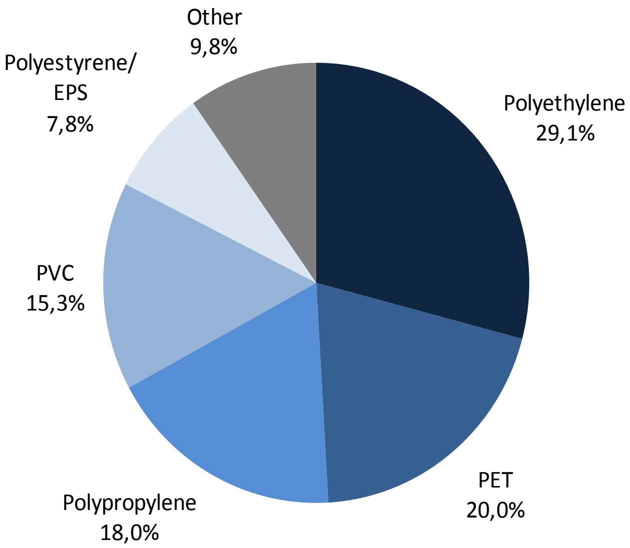
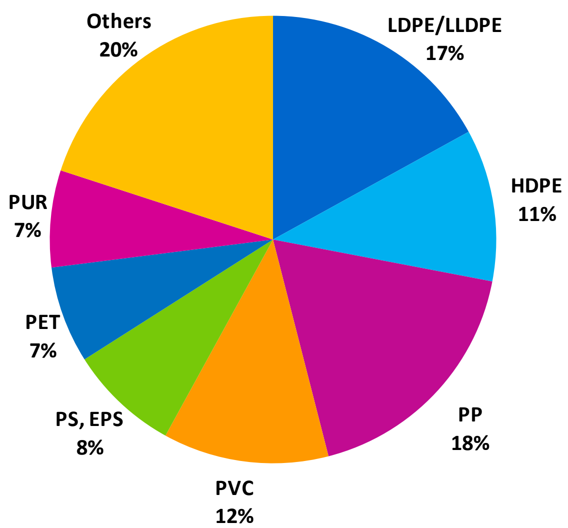


Figure 2-8 shows plastic conversion industry demand by category of plastic in EU-27, Norway and Switzerland. PE accounts for 28%, including low density LDPE, linear low density LLDPE and high density HDPE. The share of PET is low in Europe (7%) compared with the world level.

Figure 2-7: Plastics converters demand in EU-27, Norway and Switzerland by plastic polymer type, 2008[24]

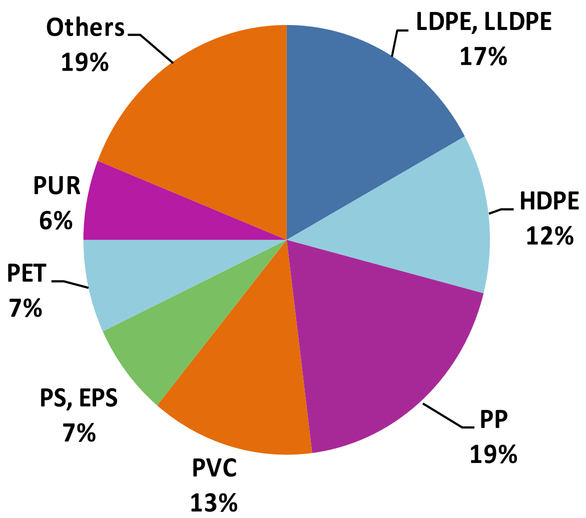


[23] Source: http://plasticsnews.com/fyi-charts/index.html?id=17731.

[24] PlasticsEurope, EuPC, EuPR, EPRO and Consultic (2009) *The Compelling Facts about Plastics - An analysis of European plastics production, demand and recovery for 2008*.

When comparing 2008 figures with data from 2006 (see Figure 2-8), the shares of all main polymer types remain almost unchanged: HDPE and PP lost 1% between 2006 and 2008 while polyurethane (PUR) and the Others category increased their shares by 1% each.

Figure 2-8: EU plastic demand by plastic type, EU-25, Norway and Switzerland, 2006[25]



Although the amounts sold for each plastic type differ from year to year, the shares remained relatively constant during the 2006-2008 period (Figure 2-9).

Figure 2-9: Volume of sales in EU-27 for different types of primary plastics, 2006-2008 (kt)[26]

[25] Adapted from PlasticEurope 2006 statistics.
[26] Adapted from Eurostat PRODCOM database, NACE 2.0, category 20.16.

2.1.4. END PRODUCTS

The following subsection details the production of plastics based on product type (and where possible, aggregated by sector and plastic type).

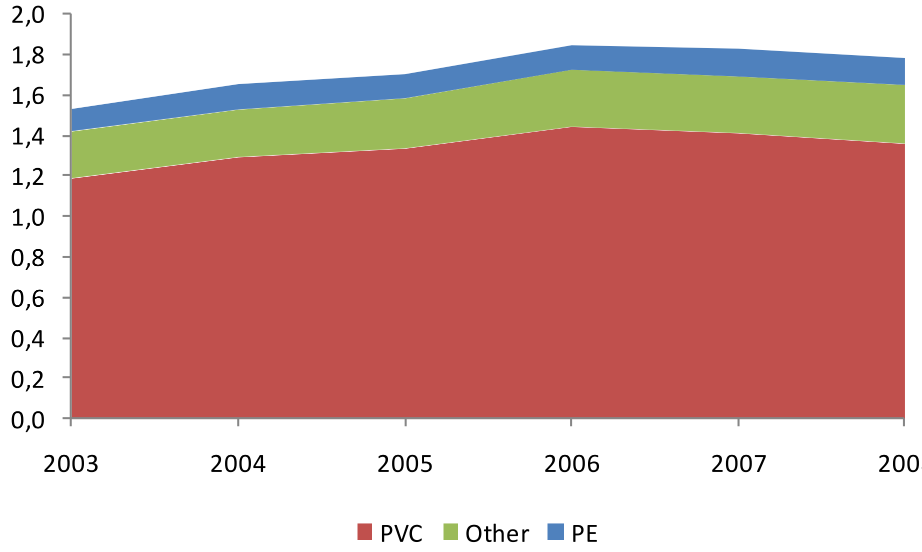
2.1.4.1 Plastic profiles, tubes, plates and sheets

Although these plastic products are commonly used in construction, they can be used in a variety of sectors, such as electronic and electrical products, agriculture, cars, the energy sector and medical devices.

- **Monofilament rods, sticks and profiles**

Between 2003 and 2008, the majority of monofilament rods, sticks and profiles have been produced from PVC (Figure 2-11). Production grew slightly over the first three years before falling slightly in 2007 and 2008. Over the same period, the level of production of monofilament rods, sticks and profiles from PE and other plastic types (excluding PVC) has remained steady and much lower than PVC.

Figure 2-10: EU-27 production of monofilament rods, stick and profiles >1 mm (Mt)[27]

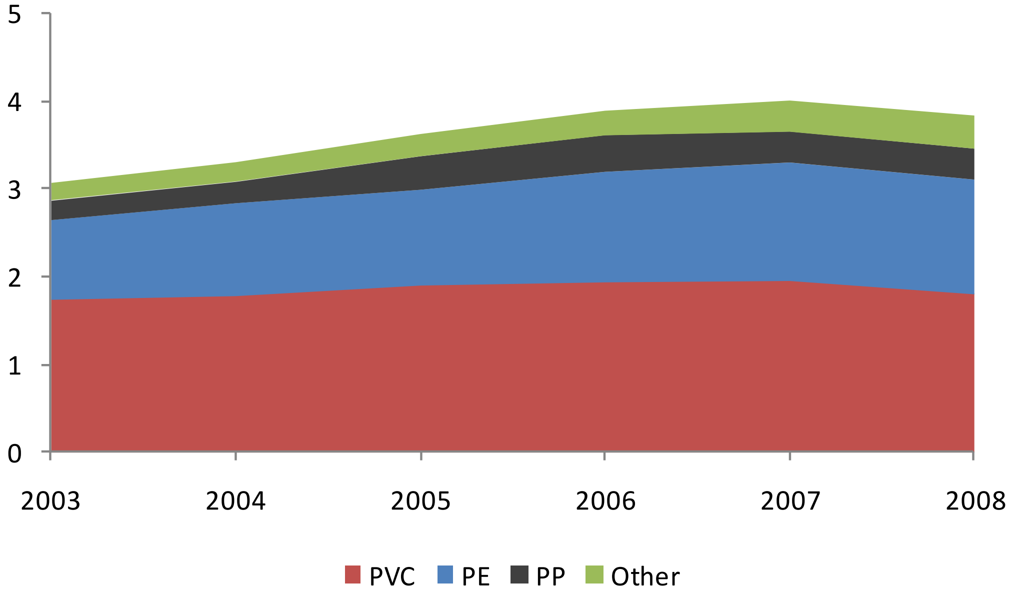


- **Rigid tubes, pipes and hoses**

Total production of tubes, pipes and hoses in EU-27 reached approximately 5.4 Mt in 2008,[28] more than half of which was rigid tubes, pipes and hoses (3.5 Mt). Figure 2-11 shows that this fraction was dominated by PVC. However, PE was also produced in significant amounts and this plastic type experienced some growth between 2003 and 2007. However, since 2007, production using most of these plastic types appears to have fallen in Europe (with the exception of the Other category, which grew slightly but not enough to compensate for the overall decline in production).

[27] Source: Eurostat.
[28] Ibid.

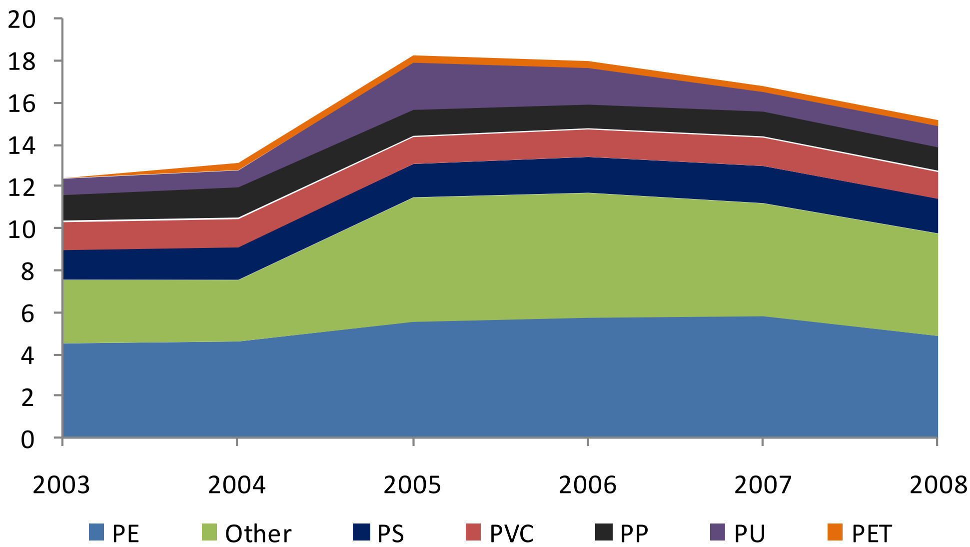
Figure 2-11: EU-27 production of rigid tubes, pipes and hoses (Mt)[29]



- **Plates, sheets, films, foils and strips**

In 2008, production of plastic plates, sheets, films, foils and strips collectively reached 15.2 Mt. This significant amount can be attributed to the versatility of sectors and uses for each of these products. It is not clear from the data whether these amounts relate only to en d products, or also to intermediate materials that would later be used in other products (e.g. sheets in plastic packaging). Due mainly to the growth in use of other plastics, total production grew significantly between 2004 and 2005, before falling gradually from then onwards.

Figure 2-12: EU-27 production of plates, sheets, films, foils and strips of different plastic types[30]



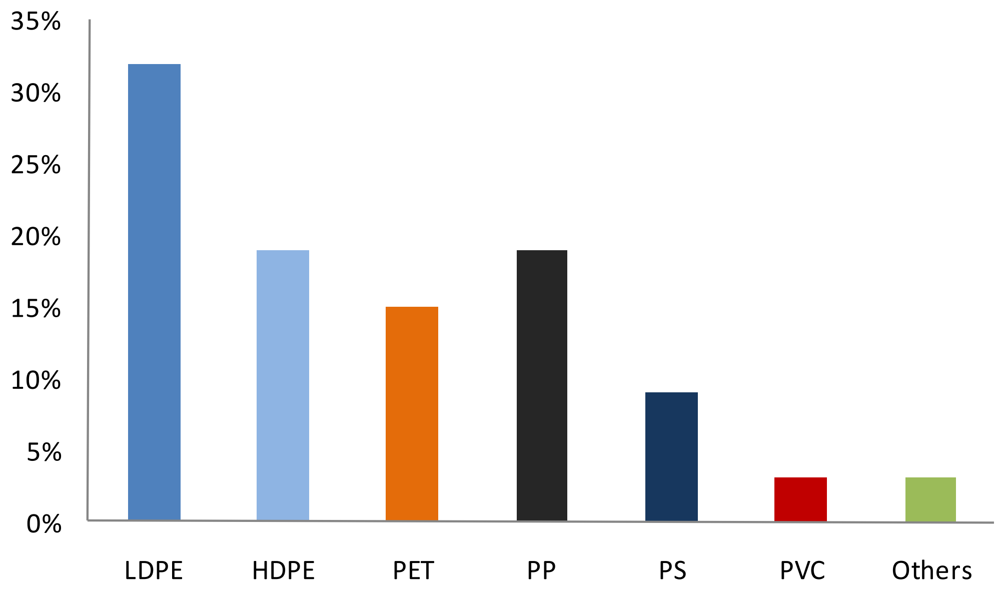
[29] Source: Eurostat.
[30] Ibid.

2.1.4.2 Plastic packaging

Plastic packaging accounts for the largest share of plastic production in the EU and at world level. The following subsections present data collected for the quantification of individual products expressly designed for packaging purposes (including coverings such as lids, stoppers and caps). It was not possible to directly compare the significance of some product types in relation to others (e.g. bags compared to bottles) due to differences in the data units used.

The most common polymer types found in packaging plastic products are presented below. LDPE was the most used polymer in 2002 (32%), followed by HDPE (19%), PP (19%) and PET (15%).

Figure 2-13: Packaging by polymer type in EU-15, Norway and Switzerland, 2002[31]



Plastic packaging for food and beverage products frequently relies on different types of plastics and can incorporate additional materials and adhesives. Clear plastic bottles, for example, may be composed of PET, whereas the caps are often composed of PE, and the labels that are around the bottles may be composed of another type of plastic film (PS, PVC, PP) or material (paper). Each of these materials has very different properties and needs different recycling methods. This may become a bigger issue in future, should packaging incorporate a greater variety of polymers and become more complex.

The table below presents the main polymers used in packaging applications. As already presented, bottles are mainly made of PET and HDPE, while plastic bags and sacks mainly contain HDPE and LDPE. Many different polymers can be used to manufacture films (e.g. LDPE, PP, PET, OPP, PVC) while PS is mainly used in trays and protective and service packaging.

[31] APME (2004) *Plastics in Europe – An analysis of plastics consumption and recovery in Europe 2002 & 2003*.

Table 2: Polymers in main household packaging applications[32]

Applications		Most common polymers used
Bottles	Dairy products	HDPE
	Juices, sauces	HDPE, barrier PET, PP
	Water, soft drinks	PET, barrier PET
	Beer and alcoholic beverages	Barrier PET
	Oil, vinegar	PET, PVC
	Non-food products (cleaning products, toiletries, lubricants, etc.)	HDPE, PET, PVC
	Medical products	PET
Closures	Caps and closures of bottles, jars, pots, cartons, etc.	PP, LDPE, HDPE, PVC
Bags and sacks	Carrier bags	LDPE, HDPE
	Garbage bags	HDPE, LDPE, LLDPE
	Other bags and sacks	LDPE, LLDPE, HDPE, PP, woven PP
Films	Pouches (sauces, dried soups, cooked meals)	PP, PET
	Overwrapping (food trays and cartons)	OPP, bi-OPS
	Wrapping, packets, sachets, etc.	PP, OPP
	Wrapping (meat, cheese)	PVDC
	Collection shrink film (grouping package for beverages, cartons, etc.)	LLDPE, LDPE
	Cling stretch rap film (food)	LLDPE, LDPE, PVC, PVDC
	Lidding (heat sealing)	PET, OPA, OPP
	Lidding (MAP and CAP foods)	Barrier PET, barrier layered PET/PE and OPP/PE
	Lidding (dairy)	PET
Trays	Microwaveable ready meals, puddings	PP,C-PET
	Ovenable ready meals	C-PET
	Salads, desserts	A-PET, PVC
	Vegetables	PP, EPS
	Fish	PP, PVC, A-PET, EPS
	Confectionery	PVC, PS
	Dairy products	PP,PS
	Meat, poultry	A-PET, PVC, EPS
	Soup	PP, A-PET
Others	Blisters	PET, PVC
	Pots, cups and tubs	PP, PS
	Service packaging (vending cups, etc.)	PS
	Protective packaging (“clam” containers, fish crates, loose filling, etc.)	EPS

[32] JRC IPTS (2007) *Assessment of the Environmental Advantages and Disadvantages of polymer recovery processes*.

As an example, Figure 2-14 describes the polymer market share of the packaging sector in Spain: 28% of polymers are used to manufacture films, 25% for bags and sacks, and 20% for bottles. The remaining share is split between miscellaneous applications (containers, protection, etc.). Given the share of the polymer types in the different applications, LDPE (76% of films and 61% of bags and sacks) appears to be the most used polymer, closely followed by PET (66% of bottles) and HDPE (28% of bottles and 31% of bags and sacks). PP represents 73% of closure items, e.g. bottle caps.

Figure 2-14: Approximate polymer market share in the packaging sector in Spain, 2003[33]

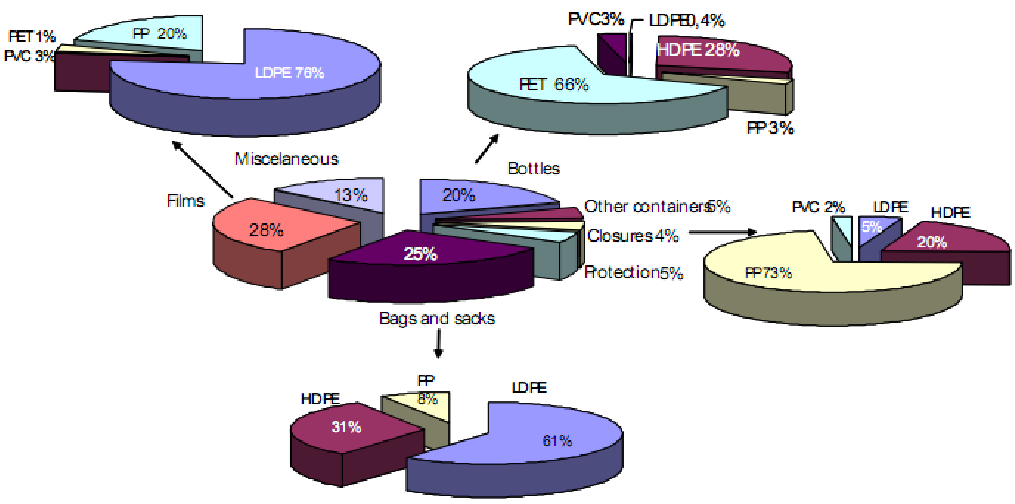


Table 3 lists the composition by application of plastic packaging waste in France as another example. Bottles and flasks account for 39%, while films, bags and sacks account for 27% of packaging waste. No definitive conclusion can be made by comparing this data with waste generation by polymer type, because of the difference in year and geographical scope.

Table 3: Composition of plastic packaging waste in France, 2006[34]

Plastic products	Percentage (weight)
Bottles and flasks	39%
Films, bags, sacks	27%
Jars, boxes, tubs	18%
Cases	6%
Other	10%

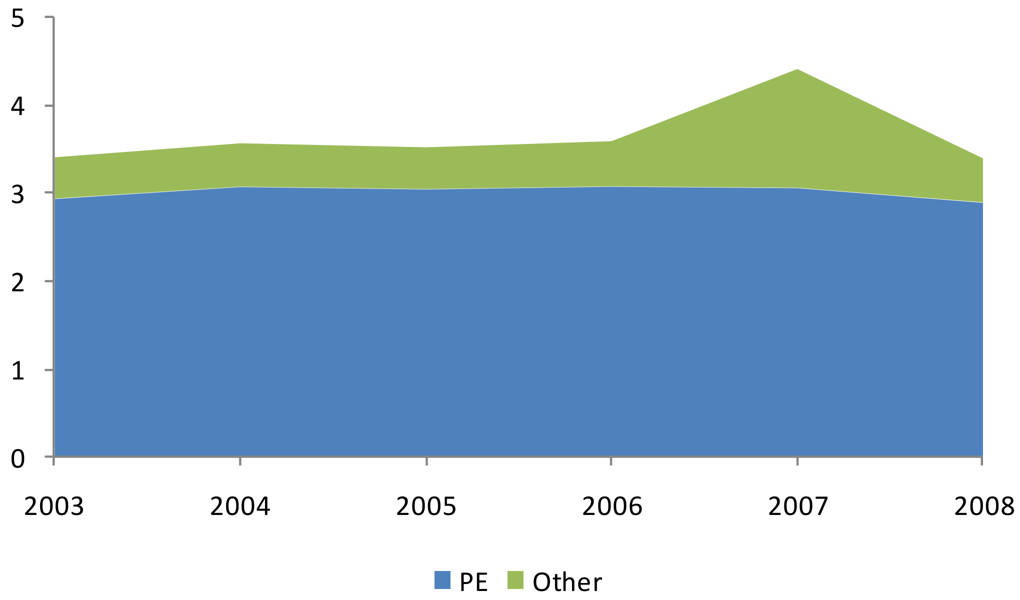
Market data for specific product types in EU-27 are presented below.

[33] ANAIP (2004) *Annual report 2003: Los plásticos en España*.
[34] Adapted from ADEME, Ecoemballages and Adelphe (2006) *Le gisement des emballages ménagers en France*.

- **Bags and sacks**

Plastic bags and sacks make up a large share of the packaging sector and are a product type that has been subjected to significant scrutiny globally over the last few years. The available data shows that the total volume of production was 3.4 Mt in EU-27 in 2008. This number takes on an even greater significance when considering the weight of each individual bag. Assuming a range in weight of 8-60 g per bag,[35] this translates into an average of 57-425 billion plastic bags and sacks consumed yearly in EU-27. Assuming an EU-27 population size of 500 million, this amounts to an annual consumption of 113 to 850 bags per person.

Figure 2-15: Volume of plastic sacks and bags produced in EU-27, 2003-2008 (Mt)[36]

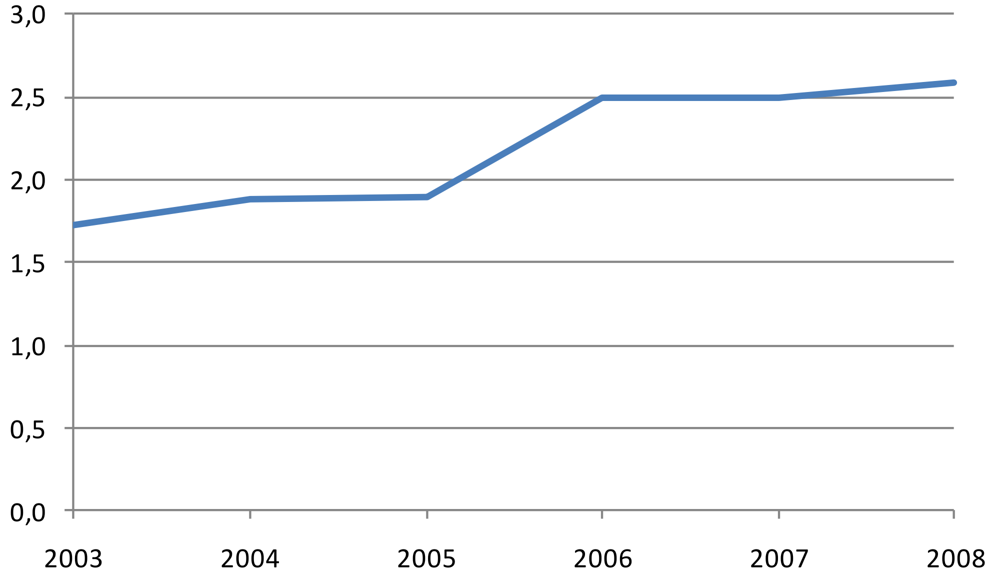


- **Boxes, cases, crates and similar articles**

Although the total weight of production of boxes and crates is comparable to that of plastic bags, they can be considerably heavier as individual items and therefore it can be deduced that they are produced and consumed in far lower numbers. As weights can vary considerably depending on the material type and size, calculating per capita consumption may not be possible.

[35] Simmons, C. (2002) *It's in the bag*. Accessed at: http://old.bestfootforward.com/downloads/itsinthebag.PDF, 24 April 2010.
[36] Source: Eurostat.

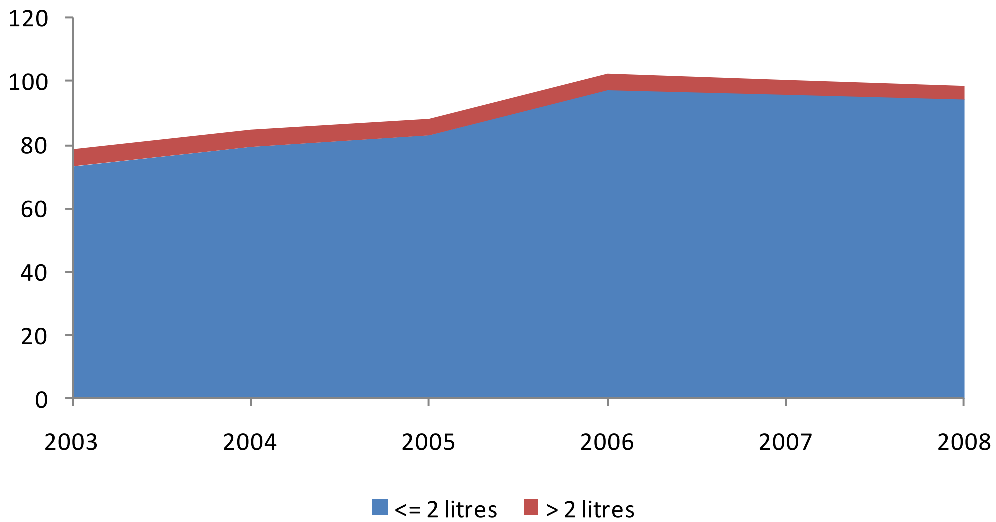
Figure 2-16: Volume of plastic boxes, cases, crates and similar articles produced in EU-27, 2003-2008 (Mt)[37]



Bottles, closures and similar articles

Plastic bottle sales rose gradually until 2006, when they began to fall (Figure 2-17). The production of plastic bottles with capacities of less than 2 litres dominates the market. Based on a total of 99 billion units produced in 2008, this amounts to approximately 200 bottles consumed per person per year.

Figure 2-17: Plastic carboys, bottles, flasks and similar articles produced in EU-27, 2003-2008 (billion units)[38]

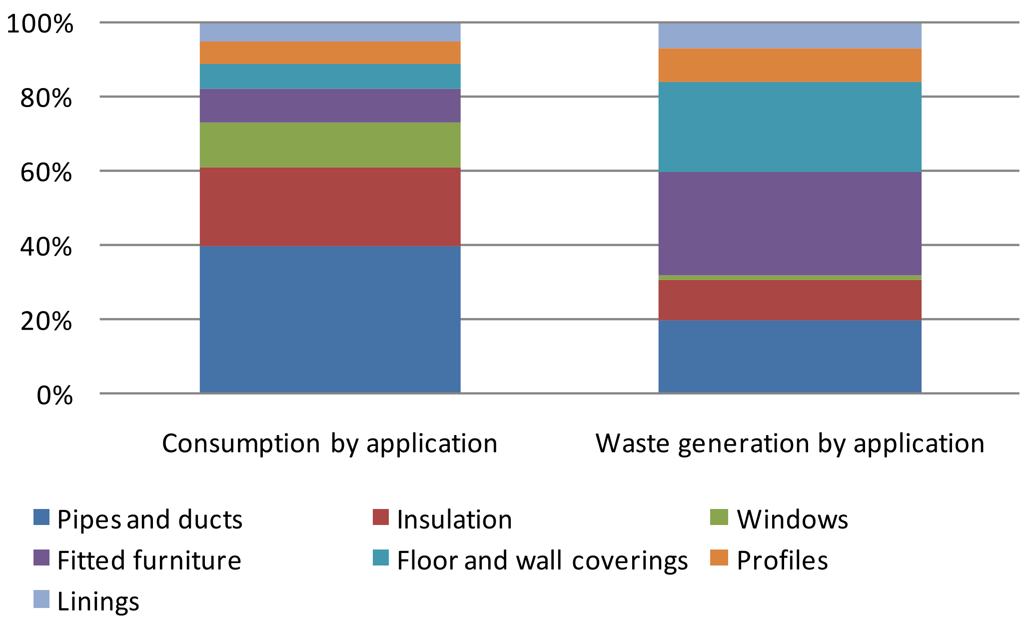


[37] Includes boxes, cases, crates and similar articles for the conveyance or packing of goods.
[38] Source: Eurostat.

2.1.4.3 Construction and demolition

The main applications generating waste in the construction and demolition (C&D) sector are fitted furniture, floor and wall coverings (PVC), pipes and ducts, insulation materials (PU) and profiles (PVC) (see Figure 2-18).

Figure 2-18: Plastic consumption and waste generation by application, 2005[39]



Plastics used in construction have long lifespans, so the generation of plastic waste by this sector is low compared to consumption. Polymer types used in various construction applications are described in Table 4.

Table 4: Main polymers used by application

Application	Most common polymers used
Pipes and ducts	PVC, PP, HDPE, LDPE, ABS
Insulation	PU, EPS, XPS
Windows profiles	PVC
Other profiles	
Floor and wall coverings	
Lining	PE, PVC
Fitted furniture	PS, PMMA, PC, POM, PA, UP, amino

2.1.4.4 Electrical and electronic equipment

In 2004, approximately 1.82 Mt of plastic destined to be used in EEE was produced in EU-27. This is a slight rise from the 2003 figure of 1.78 Mt of plastic produced for this purpose. This amount relates to the products listed in Table 5. As this list does not

[39] JRC IPTS (2007) *Assessment of the Environmental Advantages and Disadvantages of polymer recovery processes.*

include all possible EEE that incorporates plastic parts, it is likely that the above figure is lower than the actual amount.

Table 5: Harmonised System (HS) customs list and additional products[40]

HS code	Products
85.09	Electro-mechanical domestic appliances with self-contained electric motor; parts thereof vacuum cleaners, floor polishers, food processors, humidifiers, can openers
85.16	Electric heating/drying water, space, soil, hair, hand & domestic appliances; electric heating resistors hair dryers, curlers, curling tongs, microwave ovens, cooking stoves, ovens, coffee/tea makers
85.25	Transmission apparatus for radio-telephony, radio-telegraphy, radio-broadcasting or television; television cameras, etc
85.26	Radar apparatus, radio navigational aid & remote control apparatus
85.27	Reception apparatus for radio-telephony, radio-telegraphy or radio-broadcasting
85.28	Television receivers, video monitors, video projection television receiver
85.35	Electrical apparatus for switching or protecting electrical circuits, for electrical connection over 1 000 volts switches, fuses, lightening arresters, surge suppressors, plugs, junction boxes
85.36	Electrical apparatus for switching or protecting electrical circuits, for electrical connection not over 1 000 volts switches, relays, fuses, surge suppressors, plugs, junction boxes, lamp-holders
85.37	Boards, panels, consoles, desks, cabinets, etc with electrical switching apparatus etc. of HS 85.35 or 85.36
85.42	Electronic integrated circuits & micro-assemblies; parts thereof
N/A	Plastic parts for turntables, record players, cassette-players, magnetic tape recorders, other sound or video recording/reproducing apparatus excluding pick-up cartridges
N/A	Plastic parts for electrical machinery and equipment, sound recorders and reproducers, television image and sound recorders and reproducers
N/A	Plastic parts for optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus

The principal polymers used in EEE are PP, PS and ABS, the latter being increasingly used. Table 6 presents the polymer composition of some EEE.

[40] Products registered under the HS and additional products based on BIO research. The HS is a systematic list of commodities run by the World Customs Organisation, see http://ec.europa.eu/taxation_customs/customs/customs_duties/tariff_aspects/combined_nomenclature/index_en.htm.

Table 6: Typical applications of plastic polymers in EEE

Application	Type of plastic
Components inside washing machines and dishwashers, casings of small household appliances (coffee makers, irons, etc.) Internal electronic components	PP
Components inside refrigerators (liner, shelving) Housings of small household appliances, data processing and consumer electronics	PS (HIPS)
Housings and casing of phones, small household appliances, microwave ovens, flat screens and certain monitors Enclosures and internal parts of ICT equipment	ABS
Housings of consumer electronics (TVs) and computer monitors and some small household appliances (e.g. hairdryers) Components of TV, computers, printers and copiers	PPO (blend HIPS/PPE)
Housings of ICT equipment and household appliances Lighting	PC
Housings of ICT equipment and certain small household appliances (e.g. kettles, shavers)	PC/ABS
Electrical motor components, circuits, sensors, transformers, lighting Casing and components of certain small household appliances (e.g. toasters, irons). Handle, grips, frames for ovens and grills Panel component of LCD displays	PET (PBT)
Insulation of refrigerators and dishwashers	PU (foam)
Lamps, lighting, small displays (e.g. mobile phones)	PMMA
Lighting equipment, small household appliances Switches, relays, transformer parts, connectors, gear, motor basis, etc.	PA
Gears, pinions	POM
Cable coating, cable ducts, plugs, refrigerator door seals, casings	PVC
Cable insulation and sheathing	PE
Housing, handles and soles of domestic irons, handles and buttons of grills and pressure cookers	UP polymers
Printed circuit boards	EP polymers

Table 7 describes the composition by polymer of the main Waste Electrical and Electronic Equipment (WEEE) items collected. The complexity of WEEE items is illustrated by the fact the all items contain at least three different types of polymers. Small household appliances can contain as many as six different plastic types.

Table 7: Main polymers used in the manufacture of the most common WEEE items collected[41]

WEEE item	Polymer composition
Printers/faxes	PS (80%), HIPS (10%), SAN (5%), ABS, PP
Telecoms	ABS (80%), PC/ABS (13%), HIPS, POM
TVs	PPE/PS (63%), PC/ABS (32%), PET (5%)
Toys	ABS (70%), HIPS (10%), PP (10%), PA (5%), PVC (5%)
Monitors	PC/ABS (90%), ABS (5%), HIPS (5%)
Computer	ABS (50%), PC/ABS (35%), HIPS (15%)
Small household appliances	PP (43%), PA (19%), ABS-SAN (17%), PC (10%), PBT, POM
Refrigeration	PS&EPS (31%), ABS (26%), PU (22%), UP (9%), PVC (6%),
Dishwashers	PP (69%), PS (8%), ABS (7%), PVC (5%)

2.1.4.5 Automotive

Plastics are used in vehicles for their impact and corrosion resistance but more importantly for their low weight and cost. EU-27 production of plastic parts for all land vehicles (excluding locomotive or rolling stock) was about 2.3 Mt in 2004.[42] This was slightly higher than in 2003 (2.1 Mt).

Plastics are used for a variety of parts and functions in automotive vehicles. The biggest share of plastic used goes into the passenger cell (the interior of the vehicle), followed by the vehicle's bodywork (Figure 2-20). On average, plastics account for around 9-12% of a vehicle's weight, or around 150-180 kg,[43] of which about 20% is composite material (i.e. plastic mixed with other materials).[44]

The most common automotive plastic types are PP, PE, PU and PVC. PP (common in bumpers, wheel arch liners and dashboards) accounts for about 41% of all car plastic and like PE and PU (most commonly used in seat foam) it is easily recycled.[45]

Viable markets for PP, PE and PU from non-automotive sources already exist. PVC however is relatively difficult to recycle and there are currently no large-scale recycling schemes operating for post-consumer PVC. PVC makes up about 12% of the plastics content of an average 1990s European car. Alternative disposal methods such as incineration have raised a number of environmental concerns including dioxin emissions during incineration and the use of phthalate plasticisers, which are thought

[41] JRC IPTS (2007) *Assessment of the Environmental Advantages and Disadvantages of polymer recovery processes*.

[42] Source: Eurostat.

[43] PlasticsEurope, private communication.

[44] See www.reinforcedplastics.com/view/1089/ecrc-heads-search-for-composites-recycling-solutions and *GHK/BIOIS report on the ELV directive for the European Commission, confirmation sought on issues*, available at: ec.europa.eu/environment/waste/pdf/info_stakeholders.pdf and www.mvda.org.uk/recycling.aspx.

[45] Website of the Motor Vehicle Dismantlers' Association. Available at: www.mvda.org.uk/recycling.aspx.

to be disrupters of hormone systems. Car manufacturers are currently looking for alternatives to PVC.[46]

Figure 2-19: Technical plastic parts in automotive vehicles, 2005[47]

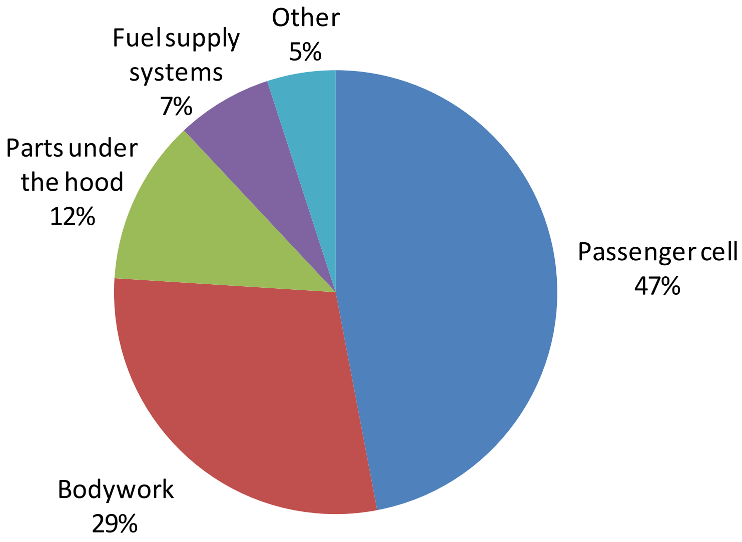


Table 8 describes the precise applications of the main polymers found in the automotive industry. Many components can be manufactured from different types of plastics and PP can be used almost everywhere.

Table 8: Polymers used in a typical car[48]

Component	Types of plastic	Weight in average car (kg)
Bumper	PP, ABS, PC/PBT	10
Seating	PU, PP, PVC, ABS, PA	13
Dashboard	PP, ABS, SMA, PPE, PC	7
Fuel system	HDPE, POM, PA, PP, PBT	6
Body (incl. panels)	PP, PPE, UP	6
Under-bonnet components	PA, PP, PBT	9
Interior trim	PP, ABS, PET, POM, PVC	20
Electrical components	PP, PE, PBT, PA, PVC	7
Exterior trim	ABS, PA, PBT, POM, ASA, PP	4
Lighting	PC, PBT, ABS, PMMA, UP	5
Upholstery	PVC, PU, PP, PE	8
Liquid containers	PP, PE, PA	1

[46] Website of the Motor Vehicle Dismantlers' Association. Available at: www.mvda.org.uk/recycling.aspx.
[47] See www.reinforcedplastics.com/view/1089/ecrc-heads-search-for-composites-recycling-solutions.
[48] JRC (2007) *Assessment of the Environmental Advantages and Drawbacks of Existing and Emerging Polymers Recovery Processes*.

The weight percentages of most common polymers in current and future plastic waste in ELVs have been estimated as follows by JRC-IPTS:

Table 9: Most common polymers in ELV waste[49]

Plastic type	Current use	Future use
PP	33-28%	43-38%
PU	22-17%	13-8%
ABS	17-12%	10-5%
PVC	13-8%	10-5%
PA	9-4%	11-6%
HDPE	8-3%	12-7%

2.1.4.6 Agriculture

The most common polymers in the agricultural plastic waste stream are LDPE and PVC: LDPE accounts for around 60-65% of the waste stream while PVC represents 18-23%. Table 10 lists the types of polymers used in agricultural applications. LDPE can be used in all types of bags and nets, while PVC is used to manufacture pipes and fittings. Some PP is found in ropes and bags.

Table 10: Types of plastic by agricultural application[50]

Application	Type of plastic
Fertiliser bags, liners	PP
	LDPE
Seed bags	PP
Feed bags	LDPE
Agrochemical containers	HDPE
Pots and trays	LDPE
	HDPE
Pipes and fittings	PVC
	LDPE
Nets and mesh	LDPE
	HDPE
Rope, strings	PP

2.1.4.7 Bioplastics

Bioplastics are not a single class of polymers but rather a family of products. Bioplastics fall into either or both of the following categories:[51]

[49] JRC (2007) *Assessment of the Environmental Advantages and Drawbacks of Existing and Emerging Polymers Recovery Processes*.
[50] Ibid.

- **Bio-based plastics** or plastics derived from renewable resources such as starch, sugar, vegetable oil or wood pulp. Bio-based plastics can be either biodegradable or non-biodegradable. For example, PE derived from bioethanol would be bio-based but not biodegradable.
- **Biodegradable (compostable) plastics** that meet scientific standards for biodegradability and compostability of plastics and plastic products. Biodegradable polymers are often bio-based but they can also be petroleum-based (e.g. polycaprolactone). Some biodegradable plastics even contain a mixture of petroleum-based polymers and biopolymers. Biodegradable plastics can be completely broken down by micro-organisms in the environment into non-toxic compounds (water, CO_2 and biomass under aerobic conditions, as well as methane under anaerobic conditions).[52] The following criteria also have to be met in order to meet national and international standards:[53] no negative effect on the composting process (breaks down into water, biomass and CO_2), disintegration (the material must become indistinguishable in the compost after a certain time) and non-toxicity (e.g. low levels of heavy metals and the compost can sustain plant growth).

There is an important distinction between biodegradable and degradable plastics that should be highlighted: degradable plastics are usually petroleum-based plastics, containing additives that catalyse the degradation of the polymer in the environment through light, heat or mechanical stress,[54] producing smaller plastic fragments and CO_2.[55] These plastics are also called "oxodegradable" and do not meet biodegradability or compostability standards. There is no certification for oxo-/UV-degradability in Europe yet.

Worldwide bioplastics production is approximately 0.3 Mt per annum (Mtpa), which equates to about 0.1% of world plastic production capacity.[56] In Europe, bioplastics consumption is estimated at 0.06-0.1 Mtpa, which represents around 0.1-0.2% of EU plastics consumption. According to PlasticsEurope, bio-based plastics had a share of less than 0.25% of the world plastics market in 2009.

In the EU, bioplastics are used mainly in packaging, loosefill packaging and waste collection bags with 37%, 28% and 21% bioplastics market share respectively. In comparison, fossil-fuel based plastics usage covers packaging but also other applications including construction, car parts and electronics with 37%, 21%, 8% and 6% market share respectively.

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[51] See www.european-bioplastics.org/index.php?id=182.

[52] Criteria are defined in standard EN 13432 or ISO 17088: a material is "compostable" if it is 90% degraded within six months in commercial composting conditions in the EU and 60% in 180 days in the United States (ASTM 6400).

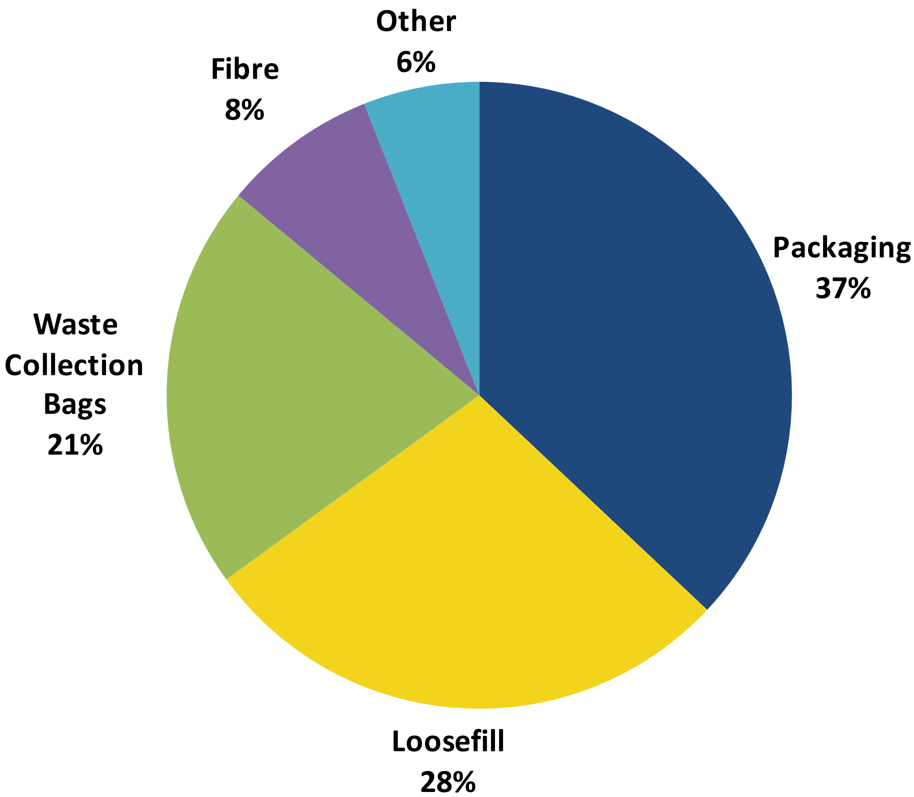
[53] SRI Consulting (2010) *Biodegradable polymers*. Available at: www.sriconsulting.com/CEH/Public/Reports/580.0280.

[54] Barker, M. And Safford, R. (2009) *Industrial uses for crops: markets for bioplastics*, HGCA.

[55] It is possible that micro-organisms are involved in the assimilation of some of the carbon into the biomass.

[56] Barker M. and Safford, R. (2009) *Industrial uses for crops: markets for bioplastics*, HGCA.

Figure 2-20: Bioplastics in Europe by use[57]



Types of bioplastics

Table 11 shows the main types of bioplastics and illustrates the wide variety of end products and raw materials possible. Bioplastics can be made from starch itself, starch-sugar fermentation products, cellulose, lignin, etc. Different types of bioplastics can be combined to form materials with improved properties such as improved waterproofing. Some of the main groups of bioplastics are:

- Starch bioplastics, which can replace PE or PS in disposable cutlery, food packaging, plastic bags or mulch film.
- Starch and sugar-based bioplastics include PLA, polyhydroxyalkanoates (PHA), 1.3 propanediol (bio-PDO) and 1.4 butanediol (bio-BDO). PLA is currently the most commonly used bioplastic on the market. It can be used in the production of bottles, packaging, carrier bags and apparel, replacing conventional plastics such as PE or PET. PHAs (polyhydroxybutyrate for instance) represent an alternative to a wide range of petroplastics such as PP and can be processed into packaging, cups or compostable bags. Sales of PHA are low at the moment but expected to see rapid growth. Finally, bio-PDO and bio-BDO are precursors for bioplastics production. These processes are still being refined.

[57] European Bioplastics. (2008) *Proceedings of the Third European Bioplastics Conference*.

- Cellulose-based bioplastics are used to produce biodegradable films for applications in food and cosmetic packaging.
- Lignin-based bioplastics can be used to manufacture automotive interior parts, toys, electronics housings or construction components.
- Several types of conventional plastics (e.g. PE, polyamide, polyurethane, PBT, plexiglass) can also be produced from renewable resources such as oils, starch and cellulose.
- Hybrid bio/petroplastics can be manufactured by mixing polymers to combine some of the environmental benefits of bioplastics with some important characteristics of petroplastics. However, end-of-life management may be problematic if the petroplastics polymers are not designed to be fully biodegradable when the bioplastics are.

Table 11: Examples of bioplastics[58]

Type of bioplastic	Primary feedstock	End use
Thermoplastic starch (TPS)	Starch	Disposable cutlery
Plastarch material (PSM)		
Starch/polycaprolactone (or polyvinyl acetate) mix	Starch/petroleum	Plastic bags
PLA	Starch sugars	Cold drink cups, bottles
PHA		Cups
Polyester made with 1.3-propanediol		Glass reinforcement (under development)
Polyester made with 1.4-butanediol		Electrical insulation
Cellulose acetate	Wood, cotton or hemp cellulose	Food packaging film
Lignin	Wood (lignin)	Electronic housings
PP	Starch/petroleum	Packaging
PE	Sugarcane-derived bioethanol	
PU	Soya beans	Construction insulation

Thermoplastic starch, extruded starch and starch blends supply about 60% of the European bioplastics market today. Most of this starch is derived from maize (and to a lesser extent potatoes). However, other high starch crops such as wheat could be used as feedstock to manufacture bioplastics.[59]

[58] Barker, M. and Safford, R. (2009) *Industrial uses for crops: markets for bioplastics*, HGCA.
[59] Ibid.

Bioplastics can thus potentially be used for a wide range of applications such as packaging (e.g. food packaging, compostable waste bags), catering products, products used outdoors and not recovered (golf tees, planting pots, etc.), car components, computers, insulation and mobile phone casings. Agriculture is also an important target sector: biodegradable mulch and seed films can be ploughed into the ground. Table 12 lists several EU biopolymer manufacturers, their products and production volumes.

Table 12: Main biopolymer manufacturers[60]

Manufacturer	Country	Product	Production volume (applications)
NatureWorks	USA	PLA	0.14 Mt/year (films, moulding, fibers)
PURAC	Netherlands	PLA	0.08 Mt/year
Novamont	Italy	Mater-Bi	0.06 Mt/year (films, moulding, extrusion)
Metabolix	USA	Polyhydroxybutyrate (PHB)	0.05 Mt/year, plant to become operational in 2009 (moulding, films)
Rodenburg Biopolymers	Netherlands	Solanyl	0.04 Mt/year (films, moulding, extrusion)
Tate & Lyle	UK	1.3-propanediol	In partnership with Dupont (USA). Future production estimated between 0.023-0.045 Mt/year
GALACTIC	Belgium	Galactic (PLA)	0.025 Mt/year
BASF	Germany	Ecoflex® (biodegradable polyester petroleum-based)	0.014 Mt/year (films, moulding)
Innovia Films	UK	Cellulose acetate	0.0025 Mt/year (films, injection moulding)
Hycail (bought by Tate & Lyle in 2006)	Netherlands	PLA	Pilot production stage
Uhde Inventa-Fisher	Germany	PLA	Pilot production stage
Biomer	Germany	Biomer (PHB)	-
Boehringer Ingelheim	Germany	Resomer (PLA)	-

[60] Barker M, and Safford R (2009) *Industrial uses for crops: markets for bioplastics*, HGCA, inter alia.

2.2. TRENDS IN PLASTIC WASTE GENERATION

The plastics industry is in constant development, with technology evolving in response to ever-changing demand. This section identifies market and development trends for plastics as well as novel applications for future use (e.g. increasing use of plastics[61] and bioplastics[62] for the manufacture of vehicles). A particular focus is the development status, comparative performance and growth drivers of bioplastics.

2.2.1. PRIMARY PLASTIC DEMAND AND CONSUMPTION

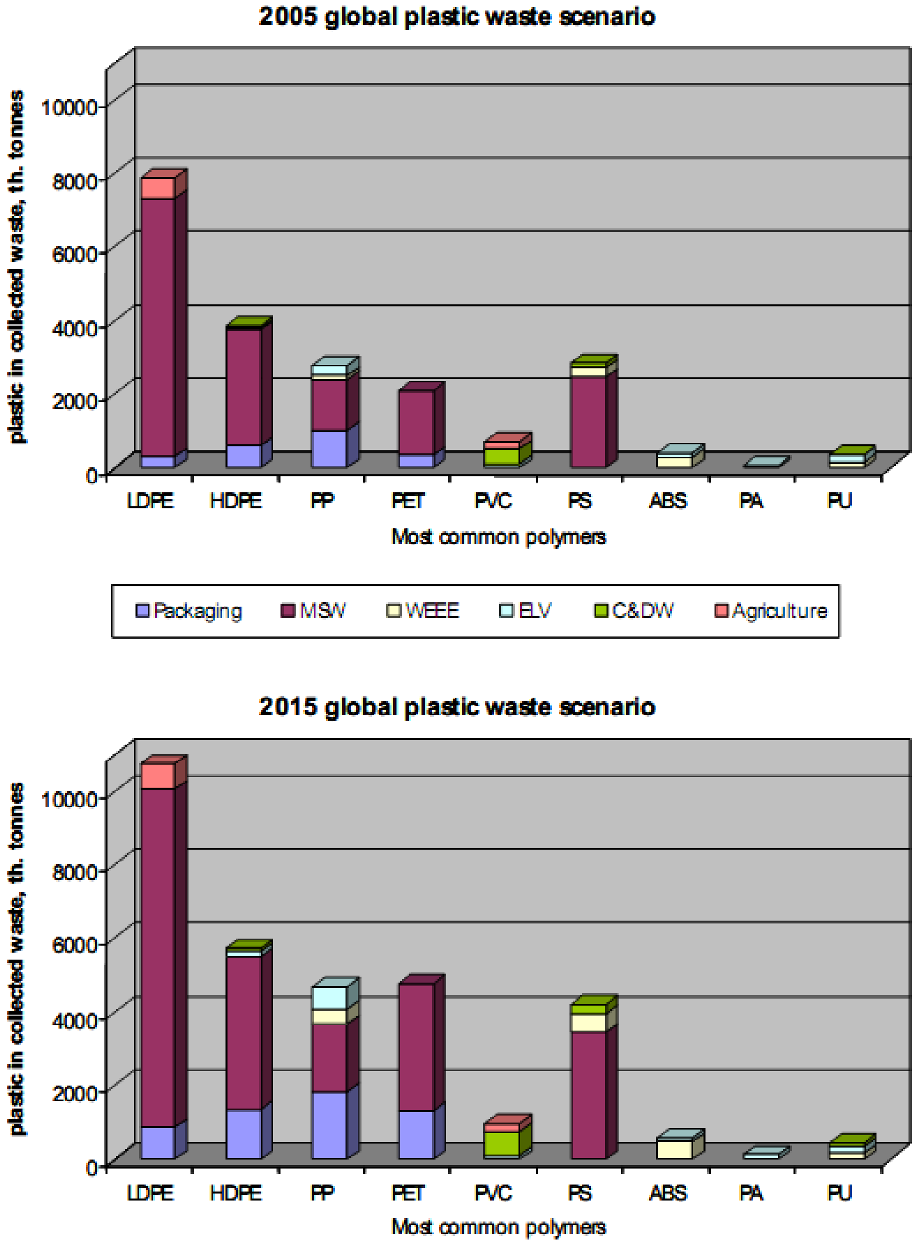
Ongoing developments in the plastics industry enable the appearance of new plastic applications and in turn affect plastics consumption and waste generation. Meanwhile, the shift in primary plastic production to transition and emerging economies looks set to continue. Converter demand in those regions may also increase.

Recent case studies have shown that the average weights of individual items of packaging have been decreasing.[63] Drinks bottles made of plastic have dropped in weight by 7.5% and plastic film contains on average 11-15% less material. Despite this, per capita quantities of packaging are increasing across the EU-27 Member States.[64]

Packaging accounts for more than half of total plastic waste and can be collected either in separate packaging streams or in MSW. Thus, because of its abundant use in packaging, LDPE is the most-recovered polymer in plastic waste (Figure 2-21). PP and PET volumes are projected to grow strongly because of their increasing use in packaging and also in the automotive and EEE sectors for PP. Volumes of more technical plastic waste (ABS, PA, PU) are not expected to grow substantially. The total volume of polymers in collected EU waste in 2005 and 2015 are described below for each waste stream.

[61] Waste Online (2004) *End of life vehicle and tyre recycling information sheet*.
[62] Toyota (2008) *Toyota to Increase 'Ecological Plastic' in Vehicle Interiors*.
[63] WRAP (2007) *Packaging optimisation: the impact to date*.
[64] EEA (2010) *Generation and recycling of packaging waste (CSI 017)*. Available at: www.eea.europa.eu/data-and-maps/indicators/generation-and-recycling-of-packaging-waste/generation-and-recycling-of-packaging-2.

Figure 2-21: Estimated volumes of the most common polymers in total EU-25 waste, 2005 and 2015[65]



2.2.1.1 Ethylene/PE

In January 2009, production capacity of the petroleum/natural gas derivative ethylene reached 126.7 Mt, which exceeded the demand of 115 Mt. This was largely due to an increase in production in the Middle East of 56%, which raised total production to 19 Mt. Global ethylene capacity is predicted to continue to rise to 145 Mt by 2010. However, consumption is predicted to stay relatively level at around the current rate.[66]

[65] JRC IPTS (2007) *Assessment of the Environmental Advantages and Disadvantages of polymer recovery processes*. Note that the "global" scenario is the sum of all sectoral scenarios for EU-25.

[66] Plastemart.com (2010) *Overcapacity expected in ethylene uptil 2013*. Available at: www.plastemart.com/Plastic-Technicle-Article.asp?LiteratureID=1380.

This contrasts with the growth in global demand figures for ethylene, prior to 2008, which remained at an average annual rate of 4-4.5%. In 2008, due to the global financial crisis, demand fell by approximately 4 Mt (around 3%). Studies indicate that demand levels will return to those prior to 2008 by 2010.

Approximately 60% of ethylene production goes toward producing polyethylene thermoplastic resins (LDPE, LLDPE and HDPE). Despite a decline of PE consumption in China in 2008, demand in the area rebounded in 2009, where PE imports were higher by 50-60% in comparison to those in 2008. In particular, HDPE import levels rose by 90% in 2009 compared to 2008. In the first half on 2009, PE imports to China were as high as 3.75 Mt, which contrasts with 4 Mt imports for the whole of 2008.

Although China and other major importers of PE in Asia are said to be bracing for the increased flux of PE production, markets in Europe and the United States are expected to consolidate within the next few years, which could lead to more supplies from the Middle East to Europe, potentially easing the over-supply of PE.[67]

2.2.1.2 Styrene/PS[68]

In 2008, global styrene consumption was 26 Mt, which accounted for 87% of total production (30 Mt in 2008). Although some studies seem to indicate a modest rise in consumption in comparison to 2007, others indicate that consumption in fact fell. Unlike ethylene, styrene capacity is predicted to grow but not at a significant rate over the next few years. Experts believe that styrene consumption will grow at an average of 3- 4% between 2009 and 2013.

Despite the optimistic outlook for styrene, polystyrene has declined globally since 2005. Despite this fall in consumption, PS still accounts for 43% of styrene consumption (11.2 Mt). In 2008, PS consumption levels fell almost to 2001 levels, most likely due to higher feedstock prices which resulted from the rising price of oil during that period. Consumers also began to favour PP over PS, although both materials suffered declines in 2008 due to the global financial crisis.

In relation to sector-specific functions, CD sales have fallen, which in turn has had an impact on PS as one of the main components of CD media casings. Its usage in food packaging has remained stagnant due to increased preference for paper-based products, which are seen as more environmentally friendly.

2.2.1.3 PVC[69]

In comparison with most thermoplastics, PVC needs relatively little oil for its production (ethylene makes up only 43% of PVC). Its durable and fireproof nature also gives it some advantage over other types of plastics, particularly in the construction

[67] Plastemart.com (2010) *PE, PP grow in 2009 in China, but supply to outpace demand growth in 2010*. Available at: www.plastemart.com/Plastic-Technicle-Article.asp?LiteratureID=1378.
[68] Plastemart.com (2010) *Growth in styrene that slowed in 2008, expected to remain slow until 2013*. Available at: www.plastemart.com/Plastic-Technicle-Article.asp?LiteratureID=1377.
[69] Plastemart.com (2010) *China to drive global growth of PVC*. Available at: www.plastemart.com/upload/Literature/China-to-drive-global-growth-of-%20PVC-polyvinyl-chloride.asp.

sector where 38% of global production is used for pipes, and 20% is used for window profiles. Due to these factors, PVC consumption is expected to continue growing, from 34 Mt in 2007 to more than 40 Mt in 2016, despite the effects of the 2008 crisis (during which PVC consumption declined by 8%).

The 5% average rate of growth seen between 2000 and 2007 is not likely to continue, and experts predict an average of 2% growth per year until 2016. Chinese demand for PVC is seen as a major driver of PVC consumption out to 2020, growing from 15% of global consumption to approximately 44%. However, Europe's consumption of PVC is expected to fall from 18% to 14% over the same period. PVC is expected to be oversupplied by 2014 by almost 4%.

2.2.1.4 PP

Due to its versatility and low cost, the average PP growth rate has conventionally been above an average of 7-8%. However, in 2008, world consumption of PP fell to 45.5 Mt, dropping 1.4 Mt compared to 2007. Although the recovery of the global economy will boost PP consumption to a growth rate of just under 1%, 2007 levels are only expected to be regained in 2010.

Despite its beneficial properties, PP is beginning to lose its competitive price position to other polymers, due to the increase in feedstock prices. This increase is attributed to two main factors:

- Demand for PP outstrips supply, resulting in the need for more expensive technologies used to supplement production;
- Increasing oil prices prior to 2008.

Over the next five years, experts expect PP consumption to grow at an annual average of 3.7%, which is lower than the average rate of 6% for the period 2007-2012 projected before the 2008 crisis. During this same period, PP production capacity is expected to grow by 10 Mt/year, which may result in utilisation levels below 80% by 2012. Chinese consumption of PP is expected to grow by 10%, accounting for 40% of global PP demand in 2020.

2.2.1.5 Recycled PET

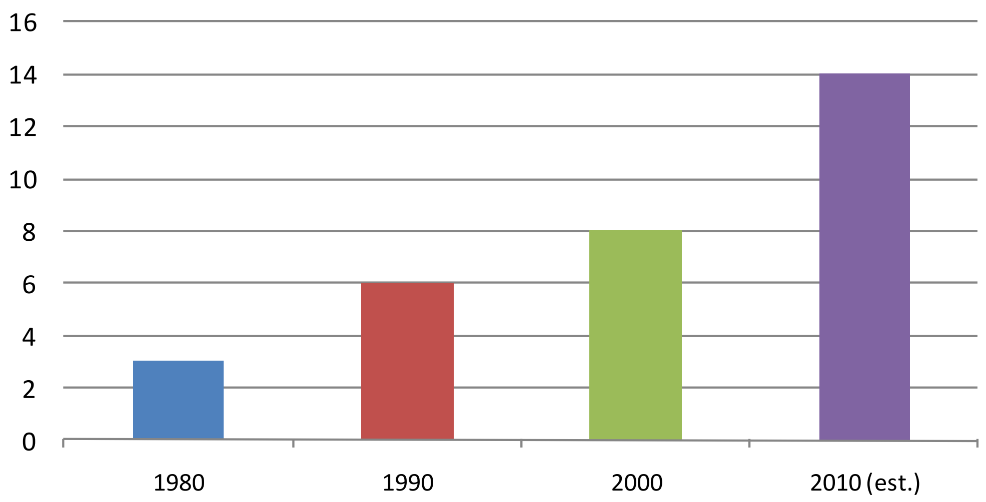
Post-consumer PET is often an attractive material for recycling. Unlike other polymers, recycled PET can be produced that is suitable for contact with food. PET can also be used in applications such as carpet fibers, geo-textiles, packaging and fiber fill. PET can be converted into polybutylene terephthalate (PBT) resin, which can be a valuable material for injection and blow-moulding applications. PBT is created through chemical polymerisation which converts the PET molecular chain into small "repeating units", and through additional catalyst-assisted processes, PBT is produced. The polymerised PBT contains approximately 60% of the original mass of PET, and can reduce solid waste by up to 900 kg for each tonne of PBT produced. Making PBT from recycled PET is often less energy consuming than producing the resin directly from oil stock (at 50 GJ/t to 20 GJ/t respectively).

However, producing PBT from PET does have its limitations. Mechanical properties can suffer during the conversion process from PET to PBT. For this reason, PBT derived from PET is often used for less demanding applications.[70]

2.2.1.6 Automotive composites

Plastic composites are playing an increasingly important role in the automotive construction sector. The use of plastic composites has grown significantly over the past few decades due to the possibility of combining mechanical strength, design flexibility and relatively low cost. Composites in bodywork also allow for better aerodynamic design and lighter weight. Composites have reportedly contributed to lowering the weight of an average passenger car by more than 200 kg.[71] This translates into yearly savings of approximately 35 litres of gasoline per vehicle. Global demand for plastic composites has grown significantly over the past few years (Figure 2-22).

Figure 2-22: Global demand in the composites industry (Mt)[72]



Although cement kiln waste management is accepted by the European Composites Industry Association and EuPR to be a viable "recycling" method for automotive plastic composites,[73] research is continuing into additional methods of waste management.[74]

2.2.2. BIOPLASTICS

The plastics market is currently dominated by petroleum-based plastic products. For bioplastics producers, an important challenge is to widen the range of bioplastics types and possible applications so that they become functionally equivalent to petroplastics.

[70] See www.plastemart.com/upload/Literature/Green-method-manufacture-virgin%20PET-PBT-recycled-products-energy%20saving-Valox%20iQ-Xenoy%20iQ.asp.
[71] See www.reinforcedplastics.com/view/1089/ecrc-heads-search-for-composites-recycling-solutions.
[72] Witten, E. (2009) *The Composites Market in Europe*, AVK.
[73] De Backer, A. (2009) *Thermosets Composites are compliant with EU Directive*, Position Paper on Recycling of Thermosetting Composite Parts in the Automotive Industry.
[74] See www.reinforcedplastics.com/view/1089/ecrc-heads-search-for-composites-recycling-solutions/.

Bioplastics can even have new functional properties: for example, starch foams have better anti-static properties than conventional foams. However, bioplastics cannot yet replace all types of petroleum-based plastics for all applications. In particular, packaging material can have stringent requirements such as gas permeability. It may be that bioplastics will not be able to replace all types of food packaging for such technical reasons (resistance, durability, etc.).

When bioplastics can match the functionality of petroplastics, the next barrier is the manufacturing chain, which may require adaptation and investment by companies. Therefore, manufacturers of biopolymers strive to have the best compatibility possible with existing equipment.

Integration of bioplastics into current end-of-life management systems (collection, sorting, recycling, etc.) will also be an important factor in the development of bioplastics. For instance, bioplastics can lower the quality of recycled material such as PET bottles if they are not properly removed during the separation stage.

In addition, the bioplastics industry would need to reduce production costs in order to increase market penetration.[75] Bioplastics were 1.5 to 4 times more expensive than conventional plastic materials in 2006. The price of crude oil is an important factor in this respect. Bioplastics become more competitive if the price of oil increases, even though the cost of bioplastics production itself is also linked to the oil price.[75] On the other hand, high prices of cereals may hamper the development of the bioplastics market and they have also been highly variable in recent years.

The market drivers for biodegradable polymers vary around the world:

- In Europe: legislation, depleting landfill capacity, pressure from retailers, growing consumer interest in sustainable plastic solutions, fossil oil and gas independence and greenhouse gas emissions reduction;
- In North America: increased cost-competitiveness of biodegradable polymers, growing support from authorities for addressing solid waste disposal needs, growing public and industry awareness of environmental issues and improvements in the properties of biodegradable polymers.
- In Japan: promotion of biodegradable polymers by the government and industry, and increased cost-competitiveness of biodegradable polymers.
- In China: high growth is expected in the coming years because of an increase in production capacity, higher demand for greener products and plastic waste control legislation.

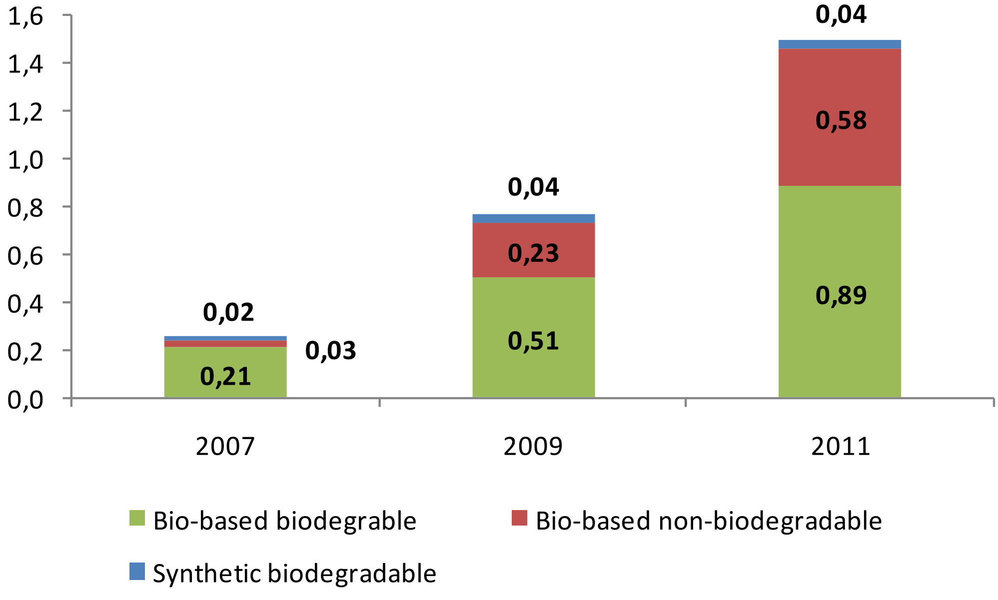
In the EU and the United States, the emphasis is placed on bio-based plastics because of their low carbon footprint. A bio-based labelling programme has been created by the United States Department of Agriculture to promote the use of these products. In Japan, bio-based renewability seems to be more important than biodegradability.

[75] Barker, M. and Safford, R. (2009) *Industrial uses for crops: markets for bioplastics*, HGCA.

According to a recent report, the market for biodegradable polymers grew in 2009 in each of the main consuming regions (Europe, North America and Asia). In Europe, 2009 market growth was in the range of 5-10%.[76] Europe accounts for around half of global consumption, while North America and Asia (including Japan) account for around a quarter each. This difference may stem from the fact that Europe already has large-scale composting capacity which makes this material more economically attractive than in the United States for now.

The global bioplastics market is thought to be growing at a rate of as much as 20% per year.[77] In 2008, European Bioplastics[78] projected that the global bioplastics market would undergo a six-fold increase from 0.26 Mtpa in 2007 to around 1.5 Mtpa in 2011.[79] Bio-based (renewable feedstock) *non-biodegradable* bioplastics were projected to expand their market share from 12% in 2007 to approximately 38% in 2011, with production increasing from 0.03 Mtpa in 2007 to 0.575 Mtpa in 2011. Bio-based *biodegradable* bioplastic production was projected to see its market share decline from 80% in 2007 to 59% in 2011, despite an increase in production from approximately 0.21 Mtpa in 2007 to 0.885 Mtpa in 2011. Petroleum-based (synthetic) biodegradable plastics were projected to increase their market share from 8% in 2007 to 28% in 2011 with an increase in production from 0.022 Mtpa to 0.042 Mtpa (Figure 2-23).

Figure 2-23: Projected global bioplastics market growth (ktpa)[79]



A more recent projection (Figure 2-24) shows slightly slower growth, to just over 1.4 Mt in 2013, but the trend is still strongly positive. The SRI study projects total

[76] SRI Consulting (2010) *Biodegradable polymers*. Available at: www.sriconsulting.com/CEH/Public/Reports/580.0280/

[77] See http://pakbec.blogspot.com/2009/09/slow-down-needed-on-biodegradable.html.

[78] European Bioplastics is the European branch association representing industrial manufacturers, processors and users of bioplastics and biodegradable polymers (BDP) and their derivative products.

[79] European Bioplastics (2008) *Proceedings of the Third European Bioplastics Conference*. Available at: www.european-bioplastics.org/index.php?id=621.

consumption of biodegradable polymers worldwide at an average annual growth rate of 13% from 2009 to 2014.[80]

Figure 2-24: Global production capacity of bioplastics (Mt)[81]

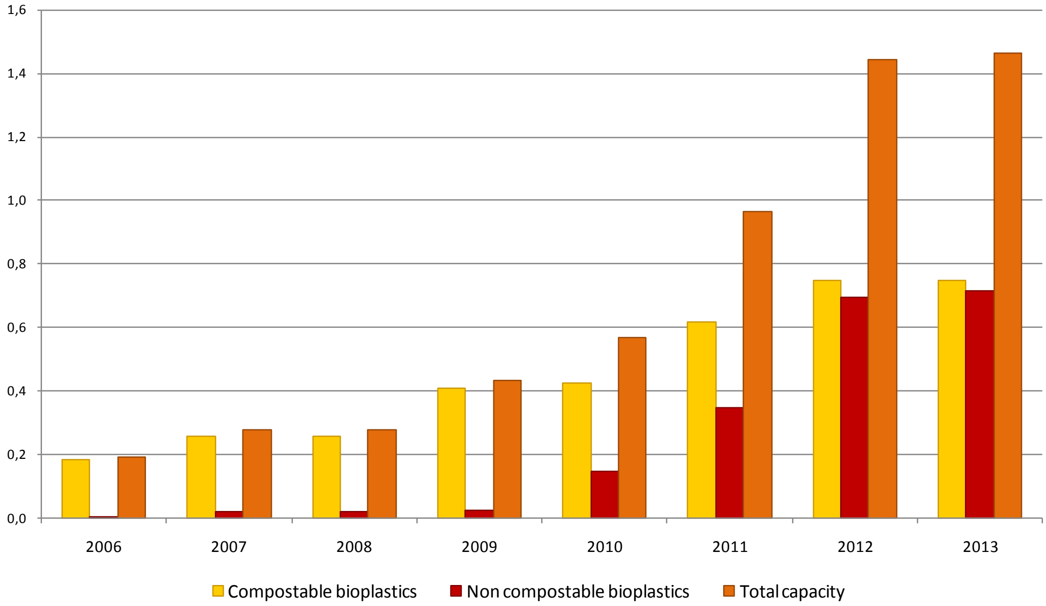
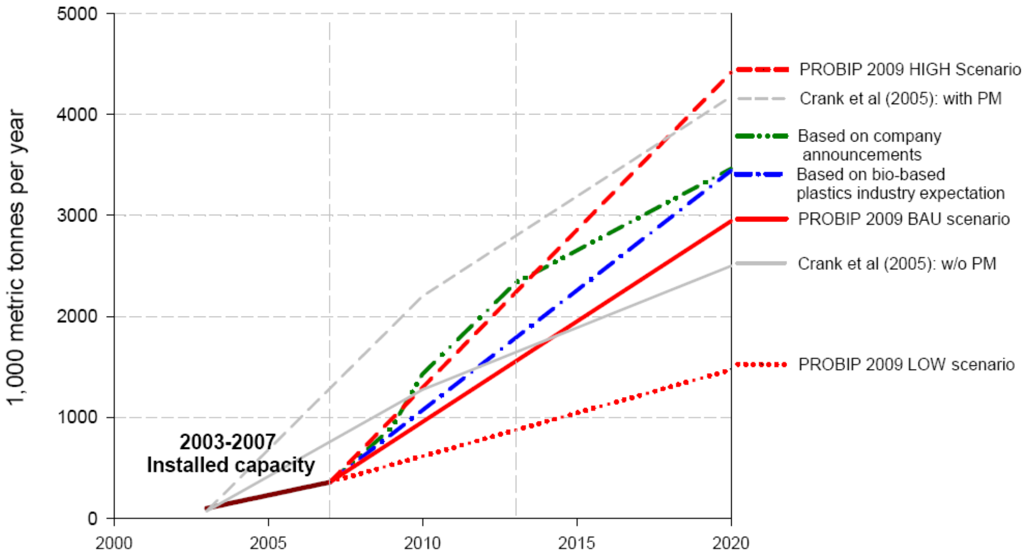


Figure 2-26 shows the expected high growth rate in world production of bio-based plastics (see above for definition) to 2020. Agriculture and Agri-food Canada came up with an estimate in the same range, showing that the European bioplastics market may reach 0.4-0.9 Mt in 2010 and 3-5 Mt in 2020.[82]

Figure 2-25: Projection of worldwide production capacity of bio-based plastics, 2003-2020[83]



[80] SRI Consulting (2010) *Biodegradable polymers*. Available at: www.sriconsulting.com/CEH/Public/Reports/580.0280/

[81] European Bioplastics website: www.european-bioplastics.org/index.php?id=141.

[82] See www.industrie.com/it/materiaux/les-bioplastiques-futur-des-emballages-de-la-distribution-et-de-l-industrie-agroalimentaire.5271.

[83] PRO-BIP (2009) *Product overview and market projection of emerging bio-based plastics*.

The main applications are expected to be disposable plastic bags and packaging items. Growth of the bioplastics market is likely to be strong in food packaging applications, dishes and cutlery, electronics casings, recordable media (e.g. DVDs) and car components.[84] For instance, in 2009 the car manufacturer PSA Peugeot Citroen announced a new ecodesign objective: in 2011, all plastic components in their cars should contain at least 20% bioplastics.[85]

In the EEE sector, new technologies are being developed in order to replace conventionally used materials with renewable counterparts. One such technology is to use biofiber-reinforced bioplastics. The biofiber can for example be made of linen, kenaf or cellulose. Bioplastics for EEE applications can for example be made using a polylactic acid polymerisation process, from corn to polymer.[86] There are already mobile phones on the market containing plastics based on such technologies.

The environmental qualities of bioplastics have not yet been documented comprehensively. A key consideration is the amount of non-renewable energy used in the manufacture of the various materials.[87] Research is also underway in the UK and elsewhere into potential implications for land use (e.g. impacts on forests) and food crops.

2.3. SUMMARY

The information collated above provides some insight into the market prospects of plastics. In the case of recovered plastics, only recycled PET has been presented here. In relation to primary plastics, most are predicted to continue to grow in production capacity over the next decade. However, polystyrene is becoming less favoured than other primary plastic types and demand for it is expected to decline over the next decade. Demand for plastic by European converters may decrease in the coming decades if the trend of primary plastic production moving to countries outside the EU continues.

The information gathered in this section has focused on some trends in specific plastics markets. Although the information provides some insight into these products and sectors, not all of it is quantitative. Nevertheless, some trends that emerge clearly are for continued innovation and improvements such as weight reduction, and for continued growth in the market share of bioplastics despite some sorting and price barriers.

[84] Barker, M. and Safford, R. (2009) *Industrial uses for crops: markets for bioplastics*, HGCA.
[85] See www.industrie.com/it/conception/les-materiaux-verts-poussent-dans-les-voitures.8684.
[86] Nakagawa T., Nakiri T., Hosoya R., and Y. Tajitsu (2003) "Electrical properties of biodegradable polylactic acid film" in *Proceedings of the 7th International Conference on Properties and Applications of Dielectric Materials, 2003*.
[87] Pilz, H., Brandt, B. and R. Fehringer (2010) *The impact of plastics on life cycle energy consumption and greenhouse gas emissions in Europe*, Summary report, Denkstatt.

3. PLASTIC WASTE MANAGEMENT

This chapter presents some broad trends in relation to plastic waste management options. Section 3.1 quantifies the plastic waste volumes generated, by source of waste and type of plastic. This provides an indication of the complexity of the pre-treatment and required recycling processes covered in sections 3.2 and 3.3, where waste plastic volumes processed through different treatment options are quantified by plastic type.

Although most of the information included relates to plastic waste recycling and its impacts, incineration and energy recovery from waste are also important options. The factors that favour one type of treatment over another help determine future plastic waste treatment trends. This chapter is important in giving an overall picture of the management of plastic waste, its treatment destination and the future development of treatment processes.

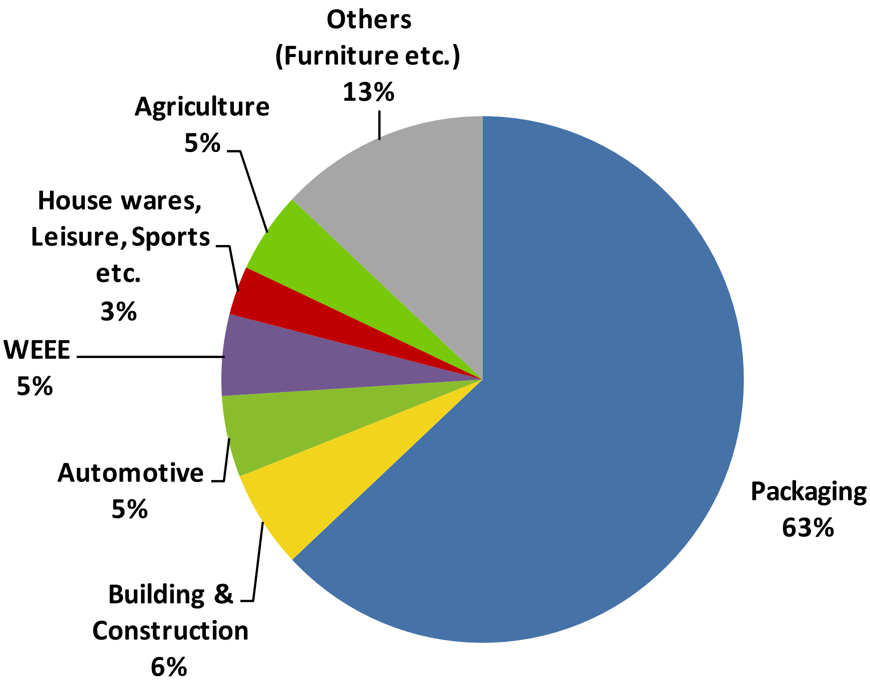
3.1. INVENTORY OF PLASTIC WASTE SOURCES AND TYPES

In 2008, total generation of post-consumer plastic waste in EU-27, Norway and Switzerland was 24.9 Mt (26.2 Mt in 2004, 23.7 Mt in 2006 and 24.6 Mt in 2007).[88,89] The disparity between converter demand and waste generation is due to the service life of plastics. Of plastics converted, 60% were designed with a long service life, while 40% had a shorter service life. Although pre-consumer plastic waste and scrap is often recovered at high rates, data on amounts collected in Europe is not available.

The main sources of plastic waste are typically the sectors which represent the highest plastic consumption. Figure 3-1 shows the contribution of the different sectors to the plastic waste stream in the EU-27, Norway and Switzerland in 2008. Packaging is the largest contributor to plastic waste at 63%, well ahead of “Others” (13%), which includes furniture, medical waste, etc. The remaining sectors include: automotive (5%), EEE (5%), B&C (6%) and agriculture (5%).

[88] PlasticsEurope, EuPC, EuPR, EPRO and Consultic (2009) *The Compelling Facts about Plastics - An analysis of European plastics production, demand and recovery for 2008*.
[89] Prognos (2008) *European Atlas of Secondary Raw Materials – 2004 Status Quo and Potentials*.

Figure 3-1: Proportions of post-consumer plastic waste in EU-27, Norway and Switzerland by application, 2008[90]



3.1.1. MUNICIPAL SOLID WASTE

In 2008, MSW accounted for approximately 40-50% of plastic waste in the EU-27.[91] In MSW, all plastics (packaging, plastic toys, furniture, etc.) are found commingled with other types of waste (organic material, metal, paper, etc.). The plastics fraction of MSW can differ from one country to another and is also dependent on the season.[92] In 2007, MSW plastic generation in central Europe ranged from 9.6% in the winter to 10.5% in the summer. In eastern Europe, plastic waste accounted for 5% of MSW in winter and 13% in summer. No recent data on the breakdown of this waste stream by polymer has been found at the EU level.

A large share (70%) of MSW plastics consists of packaging items but houseware items (toys, leisure and sports goods) or small EEE are also discarded by households.[93] The compositions of packaging and EEE will be described further in the following sections. Data for the 1990s gives the following polymer breakdown:[93] HDPE, LDPE and PP together account for 60% of plastics in MSW, PET and PS are also significant and the share of the remaining resins represents approximately 10%.

[90] PlasticsEurope, EuPC, EuPR, EPRO and Consultic (2009) *The Compelling Facts about Plastics - An analysis of European plastics production, demand and recovery for 2008*.

[91] JRC IPTS (2009) *Study on the selection of waste streams for End of Waste assessment* and PlasticsEurope, EuPC, EuPR, EPRO and Consultic (2009) *The Compelling Facts about Plastics - An analysis of European plastics production, demand and recovery for 2008*.

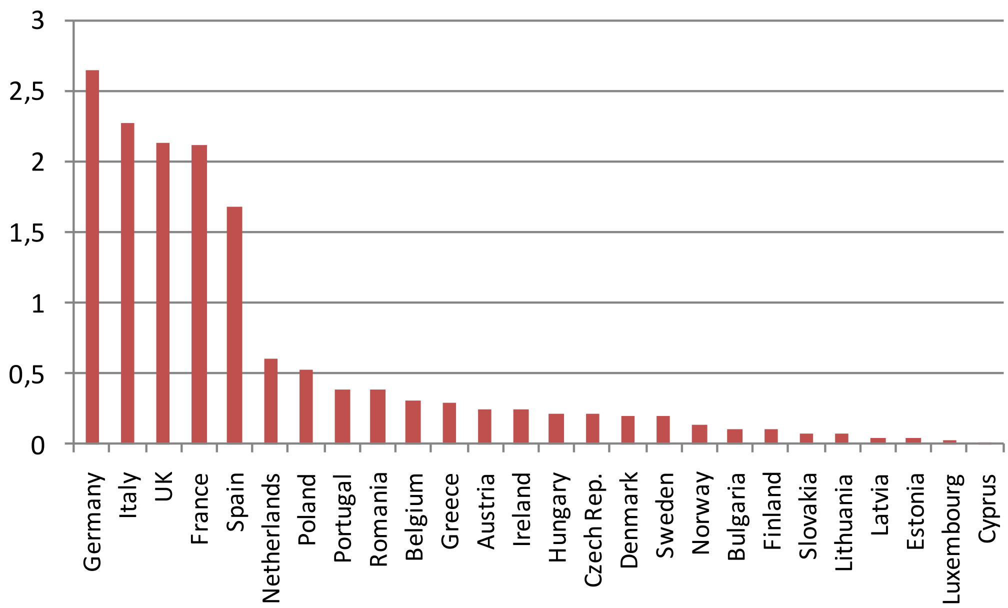
[92] Council of Europe (2007) *Management of municipal solid waste in Europe*; nations included in Central Europe and Western Europe not indicated.

[93] JRC IPTS (2007) *Assessment of the Environmental Advantages and Disadvantages of polymer recovery processes*.

3.1.2. PACKAGING

Plastic packaging accounts for a significant majority of total plastic waste in most Member States. In 2008, figures show that total generation of plastic packaging reached 15.6 Mt in EU-27, Norway and Switzerland (63% of the total).[89] In 2007, Germany was the biggest contributor to plastic packaging waste generated in EU-27, having generated 2.6 Mt, followed by Italy at 2.3 Mt and the UK and France, with 2.1 Mt each (Figure 3-2, Table 13).

Figure 3-2: Plastic packaging waste generation by Member State, 2007 (Mt)[94]



Although these countries produce a significant level of plastic packaging waste, it is worth noting that their per capita consumption is not the highest in Europe. Average EU-27 per capita generation in 2007 was 30.6 kg. Most of the countries that generate most plastic packaging waste have higher per-capita generation amounts than the EU average. However, despite Ireland's comparatively small contribution (0.238 Mt), its per capita generation of plastic packaging waste in 2007 was the highest in Europe, at 55.2 kg, followed by Luxembourg (which only produces a total of 0.025 Mt of plastic packaging waste) at 52.1 kg.

[94] Source: Eurostat database. Available at: http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database.

Table 13: Annual total and per capita plastic packaging waste generation, 2007 (ranked by per-capita generation)[95]

Country	Total plastic packaging generation (Mt)	Population (millions)[96]	Per-capita generation (kg)
Ireland	0.238	4.31	55.2
Luxembourg	0.025	0.48	52.1
Italy	2.27	59.13	38.4
Spain	1.679	44.47	37.8
Netherlands	0.606	16.36	37.0
Portugal	0.378	10.60	35.7
Denmark	0.192	5.45	35.2
United Kingdom	2.121	60.78	34.9
France	2.114	63.62	33.2
Germany	2.644	82.31	32.1
Austria	0.245	8.28	29.6
Norway	0.141	4.68	30.1
Belgium	0.309	10.58	29.2
Estonia	0.037	1.34	27.6
Greece	0.295	11.17	26.4
Hungary	0.218	10.07	21.6
Czech Republic	0.217	10.29	21.1
Sweden	0.191	9.11	21.0
Cyprus	0.015	0.78	19.2
Lithuania	0.064	3.38	18.9
Finland	0.099	5.28	18.8
Latvia	0.040	2.28	17.5
Romania	0.375	21.57	17.4
Slovakia	0.075	5.39	13.9
Poland	0.516	38.13	13.5
Bulgaria	0.102	7.68	13.3
Total	15.206	497.52	30.6

As mentioned earlier, total plastic packaging waste generation in 2008 for the EU-27, Norway and Switzerland was approximately 15.6 Mt.[89] This is not very different from the total amount calculated in Table 13. This slight discrepancy can be put down to the difference in years the data was gathered, as well as the different number of countries included in each dataset, where the more recent figures include both Switzerland and Norway.

Its short lifespan means that the share of packaging in plastic waste generation (63%) is much higher than its share in plastic consumption (38%, see Figure 2-4). Much of the packaging is collected from the commercial and industrial sectors (crates, distribution and commercial films, EPS packaging, etc.). From MSW, mainly PET and HDPE bottles are being recovered. The large share of packaging in plastic waste can have important

[95] Source: Eurostat database.

[96] Eurostat (2007) Population Estimate 2007. Available at : epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&language=en&pcode=tps00001&tableSelection=1&footnotes=yes&labeling=labels&plugin=1.

implications for the plastics recycling industry, affecting collection systems and quality (due to contamination and use of mixed plastics).

3.1.3. Construction and demolition

Although the construction sector is the second largest consumer of plastics in Europe (21%),[97] it only accounts for 6% of plastic waste generated per year.[98] The main reason for this is that plastics used in construction often have a significantly longer design life than plastics used for other purposes. Plastic products in the construction sector are designed to be durable and can last between 30 and 40 years before being disposed of.[99] Table 14 shows that although plastic consumption in this sector in western Europe in 2002 reached 7.3 Mt, only 1 Mt of plastic waste was generated – approximately 14% of consumption. However, plastic building materials are often contaminated, making recycling difficult.

Table 14: Plastics in the construction sector, 2002[100]

Country	Plastic consumption	Plastic waste	Share of waste in consumption
	Mt per year		*(%)*
Austria	0.19	0.025	13.2
Belgium	0.24	0.03	12.5
Denmark	0.13	0.017	13.1
Finland	0.12	0.015	12.5
France	1.25	0.175	14.0
Germany	2.3	0.26	11.3
Greece	0.06	0.010	16.7
Ireland	0.08	0.011	13.8
Italy	0.74	0.13	17.6
Netherlands	0.35	0.05	14.3
Portugal	0.08	0.012	15.0
Spain	0.55	0.1	18.2
Sweden	0.16	0.023	14.4
UK	0.8	0.135	16.9
Total EU	7.05	0.993	14.1
Norway	0.07	0.01	14.3
Switzerland	0.15	0.018	12.0
Western Europe	7.27	1.021	14.0

3.1.4. Electrical and electronic equipment

In 2008, 1.4 Mt of plastic waste was generated from EEE.[101] On average, electrical and electronic devices have a service life of 3-12 years, with larger objects having a longer

[97] PlasticsEurope (2008) *An analysis of plastics production, demand and recovery for 2007 in Europe*.
[98] EuPR (2010) *How to increase the mechanical recycling of post-consumer plastics - Strategy paper of the European Plastics Recyclers association*.
[99] See archive.greenpeace.org/comms/pvctoys/reports/loomingplasticsboom.html.
[100] European Commission (2006) APPRICOD - Towards Sustainable Plastic Construction and Demolition Waste Management in Europe.

service life. As the Directive was introduced in 2002, it may be some time before recyclable plastics begins to be collected in higher quantities. Furthermore, older appliances may have plastics containing brominated flame retardants. These chemicals can have an effect on the integrity of the resulting recyclate and may require special consideration during recycling.

3.1.5. AUTOMOTIVE

The recovery and reuse of 70-80% of vehicle material is relatively easy as this can be achieved mainly by recovering tyres, metals, etc. Plastics recovery and the recovery of non-ferrous metals will be necessary to achieve the rest.

However, despite a relatively high recycling rate for ELVs, the proportion of plastics from ELVs being recycled is extremely low. One reason for this is the wide variety of polymer types used. Identification, by marking components at production or by improved sorting technologies, will be vital if the practice of recovering plastic parts is to become viable. Such novel technologies are under development, which may help to increase the rate of ELV plastic recycling.

The average service life of vehicles is around 13.5 years.[102] Generation of automotive plastic waste is increasing at a slower rate than packaging plastic. There are few comprehensive sources detailing quantities of automotive plastic waste collected from ELVs in individual Member States. At European level, 1.5 Mt of plastic waste was generated from ELVs in 2008.[103]

The main method of end-of-life management of composite waste from the automotive sector is through the cement kiln method, where the resulting material is used for the production of cement and/or energy to produce cement (Table 15).

Table 15: The relationship between fiber-reinforced plastics (FRP) and cement[104]

Typical FRP composition	Use in cement
25-35% resin	Energy for making cement
25-45% glass fiber	Raw material for cement
20-50% inert filler	Raw material for cement

3.1.6. AGRICULTURE

Agriculture generates about 0.4-0.6 Mt of plastic waste per year in the EU.[105] Table 16 below contains data on plastic waste from agricultural sources in Europe. The most

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[101] PlasticsEurope, EuPC, EuPR, EPRO and Consultic (2009) *The Compelling Facts about Plastics - An analysis of European plastics production, demand and recovery for 2008*.

[102] Waste Online (2004) *End of life vehicle and tyre recycling information sheet*. Available at: www.wasteonline.org.uk/resources/InformationSheets/vehicle.htm.

[103] PlasticsEurope, EuPC, EuPR, EPRO and Consultic (2009) *The Compelling Facts about Plastics - An analysis of European plastics production, demand and recovery for 2008*.

[104] See www.reinforcedplastics.com/view/4298/recycling-threat-to-europes-composites-industry-/.

[105] Bos U., Makishi C. and M. Fischer (2007) *Life Cycle Assessment of common used agricultural plastic products in the EU*. ISHS Acta Horticulturae 801: International Symposium on High Technology for

significant source of plastic waste is pipes and fittings at 0.2 Mt, with agricultural packaging (bags, liners and containers) collectively accounting for 0.079 Mt.

Table 16: Estimated amount of plastic agricultural waste in Europe by application[106]

Application	Type of plastic	Mt
Fertiliser bags, liners	PP	0.027
	LDPE	0.026
Seed bags	PP	0.005
Feed bags	LDPE	0.010
Agrochemical containers	HDPE	0.011
Nets and mesh	LDPE	0.045
Pots and trays	LDPE	0.008
	HDPE	0.008
Pipes and fittings	PVC	0.157
	LDPE	0.043
Nets and mesh	LDPE	0.013
	HDPE	0.013
Rope, strings	PP	0.036

In the UK, non-packaging plastic film in this sector accounts for around 0.085 Mt of the plastic disposed of each year.[107]

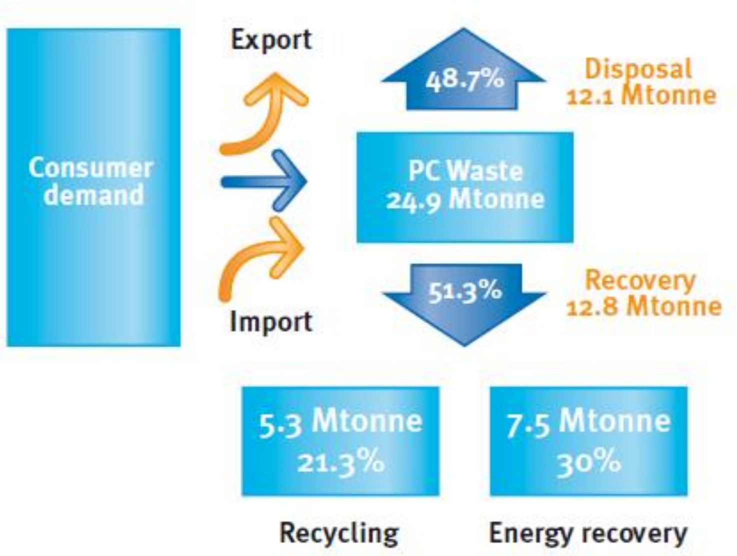
3.2. MANAGEMENT OPTIONS

This section presents detailed information on the treatment of various plastic waste streams. Several end-of-life options exist to deal with plastic waste, including disposal, incineration with or without energy recovery and recycling. Figure 3-4 shows the percentage shares of these different options for post-consumer plastic waste in the EU.24 Post-consumer plastic recycling grew by 4.3% in 2007. The rate of recycling was 21.3% in 2008 (up 0.9 percentage points compared to 2007), helping to drive the total recovery rate (energy recovery and recycling) for plastics to 51.3% (a 3.6% increase compared to 2007). However, due to the recent economic crisis, this represented a lower year-on-year increase than in previous years.24 Mechanical recycling was 21% in 2008, up 0.9 percentage points over 2007. Feedstock recycling was unchanged compared to 2007, at 0.3%.

Trends in recycling show that waste plastic from packaging streams such as PET bottles and PE containers are one of the main sources driving the waste plastic recycling industry.

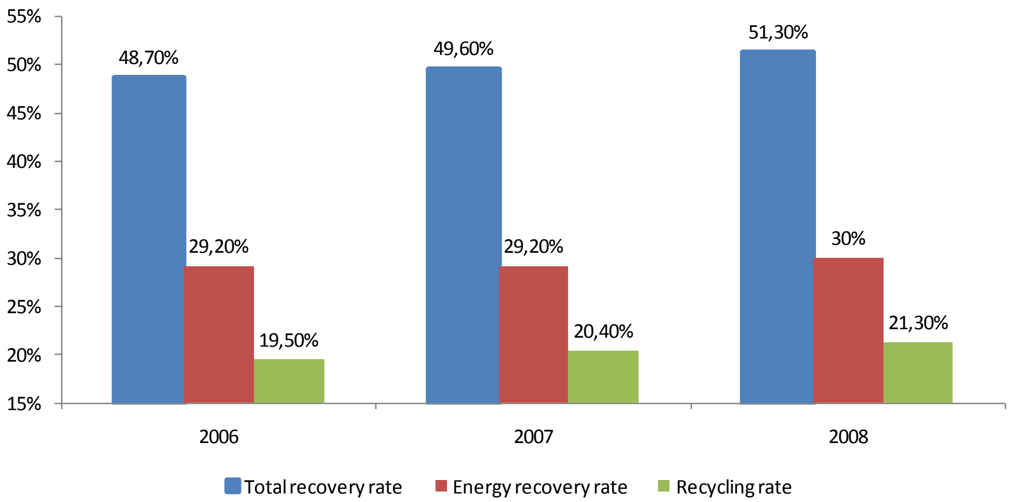
Greenhouse System Management: Greensys2007; and JRC IPTS (2007) *Assessment of the Environmental Advantages and Drawbacks of existing polymer recovery processes*.
[106] JRC IPTS (2007) *Assessment of the Environmental Advantages and Drawbacks of existing polymer recovery processes*.
[107] letsrecycle.com website, Defra. Available at: www.letsrecycle.com/materials/plastics.

Figure 3-3: Plastics end-of-life options in EU-27, Norway and Switzerland, 2008[24]



In EU-27, Norway and Switzerland, 51.3% (12.8 Mt) of post-consumer plastic waste generated in 2008 was recovered and the remaining amount (12.1 Mt) was disposed of, either in landfills (12.1 Mt) or in incinerators without energy recovery (just 0.046 Mt). The plastic waste recovered went either to energy recovery (7.4 Mt, or 30% of post-consumer waste) or recycling (5.3 Mt, or 21.3% of post-consumer waste). Figure 3-4 shows the evolution of the recovery, energy recovery, recycling and mechanical recycling rates between 2006 and 2008. All rates have been increasing in the past two years but recycling had a more substantial rise (1.8%) than energy recovery (0.8%).

Figure 3-4: Rate of recovery in EU-27, 2006-2008[108]



[108] Source: EPRO.

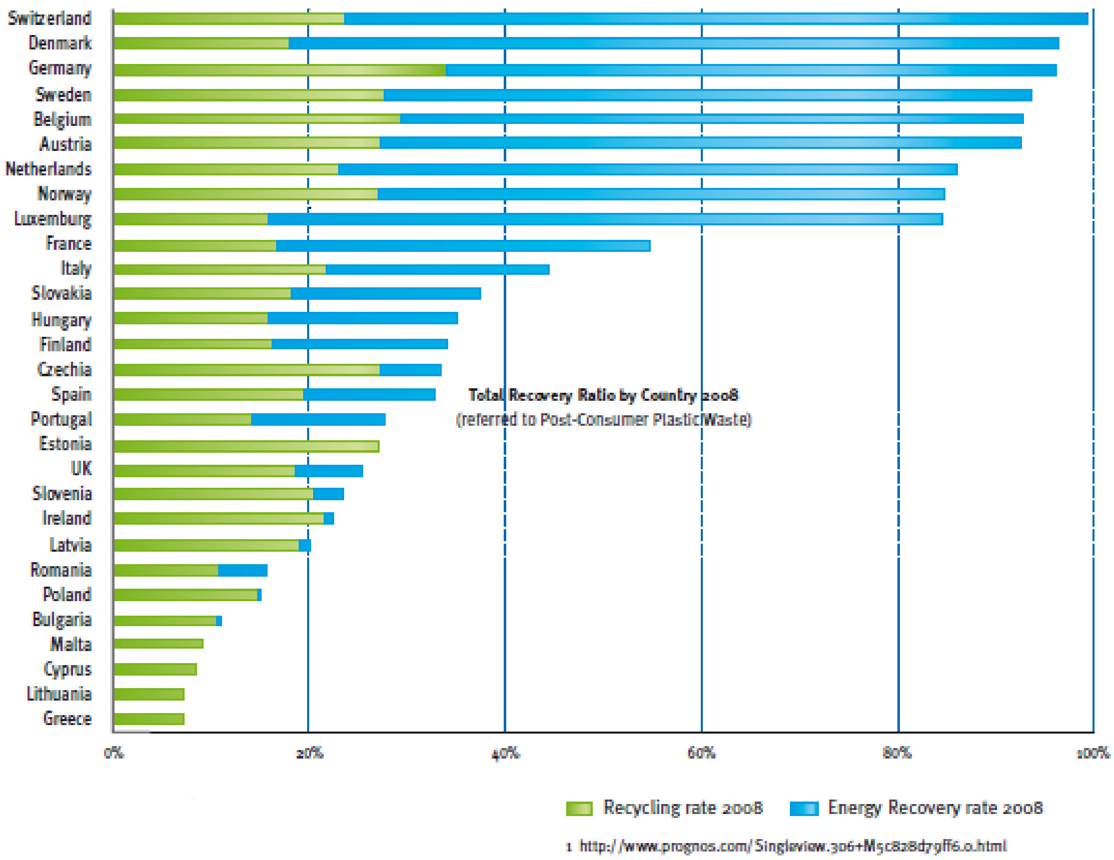
Energy recovery in MSW incinerators was achieved for 6.8 Mt of plastic waste (27.3% of post-consumer waste) and through other processes (power plants, cement kilns, waste derived fuel) for 0.675 Mt of plastic material (2.7% of post-consumer waste).

Mechanical recycling is not the only recycling option. Feedstock recycling (also called chemical recycling) represented 0.07 Mt in 2008. However, mechanical recycling is the main driver of the increase of the recycling rate from 19.5% in 2006 to 21.3% in 2008.

Large differences can be observed across countries: Norway, Sweden, Germany, Denmark, Belgium and Switzerland have the highest recovery rates (over 85%, and up to 99.5% for Switzerland). The top nine countries are doing better in part because they have restrictions or bans on landfilling. There is a large gap between this group of countries and others – the next countries are France with a rate close to the EU average (54.7%) and Italy (44.4%). The remaining countries such as Spain (32.7%), Portugal (27.6%) and the UK (25.3%) have relatively low recovery rates. The lowest rates are found in Romania (15.5%), Bulgaria (10.9%) and Lithuania (7.2%).

The highest rate of recycling is seen in Germany at around 34% and the lowest in Greece at 8%. Some countries recycle almost all recovered waste (e.g. Greece, Lithuania, Poland and Estonia), while Nordic countries have recycling rates of around 30% but have very high total recovery rates.

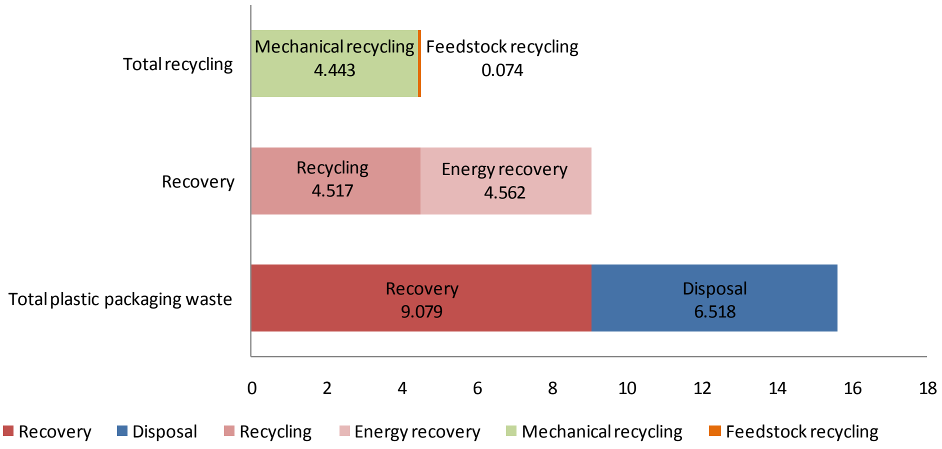
Figure 3-5: Recycling and energy recovery rates by country, 2008[24]



3.2.1. Packaging

In 2008, 15.6 Mt of plastic packaging waste was generated in EU-27, Norway and Switzerland. Of this total, 6.5 Mt was disposed of (41.8%) and 9.1 Mt was recovered (58.2%). Mechanical recycling accounted for 4.4 Mt of the recovered fraction (28.5% of total packaging waste), feedstock recycling reached 0.074 Mt (0.5%) and energy recovery amounted to 4.6 Mt (29.2%) (Figure 3-6).

Figure 3-6: Treatment of total plastic packaging waste in EU-27, Norway and Switzerland, 2008 (Mt)[109]



To date, the most comprehensive recovery figures at Member State level have focused on plastic packaging waste, which is the most significant plastic waste stream. The recovery and recycling rates mentioned hereafter have been based on the data gathered in Table 13 and Table 17.

With an average generation rate per capita of 3.5 tonnes per year, Denmark has the highest rate of recovery at 98%, although this is mainly due to its high rate of incineration (76%).[110] As the biggest contributor to plastic packaging waste generation, Germany also has a high rate of recovery, at 95%, and mechanically recycles the greatest amount of plastic packaging waste in Europe (1 Mt). Germany is also one of only two countries shown to chemically recycle plastic packaging waste (0.054 Mt).

Although low rates of recovery occur in Bulgaria, Cyprus and Greece, these countries may not have adequate infrastructure for alternatives to disposal (e.g. incineration and energy recovery). In fact, the rate of recycling in Bulgaria is only slightly below that of Denmark, at 20% and 22% respectively. However, in the case of Denmark, the remaining waste is incinerated or used for energy recovery (the figures are not clear, as incineration in this context may also include energy recovery), while in Bulgaria the majority of the remaining plastic packaging waste is disposed of.[111]

[109] PlasticsEurope, EuPC, EuPR, EPRO and Consultic (2009) *The Compelling Facts about Plastics - An analysis of European plastics production, demand and recovery for 2008*.
[110] Recovery in this context refers to recycling, energy recovery and incineration.
[111] Hlebarov I. (2009) *Management of packaging waste in Bulgaria*.

It should be noted here that for the majority of figures, the data does not seem to distinguish between household and commercial packaging. It is assumed that the figures include both. The results below indicate that a significant amount is incinerated, though the figures include energy recovery, not disposal.

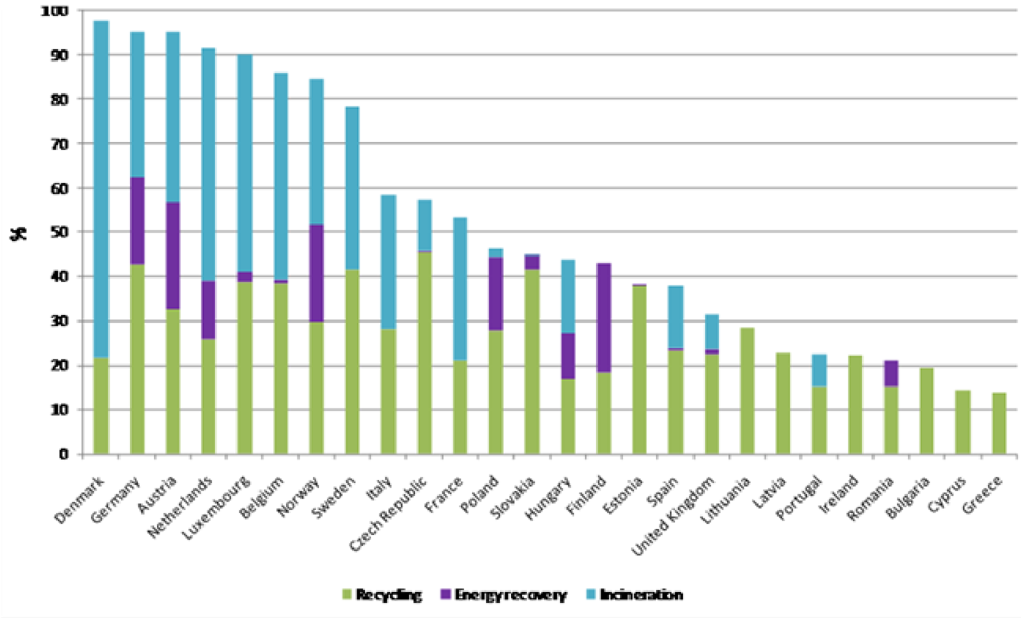
Table 17: Plastic packaging waste treatment by Member State, 2007 (Mt)[112]

	Material recycling	Other forms of recycling	Energy recovery	Other forms of energy recovery	Incineration with energy recovery
Germany	1.075	0.054	0.516	-	0.874
Italy	0.642	-	-	-	0.687
UK	0.477	-	0.024	-	0.167
France	0.446	-	-	-	0.683
Spain	0.392	-	0.010	-	0.238
Netherlands	0.157	-	0.079	-	0.318
Poland	0.144	0.0005	0.084	0.010	0.011
Belgium	0.119	-	0.003	-	0.144
Czech Republic	0.099	-	0.001	-	0.025
Austria	0.080	-	0.059	-	0.094
Sweden	0.080	-	-	-	0.070
Portugal	0.058	-	-	-	0.028
Romania	0.057	-	0.022	-	-
Ireland	0.053	-	-	-	-
Norway	0.042	-	0.031	-	0.046
Denmark	0.042	-	-	-	0.146
Greece	0.041	-	-	-	-
Hungary	0.037	-	0.023	-	0.036
Slovakia	0.031	-	0.0001	0.002	0.0001
Bulgaria	0.020	-	<0.00001	-	-
Lithuania	0.018	-	-	-	-
Finland	0.018	-	0.024	-	-
Estonia	0.014	-	0.00004	-	-
Luxembourg	0.010	-	0.001	-	0.012
Latvia	0.009	-	-	-	-
Cyprus	0.002	-	-	-	-
Total	4.162	0.055	0.875	0.003	3.580

The rate of recycling of plastic packaging waste in Europe ranges from 14% in Greece to 46% in the Czech Republic as shown in the figure below, which is based on the results gathered in Table 17. As shown, in some countries such as Denmark, although the recycling rate is relatively low in comparison with other Nordic countries the total rate of recovery is very high due to the share of plastic that is used for energy recovery.

[112] Eurostat database. Includes separately collected municipal packaging waste.

Figure 3-7: Rate of plastic packaging waste treatment by Member State, 2007 (%)[113]



In total, recycling amounts for plastic packaging waste in EU-27 are higher than other forms of recovery, calculated here at 4.2 Mt. Figures for plastic packaging recycling in 2008 for EU-27, Norway and Switzerland totalled 4.5 Mt. The slight difference in figures can be attributed not only to the difference in year the data was collected (where some change is naturally expected), but also to the fact that the later dataset includes figures from Switzerland (absent in Eurostat figures).

Packaging was the first type of waste to be recovered and is largely mechanically recycled. However, the recycling rates are very different depending on the type of plastics:[114]

- 40% of bottles and industrial film are mechanically recycled in the EU;
- Over 90% of crates and boxes are recycled;
- Less than 10% of remaining mixed plastics are recycled across the EU.

The overall recycling rate of packaging waste (household and commercial) across the EU in 2008 was 29% (28.5% mechanical recycling and 0.5% feedstock) and the recovery rate was estimated at 58%.[115]

Legislation, in particular the Packaging and Packaging Waste Directive, 94/62/EC, has led to a significant increase in the recycling of packaging products. Much of the recycled packaging is collected from the commercial and industrial sectors (crates, distribution and commercial films, EPS packaging). From domestic sources, mainly PET and HDPE bottles are being recovered.

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[113] Source: Eurostat database. Available at: http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database.

[114] PlasticsEurope, EuPC, EuPR, EPRO and Consultic (2009) *The Compelling Facts about Plastics - An analysis of European plastics production, demand and recovery for 2008*.

[115] Ibid.

Figure 3-8 shows the EU countries performing above and below the packaging directive target of 22.5% for 2008.

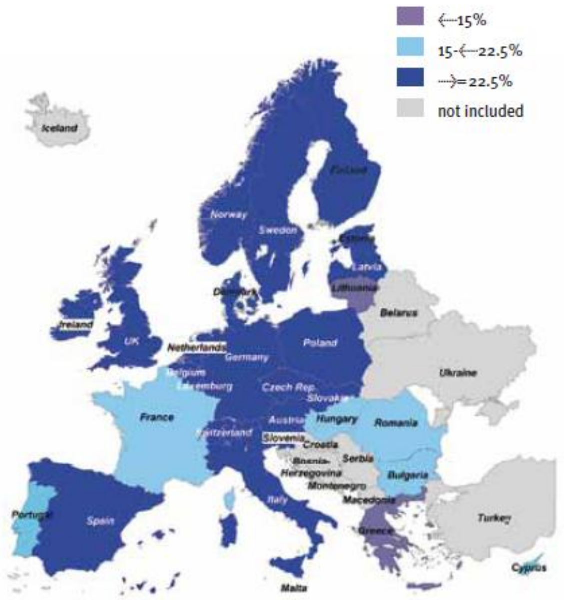
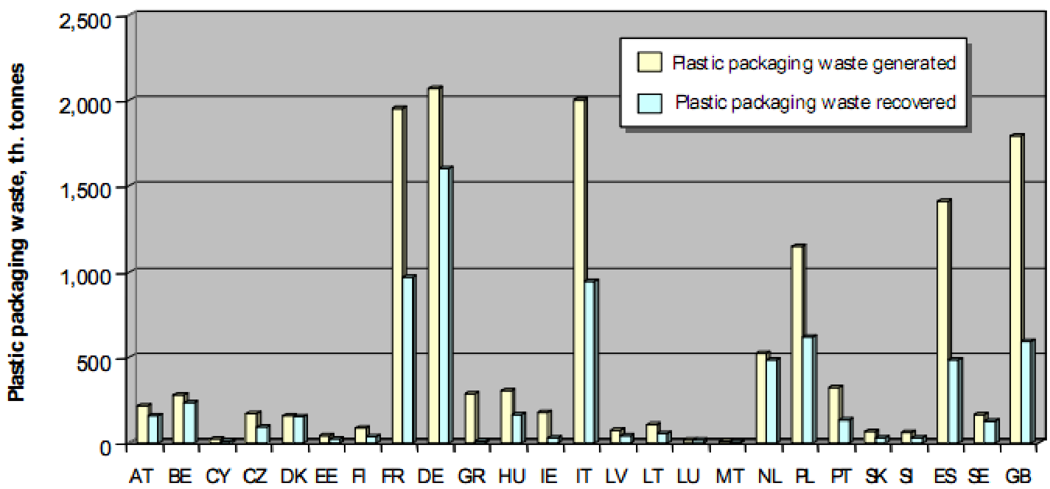


Figure 3-8: Recycling rates of plastic packaging waste across EU in 2008[116]

Figure 3-9 presents total plastic packaging waste generated and recovered by Member State in 2005. Figure 3-10 shows projections to 2015. Of the six major waste-generating countries (France, Germany, Italy, Spain, UK and Poland), Germany has the highest recycling rate (over 75%); France, Italy and Poland recycle around 50% of material, while Spain and the UK achieve relatively low levels of recycling (around 33%). Denmark and the Netherlands have the best recycling performance for packaging recycling, though they do not consume or produce as much.

Figure 3-9: Total EU-25 plastic packaging waste generated and recovered, 2005[117]



[116] PlasticsEurope, EuPC, EuPR, EPRO and Consultic (2009) *The Compelling Facts about Plastics - An analysis of European plastics production, demand and recovery for 2008*.
[117] JRC IPTS (2007) *Assessment of the Environmental Advantages and Disadvantages of polymer recovery processes*. Note that GB here is an ISO 3166-1 country code and refers to the United Kingdom.

Figure 3-10 shows that recovery rates are expected to increase for all countries by 2015, especially for countries that currently have low recovery rates such as the UK, Greece, Spain and Portugal.

Figure 3-10: Projected EU-25 plastic packaging waste generated and recovered, 2015[117]

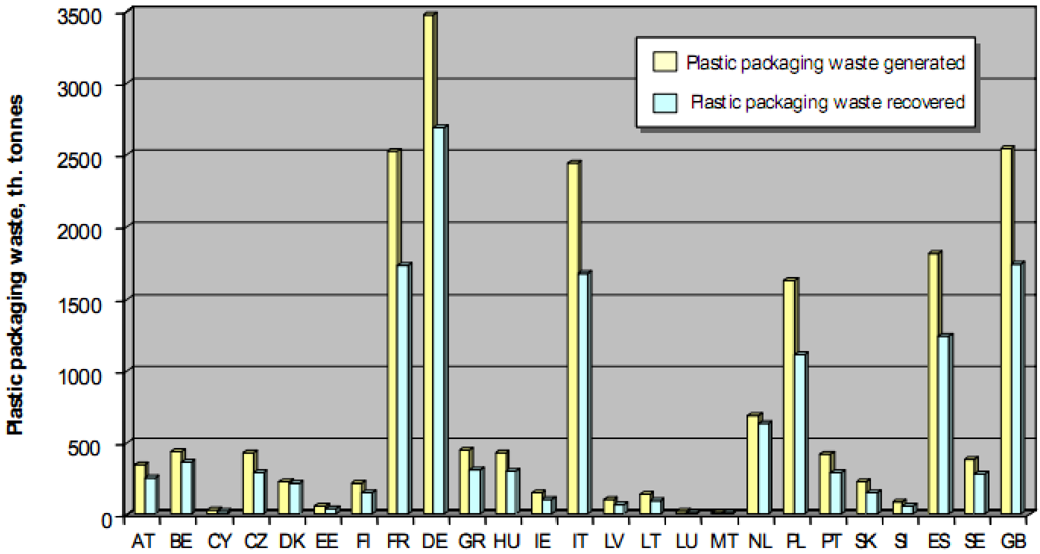


Table 18 describes the collection rates depending on the applications of packaging plastics. HDPE boxes are all recovered, because they are mainly used in the industrial and commercial sectors, where the recovery paths are better established. Bottles and containers are second with 25% of collection; these products are mainly made out of PET. Other plastic waste is not collected to the same extent (less than 10%) but small increases are expected to occur.

Table 18: Separate collection rates estimated by application in EU-25[117]

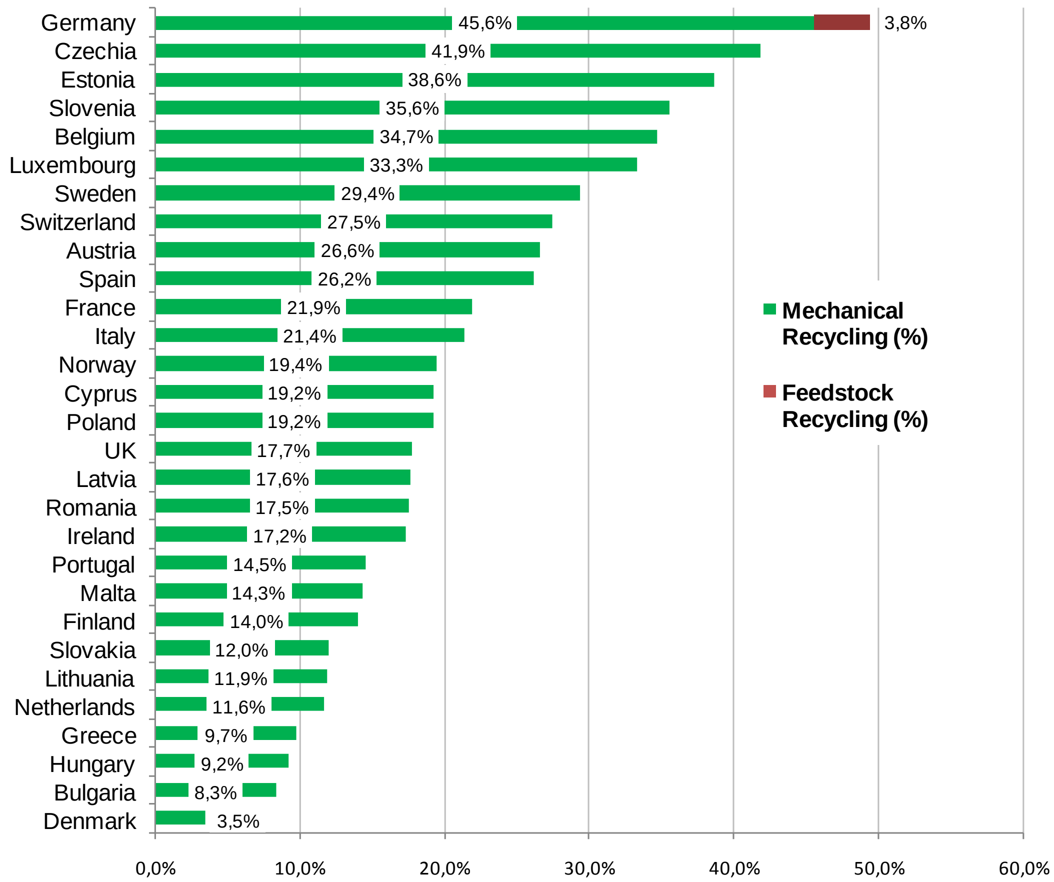
Packaging application	Current collection rate	Future collection rate
Bottles, containers and closures	25%	37.5%
EPS	10%	15%
HDPE boxes	100%	100%
Shrink wrap	10%	15%
Stretch wrap	10%	15%
LLDPE shrink wrap	10%	15%
Film	10%	15%
Sacks	5%	7.5%
Bags	5%	7.5%
Trays	10%	15%
Other small packaging	3%	4.5%

3.2.1.1 Household packaging

The amount of household packaging plastics recycled has been increasing constantly over the past few years: in 2008, approximately 25% of total household plastic packaging waste was mechanically recycled (23% in 2007) and 0.7% was feedstock recycled which gives a total recycling rate of 25.5%.

The recovery rate is estimated at 55.5% (51.5% in 2007), which means that big improvements are still possible in terms of selective collection and consequently recycling. Figure 3-12 presents the recycling rates of household packaging across the EU in 2008. Only Germany is processing some waste with feedstock recycling and mechanical recycling rates are in the range of 3.5% (Denmark) to 45.6% (Germany), which shows important differences in the management of this type of waste.

Figure 3-11: Recycling rates of household plastic packaging by Member State, 2008[118]



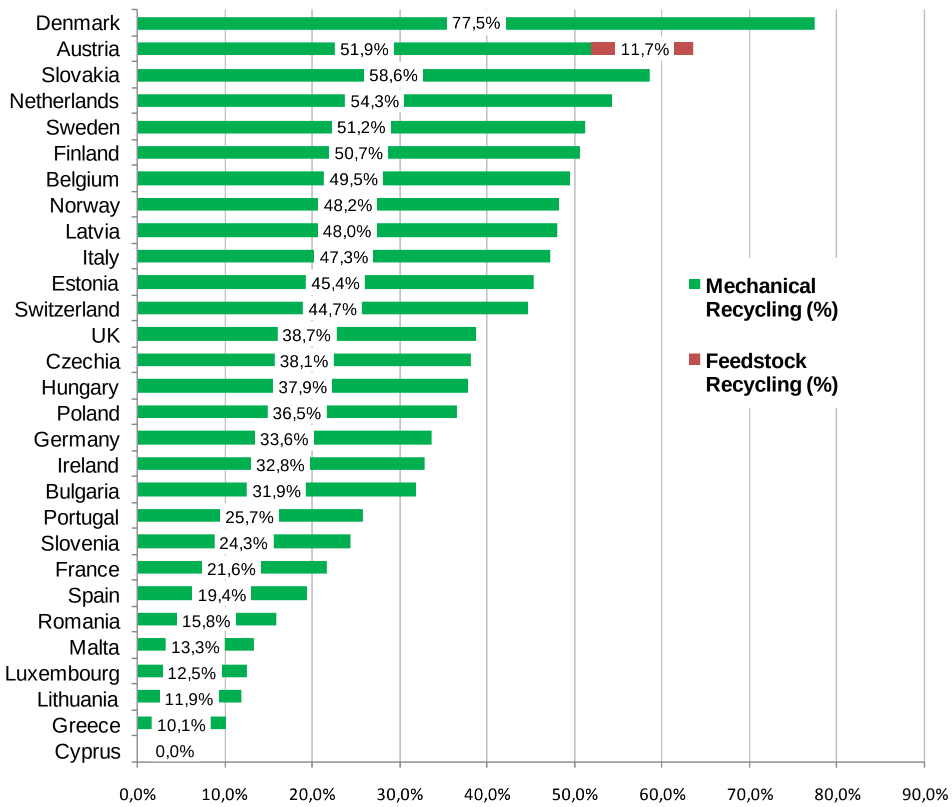
3.2.1.2 Distribution/commercial packaging

Industrial and commercial packaging has well-established recovery schemes to reuse or recycle plastic waste. The situation for commercial packaging remained unchanged with a recovery rate of 62.8% and a recycling rate of 34.9% (34.7% for mechanical recycling and only 0.2% for feedstock recycling). Figure 3-12 presents the recycling

[118] PlasticsEurope, EuPC, EuPR, EPRO and Consultic (2009) *The Compelling Facts about Plastics - An analysis of European plastics production, demand and recovery for 2008*.

rates of commercial plastic packaging across the EU in 2008, which are very different from the household plastic packaging recycling rates. Again, only one country is using feedstock recycling to any great degree (Austria with 11.7%). Denmark, which was ranked last in terms of household packaging recycling, is now first with 77.5%, whereas Germany has a rate of just 33.6%. This highlights the variety of possible waste management strategies as Denmark and Germany are two of the Member States that currently recycle the most.

Figure 3-12: Recycling rates of commercial plastic packaging by Member State, 2008[119]

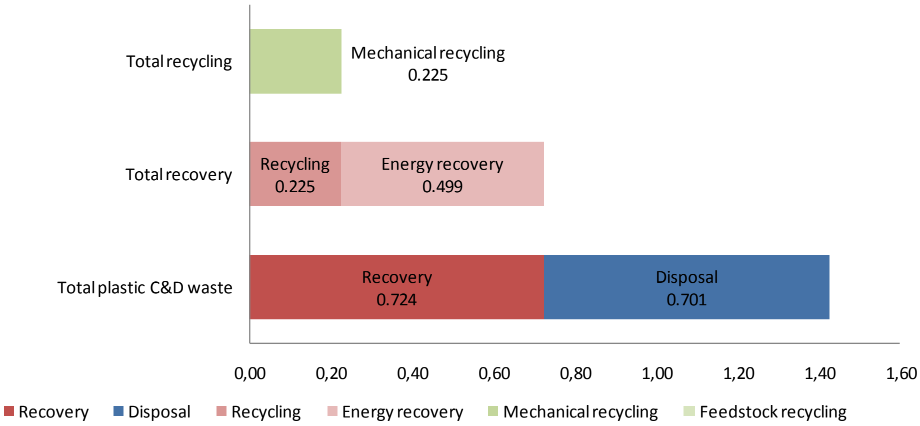


3.2.2. Construction and Demolition

In 2008, 1.4 Mt of construction and demolition waste was generated in EU-27, Norway and Switzerland. Of this, 0.7 Mt was disposed of (49.1%) and 0.7 Mt was recovered (50.8%). Mechanical recycling accounted for 0.2 Mt of the recovered fraction (15.8% of total) and energy recovery amounted to 0.5 Mt (35.0%) (Figure 3-14).

[119] PlasticsEurope, EuPC, EuPR, EPRO and Consultic (2009) *The Compelling Facts about Plastics - An analysis of European plastics production, demand and recovery for 2008*.

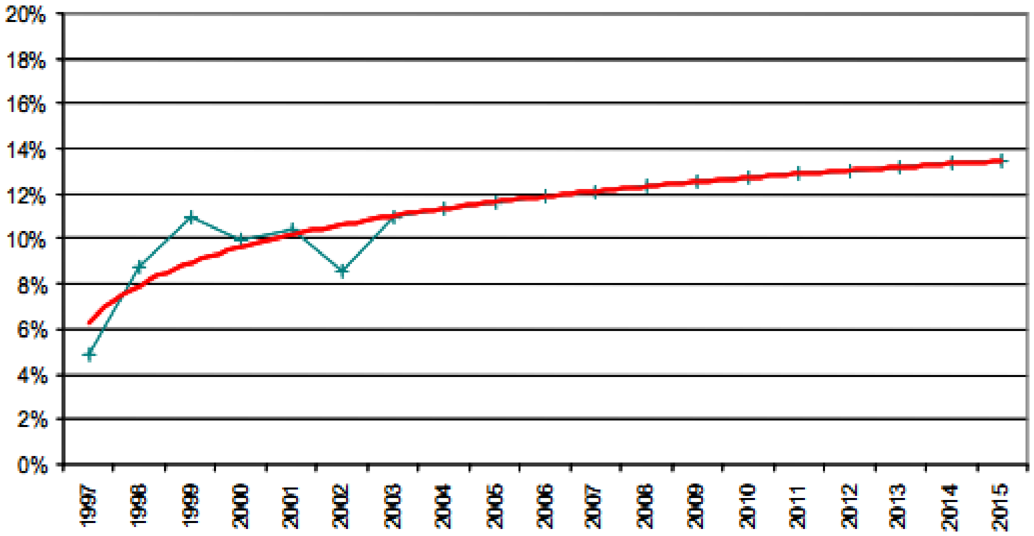
Figure 3-13: Treatment of total plastic waste from construction and demolition in EU-27, Norway and Switzerland, 2008 (Mt)[120]



Although plastics used in construction have long lifespans, so that the ratio of plastic waste over plastics used is low for the B&C sector, the recycling rate reached 15.8% in 2008 (all mechanical recycling), in particular thanks to the recycling of PVC pipes and window profiles. The recovery rate is estimated at 50.8%.

Figure 3-14 shows the trends for the past and coming decades. It seems that the increase in the recycling of construction waste is much smaller according to the data from IPTS as it indicates a rate of 6% in 1997 and 12% in 2008. The difference in the figures might come from the aggregation of the data and the different types of plastics considered as construction waste.

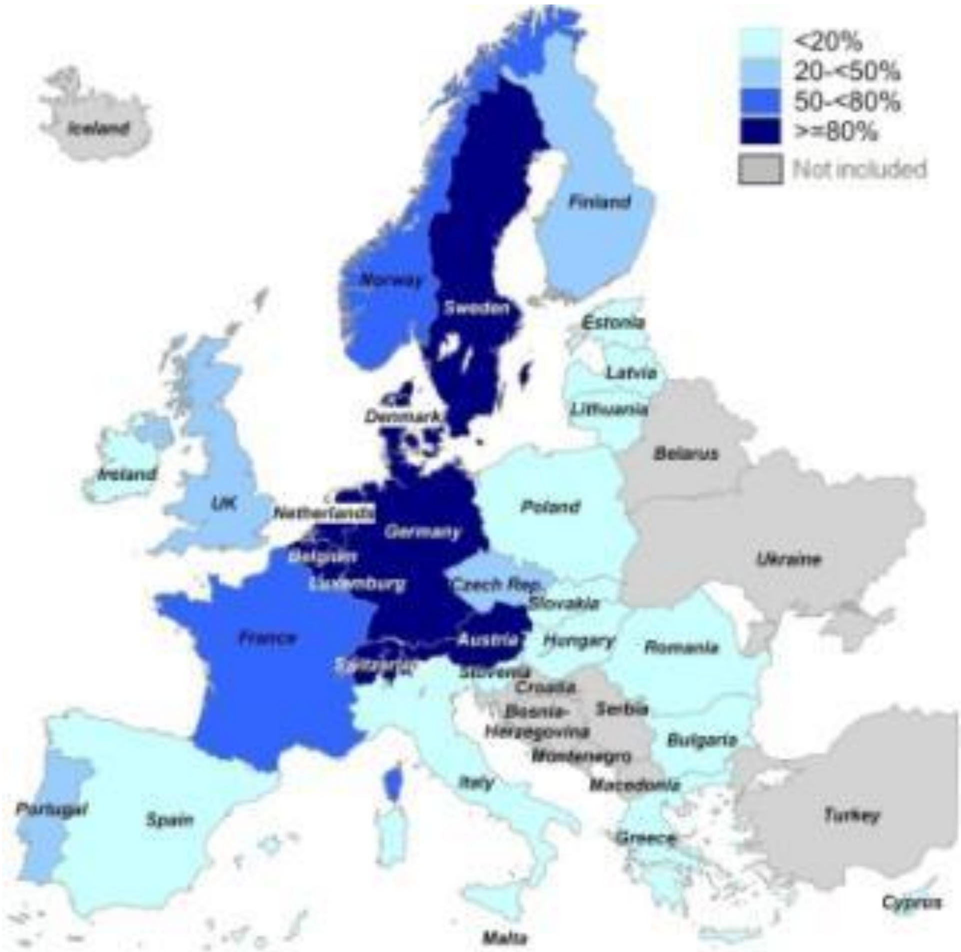
Figure 3-14: Total recovery percentage of plastic waste in the construction sector in EU-25, aggregated APME data, trend line in red117



120 PlasticsEurope, EuPC, EuPR, EPRO and Consultic (2009) *The Compelling Facts about Plastics - An analysis of European plastics production, demand and recovery for 2008.*

Figure 3-15 presents the recycling rates of C&D plastic waste across the EU in 2008. The rates span a very broad range, from below 20% (Spain, Ireland, Italy) to over 80% (Germany, Sweden).

Figure 3-15: Recycling rates of plastic B&C waste in the EU, 2008[121]



Systems to collect plastic waste are currently not envisaged during the design of construction sites[122] and the management of this waste stream for plastics is still at an early stage.[123]

[121] PlasticsEurope, EuPC, EuPR, EPRO and Consultic (2009) *The Compelling Facts about Plastics - An analysis of European plastics production, demand and recovery for 2008*.

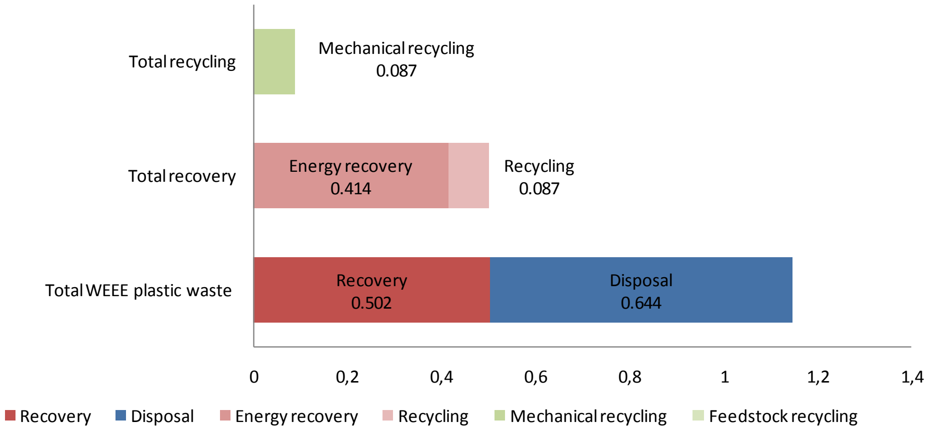
[122] Rx3, private communication.

[123] FEDEREC, private communication.

3.2.3. Electrical and electronic equipment

In 2008, 1.1 Mt of WEEE was generated in EU-27, Norway and Switzerland. Of this total amount, 0.6 Mt (55.2%) was disposed of and 0.5 Mt (43.8%) was recovered. Mechanical recycling accounted for 0.09 Mt of the recovered fraction (7.6% of total), and energy recovery amounted to 0.4 Mt (36.2%) (Figure 3-16).

Figure 3-16: Treatment of total plastic waste from WEEE in EU-27, Norway and Switzerland, 2008 (Mt)[124]



According to PlasticsEurope, mechanically recycled plastics coming from EEE represent less than 2% of the total amount of mechanical recycling:[125] the origin of this material is mainly large domestic appliances (e.g. refrigerators). The inner liner of refrigerators is an example of an appliance with an increasing recycling rate. Currently available data on volumes of WEEE are not considered 100% reliable and it is assumed that some is exported outside the EU.

The WEEE Directive is contributing to some improvement in the management of WEEE, which should help the development of plastic recycling in this waste stream. The quantity of WEEE recovered for treatment, for instance, is expected to increase. Under the Directive, an overall recovery rate of 70-80% must be reached for products produced since its introduction (50-70% of materials must be recycled).[126]

However, the primary driving forces for any WEEE treatment operation are the removal of any hazardous materials and the recycling of metals. It is thus not clear to what extent any plastics can be recovered for recycling into similar or alternative applications. Because WEEE legislation is relatively new, systems for dealing with this waste stream may be relatively new and not yet fully operational.

The content of metals, heavy metals (Cd, Pb, Cr(VI) and Hg are under RoHS), halogens or dioxins/furans is a critical criterion for determining the suitability of recycled plastics as final products that have to comply with limit values. According to the provisions in

[124] PlasticsEurope, EuPC, EuPR, EPRO and Consultic (2009) *The Compelling Facts about Plastics - An analysis of European plastics production, demand and recovery for 2008*.
[125] APME (2001) *Plastics – Insight into consumption and recovery in Western Europe 2000*.
[126] European Commission (2007) *Plastics Composition of WEEE and Implications for Recovery*.

the regulation, plastics containing brominated flame retardants have to be separated and subject to an appropriate disposal/recovery operation. Mixing of these fractions with other plastic wastes in order to dilute the pollutant content is prohibited.

Plastics-rich WEEE streams (>95% plastics by weight) can be achieved by manual dismantling (but at a high cost), or through a multistep mechanical separation. However, economic pressures on shredder operators may lead them to optimise towards metal recovery, which results in waste plastic that is not suitable either for mechanical recycling or feedstock recycling.

A post-refining step using a wet/gravity separation is therefore required to produce a plastics mix that meets the high purity requirements with respect to inert material, metals, halogens and heavy metal content. However, this additional step will result in the loss of more than 50% of the plastics material (landfill or alternative outlet), which can bring additional landfilling costs. The high cost of this operation means that it is only economically justified in the case of high value plastics products.

The MBA polymers plant is one of the rare facilities recycling plastics from WEEE at an industrial scale today.[127] In view of the challenge to mechanically remove metals, heavy metals and halogens from EEE plastics to comply with legislation, it is prudent to explore the benefits of other end-of-life options such as chemical feedstock recycling and energy recovery.[128]

Still, the recycling of plastics in WEEE may grow once the current stock of EEE containing brominated flame retardants that are now banned (under RoHS:[129] upper limit of 1 g/kg in EEE for the sum of PBBs and PBDEs) are out of the market and waste streams.[130] Plastic recycling usually aims at using one category of waste plastic in the same application it comes from for practical reasons. However, the presence of forbidden brominated flame retardants and difficulties linked to separating plastics result in a low recycling rate of these plastics today.

The average recycling rate across the EU is 7.6% (all mechanical recycling) with a recovery rate of plastic waste in WEEE of 43.8%. Figure 3-17 presents the recycling rates of EEE plastic waste across the EU in 2008. Despite the low global recycling rate, some countries (Norway, Germany, Austria) manage recycling rates over 80% for this waste source.

[127] More information available at: www.mbapolymers.at.

[128] Mark, F. (2006) *The characteristics of plastic-rich waste streams from end-of-life electrical and electronic equipment*.

[129] Restriction of Hazardous Substances (2002/95/EC)

[130] FEDEREC, private communication.

Figure 3-17: Recovery rates of plastic WEEE in the EU, 2008[131]

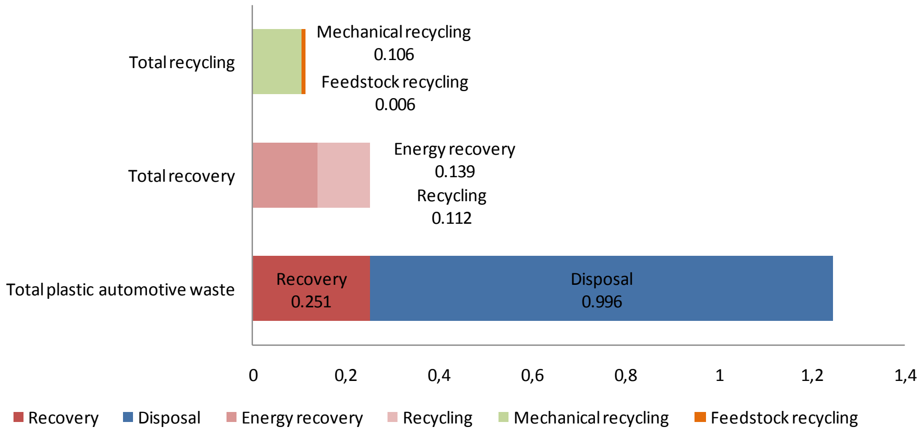
The potential of WEEE is being investigated as some suppliers already offered reprocessors to work with plastics from WEEE or WEEE in general but for now this stream still suffers from the presence of contaminants such as brominated flame retardants.[132]

3.2.4. Automotive

In 2008, 1.247 Mt of automotive plastic waste was generated in EU-27, Norway and Switzerland. Of this, 0.996 Mt (79.8%) was disposed of and 0.251 Mt (20.1%) was recovered. Mechanical and feedstock recycling reached 0.106 Mt and 0.006 Mt respectively (8.5% and 0.5% of total) and energy recovery amounted to 0.139 Mt (11.1%).

[131] PlasticsEurope, EuPC, EuPR, EPRO and Consultic (2009) *The Compelling Facts about Plastics - An analysis of European plastics production, demand and recovery for 2008*.
[132] Private communication with Golden Recycling.

Figure 3-18: Treatment of total automotive plastic waste in EU-27, Norway and Switzerland, 2008 (Mt)[133]



The overall recycling rate of automotive plastic waste is 9% in the EU (8.5% mechanical recycling, less than 0.5% feedstock). The corresponding recovery rate represents 20.1% of the total plastic waste in this stream.

Figure 3-19 presents the recovery rates of automotive plastic waste across the EU in 2008. Only Belgium, Denmark and Switzerland manage to achieve recycling rates above 80% while most Member States do not reach 20%.

Figure 3-19: Recovery rates of automotive plastic waste in the EU, 2008[134]

[133] PlasticsEurope, EuPC, EuPR, EPRO and Consultic (2009) *The Compelling Facts about Plastics - An analysis of European plastics production, demand and recovery for 2008*.
[134] Ibid.

In most Member States, these plastics are not recycled, despite the End-of-Life Vehicles Directive (2000/53/EC), which aims to reduce the amount of waste from vehicles (cars and vans) when they are finally scrapped: for instance, large plastics components such bumpers, dashboards or fluid containers have to be separated by recovery operators before shredding if this process prevents effective recycling subsequently.

EU policies are progressively forbidding the use of heavy metals in new products and this is already the case for ELVs. Denmark is the only country where these plastics are specifically recovered for recycling.[135] However, specific recycling processes are currently under improvement and more efficient Automotive Shredder Residue (ASR) plants are being set up, resulting in an increase in recycling rates. Also, the ELV Directive includes tightened environmental standards for vehicle treatment sites and restricts the use of hazardous substances in both new vehicles and replacement vehicles.

According to the ELV Directive, for the labelling and identification of vehicle plastic components and materials weighing more than 100 g, the following nomenclature applies:

- ISO1043-1Plastics –symbols and abbreviated terms. Part 1: basic polymers and their special characteristics.
- ISO1043-2Plastics – symbols and abbreviated terms. Part 2: Fillers and reinforcing materials.
- ISO11469 Plastics – Generic identification and marking of plastic products.

Identification, by marking components at production or by improved sorting technologies, will be vital if the practice of recovering plastic parts is to become viable. At present, targets in the Directive are not specific to material types but increased treatment of plastics will be necessary to meet higher recycling targets of the Directive (85% reuse/recycling and 95% recovery targets by 2015).

The car company Volkswagen won the “European Business Award for the Environment” for their SiCon process, which is a mechanical process aiming at extracting usable secondary raw materials from the residues of vehicles and sending them back into production processes.[136]

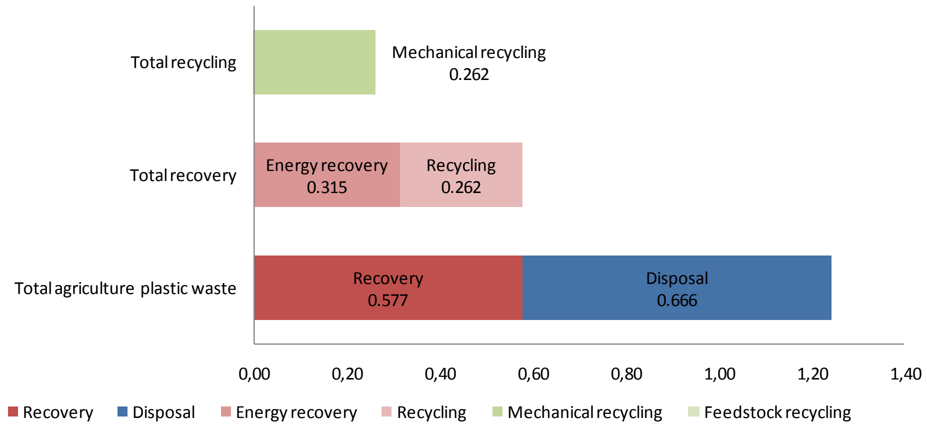
[135] GHK and Bio Intelligence Service (2006) *A study to examine the benefits of the End-of-life Vehicles Directive and the costs and benefits of a revision of the 2015 targets for recycling, reuse and recovery under the ELV Directive*, DG ENV. Available at: ec.europa.eu/environment/waste/pdf/study/final_report.pdf.

[136] More information available at: en.sicontechnology.com.

3.2.5. Agriculture

In 2008, 1.243 Mt of agricultural plastic waste was generated in EU-27, Norway and Switzerland. Of this total amount, 0.666 Mt was disposed of (53.6%) and 0.577 Mt was recovered (46.4%). Mechanical recycling accounted for 0.262 Mt of the recovered fraction (21.1% of total) and energy recovery amounted to 0.315 Mt (25.3%).

Figure 3-20: Treatment of total agricultural plastic waste in EU-27, Norway and Switzerland, 2008 (Mt)[137]



Agricultural waste is controlled waste under the Waste Framework Directive. However, there are no specific targets for agricultural waste recovery (unlike for WEEE and ELV) and most schemes are voluntary initiatives. Nevertheless, the mechanical recycling rate is fairly high at 21.1%. A European labelling project for this waste stream was launched in 2006. The recovery rate is estimated at 46.4% across the EU. The homogeneous nature of agriculture plastics and their easy recovery make these initiatives successful despite some problems due to soil contamination (soil and vegetable matter, humidity, UV radiation). These contaminants mechanically and chemically lower the integrity of the material. Mechanical recycling is suitable for agricultural plastic wastes when they are made from a limited range of plastics, such as silage bale film. Figure 3-21 presents the recovery rates of agricultural plastic waste across the EU in 2008. Again, Nordic countries show the highest recycling rates along with Austria and Switzerland (above 80%) while the UK and central and eastern European countries recycle less than 20% of agricultural plastic waste.

[137] PlasticsEurope, EuPC, EuPR, EPRO and Consultic (2009) *The Compelling Facts about Plastics - An analysis of European plastics production, demand and recovery for 2008*.

Figure 3-21: Recovery rates of agricultural plastic waste in the EU, 2008[138]

3.2.6. PRE-CONSUMER WASTE

Unless otherwise stated, the data presented in this report is based on post-consumer waste generation figures. Pre-consumer plastic waste streams are not well recorded and are considered outside the boundaries of the common definition of recycling. National authorities do not have much information since pre-consumer waste streams are generally dealt with directly by industry, either reused in industrial processes (melted and fed back into the production process in-house) or sold to reprocessors (i.e. dealt with by the private sector), without entering the usual waste management system.[139]

Pre-consumer waste plastic generation for thermoplastics such as PVC is very low because the majority of this scrap is reprocessed without leaving the facility.[140] However, waste plastic scrap can also consist of unusable material such as samples used for quality tests or plastics deteriorated by the start-up and shutdown periods of the machines (due to large heat variations). For the share that cannot be fed back into the production process, open-loop recycling and other forms of recovery can be used.

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[138] PlasticsEurope, EuPC, EuPR, EPRO and Consultic (2009) *The Compelling Facts about Plastics - An analysis of European plastics production, demand and recovery for 2008*.

[139] Reprocessors are companies involved in one or more of the recycling stages of waste plastics, from crushing and washing through to production of end-products.

[140] Solvay, private communication.

Some reprocessors specialise in the recycling of pre-consumer plastic waste streams, and these markets are functioning relatively well, showing high recycling rates.[141] According to figures from 2000, the quantity of plastic waste being reabsorbed into the production system almost matched the quantity of pre-consumer waste. Pre-consumer plastic waste is currently recycled to a greater extent than post-consumer plastic waste, as it is a homogeneous contaminant-free material, is easier to recover and is available in large volumes from individual sources (e.g. from a factory).[142]

In 2004, approximately 90% of industrial scrap was recovered in all Member States, with the majority being mechanically recycled.[143] In the UK for example, 95% of the 0.25-0.3 Mt of industrial scrap produced is recycled[144] and in Germany almost 100% of pre-consumer plastic waste was recovered in 2007.[145]

3.2.7. Summary of waste treatment rates

The table below summarises the rates for different plastic waste treatment methods, according to each sector in EU-27, Norway and Switzerland. It is clear from the results that the majority of streams have similar disposal rates, with the exception of ELV waste, which has a 79.8% disposal rate. Although ELV plastic waste is currently legislated by the ELV Directive, rates of overall recovery remain low, most likely due to the lack of adequate technology to process this type of waste. However, new technologies are currently being investigated, which may increase the rate of recovery. Furthermore, the terminology of the Directive may change, as certain viable options for treatment of ELV plastics may presently be thought of as disposal methods but may in fact be considered under the umbrella of recovery activities.

Table 19: Post-consumer waste plastic generation treatment rates by sector in EU-27, Norway and Switzerland, 2008[146]

Sector	Plastic waste generated (Mt)	Disposal (%)	Mechanical recycling (%)	Feedstock recycling (%)	Energy recovery (%)
Packaging[147]	15.6	41.8	28.5	0.5	29.2
C&D	1.4	49.1	15.9	-	35.0
ELV	1.2	79.8	8.6	0.5	11.1
Agricultural	1.2	53.5	21.1	-	25.3
WEEE	1.1	55.2	7.6	-	36.2

As plastic packaging has the longest established system for the recovery and recycling of plastic waste, it is natural that the overall rate would be higher than other streams

[141] Ingham A. (2005) Chapter 3 in *Improving recycling markets*, OECD, Paris.

[142] Hopewell, J. et al. (2009) *Plastics recycling: challenges and opportunities*.

[143] Plastics Europe (2006) *An analysis of plastics production, demand and recovery in Europe 2004*.

[144] The sources do not mention whether this quantity contains both the reprocessing in the original process as well as recycling by a third party, or only the latter; British Plastics Foundation, *Plastics Recycling* available at: www.bpf.co.uk/bpfindustry/process_plastics_recycling.cfm; www.wasteonline.org.uk/resources/InformationSheets/Plastics.htm.

[145] OECD (2009) *Plastic from the commercial and private household sectors*, OECD, Paris.

[146] PlasticsEurope, EuPC, EuPR, EPRO and Consultic (2009) *The Compelling Facts about Plastics - An analysis of European plastics production, demand and recovery for 2008*.

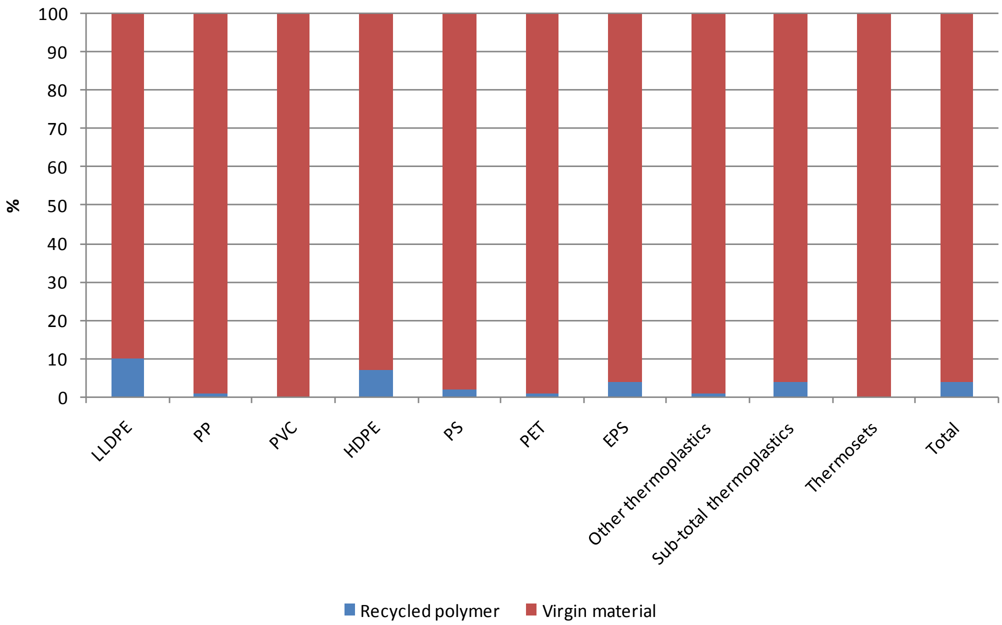
[147] Includes both household and commercial packaging.

(28.5% mechanical recycling, 0.45% feedstock recycling). It is followed by agricultural waste plastic, which has an overall recycling rate of 21.1%. Although agricultural plastic waste is one of the only plastic waste streams not under direct legislative pressure to increase recovery, economic reasons linked to the availability of homogenous materials help to explain its high recycling rate. Although WEEE and C&D plastic waste sources have relatively low rates of recycling overall, the rate of energy recovery is relatively high at 36.2% and 35.0% respectively. Overall, total recovery is highest for plastic packaging at 59.8% and lowest for ELV plastics at 19.2%.

3.3. TRENDS IN PLASTIC WASTE TREATMENT AND REDUCTION

There is a wide variety of recycled plastic applications.[148] However, 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 resin.[149] In 2000, it was estimated that recycled LDPE resin had the highest rate of use (10%) in comparison with other polymers (Figure 3-22). According to the available data, other recycled polymers such as PVC and thermosets were not used at all. It is worth noting that these figures are from 2000 and therefore may not provide an accurate picture of the current market for recycled plastic polymers. However, the figures do indicate that use of recycled plastics is marginal compared to virgin plastics across all plastic types.

Figure 3-22: Ratio of recycled to virgin polymer use in Europe[150]



[148] Bin liners and carrier bags; PVC sewer pipes, flooring and window frames; building insulation board; video and compact disc cassette cases; fencing and garden furniture; garden sheds and composters; seed trays; anoraks and fleeces; fiber filling for sleeping bags and duvets, etc.
[149] The term “recyclates” refers to recycled plastic material.
[150] Association of Cities and Regions for Recycling (2004) *Good Practices Guide On Waste Plastics Recycling, A Guide by and for Local and Regional Authorities*.

The low ratio of recyclate to virgin material can be attributed to factors such as contamination, technological availability and market demand. For example, PET and PVC have many problems with cross contamination as they appear visually very similar to one another. They also have the same specific gravity, therefore the use of conventional float and sink techniques may not be successful in separating them. Separation is very important as just a small amount of PVC can seriously impair the integrity of PET melted plastic. That said, significant progress has been made in PVC recycling in recent years (e.g. the Recovinyl initiative described in section 4.1.3).

Recycled plastics are not commonly used in food packaging (although this segment is one of the biggest single markets for plastics) because of concerns about food safety and hygiene standards. Multi-layered containers which enclose the recycled plastic between layers of virgin plastic are therefore being used in some drinks bottles, but recycling cannot eliminate the colours from plastics so they cannot be used in transparent or light coloured applications. However, some plastics, e.g. PET or HDPE in the UK, are increasingly being recycled back into food contact applications.

Another constraint on the use of recycled plastics is that plastic processors require large quantities of recycled plastics, manufactured to strictly controlled specifications at a competitive price in comparison to virgin plastic. Such constraints are challenging, in particular because of the diversity of sources of waste plastics, the wide range of plastics used and the high potential for contamination of plastics waste.

Trends in recycling show that waste plastic from packaging streams such as PET bottles and PE containers are a driver for the waste plastic recycling industry. In contrast, despite being the fastest growing plastic type for use in the packaging, electrical and electronics, and automotive sectors, PP still shows a low recycling rate due to a number of technical issues: PP comes in very many types (more than any other polymer), which makes separation and reprocessing into new products more demanding; also, PP is often used with other plastics, metals or other materials, which makes its recovery and separation difficult. Work is underway on recycling processes for PP but there is some way to go.

The market for recycled plastics is growing and applications include soft drink and milk bottles, carrier bags, window frames and beer crates – all made from recycled material in closed-loop systems. As with other materials, the use and recycling phases affect the properties of plastics but if properly managed this should be marginal. Plastics can also be contaminated with hazardous substances during or after the use phase and technical standards need to be established for safe use of recycled material in some applications.

However, over the last five years, the price index has almost doubled and a further strong increase in plastic prices is expected in the medium term due to rising crude oil prices. Plastic recycling is therefore attractive due to the potential environmental and economic benefits it can provide. However, plastic recycling needs to be carried out in a sustainable manner.

According to Plastics Europe, post-consumer plastics recycling increased by 4.3% in 2008, helping to drive the total recovery rate for plastics to 51.3% in 2008. Energy recovery experienced some growth, rising by 3.6% in 2008 in relation to the previous year. The rate of growth for mechanical recycling slowed in relation to previous years, seemingly due to the impact of the global financial crisis.

Figure 3-23 shows the shares of the different end-of-life options for European post-consumer plastic waste. The overall recycling rate of post-consumer plastics rises to 21.3%, which represents 5.3 Mt of materials (mechanical recycling is at 21%, up 0.9 percentage points over 2007; feedstock recycling unchanged at 0.3%.[151]

Figure 3-23: Plastics end-of-life options in EU-27, Norway and Switzerland, 2008[152]

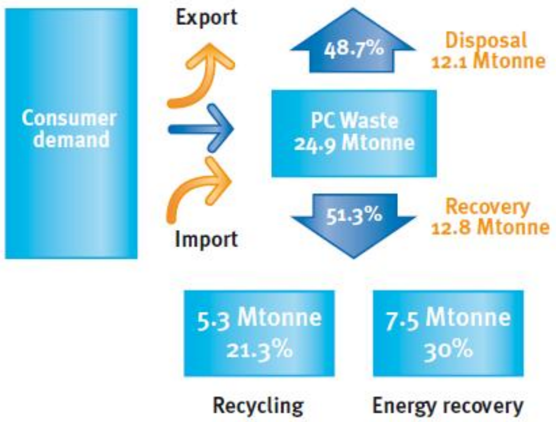
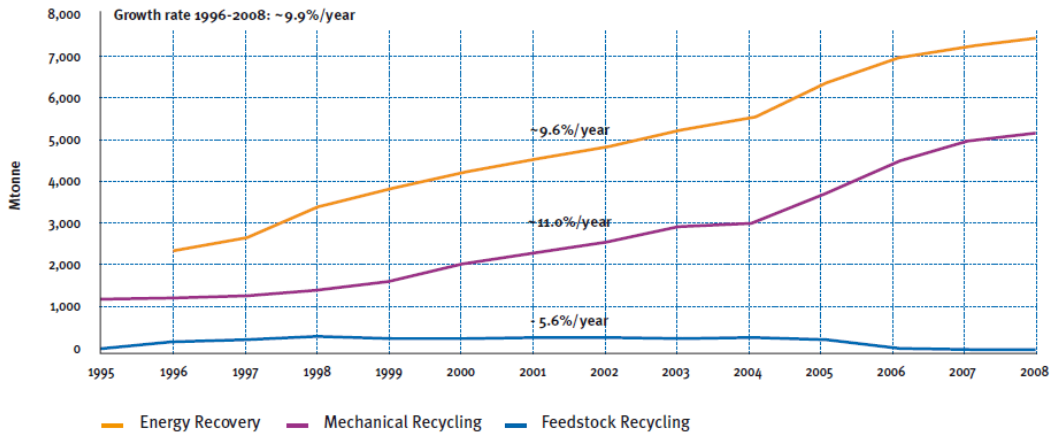


Figure 3-24 displays the growth of mechanical recycling and energy recovery, as well as the stagnation of feedstock recycling over the last decade in the EU-27 with Norway and Switzerland.

Figure 3-24: Plastic recovery options in EU-15, 1996-2008 (EU-15, Norway and Switzerland until 2004; EU-27, Norway and Switzerland from 2005 onwards)[153]



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[151] Note that these data refer to collected materials ready for recycling; the materials were not necessarily recycled in Europe.
[152] PlasticsEurope, EuPC, EuPR, EPRO and Consultic (2009) *The Compelling Facts about Plastics - An analysis of European plastics production, demand and recovery for 2008*.
[153] Ibid.

Mechanical recycling of PET bottles back into bottles with food contact is increasingly approved due to technical developments in this field. The technique could benefit from the expected global increase in bottle-to-bottle recycling.

Other chemical recycling projects under development include:

- The use of an integrated non-ferrous metal smelter for the treatment of WEEE plastics containing non-ferrous metal;
- The application of catalysts, which is expected to boost feedstock recycling;[154]
- Processes which convert various mixtures of waste plastics into liquid fuels to be used for transportation or stationary engines. Recent new activity in Europe has been announced.

After initial modest growth and stabilisation between 1995 and 2005, feedstock recycling dropped to near negligible amounts after 2005 due to a combination of technological and economic reasons.

3.4. PLASTIC WASTE TRADE

This section provides summary tables showing waste plastic traded (imports and exports), where data is available, and the volumes of plastic waste that are estimated to end up in the environment. Issues associated with illegal disposal or treatment of plastic waste are highlighted and quantified impacts provided where data is available.

3.4.1. SOURCES OF TRADED PLASTIC WASTE

In this sub-section, trade data is based on plastic packaging waste due to the lack of data for overall plastic waste trade. Plastic waste trade is an important aspect of plastics recycling in the EU. As some Member States do not have the capacity, technology or financial resources to treat plastic waste locally, a significant amount is exported for treatment. The price of plastics is also an important factor which heavily influences the trade of plastic packaging waste (Table 20).

[154] Aguado, J., Serrano, D.P. and San Miguel, G. (2006) "European trends in the feedstock recycling of plastic wastes", to be published in *Global NEST Journal*.

Table 20: Plastic packaging waste materials trade for recycling by Member State, 2007 (Mt)[155]

	Material imports for recycling	Material exports for recycling
Austria	-	0.010
Belgium	-	0.084
Bulgaria	0.003	0.001
Cyprus	-	0.001
Czech Republic	-	0.028
Denmark	0.017	0.042
Estonia	-	0.005
Finland	-	-
France	0.013	0.189
Germany	-	0.273
Greece	-	0.041
Hungary	-	0.001
Ireland	0.059	0.039
Italy	-	0.004
Latvia	-	0.001
Lithuania	-	0.008
Luxembourg	-	0.010
Netherlands	-	0.060
Norway	-	0.013
Poland	-	0.048
Portugal	-	0.0001
Romania	-	0.003
Slovakia	-	0.0001
Spain	0.003	-
Sweden	-	0.034
UK	-	0.357

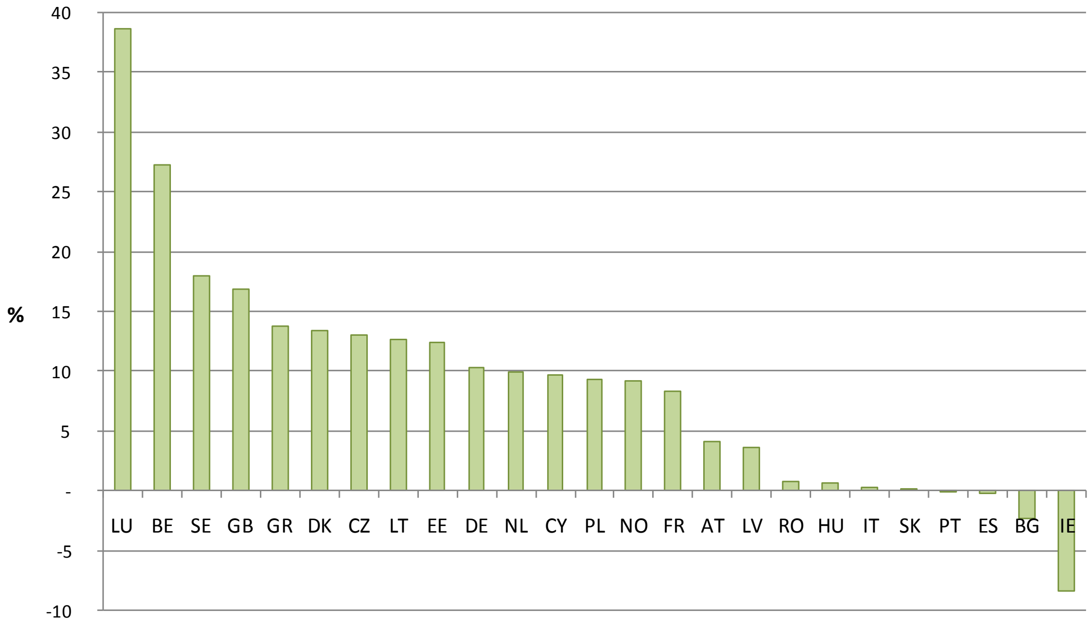
In order to determine just how much plastic packaging waste is treated outside of each EU Member State, it was necessary to calculate net trade. To determine the net trade of plastics recycling in each Member State, the following calculation was used:

Net trade = (Exports - Imports) ÷ Total generation

The final figure is converted into a net exports percentage value. The chart below shows that the biggest net exporter of plastic packaging waste in relation to domestic generation is Luxembourg, at approximately 39% of total generation, followed by Belgium at 27% and Sweden at 18%. Conversely, in Ireland and Bulgaria more plastic is imported than is exported, resulting in a negative net trade of approximately -8% and -2% respectively. What this means is that as well as treating domestically produced plastic packaging waste, these Member States also process an additional amount from other countries.

[155] Source: Eurostat data. Includes municipal packaging waste which has been separated at the source.

Figure 3-25: Share of plastic packaging waste trade in annual plastic waste generation by country, 2007 (%)[156]



3.4.2. DESTINATIONS OF TRADED PLASTIC WASTE

3.4.2.1 Imports

- **Intra-EU sources**

In 2004, intra-EU trade of waste plastics was approximately 0.85 Mt.[157] Approximately two-thirds of intra-EU imports were directed towards four main importers: the Netherlands (19.3%), Belgium (17.5%),[158] Italy (15.6%) and Germany (14.1%).[157] In addition to having significant reprocessing capacities, both the Netherlands and Belgium are also transit ports for recycled plastics which are exported to non-EU destinations (and may be included in records).

The largest exporters of waste plastic to other Member States were Germany (26.5%), France (23.6%), the Netherlands (15.2%) and Belgium (8.5%), accounting for almost three-quarters of intra-EU exports. The inclusion of the Netherlands and Belgium as both significant importers and exporters of plastics is mainly due to the availability of recycling technologies in each country. For example, the largest recycling plant for EU-generated LDPE films is found in the Netherlands (up to 0.037 Mt in one facility). The most significant intra-EU plastic waste trade flows in 2004 were from Germany to the Netherlands (0.077 Mt), France to Italy (0.065 Mt) and from the Netherlands to Belgium (0.058 Mt).[157]

[156] Source: Eurostat database.
[157] WRAP (2006) *UK Plastic waste – A review of supplies for recycling, global market demand, future trends and associated risks*.
[158] In the case of Belgium, these are commercial only because there is no recycling capacity for household bottles and containers.

■ **Extra-EU sources**

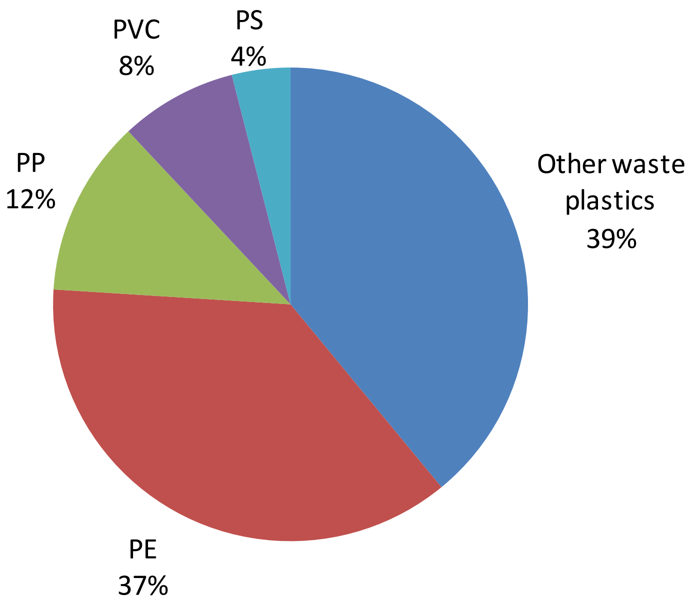
In 2004, the majority of imports into Member States originated within the EU-27.

Table 21: Net weight of EU waste plastic imports by exporting country, 2004 (Mt)[157]

Exporting country	Net weight
Germany	0.225
France	0.202
Others	0.165
Netherlands	0.129
Belgium	0.073
Switzerland	0.072
UK	0.036
Sweden	0.029
Italy	0.028
Austria	0.021
Spain	0.014
Total	0.993

In fact, imports to Member States from other Member States were five times higher than imports from non-EU countries. Total imports into the EU, including non-EU countries, reached 0.993 Mt. The largest non-EU exporter was the United States. PE made up the largest fraction of plastic waste imported into the EU (37%), followed by PP (12%), PVC (8%) and PS (4%). Other types of plastics also made up a significant portion of plastics imported into the EU (39%).[157]

Figure 3-26: EU imports of plastic waste by material type, 2004[157]

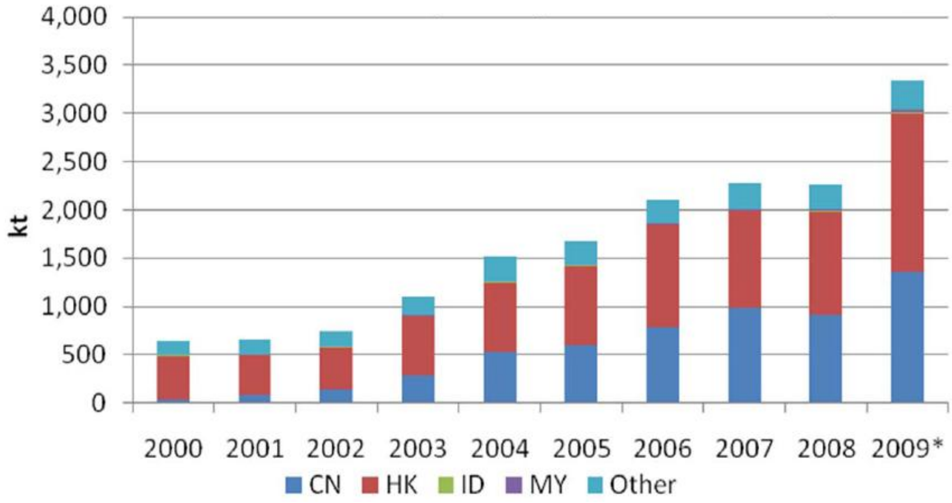


3.4.2.2 Exports

Asian countries, in particular China and Hong Kong, are the main destination for EU-27 waste, parings and scrap of plastic exports. Since 1999, exports to Hong Kong increased from 0.34 Mt to 1.10 Mt in 2006, while the share of total EU-27 exports decreased to

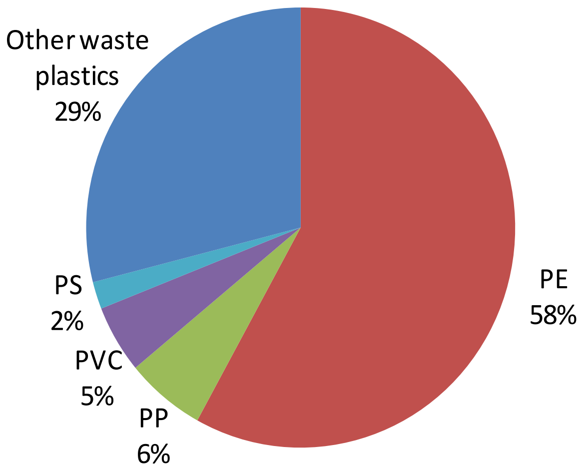
51% in 2006. During this period, exports to China increased from 0.018 Mt in 1999 to 0.79 Mt in 2006. The share of total exports also increased from 4% to 37%. In 2006, China and Hong Kong accounted for 88% of total EU waste, parings and scrap of plastic exports, representing 1.85 Mt. (Figure 3-27).

Figure 3-27: EU-27 plastic waste exports by destination country[159]



In 2004, PE was the largest declared plastic waste type exported from the EU (58.4%), followed by other unspecified waste plastic types (29.1%). Figure 3-28 presents the breakdown of extra-EU waste plastic imports by polymer type in 2004. It is worth noting that since that year, waste plastic exports outside the EU have increased significantly and continue to grow.

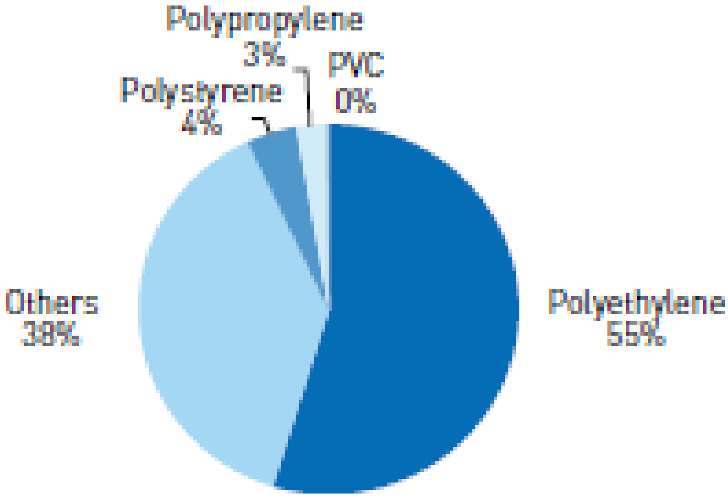
Figure 3-28: EU exports of waste plastics by polymer, 2004[157]



According to WRAP, 0.155 Mt of waste plastic packaging is reprocessed in the UK each year while 0.325 Mt is exported. China currently accounts for 80% of UK exports of recovered plastics. Exports were also encouraged by relatively low shipping costs.

[159] EuPR (2009) "Plastics Recycling in Europe - Achievements & Threats" at *Compelling Facts About Plastic* press conference. Available at: www.plasticsrecyclers.eu/uploads/media/eupr/Compelling/Comp_Facts_Press_Conference_EuPR.pdf.

Figure 3-29: UK exports of recovered plastic to China, 2008[160]



Although a significant amount of plastic waste produced in EU-27 is still treated within Europe, the data in this section show that a growing amount of plastic waste is being treated outside of Europe. Information on movements and breakdown of plastic wastes being imported and exported from the EU has been provided, though data may be outdated as some figures relate to 2004. Since that time, exports to Asia may have increased and demand patterns may also have changed.

3.5. SUMMARY

In 2008, total generation of post-consumer plastic waste was 24.9 Mt in EU-27, Norway and Switzerland. Plastic packaging makes the most significant contribution to total plastic waste generation and is also the fraction with the highest rate of recycling (approximately 29% of the total generated is recycled). Other plastic waste types have much lower generation amounts. The ELV and WEEE sectors have the lowest amounts of recycling, despite their shares of plastic waste generated being similar to those of C&D and agricultural plastic waste.

Packaging generates around two-thirds of total plastic waste generation, partly because of its short life span. This waste can be found in either the MSW stream or the distribution stream (commercial packaging). Other significant sources of plastic waste include the C&D sector, WEEE, automotive waste and waste from the agriculture sector. Because of their widespread use in the packaging sector, LDPE, HDPE and PP make up around half of global waste plastic. PP is also the polymer most often found in automotive waste while LDPE is the main one used in agricultural applications. Finally, PP, PS and ABS are the most commonly found polymers in WEEE. Nevertheless, a wide variety of plastic types can be used to manufacture the different products in each sector.

[160] WRAP (2009) *The Chinese markets for recovered paper and plastics*.

Several end-of-life options can be chosen to deal with plastic waste, including disposal, incineration with or without energy recovery and recycling. The rate of recycling was 21.3% in 2008, helping to drive the total recovery rate for plastics to 51.3%.

Large differences can be observed across Member States: Norway, Sweden, Germany, Denmark, Belgium and Switzerland have the highest recovery rates. There is a large gap between this group of countries and others. The highest rate of recycling is seen in Germany at around 34% and the lowest in Greece at 8%.

Plastic waste trade is an important aspect of plastics recycling in the EU. The biggest net exporter of plastic packaging waste is Luxembourg at approximately 39% of total generation, followed by Belgium at 27% and Sweden at 18%. Conversely, in Ireland and Bulgaria more plastic is imported than is exported. In 2004, intra-EU trade of waste plastics was approximately 0.85 Mt; with around two-thirds directed towards four main importers: the Netherlands, Belgium, Italy and Germany.

In most sections, accurate and updated data for the total generation and treatment of plastic waste has been provided. Although the data presented in this section can be considered a good representation of the current situation in the EU-27, the most comprehensive figures at Member State level have been gathered for total plastic waste generation and plastic packaging waste generation. Data is not consistently available for the same year across all waste streams for all Member States. In some cases, the data that has been found dates from more than five years ago, and may not accurately represent the situation in the EU today. In the case of construction waste generation, for example, figures at Member State level are from 2002, though total figures are available for 2008.

Another significant limitation of the data relates to the method of data collection in individual Member States. In the case of most packaging waste, Member States are obligated to collect and submit data of high quality, and the format must be uniform across all Member States. However, this decision does not define the method used to estimate the quantities of packaging put on the market, or to calculate the recovery and recycling rates in more detail to ensure data comparability.[161] As the methodology may not be uniform across all Member States, data on packaging waste are not always comparable.

[161] EEA (2006) *Generation and recycling of packaging waste (CSI 017)*.

4. IMPACTS OF PLASTIC WASTE

Several reviews have been produced over the last decade that summarise studies investigating the environmental burden and benefits of the various recycling and energy recovery processes. The main purpose of this chapter is to review those end-of-life impacts rather than the impacts of plastics over the full life cycle.[162] The chapter does however present three particular types of plastic in more detail: use phase health impacts of heavy metals in plastic crates, bioplastics and marine plastic waste.

4.1. ENVIRONMENTAL IMPACTS OF PLASTIC WASTE TREATMENT OPTIONS

Several reviews have been produced over the last decade that summarise the results of studies investigating the environmental burden and benefits of the various recycling and energy recovery processes.

4.1.1. LANDFILL

Landfill not only takes up large areas of land but can also generate bio-aerosols, odours, visual disturbance and may lead to the release of hazardous chemicals through the escape of leachate from landfill sites.[163] Organic breakdown following landfill disposal of biodegradable waste, including bioplastics, causes the release of greenhouse gases. Landfill of waste usually implies an irrecoverable loss of resources and land (since landfill sites can normally not be used post closure for engineering and/or health risk reasons), and in the medium to long term it is not considered a sustainable waste management solution.[164]

4.1.2. ENERGY RECOVERY / INCINERATION

The environmental performance of incineration of plastic waste depends on whether or not energy is recovered as well as other factors such as fuel quality and the energy efficiency of installations. The energy efficiency of current plastic-waste incinerators varies considerably, depending mainly on whether an incineration plant delivers heat, electricity or both (as in combined heat and power plants) as well as the technology used (e.g. flue gas condensation allows higher efficiencies to be achieved).[164]

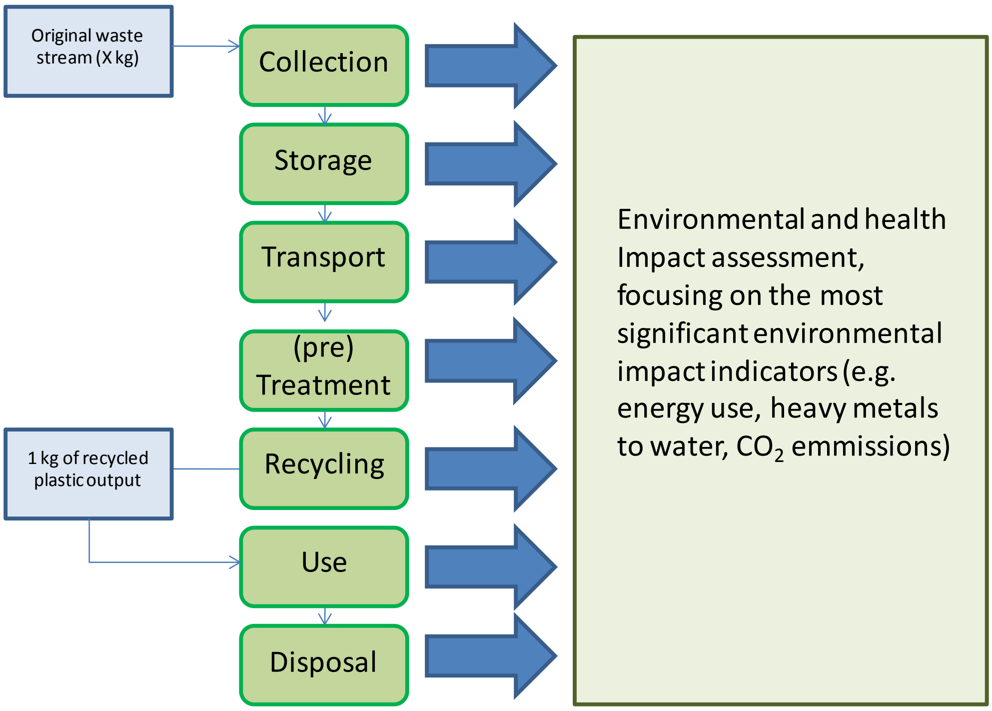
[162] For a recent review of the energy and greenhouse gas impacts of plastics from a life-cycle perspective, see Pilz, H., Brandt, B. and R. Fehringer (2010) *The impact of plastics on life cycle energy consumption and greenhouse gas emissions in Europe*, Summary report, Denkstatt.
[163] Leachate is the liquid that drains or 'leaches' from a landfill.
[164] Green Paper on the management of bio-waste in the European Union, COM(2008).

The environmental impacts of incinerating plastic waste (as for most solid wastes or fuels) can include some airborne particulates and greenhouse gas emissions. Plants that are compliant with the Waste Incineration Directive are not thought to have any significant environmental impact. However, in some circumstances, energy recovery of plastic waste in MSW incinerators can result in a net increase in CO_2 emissions due to substituted electricity and heat production.[165] There will also be an environmental burden due to the disposal of ashes and slag. For example, flue gas cleaning residues often have to be disposed of as hazardous waste due to the toxicity of the compounds they absorb. The net societal cost or benefit would of course depend on the alternatives, e.g. the existing power generation mix and the risk of open-air burning or landfill fires.

4.1.3. Recycling

Recycling conserves resources embodied in waste plastic but requires inputs to perform the transformation process, which may lead to environmental and cost impacts. Cost could be an issue if recycled plastic has to compete with virgin plastics that are manufactured at a comparatively low cost. In addition, not all plastic products are equally suitable to be recycled. The bottle has strong advantages whilst more complex products like composites, low weight articles or products contaminated with other products are less conducive to recycling. Figure 4-1 is an example of the life cycle of recycled waste.

Figure 4-1: Life-cycle approach for analysing the environmental impacts of plastic recycling



[165] Pilz, H., Brandt, B. and R. Fehringer (2010) *The impact of plastics on life cycle energy consumption and greenhouse gas emissions in Europe*, Summary report, Denkstatt.

The following economic factors are also crucial:

- Costs of plastic recycling by process (collection, transport, etc.);
- Costs of regulatory compliance and administrative work (licences, fees, paper work etc.);
- Market price for recycled plastic in comparison to the virgin material they replace;
- Recycled plastic price volatility and transport costs estimates.

This global approach allows any trade-offs in plastic waste treatment to be identified. For example, there is a possibility that applying strict quality standards to recycled plastic in order to reduce its environmental and health impacts (use phase) will actually have a greater overall impact on the environment/health due to increased processing needs and associated impacts.

The main results concerning the environmental impacts of mechanical recycling are:

- Of all the waste treatment options reviewed (mechanical recycling, feedstock recycling, energy recovery and landfill), mechanical recycling appears most beneficial, provided that at least some portion of the recycled material substitutes for virgin polymers and losses remain low.[166] Substitution appears to have lower benefits than substitution of virgin plastic materials (Table 22). This is the case with most plastic types, except PVC for some indicators. PVC is sometimes considered to be harder to recycle than other plastic types due to its chlorinated nature (making it more brittle and affecting the structural integrity of the recycled material). Nevertheless, in part as a result of the Vinyl 2010 Recovinyl initiative, up to 0.2 Mt of PVC is being recycled for use in window frames, pipes and other applications.[167]

Table 22: Influence of the choice of material substitution for recycling[168]

	Recycling scenario 1		Recycling scenario 2	
	Substitutes 100% virgin plastic	Substitutes 20% virgin plastic, 40% wood, 40% concrete	Substitutes 100% virgin plastic	Substitutes 20% virgin plastic, 40% wood, 40% concrete
Global warming potential (kg eq CO_2/ton)	-620	439	-464	415
Depletion of abiotic resources (kg eq Sb/ton)	-14 667	-2 547	-13 735	-2496
Energy demand (MJ/ton)	-12 897	-7 363	-9 753	-1457

- One review showed that the benefits of mechanical recycling are the same whether materials are taken by consumers to a specific collection point or

[166] WRAP (2006) *Environmental Benefits of Recycling*.
[167] See www.recovinyl.com.
[168] WRAP (2010) *Life cycle assessment of example packaging systems for milk*.

mixed plastics are collected at the kerbside and separated at a materials recovery facility.[169] The same study showed that the system steps collection, sorting and pre-treatment of waste for recycling contribute only slightly to the environmental impact of the recycling system (Table 23). The environmental burden depends instead on the process itself.

Table 23: Contribution to the reduction (-) or increase (+) of GWP compared with reference scenario landfill by system step (kgCO_2eq per kg recycled plastic)

Scenario	Collecting/sorting	Treatment	Process	Landfill	Total
Bottle recycling	0,1	0,54	-1,27	-0,31	-0,95
Film recycling	0,1	*	-0,48	-0,36	-0,74

** Process and treatment were not identified separately*

- According to the same review, transport can account for 10-20% of the ecological burden, in some cases contributing to 30% of total impacts in the recycling chain. However, transport impacts are not enough to reduce the overall benefits of recycling over other waste treatment options.[169]
- The same review also showed that although feedstock recycling is not more beneficial than mechanical recycling, it has lower impacts than energy recovery.[169] However, there is some evidence to contradict this statement, showing that feedstock recycling leads to lower environmental benefits than plastic waste incineration in a high performance facility. A more recent review finds that feedstock recycling of PS ranks lower than energy recovery in terms of energy consumption but is more beneficial in terms of greenhouse gas emissions avoidance.[170]
- Another review demonstrated that back-to-monomer recycling (splitting polymers into monomers) has ecological advantages over back-to-feedstock recycling (splitting polymers into raw materials substituting fuel or gas) and is, to some extent, comparable with mechanical recycling.[171] However, this method is only practical for certain types of polymers (PU, PA and polyester) and therefore the overall benefits may not outweigh the costs of using this technology.
- One study has shown that in the case of bottle recycling, recycling of a material for its original purpose is often more advantageous than recycling of materials for alternative purposes.[168] This appeared to be the case for both HDPE and PET bottle recycling (Table 24). This study also demonstrated that in the case of some indicators, recycling was less beneficial when carried out abroad (in China) rather than closer to the source (in the UK). Further analysis would be necessary to determine whether this is the case in other countries.

[169] Wollny V. and Schmied M. (2000) *Assessment of Plastic Recovery Options*.
[170] WRAP (2010) *Environmental benefits of recycling – 2010 update*.
[171] Wollny V. and Schmied M. (2000) *Assessment of Plastic Recovery Options*.

Table 24: Impacts of recycling options for 100% virgin HDPE and PET bottles (per 1 000 pints)

Impact category	Unit	Bottle to bottle recycling, UK	Bottle recycling, UK	Bottle recycling, China
		High-density polyethylene (HDPE)		
Abiotic depletion	kg Sb eq	0.242	0.326	0.345
Climate change	kg CO_2 eq	31.5	32.9	35.9
Photo-oxidation	kg C_2H_4 eq	0.01	0.0352	0.0395
Eutrophication	kg PO_4^{3} eq	0.0116	0.0051	0.011
Acidification	kg SO_2 eq	0.0671	-0.0513	0.0109
Human toxicity	kg 1.4-DB eq	3.66	3.51	5.24
Freshwater ecotoxicity	kg 1.4-DB eq	0.523	0.732	0.763
		Polyethylene terepthalate (PET)		
Abiotic depletion	kg Sb eq	0.445	0.573	0.606
Climate change	kg CO_2 eq	54.1	68.3	73.5
Photo-oxidation	kg C_2H_4 eq	0.026	0.0455	0.0528
Eutrophication	kg PO_4^{3-} eq	0.0222	0.0655	0.0754
Acidification	kg SO_2 eq	0.131	-0.00779	0.0973
Human toxicity	kg 1.4-DB eq	7.15	17.4	20.4
Freshwater ecotoxicity	kg 1.4-DB eq	1.16	2.73	2.78

4.2. HEALTH IMPACTS OF PLASTIC WASTE RECYCLING

In some cases, recycled plastics can have negative impacts on human health. At a basic level, in facilities where manual sorting is still in place, workers may risk injury and disease while sorting materials. At times, consumers are unaware of what can and cannot be recycled, and items such as hypodermic needles and broken glass may get mixed in and potentially injure workers.[172]

There is a risk of plastic waste recycling affecting local populations in countries with less stringent regulations than in the EU. Recycling techniques used to treat plastic waste can be relatively primitive in those countries, and in some cases there is a lack of appropriate facilities to safeguard environmental and human health. For example, chipping and melting of plastics in unventilated areas (a practice not seen in Europe) can have negative consequences on human health.[173]

One particular study attributed the higher concentrations of POPs and heavy metals/metalloids detected in the air of the Guiyu region of China to incomplete combustion of WEEE from materials such as plastic chips and PVC.[173] In particular, the study showed high concentrations of polybrominated diphenyl ethers (PDBEs) in the

[172] Communication with stakeholder who requested that their name and organisation's name remain confidential.
[173] Wong M.H., Wu S.C., Deng W.J., Yu X.Z., Luo Q., Leung A.O.W.,Wong C.S.C., Luksemburg W.J. and Wong A.S. (2007) "Export of toxic chemicals - A review of the case of uncontrolled electronic-waste recycling" in *Environmental Pollution*, 149: 131-140.

air, released from the melting of polymers (during open burning of WEEE) that contain brominated flame retardants.

High exposure to PDBEs, which accumulate in the human body, has been linked to thyroid hormone disruption, permanent learning and memory impairment, behavioural changes, hearing deficits, delayed puberty onset, impaired infant neurodevelopment, decreased sperm count, fetal malformations and possibly cancer.[174,175] These activities lead to severe pollution of soils by POPs and heavy metals in the countries concerned, which may also affect the surrounding environment such as rice fields and rivers via atmospheric movement and deposition.[173]

Quantitative impact studies tend not to focus on human toxicity.[176] One review found that mechanical recycling is a better option than most other waste treatment methods.

Another study showed differing results when comparing recycling to pyrolysis of mixed plastic waste (Table 25). However, this was less to do with the mixture of plastics and more to do with the technologies used throughout the recycling process.[177] The final results were affected not only by the recycling method but also by the mixture of plastics and the sorting method. In particular, sorting, cleaning and mechanical recycling of PE and PP by the Swiss Polymera technique was more beneficial when compared to pyrolysis of mixed PE and PP fractions only.

Recycling scenarios using other separation techniques, or recycling of other fractions (mixed PE, PP, PET and PVC) performed less favourably than pyrolysis because landfilling of the resulting residue had a greater impact on human ecotoxicity.[177] However, it is worth noting that recycling and pyrolysis options included in this study involved at least 16% landfilling of residue that could not otherwise be recovered, which contributed in all cases to most of the overall impacts.

As a means of controlling the content of recycled plastics material streams for articles used in contact with food, these should only be obtained from processes which have been assessed for safety by the European Food Safety Authority and authorised by the European Commission.[178]

[174] Environmental Working Group (2003) *Mother's Milk Toxic Fire Retardants in Human Breast Milk*.
[175] Herbstman J. et al. (2010) "Prenatal Exposure to PBDEs and Neurodevelopment" in *Environmental Health Perspectives*.
[176] Wollny V. and Schmied M. (2000) *Assessment of Plastic Recovery Options*.
[177] WRAP (2008) *LCA of Management Options for Mixed Waste Plastics*.
[178] See www.efsa.europa.eu/en/ceftopics/topic/foodcontactmaterials.htm.

Table 25: Ranking of end-of-life options for plastic waste for human toxicity (kg 1.4-DB-eq)[179]

Case	Recycling	Incineration with energy recovery	Landfill	Pyrolysis
1[PE]	+++	++	+	
1[PET]	+++	++	+	
2[MIX1]	+++	++	+	++
2[MIX2]	++	++	+	+++
2[MIX3]	+++	++	+	++
2[MIX4]	++	++	+	+++
3[PE]	+++	++	+	
3[PP]	+++	++	+	
3[PS]	++	+++	+	
3[PET]	+++	++	+	
3[PVC]	+++	++	+	

+++	best option
++	intermediary option
+	worst option
	option not assessed

4.3. FOCUS ON POTENTIAL USE-PHASE HEALTH IMPACTS OF HEAVY METALS IN PLASTIC CRATES

Heavy metals in plastics, notably cadmium, have been highlighted as a concern, especially in applications like children's toys. These products risk being chewed by children being thus exposed to repeated and extended contact with saliva. Any heavy metal thus leached would be ingested by the child.

In the case of plastic crates and pallets, small RTP are in contact with human skin only momentarily when they are being lifted and carried by the user. Pallets and other large RTP are moved around and stocked using forklifts due to their size and weight. The only known results regarding the potential health impacts due to the handling of heavy metal-containing crates indicate that there seem to be no health risk to humans handling the crates. As analysed by Institut Nehring, the heavy metal traces of 0.8 and 0.9 ppb (Pb + Cd) are well below the European requirements for water intended for human consumption:

Table 26: Minimum quality requirements of water intended for human consumption according to the Drinking Water Directive[180]

Substance	Maximum concentration [µg/l] = [ppb]
Cadmium (Cd)	5.0
Lead (Pb)	10

These results support the claim of the plastic conversion and beverage sector that "the heavy metals contained in the crate and/or pallet are encapsulated in the plastic matrix and there is no migration."[181]

[179] WRAP (2010) *Environmental benefits of recycling – 2010 update*.
[180] Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption, Annex I, Part B.
[181] The term migration refers to the occurrence of dissolved portions of pigment migrating from their medium of application to the surface or into a similar material that their system is in contact with.

4.4. FOCUS ON BIOPLASTICS

4.4.1. LIFE-CYCLE ASSESSMENT (LCA) OF BIOPLASTICS

A number of potential benefits are claimed for bioplastics. First, reduction of oil dependency: It is thought that around 4% of oil demand is for plastics feedstock.[182] Use of plastic products manufactured from renewable resources reduces the use of fossil fuels and decouples the products from high and volatile fossil-fuel prices, though the relationship is complicated by the fact that plastic products make use of by-products of the refining process.

Second, reduction of waste at source: Bioplastics might improve manufacturing process efficiency.[183] Also, biodegradable bioplastics are less persistent in the environment than non-degradable plastics, though they may require suitable end-of-life treatment to maximise benefit. Biodegradable bioplastics can be composted, reducing the amount of waste sent to landfills.

Third, reduction of greenhouse gas emissions: It is claimed that CO_2 emissions released at the end of life of bioplastics (through incineration, decomposition, etc.) are offset by the absorption of CO_2 during plant growth.

However, these potential benefits need to be evaluated very carefully. Existing LCA results differ significantly (see Table 27) depending on the methods used, the system boundaries, the impacts considered and also their year (databases are constantly being updated). Also, because the term "bioplastics" covers a wide range of materials with various properties (bio-based or not, biodegradable or not), an LCA assessment for each application would be ideal but this is not always available. The life-cycle approach is particularly important for bio-based plastics as these might have important environmental impacts related to raw material production: biodiversity loss, potential deforestation, land-use change, soil modification, planting of genetically selected or modified high-yield crops, water consumption, fertilizer and pesticide use, etc.

According to one review,[186] most LCAs show that bioplastics have advantages over petroplastics for impacts such as fossil-energy consumption and greenhouse gas emissions, but it is not always the case for eutrophication or acidification. For many applications, bioplastics are reported to have favourable eco-profiles: they have low energy requirements during manufacture, have a CO_2-"neutral" status (an assumption based on organic carbon content), and end-of-life benefits if composted, recycled or incinerated (see also section 3.5). As the bioplastics market grows, financial and environmental economies of scale may be achieved. On the other hand, a few LCAs (15% of those reviewed in this study) indicate that petroplastics can have lower environmental impacts than bioplastics, taking into account data on the actual number

[182] The original source of this statistic could not be found yet it is widely cited; see for example www.ides.com/articles/oil.asp, www.wasteonline.org.uk/resources/InformationSheets/Plastics.htm and www.pafa.org.uk/Environment/MinimalResourceUsage/tabid/137/Default.aspx.

[183] Barker, M. and Safford, R. (2009) *Industrial uses for crops: markets for bioplastics*, HGCA.

of recycling loops possible, the energy consumed during manufacturing and end-of-life disposal (methane generation in landfills).

Table 27: Selected bioplastics LCAs

Source	Characteristics	Main conclusions
Morken, J. and Nyland, C. A. (2002) ITF Rapport: life cycle assessment of BioBags used for collection of household waste.	Comparison of Mater-Bi BioBags to PE bags Cradle to grave (land application of the compost excluded), composting , waste-to-energy and landfill assessed	The life cycle of BioBags is more energy intensive and produces more greenhouse gas emissions than the life cycle of PE bags (disposed of by composting or landfill). Incineration of Biobags for heat and power generation produced a global warming potential (GWP) only slightly higher than incinerated PE due to the oil saved by burning Biobags.
Novamont SPA www.materbi.com/ing/html/prodotto/cosematerbi/pop_lca_sacchetti.html	Comparison of Mater-Bi BioBags to PE bags and paper bags Cradle to grave (transportation excluded), disposal by composting or incineration	Mater-Bi bag manufacture uses slightly less energy than equivalent PE bags and significantly less than paper bags. The GWP for the life of Mater-Bi bags is significantly lower (over 60% reduction) than that for PE bags.
Bio Intelligence Service (2006) for Eco-Emballages, www.ecoemballages.fr/fileadmin/contribution/pdf/instit/etudes/bilan-environnemental-filieres-traitement-plastiques.pdf	Gate to cradle, comparisons of end-of-life options for LDPE, PET, PLA, PBAT (non bio-based, biodegradable), Mater-Bi and an oxo-degradable polymer	Recycling is the most beneficial option for petrochemical polymers (PE, PET, oxo-degradable). For PLA, PBAT and Mater-Bi, waste-to-energy, not composting, seems the most environmentally-friendly option, except with respect to global warming impacts if carbon is captured during composting. When modelled like PET recycling, Mater-Bi recycling has the lowest impacts (except for sediment ecotoxicity).
Vink, E.T.H. et al. (2007) The eco-profiles for current and near-future NatureWorks polylactide production	Cradle to factory gate PLA manufactured by NatureWorks	85% reduction in greenhouse gas output and 50% reduction in fossil-fuel based energy requirements for PLA production in 2006 compared to 2003.

Vink, E.T.H. et al. (2007) The eco-profiles for current and near-future NatureWorks polylactide production	Cradle to grave (recycling or incineration) PLA clamshell packaging compared to equivalent products made of PP, PS, PET	PLA clamshell manufacture, use and disposal use less fossil-fuel resources (75% less than PET) and produce less greenhouse gas emissions than other plastic types (50% less than PET).
Bio Intelligence Service (2007) for Eco-Emballages, www.ecoemballages.fr/fileadmin/contribution/pdf/instit/etudes/acv-emballages-plastique.pdf	Cradle to grave LCAs of PET, PE, PLA, PBAT (non bio-based, biodegradable) and an oxo-degradable polymer	The production phase dominates in terms of impacts for all packaging resins. The end-of-life phase has low impacts by comparison, except for PET and PE recycling which have positive end-of-life management characteristics. With the current non-selective collection scheme, composting options do not significantly improve the overall environmental impacts of bioplastics.
National Non-Food Crop Centre (2008) LCA of biopolymers for single use carrier bags.	Comparisons of degradable/non-degradable HDPE bags with starch based Mater-Bi bags and PLA/petroplastics mix bags Cradle to grave (landfill, incineration, recycling, composting considered)	Using and recycling HDPE bags results in the least environmental impact. The next best option is the incineration of Mater-Bi bags. The most important life-cycle phase is the extraction and production of material for all types of plastics. There was no evidence of energy savings in the production of bioplastics. Future improvements in energy efficiency of resin manufacture may help reduce this impact. Incineration with energy recovery is the best option for the end-of-life of bioplastics bags and composting is not a clear winner.

4.4.2. END-OF-LIFE MANAGEMENT OF BIOPLASTICS

End-of-life management of bioplastics is a key determinant of their associated environmental impacts. If treated correctly, the biodegradability of bioplastic makes it possible to return plastic waste to the natural material cycle with minimised fossil-fuel input. There are multiple end-of-life management options: composting, recycling, waste-to-energy (anaerobic digestion, incineration, etc.) and landfill.

The description of bioplastics as compostable can be confusing for the general public as not all bioplastics are compostable at home like organic food waste (such items are labelled “home compostable”) but usually require an industrial composting treatment not available at every composting site.[183]

Most of the options available still require further development and suitable collection methods implemented by local authorities in order to ensure high quality. For example, without efficient labelling and collection schemes, bioplastics can contaminate recycling streams and lower the quality of recycled petroplastic.

Lack of awareness of bioplastics, lack of willingness to separate waste and inadequate sorting instructions complicate the situation regarding sorting at source (i.e. in households). There are currently few specific regulations about the end-of-life stage of bioplastics. EU plastic standards and the Society of the Plastics Industry in the United States classify bioplastics in category 7 as “Other” without further details. A compostable labelling scheme has nonetheless been developed by European Bioplastics for all compostable EN 13432 compliant packaging materials (see Figure 4-2) but it is currently only used in Germany, Switzerland, the Netherlands, Poland and the UK.[184]

Figure 4-2: Compostability label (EN13432-compliant)

The end market for compost products may not be large enough yet to drive a significant increase in this end-of-life option. The sorting of plastics is a critical issue for proper management and to ensure quality levels both for composting and other options, and the variety of bioplastics with different degradation times might complicate the process. Biodegradable plastic waste should fit with the requirements of composting (aerobic degradation) or digestion (anaerobic degradation) facilities, when organically recycled (EN 13432 for composting).

PLA bottles can be recycled but need to be properly separated from PET to avoid contamination of recycled PET. The separation step is paramount to avoid sending petroplastics to composting facilities, for instance. The addition of bioplastics to the plastic waste stream might thus increase separation costs because more sophisticated equipment is required. Investment will have to be made in processing sites so that they can handle the new amounts and types of bioplastics. Plastic manufacturers can also propose buy-back schemes to manage the recycling operations themselves, for example like NatureWorks did.[185]

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[184] See www.european-bioplastics.org/index.php?id=160.
[185] Barker, M. and Safford, R. (2009) *Industrial uses for crops: markets for bioplastics*. HGCA.

Anaerobic digestion might also be an option for bioplastics packaging contaminated with food waste and food waste in bioplastics bags. The process is cheaper than composting (no aeration operations are needed) and produces methane which can be burnt for energy/heat production.

With the increasing market share of bioplastics, these end-of-life options would enable the quantity of plastics sent to landfills and incinerators to be reduced. Waste-to-energy can also be an interesting option for some bioplastics. A survey of several UK organisations found that municipal and domestic composting was seen as the best end-of-life option for bioplastics.[186] Recycling and anaerobic digestion were considered intermediate solutions, followed by incineration. The worst option was unanimously considered to be sending bioplastic waste to landfill.

4.4.3. SUMMARY

Based on the review of bioplastics LCAs, it is not easy to predict the environmental impacts of increasing bioplastics use. End-of-life management has a paramount influence: for instance, recycling bioplastics may be as efficient an option as composting. Combining the extensive use of bioplastics with today's collection systems may hamper the recycling of petroplastics, which highlights the need to develop efficient sorting at source and collection systems. And although some bioplastics are biodegradable, the composting process has to take place in industrial facilities for many of them, such as PLA. If bioplastics were to be released into the environment by the public based on the mistaken idea that they will soon biodegrade, they could have some of the same effects on the environment that petroplastics currently have (e.g. harm to marine life, adsorption of pollutants potentially going up the food chain).

4.5. FOCUS ON MARINE PLASTIC WASTE

In 2010, the Sea Education Association discovered a mass of plastic waste in the North Atlantic. It is similar to the one in the Pacific Ocean discovered in 1997. The Pacific patch extends over a very large area, possibly as large as twice the size of Texas in the United States, but the exact size is unknown.[187] Estimates of the amount of plastic contained in the Pacific patch are of the order of 100 Mt. These patches are also called gyres as they result from circular currents gathering the waste and keeping it in the same area.

As much as 80% of the waste material floating in these patches is plastic: it is not biodegraded by any known micro-organisms but is progressively broken down, by the

[186] Murphy, R. and I. Bartle (2004) *Biodegradable Polymers and Sustainability: insights from Life Cycle Assessment*, on behalf of the National Non-Food Crops Centre.

[187] For a discussion of the problems in determining the exact size based on current sampling techniques, see Ryan, P. Moore, C. et al. (2009) "Monitoring the abundance of plastic debris in the marine environment" in *Phil. Trans. R. Soc. B*, 27 July 2009, vol. 364, no. 1526, 1999-2012, doi: 10.1098/rstb.2008.0207.

sun (photodegradation) or mechanically (i.e. wave action, grinding from rocks and sand). The fragments are broken down from diverse containers or objects from unknown sources. All kinds of objects can be found (bottles, cigarette lighters, toothbrushes, nets, etc.). There are even microscopic plastics (< 10 nm in diameter) in the water column.[188]

The average density of plastic fragments has been estimated at 200 000 units/km^2 in the North Atlantic patch and 300 000 in the Pacific patch.[189] Overall, UNEP estimates that every km^2 of ocean contains 18 000 pieces of floating plastic, though this figure has to be considered with caution given the difficulty of assessment.[190]

Besides the two main plastic soup patches already discovered, there are now three spots (in the South Pacific, South Atlantic and Indian oceans) that are likely to be subject to the same phenomenon. In fact, plastic waste can be found everywhere in the oceans – from beaches where people go on holidays to remote uninhabited islands. Plastics have been fragmenting and accumulating in the oceans for more than fifty years and full recovery may never be possible.

Some recent findings from the Sea Education Association find that, for the North Atlantic at least, the amount of plastic waste in the ocean has not been increasing despite the rise in generation.[191] Further research would be needed in order to confirm this and, if true, to establish the reasons, which might range from better plastic waste management to sinking or microbial action.

4.5.1. ENVIRONMENTAL IMPACTS OF MARINE PLASTIC WASTE

According to UNEP, plastic waste in the ocean causes the deaths of up to one million seabirds, 100 000 marine mammals and countless fish every year.[192] Big animals (e.g. turtles, whales, seals, sea lions) can be trapped by nets and films and eat the small particles of plastics which may block their digestive systems. Entanglement and ingestion of plastic fragments can even lead to death by drowning, suffocation, strangulation or starvation through reduced feeding efficiency. At least 267 different species are known to have suffered from entanglement or ingestion of marine debris, including seabirds, turtles, seals, sea lions, whales and fish.[193] Table 28 shows the

[188] Rios, Lorena M., unpublished data, private communication.
[189] Charles Moore (2003) "Across the Pacific Ocean, Plastics, Plastics, Everywhere" in *Natural History*, vol. 112, no. 9, November.
[190] UNEP (2006) "Ecosystems and Biodiversity in Deep Waters and High Seas" in *UNEP Regional Seas Reports and Studies* No. 178, UNEP/ IUCN, Switzerland. Available at: www.unep.org/pdf/EcosystemBiodiversity_DeepWaters_20060616.pdf.
[191] Lavender Law, K., Morét-Ferguson, S., Maximenko, N. A., Proskurowski, G., Peacock, E. E., Hafner, J. and Reddy, C. M. (2010) "Plastic Accumulation in the North Atlantic Subtropical Gyre" in Science, DOI: 10.1126/science.1192321. Available at: www.sciencemag.org/cgi/content/abstract/science.1192321.
[192] UNEP (2006) "Ecosystems and Biodiversity in Deep Waters and High Seas" in *UNEP Regional Seas Reports and Studies* No.178., UNEP/ IUCN, Switzerland. Available at: www.unep.org/pdf/EcosystemBiodiversity_DeepWaters_20060616.pdf
[193] Derraik J.G.B. (2002) "The pollution of the marine environment by plastic debris: a review" in *Marine Pollution Bulletin* 44:842-852.

numbers and percentages of marine species affected worldwide. The figures might be underestimated because victims are likely to sink or be eaten by predators.

Table 28: Number and percentage of marine species worldwide with documented entanglement and ingestion records[194]

Species group	Total number of species worldwide	Number and % of species with entanglement records	Number and % of species with ingestion records
Sea turtles	**7**	**6 (86%)**	**6 (86%)**
Seabirds	**312**	**51 (16%)**	**111 (36%)**
Penguins	16	6 (38%)	1 (6%)
Grebes	19	2 (10%)	0
Albatrosses, petrels, shearwaters	99	10 (10%)	62 (63%)
Pelicans, boobies, gannets, cormorants, frigatebirds, tropicbirds	51	11 (22%)	8 (16%)
Shorebirds, skuas, gulls, terns, auks	122	22 (18%)	40 (33%)
Other birds	-	5	0
Marine mammals	**115**	**32 (28%)**	**26 (23%)**
Baleen whales	10	6 (60%)	2 (20%)
Toothed whales	65	5 (8%)	21 (32%)
Fur seals and sea lions	14	11 (79%)	1 (7%)
True seals	19	8 (42%)	1 (5%)
Manatees and dugongs	4	1 (25%)	1 (25%)
Sea otter	1	1 (100%)	0
Fish	**-**	**34**	**33**
Crustaceans	**-**	**8**	**0**
Squid	**-**	**0**	**1**
Species total		**136**	**177**

Fish and crustaceans can also be affected by "ghost fishing": derelict fishing gear left in the ocean can keep on acting as fishing tool on its own.[195] Organisms trapped in the nets and pots may die and/or attract predators, which may become trapped themselves.[196] Environmental conditions have an important influence on the lifetime of a net: nets lost in calm waters near oceanic convergence zones may continue to "fish" for decades while nets that are lost in areas of large swell and storm activity may be

[194] Adapted from Laist (1997).

[195] Matsuoka T., Nakashima T. and Nagasawa N. (2005) "A review of ghost fishing: scientific approaches to evaluation and solutions" in *Fisheries Science* 71:691-702.

[196] Joint Nature Conservation Committee (JNCC) (2005). Available at: www.jncc.gov.uk/page-1567.

rapidly torn apart and destroyed.[197] Some countries now require the use of pots with escape hatches or panels that either biodegrade or fall out of the pot after a time, in order to minimise the harm caused by such items.

Ghost fishing also imposes a large economic cost: for instance, the amount of monkfish trapped by ghost nets in the Cantabrian Sea may be equivalent to around 1.5% of the commercial landings in that region.[198] Trapped lobsters in the United States have been estimated to be worth $250m (almost €200m).[199] Indeed, plastic waste in general imposes a wide range of economic costs such as repairs to damaged propellers and lost tourism revenues through dirty and cluttered beaches.[200]

Derelict fishing gear (nets, mono-filament lines) also harms coral reefs and other invertebrates such as sponges when nets or lines get snagged by the reef and break it off. The same net can keep on breaking the reef until it becomes too heavy with the attached coral and sinks.[201] It may also be incorporated into the reef structure.

Other types of plastic particles coming from cosmetic preparations or airblast cleaning media may impact the sea-surface microlayer ecosystems. Airblasting particles may also become contaminated by heavy metals during their use phase, which are passed on to marine animals when ingested.

Small organisms can use plastic debris as rafts to grow and travel on the ocean. Observation of this phenomenon has shown that such animals or plants can travel very long distances that way and may settle in areas where they are non-native. This may result in negative effects since alien species in some marine environments may threaten or out-compete the native species.

The seabed is also contaminated by plastic waste, especially by plastic bags in coastal regions. Around 70% of plastic debris eventually sinks to the bottom of the sea.[202] PVC, ABS, HDPE, PS non-expanded, nylon and other types of plastics accumulate there, along with the non-degradable toxic substances they may carry, with detrimental effects on living organisms. The layer of plastic debris may hamper the important gas exchange that normally takes place between the sediment layers and the overlying waters, thus disturbing the ecosystem.

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[197] Michelle Allsopp, Adam Walters, David Santillo and Paul Johnston (2006) *Plastic Debris in the World's Oceans*, Greenpeace International, Amsterdam. Available at www.greenpeace.org.

[198] Sancho G., Puente E., Bilbao A., Gomez E. and Arregi L. (2003) "Catch rates of monkfish (Lophius spp.) by lost tangle nets in the Cantabrian Sea (northern Spain)" in *Fisheries Research* 64:129-139.

[199] JNCC (2005). Marine advice – Fisheries. Available at: www.jncc.gov.uk/page-1567.

[200] Save the North Sea (2004) Reduce Marine Litter: Save the North Sea Project Results. Available at: www.savethenorthsea.com/documents/Kampanjer-och-aktiviteter/Save-the-North-Sea/save_the_north_sea_low.pdf.

[201] National Oceanic and Atmospheric Association (2005) *Coral reef restoration through marine debris mitigation*, United States Department of Commerce.

[202] UNEP (2006) "Ecosystems and Biodiversity in Deep Waters and High Seas" in *UNEP Regional Seas Reports and Studies* No.178., UNEP/ IUCN, Switzerland. Available at: www.unep.org/pdf/EcosystemBiodiversity_DeepWaters_20060616.pdf

The quantity of garbage on a beach has an influence on the quantity and types of organisms living at that spot. In one study,[203] very small organisms called diatoms were reported to be affected by this phenomenon, in addition to the effects of plastic ingestion.

The full environmental impacts of marine plastic waste are not yet well understood, notably the indirect effects on the food chain. Ingestion of plastic debris may result in contamination by harmful compounds with potentially toxic effects.[204] As a result of predator-prey interactions, some harmful compounds may be passed on or accumulated along the food chain (biomagnification). Thus, the ingestion of plastic fragments by organisms such as barnacles or lugworms could result in health effects on the human being at the other end of the food chain. Animals can be contaminated by leaching chemicals from the plastic material itself, but plastic fragments can also be a carrier of pollutants agglomerated from the surrounding water.[205] Especially harmful effects have been observed from persistent organic pollutants (POPs), such as hydrocarbons, pesticides (DDT) and polychlorinated biphenyls (PCBs).[206] Adsorption of these pollutants by plastic fragments on the ocean surface creates another entry path for pollution into the food chain via marine creatures that ingest the plastics.[207] These POPs do not break down naturally but accumulate in the body tissue, and also biomagnify causing serious health effects.

4.5.2. Sources of marine plastic waste

Of plastic waste ending up in the ocean, either floating or sinking, 80% is estimated to come from land-based sources and 20% from ocean-based sources.[208] The major land-based sources identified are:[209]

- Storm water discharges: runoff water is generated during heavy rain events and collected in storm drains, carrying street rubbish on its way or even landfill waste. The drains then discharge into streams, rivers or directly into the ocean. Forestry, agriculture or construction waste may also be carried to the ocean by stormwater;
- Combined Sewer Overflows (CSOs): during heavy rainfall, combined sewer systems (carrying wastewater and stormwater) may be overloaded at the

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[203] Uneputty P.and Evans S.M. (1997) *The impact of plastic debris on the biota of tidal flats in Ambon Bay*.
[204] USEPA (1992) *Plastic pellets in the aquatic environment: sources and recommendations*.
[205] Rios, L.M., Moore, C. and P.R. Jones (2007) "Persistent organic pollutants carried by synthetic polymers in the ocean environment" in *Marine Pollution Bulletin* 54: 1230-1237.
[206] Mato Y., Isobe T., Takada H., Kanehiro H., Ohtake C. and Kaminuma T. (2001) "Plastic resin pellets as a transport medium for toxic chemicals in the marine environment" in *Environmental Science and Technology* 35(2): 318-324.
[207] Rios, L.M., Jones, P.R., Moore, C. and U. Narayan (2010) "Quantification of persistent organic pollutants adsorbed on plastic debris from the Northern Pacific Gyres' "Eastern Garbage Patch"", accepted in *Journal of Environment Monitoring*.
[208] Sheavly S.B. (2005) "Marine debris – an overview of a critical issue for our oceans" at Sixth Meeting of the UN Open-ended Informal Consultative Processes on Oceans & the Law of the Sea.
[209] Michelle Allsopp, Adam Walters, David Santillo and Paul Johnston (2006) *Plastic Debris in the World's Oceans*, Greenpeace International, Amsterdam. Available at www.greenpeace.org.

wastewater treatment plant. Some of the mixed sewage and stormwater is discharged directly into a river or the ocean without being treated. This is one of the major land-based sources of plastic marine debris in the United States;[210]

- Tourism-related litter at the coast: can consist of litter left by beach-goers (food and beverage packaging, cigarette butts, plastic beach toys) or fishermen;
- Illegal dumping of domestic or industrial waste: in countries where sanitary disposal in landfills has not been implemented, marine plastic fragments from uncontrolled dumping sites may end up in coastal and marine waters.[211] Waste may also be lost during collection or transportation to landfill if waste management procedures are inadequate;
- Industrial activities: industrial activity may result in plastic waste discharge into the ocean if products are improperly disposed of or lost during transport/handling at port facilities. For instance, plastic resin pellets can be found in most of the world's oceans, even in non-industrialised areas such as the Southwest Pacific,[212] because of accidental spillage during production and transport;

The major ocean-based sources include:[213]

- Commercial fishing: fishermen can accidentally lose or deliberately dump fishing gear into the ocean. Examples include nets, lines and ropes, strapping bands, bait boxes and bags, gillnet or trawl floats, and galley wastes;
- Recreational boaters: similar to coastal tourism-related litter. Waste such as bags and food packaging can be thrown overboard;
- Merchant, military and research vessels: like fishing vessels, these boats can release garbage into the ocean on purpose or accidentally;
- Offshore oil and gas platforms, undersea exploration: items such as hard hats, gloves, storage drums, survey materials and personal waste can be accidentally or deliberately released into the sea.

Today, most debris comes from industrialised countries but the further industrialisation of less developed countries in future may result in an increase in plastics generation and waste production and thus the quantity of waste ending up in the ocean.

[210] Nollkaemper A. (1994) "Laws of the sea, Land-based discharges of marine debris: from local to global regulation" in *Marine Pollution Bulletin* 28 (11):649-652.
[211] Liffman M. and Boogaerts (1997) "Linkages between land-based sources of pollution and marine debris" in *Marine Debris. Sources, Impacts, Solutions* pp359-366.
[212] Derraik J.G.B (2002) "The pollution of the marine environment by plastic debris: a review" in *Marine Pollution Bulletin* 44:842-852.
[213] Sheavly S.B. (2005) "Marine debris – an overview of a critical issue for our oceans" at Sixth Meeting of the UN Open-ended Informal Consultative Processes on Oceans & the Law of the Sea.

4.5.3. Responses to marine plastic waste

Attempts to tackle sea pollution include international legislation to prevent ships from dumping plastics into the ocean and campaigns to raise public awareness and prevent losses due to poor industrial practice. Concerning waste from ships, legally binding action has been agreed in the context of the International Maritime Organisation, and more needs to be done to ensure adequate port reception facilities worldwide.[214] The most relevant response to ghost fishing seems to be to prevent fishermen from losing or throwing away fishing gear. Education and legislation (e.g. the international convention MARPOL[215]) could be combined to result in an efficient strategy. Some countries have already implemented the compulsory use of equipment with biodegradable parts to enable animals to escape. Finally, recovery of nets can also be useful: the Directorate of Fisheries in Norway organised retrieval surveys that recovered 9 689 gillnets of 30 metres in length between 1983 and 2003.[216] However, this action does not tackle the problem at source.

One of the most important steps that has been taken in recent times is the adoption of the Marine Strategy Framework Directive (Directive 2008/56/EC),[217] which identifies data-gathering as a priority for the effective protection of the marine environment. Member States will be obliged under the Directive to carry out a comprehensive assessment of the status of the marine environment in their waters.[218] Also at EU level, DG Humanitarian Aid and Civil Protection of the European Commission has been taking action under the “Community framework for cooperation in the field of accidental or deliberate Marine Pollution”.[219]

4.5.4. Summary

The data collected in this chapter draws on some key studies and reviews which provide insight into the impacts of plastics and the management of plastic waste. This chapter includes focuses on two key topics: bioplastics and marine plastic waste.

In relation to the environmental impacts of plastic waste treatment, most studies speak favourably of chemical recycling for most types of plastics. In the case of feedstock recycling of mixed plastics, alternatives such as energy recovery appear more beneficial in terms of environmental impacts. In terms of impacts related to recycling,

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[214] EC (2010) *Joint answer given by Mr Potočnik on behalf of the Commission*, Written questions: E-0825/10, E-0104/10, European Parliament.

[215] International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto, see: www.imo.org/conventions/contents.asp?doc_id=678&topic_id=258.

[216] Hareide N-R., Garnes G., Rihan D., Mulligan M., Tyndall P., Clark M., Connolly P., Misund R., McMullen P., Furevik D., Humborstad O.B., Hoydal K. and T. Blasdale (2005) “A preliminary investigation on shelf edge and deepwater fixed net fisheries to the west and north of Great Britain, Ireland, and Rockall and Hatton Bank” presented at the ICES Annual Science Conference, 20-24 September 2005 in Aberdeen, UK.

[217] See http://ec.europa.eu/environment/water/marine/index_en.htm.

[218] EC (2010) *Joint answer given by Mr Potočnik on behalf of the Commission*, Written questions: E-0825/10, E-0104/10, European Parliament.

[219] See http://ec.europa.eu/echo/civil_protection/civil/marin/mp01_en_introduction.htm.

the data collected indicate that the most energy consumption and greenhouse gas emission occurs during the reprocessing of waste plastic to create recyclate material. This is followed by the collection and transport phase. Sorting/separation steps appear to have a small to negligible impact on energy consumption and greenhouse gas emissions. Although one review covers the human toxicity indicator, few resources are available in relation to health impacts.

The potential benefits of bioplastics include reduction of oil dependency, reduction of greenhouse gas emissions and reduction of waste at source. However, a review of bioplastics LCAs shows that the environmental impacts of increasing use of bioplastics are potentially mixed. End-of-life management has a paramount influence.

Giant masses of plastic waste have been discovered in the North Atlantic and Pacific Ocean. According to UNEP, plastic waste in the ocean causes the deaths of up to one million seabirds, 100 000 marine mammals and countless fish every year. The full environmental impacts of marine plastic waste are not yet well understood, notably the indirect effects on the food chain via ingestion. Attempts to tackle the problem range from international legislation to prevent dumping to public awareness campaigns.

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5. DEVELOPMENT OF A BASELINE SCENARIO

This chapter presents a projection of a baseline scenario of plastic waste volumes and management systems, in order to evaluate the economic, environmental and social impacts and provide a reference against which improvement options can be assessed.

A baseline scenario of future plastic waste generation in the EU was first projected to 2015, based on the current situation of plastic and bioplastic waste in the EU and existing policies and measures. An extrapolation was then made to 2020, to facilitate comparison with other Sustainable Management of Resources studies.[220]

The projection shows plastic waste quantities increasing significantly to 2020. The increase in plastic waste generation during this period can be attributed in large part to increasing affluence but also some population growth and other factors.

Policies to divert plastic waste from landfill will not tackle the bulk of the problem; the analysis projects that by 2020 the amount of plastic waste sent to landfill will decrease. Waste prevention initiatives could reduce plastic waste generation, but much plastic waste will need to be treated via other means. Strong and sustained efforts will be needed.

The projection results are broken down by application and presented in summary form, outlining the main findings and conclusions. In section 5.2 the sustainability impacts of the baseline scenario are assessed, in particular with respect to global warming. These projections will be a key input for Chapter 6, where policy measures to reduce plastic waste are identified.

A major conclusion of the exercise is the importance and necessity of better statistics for all Member States. More reliable, timely and complete data on plastic waste would allow for more robust and reliable estimations and projections.

5.1. PROJECTION OF PLASTIC WASTE TYPES, QUANTITIES AND TREATMENTS

5.1.1. PROJECTIONS TO 2015

Tables 29 and 30 summarise data already provided in this study for the base year 2008 and present projections to 2015 in the same format. The individual sectors do not sum to the overall totals as there is some plastic waste (estimated to be around 13%) for which data on recovery is not available. The percentage recovery of this "other" waste category is assumed to be the difference between the amount recovered by the target sectors and the overall quantity recovered.

[220] See www.eu-smr.eu.

The projections are based on a continuation of existing trends in production and recovery of material by sector, (packaging, C&D, ELV, agriculture and WEEE) and an assumption that targets are on a trajectory towards compliance. Specifically, 2015 targets for the ELV and WEEE Directives are considered, as well as proposed extensions to recycling targets under the proposal for a recast of the WEEE Directive[221] and 2020 targets for C&D waste presented in the Directive on Waste (2008/98/EC).

The projection takes into account the following factors in a qualitative way:

- treatment methods and plastic waste prevention activities already in place;
- market trends in sectors using large amounts of plastics (e.g. ICT sectors, consumer electronics, packaging, etc.);
- changes in retail or transport – for example, if products are increasingly manufactured outside the EU, resulting in greater demand for packaging to protect them;
- anticipated socio-economic changes (economic growth and disposable income, demographics, etc.);
- impacts of European policies already agreed by the end of 2009, e.g. the implementation of End-of-Waste (EoW) criteria.

In summary, the projections show:

- a 5.7 Mt (23%) increase in the overall generation of plastic waste of between 2008 and 2015, driven largely by a 24% rise in the packaging sector. The average annual growth rate between 2008 and 2015 would be 3.3%;
- while the levels of increase in C&D, ELV, agriculture and WEEE waste are relatively low in terms of Mt, the total percentage increases in these sectors are still high over the period i.e. 29%, 18%, 24% and 34% respectively;
- an overall decline in the level of disposal of plastic waste, with the most significant drop seen in packaging. The proportion of waste treated in this manner is projected to drop from 49% to 43% over the period;
- an increase in the proportion of energy recovery as a treatment option from 30% to 34% over the 2008 to 2015 period. The sector analysis shows no particular sector standing out in terms of highest level of increase;
- an increase in overall recovery (mechanical recovery, feedstock recycling and energy recovery) of 4.6 Mt or 36%;
- a rise in the overall level of mechanical recycling between 2008 and 2015 from 5.3 Mt to 6.9 Mt, representing a rise of 30%. However, the proportion of waste treated in this way only rises by 1.5% over the same period, suggesting that while overall levels of recycling will increase other treatment mechanisms remain dominant.

[221] See http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0810:FIN:EN:PDF.

Table 29: Plastic waste generation by sector and disposal route, 2008

Sector	Plastic waste (Mt)	Disposal (%)	Mech. recycling (%)	Feedstock recycling (%)	Energy recovery (%)	Total recovery	
						%	Mt
Packaging	15.59	41.8	28.5	0.5	29.2	58.2	9.01
C&D	1.43	49.1	15.9	-	35.0	50.9	0.7
ELV	1.25	79.8	8.6	0.5	11.1	20.2	0.21
Agri.	1.24	53.5	21.1	-	25.3	46.5	0.57
WEEE	1.14	55.2	7.6	-	36.2	43.8	0.48

Table 30: Plastic waste generation by sector and disposal route, 2015

Sector	Plastic waste (Mt)	Disposal (%)	Mech. recycling (%)	Feedstock recycling (%)	Energy recovery (%)	Total recovery	
						%	Mt
Packaging	19.27	35	35	-	30	65	12.53
C&D	1.84	46	18	-	36	54	0.99
ELV	1.53	77	10	-	12.5	23	0.35
Agri.	1.53	51	23	-	26	49	0.75
WEEE	1.53	52	9	-	39	48	0.73

It should be noted that levels of mechanical recycling and energy recovery represent estimates of likely levels of increase taking into account figures identified for total recovery and anticipated trends in these sectors. They do not necessarily equate directly to overall figures set out in Table 31 below.

Table 31: Overall plastic waste generation comparing 2008 and 2015

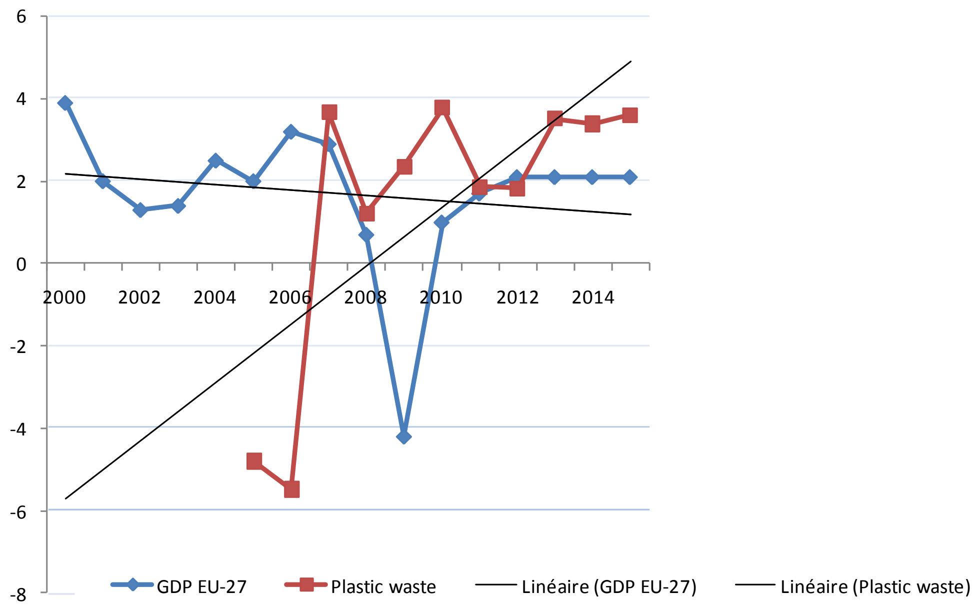
	Plastic waste (Mt)	Disposal (%)	Mech. recycling (%)	Feedstock recycling (%)	Energy recovery (%)	Total recovery	
						%	Mt
2008	24.9	49.0	21.3	-	30.0	51.3	12.8
2015	30.6	43.2	22.8	-	34	56.8	17.38

Trends in energy recovery and mechanical recycling are based on figures established through the review of the trend lines in Figure 5-4.

The relationship between GDP and plastic waste production was explored utilising the projection figures and an assumed 2.1% growth rate of GDP.[222] Growth in plastic waste declined in 2005/2006 while GDP grew, then it grew at a faster rate than GDP in 2007 following a peak GDP growth rate in 2006. Plastic waste arisings appear to follow the reported decrease in 2008 GDP, then peak to 2010, continuing to grow as GDP is projected to remain stable following the 2009/2010 slump (Figure 5.1).

[222] Energy Information Administration (2009) *International Energy Outlook 2009*, United States Department of Energy, Washington D.C.

Figure 5-1: Relationship between growth rates of EU plastic waste production and GDP, 2000-2015 (%)



5.1.2. SECTORS

Total plastic waste for 2015 was projected using a breakdown of plastic waste by sector, based on 19 Mt of packaging waste generated being equal to 63% of total plastic waste.

In the **packaging** sector, it is assumed that mechanical recycling will increase its share to 35%. Modest growth in incineration is assumed as the infrastructure is already in place in countries with high recovery/incineration rates. In general, newer Member States are more likely to increase their incineration capacity. A 3-7 year time period to commission and build an incinerator will almost be outside the projection scope. Little or no feedstock recycling is assumed, Chapters 2 and 3 show evidence of a 0.5-1% increase in feedstock recycling per annum for the packaging and ELV sectors only.

By 2015, our projection is for 1.8 Mt of plastic **C&D** waste. Article 11.2(b) of the Waste Directive 2008/98/EC states that "by 2020, the preparing for reuse, recycling and other material recovery, including backfilling operations using waste to substitute other materials, of non-hazardous construction and demolition waste excluding naturally occurring material defined in category 17 05 04 in the list of waste shall be increased to a minimum of 70% by weight." Analysis of construction and demolition waste completed in Wales on behalf of the Environment Agency, suggests that plastic makes up less than 1% if C&D waste.[223] Although comparatively small, recovery of this waste will be essential to ensure compliance with the target. It is assumed that incineration

[223] Environment Agency Wales (2006) *Building the Future 2005-06*, available at: http://publications.environment-agency.gov.uk/pdf/GEWA0308BNRR-e-e.pdf?lang=_e.

increases only slightly in the C&D sector. Recycling is assumed to reach 15-20% by 2015.

For **ELV** waste, about 74-80% of the total weight of a car is recoverable metal. Of the remainder, a maximum of 50% (13% of the total weight) is estimated to be polymers. Table 32 shows the expected polymer content of an ELV and the maximum available amounts for recovery.

The current EU average recycling rate for polymers from ELV is thought to be around 9%. Most Member States have not achieved a level of 20% recovery rate. This still leaves over 80% of the maximum recoverable amount of plastic still to be captured.

The ELV total recovery rate is projected to reach approximately 23% in 2015 and then grow at a slower rate to 2020.

Table 32: Estimated polymer content available for recovery from a car

	2005 car (made in 1992)		2015 car (made in 2002)	
	%	Kg	%	Kg
PP	31	26.04	42	44.63
PU	20	16.8	11	11.69
ABS	15	12.6	7	7.44
PVC	12	10.08	7	7.44
PA/PC	8	6.72	8	8.50
PE	7	5.88	12	12.75
Other	7	5.88	13	13.81
Total	100	84	100	106.26

It is projected that plastic waste from **WEEE** will reach 1.5 Mt by 2015, and 2.46 Mt by 2020. Again, an increase in the collection or recovery rates of plastic waste in WEEE is dependent on technology. The recovery rate of plastic waste in WEEE is estimated to be around 43.8%. In order to reach WEEE targets by 2015, more than 50% of available polymer from WEEE would need to be recycled. The recast of the Directive proposes a 65% collection rate of WEEE placed on the market in the preceding two years, equal to an 85% collection rate of WEEE arising. The priority is for reuse, followed by a high level of recycling and recovery to avoid loss of such a valuable resource. Producers are encouraged to integrate recycled material into new equipment.

In the **agriculture** sector, it remains unclear what effect voluntary recovery schemes will have. JRC IPTS (2007) has suggested recovery of agricultural plastic waste to be in the region of 0.5 Mt (440 kt) in 2015 – this figure is lower than that presented in Chapters 2 and 3 for 2008. The projections that have been completed for this chapter indicate recovery of agricultural plastics to be higher, amounting to around 0.7 Mt.

In considering the breakdown of plastic waste by type, JRC IPTS (2007) suggests a breakdown by polymer type for each sector, displayed graphically and in tabular format in Figure 5.2 below. In “Figure 60” below, numbers in brackets indicate JRC projections of plastic waste generated by sector. These figures should be discounted in the context of this report where alternative projections have been presented and the rationale explained.

Figure 5-2: Identification of prevalent polymers by waste stream[224]

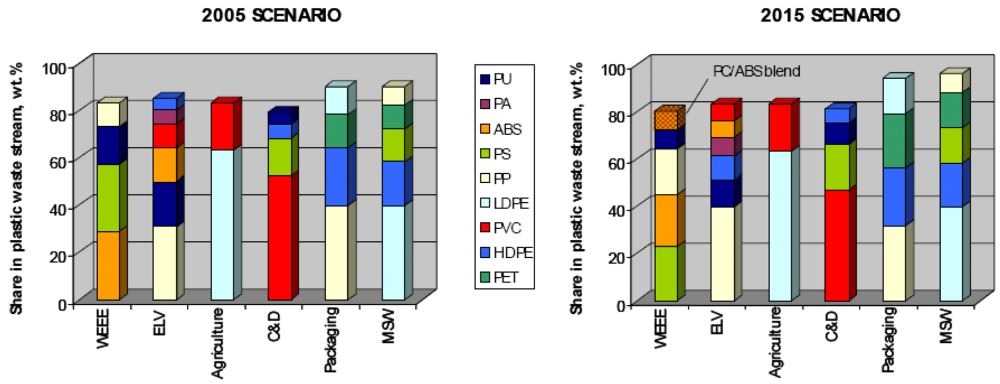


Figure 6: Identification of prevalent polymers (80 wt. % of total plastic content) in each waste stream

Figure 60. Summary charts of most common polymers in waste streams

Current scenario collectable waste arisings (wt.% in plastic waste streams)									
Waste stream	**PET**	**HDPE**	**PVC**	**LDPE**	**PP**	**PS**	**ABS**	**PA**	**PU**
WEEE (960 kt)					12-7	31-26	33-27		18-13
ELV (960 kt)		8-3	13-8		33-28		17-12	9-4	22-17
Agriculture (900 kt)			23-18	65-60					
C&D (810 kt)		9-4	55-50			19-14			8-3
Packaging (2500 kt)	17-12	25-20		18-13	40-35				
Residual MSW (17500 kt)	12-7	20-15		43-38	10-5	17-12			

2015 scenario collectable waste arisings (wt.% in plastic waste streams)									
Waste stream	**PET**	**HDPE**	**PVC**	**LDPE**	**PP**	**PS**	**ABS**	**PA**	**PU**
WEEE (2160 kt)					22-17	25-20	23-18		11-6
ELV (1500 kt)		12-7	10-5		43-38		10-5	11-6	13-8
Agriculture (1100 kt)			23-18	65-60					
C&D (1350 kt)		9-4	50-45			23-18			12-7
Packaging (5700 kt)	25-20	27-22		15-10	35-30				
Residual MSW (23000 kt)	17-12	20-15		43-38	10-5	17-12			

The exact extent to which **biodegradable plastics** and **recycled PET** will replace “traditional” plastics is not known. It is clear that demand for bioplastics is growing fast, as described in section 2.2.2. Whether this trend continues depends on a number of factors such as prices, the ability to replace functions of virgin or recycled plastics, regulations (e.g. packaging regulations), end-of-life options and public awareness.

[224] JRC IPTS (2007) *Assessment of the Environmental Advantages and Drawbacks of Existing and Emerging Polymers Recovery Processes*, European Commission.

EU recycled PET production capacity is currently estimated to be more than 0.1 Mtpa and is likely to increase significantly as more organisations become aware of the benefits of using recycled material over raw/virgin inputs.

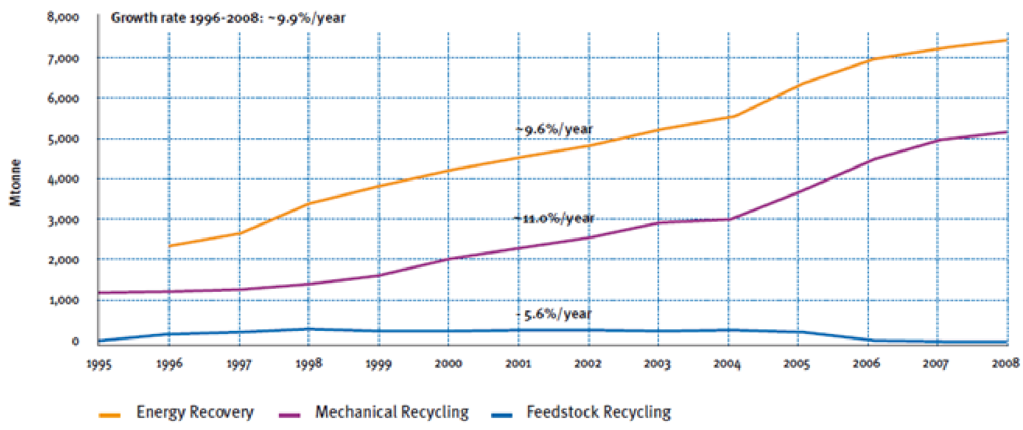
5.1.3. Recycling and energy recovery

Figures 5-3 and 5-4 track levels of plastics recycling (mechanical and feedstock) and energy recovery. The first figure sets out the trends based on data from 1995-2008. It shows the growth of both mechanical recycling and energy recovery. Plastics Europe, who developed Figure 5-3 originally, concluded that mechanical recycling increased by 4.3%, with a dip in 2008 associated with the financial crisis. Growth in energy recovery increased 3.6%. It was commented that more investment in energy recovery facilities is needed to divert streams which cannot be efficiently recycled from landfill.

Based on Figure 5-3, a projection was made to 2015 (Figure 5-4) based on the following assumptions:

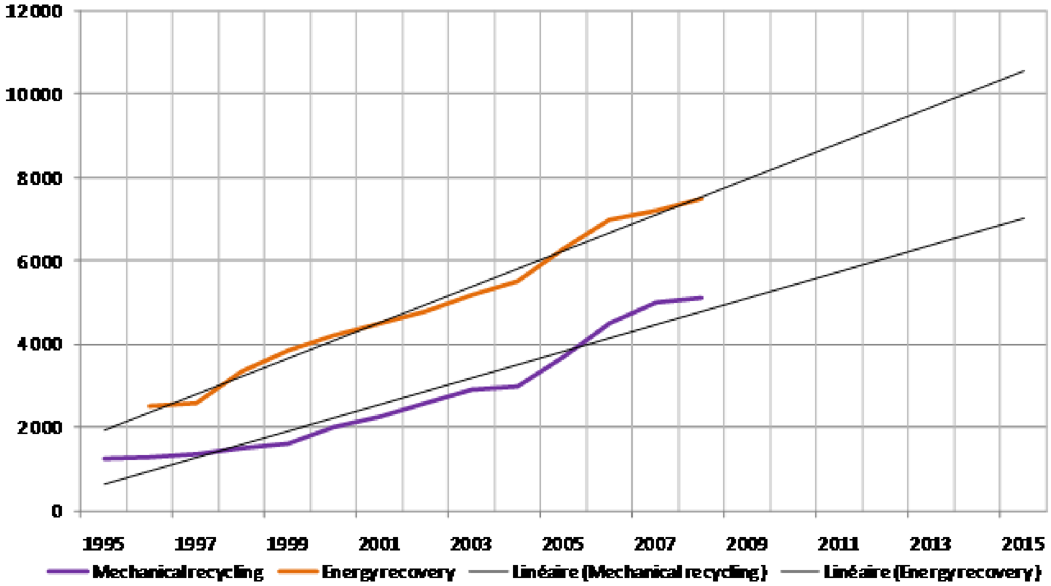
- that feedstock recycling will show no or little growth, in line with the lower growth trend seen since 2005; due to this low rate of increase, the trend line is not presented.
- that energy recovery will show a relatively low rate of increase in the period to 2015 given the 3-7 year time lag to commission and build an incinerator; therefore, one might anticipate a rise in these levels but primarily beyond 2015;
- that the highest rates of increase will be seen in the mechanical recycling sector; however, full exploitation of this (as highlighted in the Plastics Europe report) will depend on the rate of recovery from the financial crisis and levels of investment in collection and recovery infrastructure, in order to raise rates of recycling e.g. in the WEEE and agriculture sectors.

Figure 5-3: Recycling and energy recovery in the EU, Norway and Switzerland, 1995-2008 (Mt)[225]



[225] PlasticsEurope, EuPC, EuPR, EPRO and Consultic (2009) *The Compelling Facts about Plastics - An analysis of European plastics production, demand and recovery for 2008*.

Figure 5-4: Projected mechanical recycling and energy recovery in the EU, Norway and Switzerland, 1995-2015 (Mt)



5.1.4. PROJECTIONS TO 2020

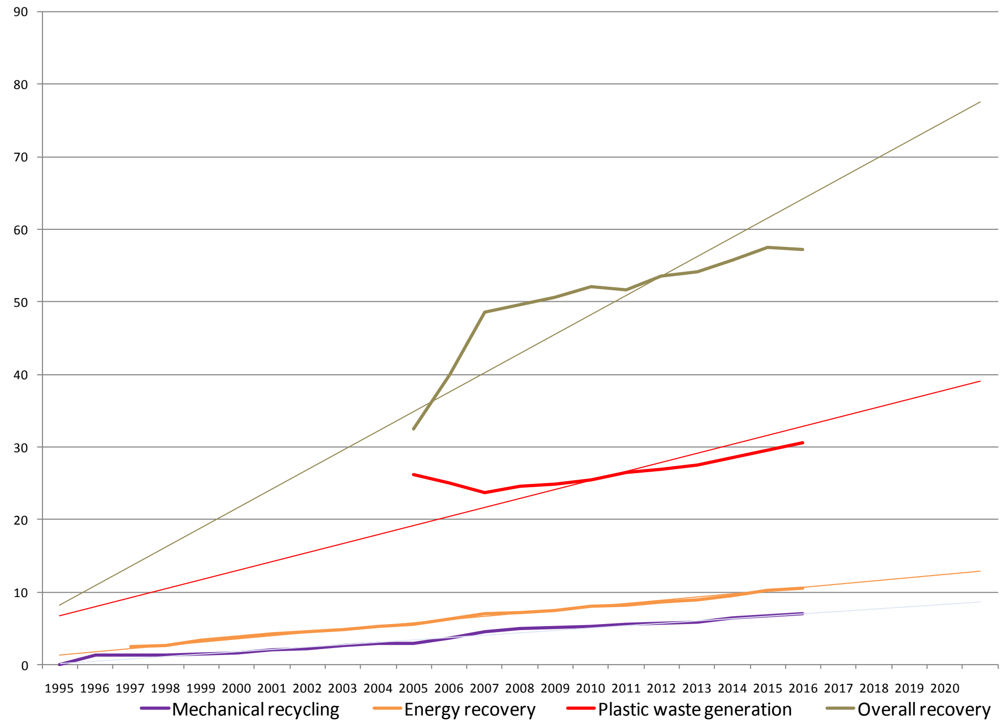
Based on the data collected in Chapters 2-4, it was not possible to make robust projections of plastic waste arisings by sector to 2020. Instead, based on the projections to 2015 and the assumptions on which those projections were based, an indication can be made of the total volume of plastic waste and the overall recovery/recycling rate by adding a trend line and projecting this to 2020.

It should be noted that this simply represents a continuation of existing trends identified to 2015 and does not take account, for example, of the potential bounce in energy recovery that might be seen between 2015 and 2020. Moreover it assumes continued investment in this sector to expand capacity in terms of collection and recycling abilities and that GDP continues to rise steadily following the recent crisis.

It can be assumed that the majority (thought to be as much as 60-65%) of plastic waste will be plastic packaging waste. Automotive, WEEE, agriculture and C&D waste would account for approximately 5-6% each. Other waste from sectors such as medical, furniture, etc. will make up the remainder.

It is not known exactly how the sectoral breakdown of plastic waste will change over time in line with changes in GDP, product production technologies, uptake of new materials such as biodegradable plastics or recycled PET, consumer behaviour and availability of resources.

Figure 5-5: Projected mechanical recycling, energy recovery and plastic waste generation (thousand Mt) and overall recovery (%), 1995-2020



5.1.5. NOTE ON PLASTIC WASTE PROJECTIONS

Although the projections were made at EU-27 level, there will be considerable variation across Member States due to differing economic and demographic trends, policy impacts, etc. Due to the complexity involved and the incompleteness of the available historical data, it was not possible to make projections at the individual Member State level.

The lack of frequent, consistent and reliable plastic waste data remains a serious obstacle to the projection of quantities of plastic waste by type. These waste generation projections are based on data from studies on plastic waste identified in earlier chapters, with additional analysis where appropriate to identify further trends and sector influences. The order of magnitude of these projections is very likely broadly correct but the details remain uncertain. Closer scrutiny is warranted and further research would be needed to improve the estimates and to establish the extent of regional variation in particular.

5.2. IMPACT EVALUATION

Based on the analysis presented in section 5.1 the following key trends were identified and are assumed to continue to 2015:

- the generation of waste plastics will increase;

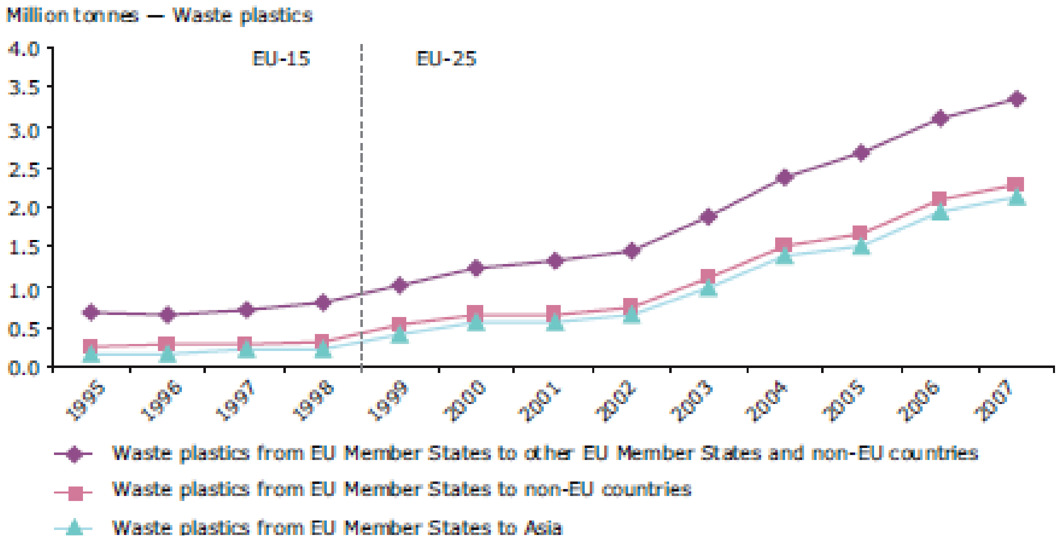
- levels of recycling, primarily mechanical, will increase;
- levels of energy recovery will increase but in a more limited way than recycling levels due to the lead times associated with plant development;
- proportional use of disposal will decrease;
- the most substantive changes in terms of volume will be seen in the treatment of packaging wastes. However, proportional changes will also occur in the other sectors analysed.

In addition to the trend analysis, the literature provides insights into other trends likely to influence the impacts associated with generation and management of plastic wastes to 2015. These are:

- as demonstrated in Figure 2.3, there will be a continuing upward trend in the demand for plastics;
- the level of exporting of waste, in particular plastic waste for recycling and recovery, looks set to increase as overall recycling levels and volumes increase – see Figure 5-6 below which shows the level of increase in exports of plastic waste among EU Member States and to third countries (particularly in Asia);
- the production of plastics will also tend to be dominated by the Asian market and particularly China;
- the production of bioplastics, while remaining a relatively low proportion of total plastic use, will increase rapidly. European Bioplastics anticipates a six-fold increase in production between 2007 and 2011 rising to an estimated production level of 1.463 Mt by 2013 (see section 2.1.5);
- incineration is set to increase, reducing the percentage of landfilling likely, and overall levels may decline looking at the trend lines on the graphs for generation, incineration and recycling combined.

It should be noted that there is insufficient information to discuss the likely impacts of individual sectors. However, waste generation of plastics is anticipated to rise in a proportionally significant way for all the sectors identified. This raises questions: firstly in relation to packaging waste and whether existing targets are sufficient to continue to address what is the most significant sector for plastic waste generation in Europe; and secondly, whether action should be taken to address sectors whose waste generation is not explicitly regulated at present, i.e. agriculture.

Figure 5-6: Waste plastics exported from EU Member States for treatment, 2007[226]



5.2.1. ENVIRONMENTAL IMPACTS

In terms of environmental impacts the following trends are considered to be of most significance:

- ***Rising use of plastics*** – The primary plastics feedstock will remain fossil fuels, despite the anticipated rapid rise in the production of bioplastics. This implies continued reliance on carbon-intensive production methods, with relatively high levels of embodied carbon and energy in the products. While traditional refineries might be driven to be more efficient over the projection period due to changes in rules surrounding for example the Fuel Quality Directive (which requires life cycle reductions in transport fuels), such efficiencies are likely to be offset by the increasing level of production and demand.
- ***Rising levels of plastic waste generation*** – This implies the need for an expanded waste management system simply to remain capable of dealing with the anticipated increase waste production.
- ***Increasing levels of recycling*** – Recycling rates are anticipated to increase over the outlook period and end markets are developing. However, the proportion of disposal is expected to remain significant. This implies a significant expansion in the overall Mt amount of waste recycled, i.e. a similar proportion of a greater quantity of waste will be recycled. This in turn implies three key evolutions in the plastic waste recycling business. Firstly, an expansion in the collection of plastic waste, secondly an expansion in processing capacity in Europe and thirdly an expansion in the use of secondary plastic materials.
- ***A post-2015 increase in energy recovery from plastic waste*** – As outlined in section 4.1, it is not anticipated that a major expansion in energy recovery from plastic waste will occur by 2015 due to the lead time in constructing new

[226] EEA (2009) *Waste without borders in the EU?*, EEA report, No. 1/2009.

plant. However, many Member States will be relying heavily on biomass as a source of renewable energy to meet their targets for 2020 under Directive 2009/28/EC. There might therefore be an increase in levels of energy recovery in the run up to this deadline, particularly in light of the fact that plastics have a relatively high calorific value when burnt. This has potential consequences for longer term balances between recycling and energy recovery and may require further promotion of effective infrastructure in order to continue to simultaneously boost both recycling and energy recovery in future.

- ***Increasing levels of export*** – At present the rising levels of recycling in terms of volume and proportion appear to also be driving an increase in the level of export of plastic waste for reprocessing. The export trend means that while environmental impacts within Europe might be reduced, Europe's contribution in terms of global environmental impact will rise, i.e. the environmental consequences of plastics use will be redistributed. Export to third countries implies reduced capability for European institutions to regulate the circumstances under which plastics are recycled. As demonstrated in Table 27, the associated local environmental consequences and epidemiological impacts associated with damage to local environmental media are higher for plastic bottles (both HDPE and PET) recycled in China than in the UK. This trend was observed for abiotic depletion, climate impacts in terms of CO_2-equivalent emissions, photo oxidation, eutrophication, acidification and freshwater toxicity.

Overall, the level of environmental impact associated with plastic waste is anticipated to increase over the period to 2015 due to continued growth in plastic waste production (associated with continued rises in plastic waste consumption). Over this period the rise in environmental impacts is anticipated to be comparatively slower than in the past as much of this increase in production is dealt with by recycling and energy recovery expansion. However, disposal levels are only anticipated to remain static or drop in a limited way, maintaining the overall picture of the environmental footprint.

More specifically, greenhouse gas emissions associated with the plastics life cycle are anticipated to increase, albeit on a lower trajectory than in the past, due to: expanded use of plastics; continued reliance on largely primary plastic materials; and continued dominance of petrochemical based plastic products. The tailing off in disposal of plastics is not anticipated to dramatically improve the greenhouse gas emissions picture, given that the majority of plastics currently on the market do not biodegrade (at least in the short term) in landfill situations. Negative consequences in terms of littering and plastic pollution in marine waters would also be anticipated to increase in the absence of any additional curbs on the management of plastic wastes and the overall picture of rising levels of waste production/plastic use.

The continued expansion of plastic exports is anticipated to expand the environmental footprint of the EU associated with plastic waste globally. Moreover, there are few controls in place to ensure environmentally responsible recycling activities are favoured during the transportation process. There is, therefore, the potential for an expanded level of environmental impact particularly in the Asian region via a process of offshoring of EU waste management.

It should be noted that the trends above assume an expansion in recycling capacity, which will require associated expansion in collection activities, use of secondary plastic materials and, associated with the latter, better methods for separating the different types of plastic to reduce contamination levels. These will allow the delivery of higher quality plastic waste streams to facilitate higher levels of recycling and to ensure quality markets for the secondary raw materials that result.

5.2.2. ECONOMIC IMPACTS

The main trends of interest in terms of economic impacts are anticipated to be the relative expansion of the recycling sector and questions regarding the economic impact of potentially lower economic growth on plastic waste treatment and secondary raw material use.

- ***The expanding recycling sector*** – The overall increase in the level of waste generation and the upward trend in recycling levels would suggest expansion in the recycling sector in order to collect, separate, treat and reprocess plastic waste. Figure 4-3 suggests an increase in the volume of material recycling from around 5.3 Mt to 6.9 Mt between 2008 and 2015 – an increase in volume of 30%. This should lead to employment opportunities in the relevant sectors, given the labour required: A recent study by Friends of the Earth estimates that recycling creates about ten times more jobs per tonne than sending waste to landfill or incineration.[227] The same study estimates that recycling has the potential to create over 500 000 jobs in the EU (direct and indirect) based on a 70% recycling rate, whereas the current target of 50% recycling of household waste by 2020 would lead to no overall increase in jobs because of a reduction in waste levels over the same period. However, the jobs created are likely to be split between the EU and third countries given the anticipated high levels of export for recycling. Moreover, while there might be a desire to label these jobs as "green" there is currently no way of identifying and promoting the best-performing recycling facilities from an environmental perspective. It should also be borne in mind that recycling has often been subsidised either directly or indirectly. There is therefore a question mark over the contribution of these jobs to developing the economy.
- ***Economics of virgin raw materials*** – The economic situation changed so substantially in 2008-2010 that it is unclear what the recovery trajectory will be in terms of the price of primary plastic materials. Current economic projections anticipate a lower growth path for EU economies over the

[227] Friends of the Earth (2010) *More jobs, less waste*. Available at: www.foe.co.uk/resource/reports/jobs_recycling.pdf.

coming years, due to the economic crisis. Thus, prices of primary raw materials may see more limited increases than previously anticipated in some projections. With potentially moderated consumption patterns in Europe, the price signals, e.g. cheaper oil prices, anticipated to drive plastics recycling may not be as strong as previously expected. Therefore additional measures might be needed in order to close recycling loops and promote use of secondary raw materials. The use of recyclates is known to be heavily dependent on demand, which is influenced by the price of virgin material as well as the quality of the recycled resin.

5.2.3. Social Impacts

The main social impacts are anticipated to be associated with: health and in particular the epidemiological impacts associated with treatment of waste in third countries; and the social perceptions around the continued use and increasing levels of plastic consumption and waste production.

- ***Health*** – There are potential health implications associated with plastic processing in Europe. However, these concerns increase when plastics are exported for treatment by third countries. For example, an analysis comparing the recycling of plastic bottles in the UK and China identified a significantly higher toxicity level for the China-based activities (see Table 27 and section 3.5.2.2 above). Reprocessing facilities in third countries are not necessarily worse in terms of their health and environmental performance than European plant but the issue is that there is little ability for the EU at present to identify to which plant materials are being sent and to what standards recycling is being completed. Moreover, there are also significant concerns about sorting processes in third countries that might rely less on mechanisation and more on separation by workers in unhealthy conditions. There is an increased risk in situations where workers have not been educated as to the health risks associated with their work.

  Given the anticipated rise in the overall levels of plastic waste being recycled and the continuation of trends towards the export of plastic waste for reprocessing there is a potentially increased level of health risk especially in third countries, assuming no further action is taken to evaluate and regulate such activities more effectively.[228]

- ***Perception of plastics*** – As we continue to expand the use of plastics, there are growing concerns among consumers regarding the associated implications. In many countries there is a desire to recycle materials rather than send these to landfill where there is already public awareness of the issues surrounding biodegradability. There is, however, relatively limited understanding among

[228] For a recent example of an initiative in this area, see Prakash, S. and A. Manhart (2010) *Socio-economic assessment and feasibility study on sustainable e-waste management in Ghana*, Öko-Institut.

the public regarding the multiplicity of different plastic types on the market place, the biodegradability of materials and what they should do with such materials or the recyclability of various plastics. Looking ahead to 2015 and given the expansion in plastic use one might assume that concern regarding the end of life of plastics will continue to rise. However, given limitations in terms of recycling technologies and uncertainty about how best they can help improve environmental performance this might lead to inappropriate actions or limited action on the part of the public unless there are further efforts to deliver guidance on how best to deal with plastic waste.

The primary social issue of concern is that of the potential for expanded health impacts associated with increasing levels of export of waste to third countries. In the absence of a better system for oversight over the end of life of exported EU waste there is a significant risk associated with this. A more limited impact of the expansion in plastics use and concerns over waste impacts is likely to be an increase in public desire to address the question of plastics. However, unless further information is provided to the public about how to make the best environmental decisions there is a risk of disillusionment and lack of effective action.

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6. POLICY OPTIONS

This chapter focuses on developing possible policy measures to be taken at various levels (EU, national, regional, local) to reduce any impacts of plastic waste, taking into account the waste hierarchy described in Article 4 of the WFD: prevention; preparing for reuse; recycling; other recovery, e.g. energy recovery; and disposal.

Five EU-level policy options will be established for reducing the environmental impact of plastic waste, focusing on actions that should be taken immediately, so that significant improvements to the baseline can be made. Three policy options will be selected that best support the most efficient practices, actions and initiatives operating at other administrative levels. The selection will include a wide range of policymaking tools, including administrative provisions, to communicate to policymakers the breadth of strategies available.

6.1. DEFINITION OF FIVE POLICY OPTIONS

The objective of this section is to identify policy options that could potentially reduce the environmental impact of plastic waste, focusing on actions that should be taken immediately, so that significant improvements to the baseline can be made. An initial list of five potential policy options is presented, with particular emphasis placed on developing policy options that include preventive measures (i.e. voluntary agreements with retailers, etc.) and options that minimise administrative burden. As will be discussed later in the report, these policy options are neither mutually exclusive nor exhaustive: apart from the policy options suggested and assessed in this chapter, there may be additional tools which would successfully contribute to more sustainable plastic use. For example, further efforts at national or local levels in the area of consumer behaviour and awareness might bear fruits.

6.1.1. OPTION 1: SUSTAINABLE PACKAGING GUIDELINES

- **Overview**

The objective of this policy option is to provide plastic packaging consumers (retailers in particular) with a standardised methodology for using plastic packaging in a way that minimises the combined environmental impacts of products and their packaging and for better management of plastic packaging waste.

- **Rationale**

  - Previous sections of this study have shown that plastic packaging not only makes up the largest share of plastic consumption, it also accounts for the largest fraction of plastic waste generated (63% of the total).

- Although the introduction of extended producer responsibility for packaging producers (via the EU Packaging Waste Directive) put the obligation to extend the life cycles of packaging items on the producer, the involvement of retailers may drive not only a reduction in plastic consumption but an increase in recycling and recovery rates through active collaboration.
- Similar instruments are often applied to all types of packaging. Under these systems, plastic packaging consumption may in fact increase. For example, plastic may be chosen instead of glass for beverages as it is often lighter and takes up less space. In those situations, plastic would have a lower environmental impact for some indicators during the production and transportation phases.
- Consumers and retailers have a significant influence on producers of plastic packaging. If demand were to increase for more sustainable plastic packaging items, producers might be incentivised to respond to these changing needs with less need for administrative involvement.

Core elements of the policy

- Voluntary initiative;
- A system by which retailers may measure the sustainability of their plastic packaging would be developed, centring on the reduction of the overall environmental impact associated with the package and its contents, the inclusion of alternative materials (e.g. multilayer films that may reduce recyclability but also reduce overall environmental impact) and allowing recovery rates to be increased more easily;
- Introduce best-practice guidelines and best-available techniques for plastic packaging producers, linked to the above system and emphasising use of plastic packaging in a way that minimises overall environmental impacts, rather than recycling alone;
- An independent labelling system may be warranted, in order to provide feedback to consumers who are interested in reducing their individual ecological footprints. Standards for these labels should be carefully designed to avoid placing an excessive burden on manufacturers and retailers, and to provide accurate and useful information to consumers. In particular, there is a lack of standards for bioplastics. It is as important to make sure standards are correctly used and understood as it is to put them in place;
- A programme or campaign of public awareness and education that would cover plastics in general and differences between the main types of plastics. The information disseminated would include basic information regarding definitions, life-cycle impacts and disposal of various types of plastic (notably biodegradable and bio-based plastics).

- **Existing framework or examples**

A multi-stakeholder platform called the Retail Forum has been set up in the context of the SCP Action Plan[229]. The Retail Forum aims to promote exchange of best practices and identification of opportunities and barriers in the area of sustainability. And in the European food sector, the European Food SCP Roundtable has been set up. Among its activities, working groups have been set up to develop an ambitious environmental assessment methodology and to promote ambitious continuous environmental improvement at all stages of the food chain.[230]

The European Organisation for Packaging and the Environment (EUROPEN) is developing a common framework and measurement system that trading partners can use to help them make better decisions about packaging and sustainability. This scheme proposes a universal measure of sustainability for packaging design. Although the ultimate aim of the initiative is to influence retailers in their choice of packaging materials and their design, it covers several different types of packaging rather than just plastics. Such an initiative may provide a framework for the one presented here, but it may also overlap with any new initiative. Some effort will be required to ensure there is as little negative overlap as possible between this and similar global packaging design initiatives. Opportunities to collaborate and integrate sustainable plastic packaging design principles within other schemes should be considered at all stages.

CEN has developed several packaging waste standards in support of the Directive on Packaging and Packaging Waste.[231]

An existing initiative in the area of plastics is the European PET Bottle Platform. The Platform brings together recyclers, industry, resin producers and collectors. The aim is to assess the recyclability of new materials on the market and several test procedures have been developed.[232]

6.1.2. Option 2: Agricultural plastic recovery and recycling guidelines

- **Overview**

This policy would aim to introduce best-practice guidelines for the preparation, collection and recovery of agricultural waste plastics, and ultimately provide targets for the recycling and recovery of agricultural plastics.

- **Rationale**

    - The agriculture sector currently generates 5% of European plastic waste, similar to the levels of both WEEE and automotive plastic waste.

[229] See http://ec.europa.eu/environment/industry/retail/index_en.htm.

[230] See www.food-scp.eu.

[231] See www.cen.eu/cen/Sectors/Sectors/TransportAndPackaging/Packaging/Pages/PPW.aspx.

[232] See www.petbottleplatform.eu.

- Currently, there is no specific EU legislation, voluntary or mandatory, that focuses on the management of agricultural plastic recovery and recycling despite its large share of plastic waste generation.

- **Core elements of the policy**
  - Voluntary initiative;
  - Provide guidelines for farmers for the adequate preparation of plastics for collection as well as alternatives for the reduction of plastics used in agricultural activities;
  - Provide best practice guidelines for collection and recovery of agricultural plastic wastes;
  - Establish a central entity responsible for organising an EU-wide network of approved collectors and reprocessors that will manage the recovery and recycling of agricultural waste plastics;
  - Set targets for the collection of agricultural plastic waste, focusing particularly on plastics with a high rate of recyclability and which make up a large fraction of the market (in cases where energy recovery may be the only viable treatment option);
  - As smaller collection schemes are already in place in some Member States (see example below), this measure should include the identification of existing networks, followed by the provision of support to expand collection.

- **Existing framework or examples**

Some initiatives are in place at national level in some Member States. In the UK, for example, the Agricultural Waste Plastics Collection and Recovery Programme provides an example of an initiative already in place at the Member State level. The objective of the Programme is to identify best practice for the cost effective collection and recovery of agricultural waste plastics. The Programme aims to assist in the development of a Producer Responsibility scheme in the UK for non-packaging farm plastics that might ultimately encourage the majority of all farm plastics to be collected and recovered. These goals will be achieved through completion of a number of activities, including: research into current collectors and reprocessors of farm plastics, trials to increase UK collection coverage and sustainability and the development of Good Practice Guides for farmers and collectors. Under the current proposal, a target for collection would be set to recycle 80% of waste non-packaging agricultural plastics within four years, compared with around 20% today.[233]

A similar approach could perhaps be extended to the rest of the EU, beginning with the investigation of the feasibility of setting targets for the recovery and recycling of agricultural plastic waste (both packaging and non-packaging), as well as establishing

[233] Non-packaging agricultural plastics include bale twine, plant jackets, greenhouse film, horticultural cover, mulch film and silage wrap. See www.defra.gov.uk/corporate/consult/agri-plastics/index.htm.

best practices for farmers to increase collection. An existing project in this area is LabelAgriWaste.[234]

6.1.3. Option 3: WEEE and automotive plastic waste targets

- **Overview**

This initiative would set specific targets for the recovery of the plastic fraction of WEEE and automotive plastic wastes.

- **Rationale**

  - Together, WEEE and automotive plastic waste account for 10% of the plastic waste generated in Europe.
  - Plastics make up an important part of both these existing waste streams and their use is likely to continue to grow (e.g. the increased use of plastic composites).
  - The legislative framework for increasing the recovery of WEEE and automotive waste already exists, although no specific targets exist specifically for plastics (nor for other materials; targets are for weight only).

- **Core elements of the policy**

  - Mandatory initiative in the form of an amendment to the Directives on WEEE and ELV;
  - Specific guidelines should be included to specifically define what is considered recovery;
  - In the case of WEEE waste, the specific inclusion of targets will need to be closely related to the design and thus dependent on the specific inclusion of plastics in the design considerations governed by the Ecodesign Directive.

- **Existing framework or examples**

See the Introduction for details of the ELV and WEEE Directives (Chapter 1).

6.1.4. Option 4: Recycled plastics and bioplastics phased targets

- **Overview**

This initiative would set targets for the increased inclusion of recycled plastics and bioplastics in place of some types of virgin petroplastics, taking into account design viability, environmental impacts and market feasibility.

[234] See http://labelagriwaste.aua.gr/law/Welcome.do;jsessionid=E9D878CC3FA6A7A580BC027C87B207E1.

- **Rationale**

  - Despite increasing rates of collection, the use of recycled plastics in products remains relatively low. Incentives would be required to raise the content of recycled plastics, either on their own or in conjunction with virgin plastics where viable. Although setting targets can lead to increased collection rates, this does not always equate to increased use of recycled materials in end products.
  - There has been extensive investigation into the impacts of recycled plastic use in comparison to virgin plastic use, which confirms that the substitution of the latter leads to lowering the impacts of production, including the reduction of resource consumption.
  - As recycling and recovery is not always a viable waste management option, increasing the use of biodegradable plastics in place of petroleum-based plastics may reduce the environmental burden related to landfilling plastic waste (though this has not been demonstrated conclusively since, for example, additional methane emissions would result).
  - In relation to some indicators, bioplastics have a lower long-term impact on global ecosystems. However, the full life-cycle impacts of bioplastics are still an important topic of research.

- **Core elements of the policy**

  - Mandatory policy;
  - Targets should be aimed at those plastic types which can:
    - be viably replaced by bioplastics,
    - suffer from low recovery and recycling targets;
  - In order to maximise its effectiveness, this option could be combined with a labelling system (as discussed in Option 1) and initiatives to increase public awareness and education about different types of plastics. The information disseminated would be aimed at helping consumers to make more sustainable choices when using and disposing of various types of recycled plastics and bioplastics.

- **Existing framework or examples**

No mandatory or voluntary schemes have been identified.

6.1.5. Option 5: Research innovation on the reduction of plastic waste

Overview

The initiative would aim to consider the most significant and viable measures for the reduction of plastic use in the design of different products.

Rationale

- Although the collection and recovery of certain types of plastics is already considered for some types of plastics, due to the variability of their design and properties, not all plastics can be adequately recovered or recycled;
- Plastics with a longer design life (e.g. construction and demolition) are much more difficult to track and recover in a targeted way, although they must also be managed. Such an initiative may help reduce the consumption of these plastics by finding viable alternatives.

Core elements of the policy

- Voluntary initiative;
- Although no specific targets may be provided, guidelines of best practices or best-available techniques (e.g. Best Available Techniques Reference Documents (BREFs)) should be developed;
- The results of this initiative should go towards informing policy makers and perhaps the integration of some measures into existing policy instruments (e.g. the Ecodesign Directive).

Existing framework or examples

No mandatory or voluntary schemes have been identified.

6.2. PROS AND CONS OF THE OPTIONS

This section analyses the effectiveness of each of the five options identified in the previous section. Environmental, social and economic impacts are identified below, along with consideration of the advantages and disadvantages of different options.

6.2.1. Option 1: Sustainable packaging guidelines

6.2.1.1 Plastic waste reduction

The goal of this policy option is to reduce the use of plastic in retail packaging, as part of a broader product sustainability strategy. This stream currently accounts for 38% of plastic demand and 63% of plastic waste generated.

Taking action to reduce the weight of packaging can lead to an overall reduction of plastics use. Between 1997 and 2007, it was estimated that the average weight of packaging decreased by approximately 28%.[235] Increasing or continuing this trend could result in a reduction of plastic packaging waste. Other options such as substitution can also result in overall reduction of plastic waste. As the guidelines could provide several different measures of sustainability, it would be difficult to determine the degree to which packaging waste reduction can be reached.

6.2.1.2 Environmental impacts

Note that not using plastic packaging at all is not always the most sustainable option from an overall resource perspective. A product (which itself has a carbon footprint) protected by plastic might otherwise go to waste. A case-by-case approach would be ideal, comparing the environmental impacts of plastic packaging to the environmental impacts of other types of packaging.

In general however, reduced production of plastic packaging should result in lower greenhouse gas and other emissions to air from manufacturing practices. In addition, if measures to reduce the weight of plastic packaging are strengthened, the reduced weight may also have an effect on emissions from transportation, although this may have a much smaller effect.[236]

Design measures such as using uniform types of plastics for different components of a plastic packaging product (e.g. producing bottles and caps using the same type of plastic or designing so as to make plastic parts easily separable) could result in the lowering of environmental impacts during later life-cycle stages. This should promote recycling of these products at the end of their life cycle and ensure a higher quality recycled product. It is not clear whether this measure would result in the increased substitution of virgin materials by recycled materials but if successful this option could lead to a reduction of environmental impacts.

6.2.1.3 Economic impacts

Costs may be incurred by private retailers and plastic packaging producers. It is uncertain, however, whether altering the design of packaging products will require increased investment in technology so that those products fit their intended purpose to the same level.

As this is a voluntary measure, public costs may be reduced, though investment will still be required to put together a central team to develop the system by which retailers may measure the sustainability of their plastic packaging.

Due to its voluntary nature, auditing may not be a strict necessity but it may be required initially to determine the progress of the measure.

[235] EuPC (2007) *Plastics: the material for the 21st century*.

[236] Fellows P. (2008) *Packaging Materials for Foods*, Practical Action.

6.2.1.4 Social impacts

This type of scheme may put pressure on plastic packaging producers to change their practices. If retailers aim towards a high level of sustainability for their plastic packaging, this could alter the infrastructure and practices on the production side, which could have an impact on employment (although not necessarily negative).

Increased investment in innovation may lead to the creation of employment for those in the research industry, as producers look towards more sustainable materials and improvements in the design of their products that meet the requirements of retailers for their packaging.

6.2.2. Option 2: Agricultural plastic recovery and recycling guidelines

6.2.2.1 Plastic waste reduction

Although not directly reducing the amount of plastic waste produced, this measure could result in the increased recycling of agricultural plastic waste, thereby diverting this type of waste from landfill, and potentially, other disposal methods such as incineration.

6.2.2.2 Environmental impacts

The increased provision of recycled plastic material could lead to the reduced consumption of virgin materials. As shown in previous sections, however, the use of recycled materials can be quite low for certain types of plastics. This may be more significant in the case of agricultural plastics which are often contaminated by organic matter, which may reduce the quality of the final recycled product. Considering the volatile nature of the recycled plastics market, it is difficult to determine whether significant mitigation of resource depletion could be achieved.

6.2.2.3 Economic impacts

Some costs will be incurred by public authorities who will need to establish, organise, monitor and maintain collection systems for agricultural plastic waste.

If targets are to be set, compliance in Member States will have to be monitored, which will result in costs to both the national authority and the EC.

The logistics may be important in this case since farming takes place far from urban areas and therefore potential collection or drop-off systems have to be studied and designed appropriately in order to avoid adverse effects from, for example, increased transport.

6.2.2.4 Social impacts

Increasing the collection of agricultural plastics may help create employment locally for those who would be involved in the collection, and potentially separation, sorting and processing of such plastics.

In relation to human health (in particular, those handling these materials) contaminants would need to be dealt with and monitored as organic material and other dangerous matter may be hazardous to workers' health if they have not been adequately trained to handle this material, or have not been provided with the necessary safety equipment.

6.2.3. Option 3: WEEE and automotive plastic waste targets

6.2.3.1 Plastic waste reduction

This option has the potential to reduce the amount of plastic waste in the environment. However, a review of the language in the Directive may be required to determine whether incineration of plastic composites for use in cement production is in fact considered disposal, or recovery. If the latter is the case, the amount of plastic waste reduction may be relatively higher. One of the main challenges of this option would be to determine feasible targets for what is often a small share of each respective product's composition. The plastic content can vary significantly, depending on the product – it may be difficult to determine a universal figure for such an array of different product. This challenge might affect the success of such an option, and this may have an effect of the actual overall reduction of plastic waste.

6.2.3.2 Environmental impacts

The increasing recycling and recovery targets for this type of material may lead to the reduced consumption of virgin materials and fossil fuels. As in previous sections, however, the use of recycled materials can be quite low for certain types of plastics. Contamination may be a concern, as it impacts on the quality of the recyclate or recycled product, which could affect the product's marketability. If recycling increases, but the use of recycled material does not, the environmental benefits of this option could, in fact, be lower in the long term. Considering the volatile nature of the recycled plastics market, it is difficult to determine whether significant mitigation of resource depletion could be achieved.

6.2.3.3 Economic impacts

Although collection systems already exist for these materials, the technology required to extract and recycle plastics in automotive and EEE products may require initial investment on the part of WEEE and ELV reprocessors. As collection systems are already in place for these products, no additional investment may be needed. Some costs may require public investment, depending on which group is responsible for organising audits to the system.

Complications with contamination of plastic material may be a barrier to the success of this option. Plastics in automotive and EEE products often consist of composites, for which there is currently no commercially viable recycling technology, though composites may be used for the production of cement in kilns, providing a portion of the energy required for this process. Although targets can be set, the legislation must encourage the increase of collection and processing of these materials, without being too restrictive.

6.2.3.4 Social impacts

As the infrastructure for this type of scheme is largely already in existence, the social impacts may be negligible. In some cases, it may lead to job creation for those involved in the recycling business for these specific types of plastics. As discussed earlier, there may also be positive spillovers to working conditions in third countries.

6.2.4. Option 4: Recycled plastic and bioplastics phasing targets

6.2.4.1 Plastic waste reduction

This initiative may not directly reduce the amount of plastic used, but instead replace petroplastics with either degradable plastics or recycled material. Introducing targets that include the substitution of petroplastics by recycled plastic materials may provide an incentive for increasing recycling rates and reducing disposal. As the recycling of most biodegradable plastics is currently not viable, this type of plastic is still disposed of. However, due to their biodegradable nature, their presence in the environment is often short-lived in comparison to petroplastics.

6.2.4.2 Environmental impacts

It is assumed that increasing the market share of bioplastics and recycled plastic products can result in overall lower environmental impacts. However, it should be underlined that biodegradable plastics, like petroleum-based ones, and recycled plastics still need to be properly disposed of.

Also, in the case of bioplastics, the burden of intensifying crop production to supply demand could have detrimental effects on the environment, which may offset the overall benefits. Soil and water pollution, for example, may be exacerbated if increased crop growth involves greater biocide use.

The increased substitution of petroplastics may have a positive effect on the reduction of virgin plastics consumption, and thus result in lower consumption of crude oil for this purpose. However, in the case of bioplastics, resources required for the cultivation of crops may be needed in greater quantities. Furthermore, there is the worry that crops otherwise used for food, may be used instead for the production of bioplastics, putting stress on food resources.

6.2.4.3 Economic impacts

The increased use of bioplastics may have implications for the recycled plastics industry, as consumers may not be able to tell the difference between this and other types of plastics. This could potentially lead to the contamination of recycled plastics by bioplastics which affects the quality and physical integrity of the resulting material. Investment may need to be made to develop and distribute adequate sorting technology which could deal with this challenge.

Administrative costs may need to be dealt with at the Member State level if systems are to be introduced. Furthermore, the administrative burden may also be somewhat high as it will involve the creation of benchmarks (hence, further study may be necessary), drafting of new policy measures, and the monitoring of compliance in different Member States.

There may also be some cost incurred by the increase in collection systems, which may be needed to deal with the increased inflow of plastics for recycling.

6.2.4.4 Social impacts

As for any other innovative sector, the management and production of bioplastics can provide a new source of employment.

6.2.5. Option 5: Research innovation on the reduction of plastic waste

6.2.5.1 Plastic waste reduction

It is difficult to estimate the degree to which investment in innovation will aid the reduction of plastic waste. Research and investment efforts will facilitate best practices and potentially lead to the introduction of novel technology, which can work towards reducing the amount of plastic waste produced. Such efforts will most likely affect the production, use and end-of-life phases, which are critical for the generation of plastic waste.

6.2.5.2 Environmental impacts

One of the drivers of this type of option will be the reduction of environmental impacts, whether directly or indirectly, through better manufacturing practices, different product design and improved end-of-life management through innovation. Although difficult to measure, it is believed that such measures will contribute to an improved environmental footprint for the plastics sector.

6.2.5.3 Economic impacts

With this initiative, there is always the question of where funds may be sourced from. Whether private or public, funding will be necessary for this measure and the distribution of funds will also need to be considered. Initiatives such as LIFE can serve as examples for setting up such a fund. This could be extended to other projects that focus on improving resource efficiency and reducing waste generation.

6.2.5.4 Social impacts

Investment in research innovation could lead to increased availability of academic and employment opportunities, particularly within the EU. Improved waste management and manufacturing practices will also potentially have a knock-on effect on health as well as the environment. However, without defining the exact measures to be taken under this policy option it is not possible to estimate the magnitude of benefits or impacts.

Improved waste management and manufacturing practices will also potentially have a knock-on effect on health as well as the environment. However, without defining the exact measures to be taken under this policy option it is not possible to estimate the magnitude of benefits or impacts.

6.3. OPTIONS EVALUATION AND SELECTION OF THREE OPTIONS

This section evaluates the five plastic waste management options and provides the rationale for the selection of the three best options. A matrix of the results of the assessment completed in section 6.2 is provided in order to compare these impacts and provide the evidence to support the selection rationale in a clear format. This section provides data for the more detailed impact assessment in Chapter 7.

6.3.1. IMPACT MATRIX

6.3.1.1 Methodology

To determine the top three options, a matrix was constructed to compare their impacts as well as the feasibility of employing each one. The performance of a given impact category for each option was given a scoring of -3 to 3. A negative score corresponds to a negative impact, and a positive score corresponds to a positive impact.

Following the first step of scoring each option based on their impacts and the feasibility of implementation, it was necessary to add a weighting each impact category. The reason weighting has been employed is due to the significance of some impact categories in relation to others. For example, although cost is an important factor, it may not take precedence over environmental impacts and plastic waste reduction, which are the ultimate goals of each of these policy options. The categories have thus received higher weighting factors, by which their score has been multiplied (by four and two respectively). One of the aims of this study was to determine which options would also have lower administrative burden and high feasibility, thus this category has received a slightly higher weighting factor of 1.5. The results of the initial comparison without weighting factors included are presented in section 6.3.1.2.

It is worth noting that due to the qualitative nature of the analysis in the previous subsection, the results presented in the matrix can be somewhat subjective, although they have been determined by considering the impacts of each option in relation to the others.

6.3.1.2 Results

Based on the results shown in Table 33, it appears that Options 1, 2 and 3 are the most favourable, despite the latter two options having overall negative impacts (i.e. benefits). The main reason for this is due to the higher costs (public or private) and the economic and administrative burdens brought on by these options.

Table 33: Impact results matrix

		Option 1: Packaging	Option 2: Agriculture	Option 3: WEEE & automotive	Option 4: Recycled & bio	Option 5: Research innovation
Plastic waste reduction		1	2	1	2	1
Environment impacts	Emissions	2	1	1	1	1
	Resource depletion	2	2	2	2	2
Economic impacts	Direct private costs	-2	-1	-1	-2	-1
	Public costs	-0.5	-1	-2	-2	-2
	Compliance & admin. costs	-0.5	-2	-1	-2	-2
Social impacts	Changes in employment	2	2	1	2	3
	Health issues	0	-1	-1	-0.5	0
	Health & safety of workers	0	1	1	0.5	0
Feasibility	Economic burden	-2	-2	-2	-1	-3
	Admin. burden	-0.5	-2	-1	-3	-2
	TOTAL	3	-1	-2	-3	-3

To balance out the benefits of each option with their intended aims, it was necessary to add a weighting factor to more significant categories as described above. The results of this calibration are presented in Table 34.

Adding greater importance to the reduction of plastic waste and the overall environmental impacts has a significant influence on some of the performance results for each option. Here it appears that Options 1, 2 and 4 have the most promising results, especially due to their environmental benefits. In this matrix, Option 3 scores lower due to having a lower reduction potential in comparison to other options and a relatively higher administrative burden than Option 4. With weighting factors taken into consideration, all options score positively, though Option 5 scores lowest at a value of 0.5. This is mainly due to the fact that economic impacts and administrative burdens that are quite high due to the funding and organisation such a scheme would require both at the EU and Member State levels.

Table 34: Calibrated impact results matrix

		Weight	Option 1: Packaging	Option 2: Agri.	Option 3: WEEE & auto	Option 4: Recycled & bio	Option 5: Research
Plastic waste reduction		4	4.0	8.0	4.0	8.0	4.0
Environment impacts	Emissions	2	4.0	2.0	2.0	2.0	2.0
	Resource depletion		4.0	4.0	4.0	4.0	4,0
Economic impacts	Direct private costs	1	-2.0	-1.0	-1.0	-2.0	-1.0
	Public costs		-0.5	-1.0	-2.0	-2.0	-2.0
	Compliance & admin. costs		-0.5	-2.0	-1.0	-2.0	-2.0
Social impacts	Changes in employment	1	2.0	2.0	1.0	2.0	3.0
	Health issues		0	-1.0	-1.0	-0.5	0
	Health & safety of workers		0	1.0	1.0	0.5	0
Feasibility	Economic burden	1.5	-3.0	-3.0	-3.0	-1.5	-4.5
	Admin. burden		-0.8	-3.0	-1.5	-4.5	-3.0
TOTAL			**7.2**	**6.0**	2.5	**4.0**	0.5

6.3.2. Final options

Based on the results of the matrix, Options 1, 2 and 4 are deemed to be the most viable and least impacting. In order to carry out an analysis of the benefits and impacts of these measures, it is necessary to draw up some details for each one, particularly how they will affect the plastics market. Benchmarking is an essential aspect of Options 2 and 4.

6.3.2.1 Option 1: Sustainable packaging guidelines

Although difficult to quantify in an accurate manner, we assume that the trend towards increased use of recycled materials and reduction in plastic waste will continue. A reduction factor of 30% of plastic packaging material use has been estimated to 2015. In addition to this, a slight increase in plastic packaging recycling is also expected to increase by 20% over this time period.

6.3.2.2 Option 2: Agricultural plastic recovery and recycling guidelines

The targets for the collection of agricultural plastics have been based on existing or potential schemes, in particular the consultation study on introducing a producer responsibility scheme for waste non-packaging agricultural plastics in the UK[237] as described in section 5.1.2. For the purpose of testing the benefits and impacts of this option, a benchmark of 70% recovery has been determined, with a recycling target of 50% for LDPE plastics by 2015. LDPE has been selected due to its significant share (approximately 70%) of agricultural plastics, as well as its high level of recyclability.

6.3.2.3 Option 4: Recycled and bioplastics phasing targets

Without an in-depth investigation of the capacity and technical viability of the bioplastics and recycled plastics markets, it would be difficult to determine concrete benchmarks for the partial phasing out of virgin plastics with bioplastics and recycled plastic material. Further study into the technical and economical feasibility would be required to draft definitive benchmarks if deemed appropriate. However, based on the assumption that substitution is to a degree possible, a target of 10% inclusion of bioplastics and 15% inclusion of recycled plastics by 2025 has been determined.

It is important to note that these targets consist of an overall average across different sectors (e.g. plastic packaging, agricultural, etc), as well as the different types of plastics.

[237] See www.defra.gov.uk/corporate/consult/agri-plastics/npap-consultation-doc.pdf.

7. COMPARISON OF THREE POLICY OPTIONS TO THE BASELINE SCENARIO

This chapter compares the baseline scenario generated in Chapter 5 to the best improvement options selected in Chapter 6, using a pre-defined and transparent methodology, to assess the improvement potential of the three proposed policy options.

7.1. IMPACTS EVALUATION

Based on the results of the analysis of impacts in sections 5.2 and 6.2, three of the policy options are selected here for comparison with the 2015/2020 baseline scenario completed in Chapter 5.

The comparison aims to determine the extent to which these policy options can reduce the quantity of plastic waste compared to the baseline and highlight their advantages and disadvantages. The comparison explores the sensitivity of the projected impacts to changes in specific factors, assumptions and initiatives.

7.1.1. OPTION 1: SUSTAINABLE PACKAGING GUIDELINES

7.1.1.1 Qualitative assessment of the impacts

These guidelines would be intended to provide packaging consumers, specifically retailers, with better information and understanding as to how best to reduce the consumption of plastics and manage the resulting waste materials. The intention is that this would complement and support the delivery of existing packaging targets.

The table below summarises the potential positive and negative consequences associated with the adoption of such a policy approach. The action could result in positive outcomes, particularly in terms of increasing levels of recycling; reducing the overall quantities of plastic packaging, hence preventing waste and reducing use of virgin raw materials; and increasing the quality of recyclables, promoting better sorting and understanding of the different materials involved and potentially leading to better/more reliable sources of secondary materials and increased confidence in the use of such materials. The approach would offer flexibility for industry in terms of their implementation approach and potentially lead to a better environmental reputation of the retail sector and increased awareness concerning the management of this key area for packaging generation. The major challenge associated with this instrument is that its voluntary nature means that outcomes cannot be guaranteed and the lack of binding requirements means that other instruments would need to be put in place in order to promote adoption by the industry, i.e. labelling schemes so that compliance can be recognised or some alternative form of incentives associated with adoption.

Table 35: Summary of the potential pros and cons associated with the adoption of Option 1

	Potential positive consequences of adoption – pros	Potential negative consequences of adoption – cons
Environmental impacts	Addresses a priority area of plastics production and use, accounting for the highest proportion of plastic waste Directly acts to help reduce the level of plastic packaging waste, which has been seen to rise as a consequence of targets requiring the overall reduction in the volume of packaging waste Promotes the use of best practice techniques and approaches, potentially reducing the overall quantity of plastic waste but also improving the quality of waste streams and improving the viability of plastics recycling Potentially increases the proportion of recycling over disposal routes Promotion of higher quality recyclates should lead to better and more reliable secondary material streams, promoting industry confidence in the use of these products and potentially reducing use of virgin materials Potential increase in prevention activities, resulting in reduced use of virgin raw materials and emissions to land, air and water	Uncertainty as to the exact impact of the action – this is highly dependent on the level of uptake and ambition on the part of packaging consumers. As a consequence, unless properly supported this initiative is unlikely to result in the desired outcomes both in terms of prevention of waste, reduced use of virgin materials and improved recycling/secondary raw material flows Potential for confusion between plastic-specific goals and overall goals to reduce packaging waste
Economic impacts	Promotes change in the industry, supporting prevention including reuse activities and potentially a more effective/higher-quality recycling industry in Europe Promotes a more positive impact of the retail sector on a question of public concern	Understanding and demonstrating compliance will involve administrative costs both for industry and the public sector May require some form of incentive on the part of governments to support action or kick start adoption

	Potential positive consequences of adoption – pros	Potential negative consequences of adoption – cons
Social impacts	Increases public awareness regarding plastics and their impacts at the waste/end-of-life stage; there remains a significant gap in public understanding regarding appropriate actions to promote better plastic waste management Improves confidence that the question of plastic packaging is being addressed	Impacts are highly variable and in the event of poor delivery this could lead to resentment that industry is simply trying to create a smoke screen rather than adequately addressing the question of plastic waste Potential health implications in third countries if the quantity of plastic waste recycled were to increase, given that increasing quantities of plastic waste are exported for reprocessing
Policy cohesion	Raises awareness regarding the question of plastic waste generally and the consequences of pursuing packaging waste reduction goals that can lead to increased plastic use Complements the delivery of existing targets on packaging and the reduction in MSW under the WFD	There is a question as to the balancing of priorities and how the guidelines might interact with higher-level environmental goals to reduce the life-cycle impacts of packaging. Could result in further confusion regarding the appropriate course of action to be taken in order to secure the best environmental outcomes There are already industry initiatives underway aimed at this question; therefore, there is a question as to whether this might undermine their efforts or lead to resentment by industries who have tried to take a positive initiative
Implementation	Voluntary approach, providing flexibility in terms of adoption Could provide a better basis for monitoring and reporting on the impacts and generation of packaging waste	Impact in terms of reduction in plastic waste as a consequence of the action is likely to be highly variable – depending on the adoption of non-binding guidelines, industry support for the initiative and the type of incentives used to promote adoption Is likely to require complementary action in, e.g., the field of labelling to enable some form of recognition of those industry actors who have taken forward action in line with the guidelines

7.1.1.2 Quantitative assessment of the impacts

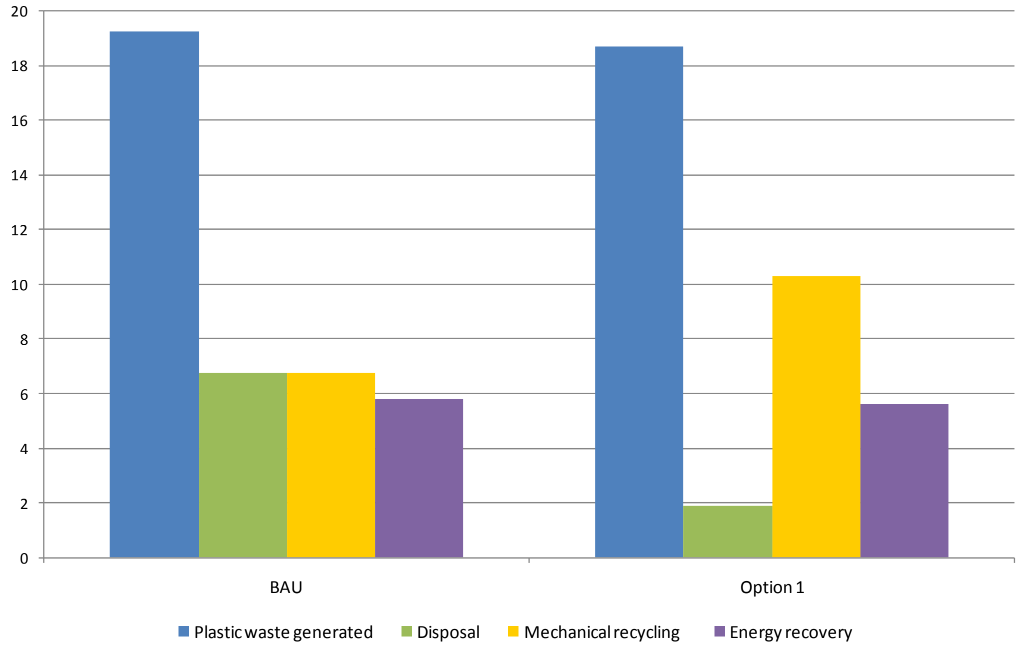
In order to provide a quantitative estimate of impacts, despite the potential high variability in the level of delivery, it is estimated that the guidelines might result in a reduction of 30% in plastic packaging material by 2015. In addition it is anticipated that plastic packaging recycling would also be expected to increase by 20% over this period – this represents an increase additional to existing estimates for 2015 based on business as usual (BAU).

The assessments of packaging waste under the BAU scenario have been revised to take account of this potential action. Table 37 presents the anticipated shift in plastic packaging waste generation and treatment as a consequence of Option 1. It should be noted that there is no 30% reduction in plastic waste generation as it is assumed that there isn't a 1:1 relationship between plastic use and waste generation.

Table 36: Packaging plastic waste generation and treatment under BAU and as a consequence of Option 1, 2015

		Generation (Mt)	Disposal	Mech. recycling	Feedstock recycling	Energy recovery	Total recovery
BAU 2015	Mt	19.27	6.74	6.74	0	5.78	12.53
	%		35%	35%	0%	30%	65%
Option 1 2015	Mt	18.69	1.87	10.28	0	5.61	15.89
	%		10%	55%	0%	30%	85%

Figure 7-1: Packaging plastics generation and recovery (Mt)



7.1.2. Option 2: Agricultural plastic recovery and recycling guidelines

7.1.2.1 Qualitative assessment of the impacts

Under this option, best practice guidelines would be implemented for the agriculture sector in order to address and better manage their plastic waste generation. While agriculture accounts for an estimated 5% of plastic waste, unlike for sectors producing waste to an equivalent scale, no direct mechanisms currently exist to promote prevention, reuse, recycling and recovery. Under this option, Member States would be encouraged to adopt guidelines for the better handling of plastic wastes in agriculture, its collection and potential targets for its recovery.

The key benefit of this approach is that it offers a flexible approach to dealing with plastic wastes generated by the agriculture sector, one of the significant sectors where there is currently no regulation to directly address this question. It also potentially supports the development of collection infrastructure in rural areas that might lead to the more effective management of waste more broadly in these regions. The guidelines should have a positive impact on the levels of recycling and recovery in this sector. However, the balance would be determined by how materials were treated following collection and would therefore be less within the control of the agriculture sector. Negative consequences might include a lack of clarity in terms of anticipated action and potential variability in approaches adopted in different Member States.

Table 37: Summary of the potential pros and cons associated with the adoption of Option 2

	Potential positive consequences of adoption – pros	Potential negative consequences of adoption – cons
Environmental impacts	Development of improved infrastructure for collection and recovery of plastics waste stimulated by additional demand in the agriculture sector Reduces levels of disposal of plastic waste from agriculture, limiting environmental consequences associated with waste treatment Increases the level of recycling and recovery, reducing the need for primary raw materials and the impacts associated with their generation	The actual level of delivery is uncertain given that this is a voluntary measure
Economic impacts	Potential generation of greener jobs in rural areas associated with collection and preparation for reuse/recycling	Potential administrative burden for farmers in terms of understanding how better to manage their waste and potential additional payments for collection of plastics Potential burden on state in terms of the setting up of systems for monitoring agricultural activities in relation to plastic waste generation and the costs of developing infrastructural arrangements
Social impacts	Increased awareness regarding the management of plastic waste	-

	Potential positive consequences of adoption – pros	Potential negative consequences of adoption – cons
Policy cohesion	Complements broader efforts to enhance environmental management in the agricultural sector Complements broader efforts to address the question of waste management and addresses a key area that is currently largely unregulated	-
Implementation	Voluntary nature allows flexibility to tailor to the variable agricultural conditions in different Member States	Lack of clarity as to whether Member States will apply approaches consistently, potentially leading to unbalanced burden being placed on agricultural production in the different Member States

7.1.2.2 Quantitative assessment of the impacts

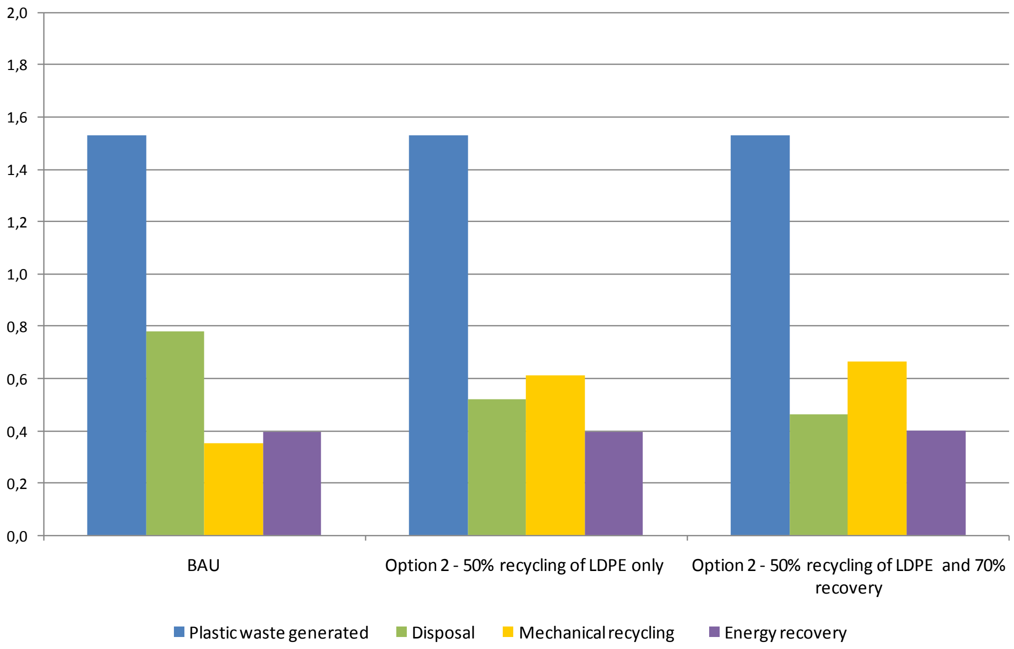
It is estimated that guidelines in this sector would lead to both an increase in recycling of particular appropriate polymers and also an increase in the overall level of recovery of agricultural waste. Values assigned for these changes are delivering 50% recycling of LDPE produced by agriculture and also achieving a 70% level of recovery for this sector – compared to the original BAU estimate of 49%. According to figures presented earlier in this report, LDPE represents the most significant polymer emerging from the agriculture sector, accounting for 71% of the plastics waste.

It should be noted that the agriculture sector represents only a limited source of plastic waste. However, under the BAU scenario the rate of increase was anticipated to be relatively substantial. Therefore this is an area of growth where little or no regulation currently exists. It is envisaged that were these guidelines to be put in place, the overall level of waste generation may not be altered substantially but at least increased recovery and recycling and the additional infrastructure that would be required in order to collect and support this would be stimulated. It could therefore set out a basis for additional future measures, where these are deemed necessary.

Table 38: Agriculture plastic waste generation and treatment under BAU and as a consequence of Option 2, 2015

		Generation	Disposal	Mech. recycling	Feedstock recycling	Energy recovery	Total recovery
BAU 2015	Mt	1.53	0.78	0.35	0	0.40	0.75
	%		51%	23%	0%	26%	49%
Option 2 2015 – 50% recycling of LDPE	Mt	1.53	0.52	0.61	0	0.40	1.01
	%		34%	40%	0%	26%	66%
Option 2 2015 – 50% recycling of LDPE and 70% recovery	Mt	1.53	0.47	0.67	0	0.40	1.07
	%		52%	9%	0%	39%	70%

Figure 7-2: Plastics generation and recovery in the agriculture sector (Mt)



7.1.3. Option 4: Recycled and bioplastics phasing targets

7.1.3.1 Qualitative assessment of the impacts

Under this option, specific targets would be set for the incorporation of bioplastics and recycling plastic materials into products, i.e. a product standard would be generated requiring a shift in plastic usage. The intention of this action is stimulate alternatives to traditional petrochemical-based plastics, reducing the demand for primary raw materials and also simultaneously reducing the reliance on oil as a source of plastic generation. This is intended to try and combat the relatively low levels of bioplastic and recycled plastic inclusion in products. Table 40 presents a summary of the anticipated impacts.

The obvious benefits of such targets would be that they would lead to a reduction in the use of primary raw materials and specifically the use of petrochemical-based plastics. They would also open up the prospect of innovation in this sector. However, the implementation of such targets would need to be associated with other supporting measures to raise awareness regarding the potential uses of bioplastics/recycled materials and their treatment at end-of-life by consumers. Otherwise there is a risk of imposing targets on industry that might lead to significant costs but without support in terms of delivery mechanisms. Moreover, there are risks of contamination between different plastic streams. In discussions in relation to the review of the Waste Thematic Strategy, stakeholders expressed concern over the broad application of targets for inclusion of certain levels of materials in products, feeling that this should be based on a more detailed assessment of how and when different targets might be appropriate.

Table 39: Summary of the potential pros and cons associated with the adoption of Option 4

	Potential positive consequences of adoption – pros	Potential negative consequences of adoption – cons
Environmental impacts	The measure would be anticipated to reduce the use of petrochemicals, thereby reducing the impacts associated with the refining and generation of plastic materials The overall demand for primary raw materials would be anticipated to fall compared to BAU, reducing environmental impacts proportionately Stimulates innovation in the fields of both recycled plastics and bioplastics	In the absence of an appropriate awareness-raising regime there is a risk of increased levels of contamination of plastic waste streams with bioplastics. Consumers need to be made fully aware of how to identify the different products and what the appropriate waste treatment option is. Depending on the conditions for the production of bioplastic feedstocks, this may lead to an increase in land-use pressures. Expansion of agricultural land area and production can impact soil quality, water and potentially biodiversity.
Economic impacts	Helps industry to reduce oil dependency Potential to stimulate new opportunities for business and alternative incomes for farmers Bioplastics and recycled plastics appear under BAU conditions to make limited progress in the market, so such an instrument would act as an incentive to deliver change in	Fails to address one of the key barriers to the use of secondary raw materials, i.e. the perceived inferior quality of these materials. Therefore, to support the targets there should be information campaigns to advise on best practices for using secondary plastic material and, additionally, measures put in place to support higher quality recycling activities to in turn deliver higher quality

	Potential positive consequences of adoption – pros	Potential negative consequences of adoption – cons
	these sectors	secondary materials. This is fundamental to ensuring that this measure does not adversely affect industry or the quality of the products produced
Social impacts	Increases awareness of the importance of closing the loop between waste generation, recycling and the use of secondary raw materials Increases awareness of the opportunities generated by the use of bioplastics Promotes public sentiment that the question of plastic waste is beginning to be dealt with and is of importance	-
Policy cohesion	Supports goals for the broader greening of packaging and plastics use under the packaging Directive and the WFD May aid the delivery of targets for the recycling of plastics under the WFD	-
Implementation	-	Requires further support measures such as information campaigns and an emphasis on the quality of recycling/secondary raw materials Industry representatives have expressed concerns regarding the blanket application of requirements for the inclusion of recycled material or materials into products. There is a feeling that any tool should be tailored to address the specific needs and opportunities in different sectors or risk having perverse consequences There are questions regarding the feasibility of the recycling of certain materials at present given issues associated with contamination.

7.1.3.2 Quantitative assessment of the impacts

Further assessment and analysis of the sector would be necessary in order to specify precise targets. However, for the purposes of this analysis it is assumed that the following targets would apply: that 10% of the plastics placed on the market are bioplastics; and that 15% of plastic materials placed on the market would be recycled by 2020.

In 2008, 48.5 Mt of plastic were estimated to be placed on the market in the EU resulting in 24.90 Mt of plastic waste. Under the BAU scenario, plastic waste is estimated to grow to 30.6 Mt by 2015, representing a rate of increase of 23% in seven years. Extrapolating this rate of increase to 2020, plastics waste would increase by an additional 16% to 34.6 Mt.

In 2008 there was a proportional relationship between plastic placed on the market and waste generated of 52%, i.e. plastics waste represented 52% of plastics placed on the market in that year. Based on this ratio it can be estimated that the BAU projection for plastic placed on the market in 2020 would be 66.5 Mt.

Based on this level of consumption of plastics, the proposed targets would assume the following quantities of bioplastics and recycled plastic being placed on the market in 2020: 6.5 Mt of bioplastics and 9.25 Mt of recycled plastics. Therefore they would be displacing 15.75 Mt of petrochemical-based plastics and the associated use of raw materials.

European Bioplastics estimates 1.463 Mt by 2013. The anticipated rate of market growth per year is 8-10%. Taking the lower estimate, this would amount to an increase between 2013 and 2020 of 0.82 Mt to reach a total of 2.28 Mt by 2020. If this were taken to represent BAU the proposed 10% target would deliver more than double the use of bioplastics by 2020.

Estimates from 2004 (see graph earlier in the report from the Association of Cities and Regions for Recycling) suggest that approximately 3% of plastics placed on the market was recycled.

7.2. METHODOLOGY FOR COMPARING OPTIONS

In the following sections, each of the options will be evaluated alongside others chosen in Chapter 6. Wherever possible, quantitative figures have been included to directly compare the benefits and impacts of each option. However, where this has not been possible, a qualitative analysis has been carried out to compare the options.

7.3. COMPARISON OF OPTIONS

7.3.1. WASTE REDUCTION AND RECOVERY POTENTIAL

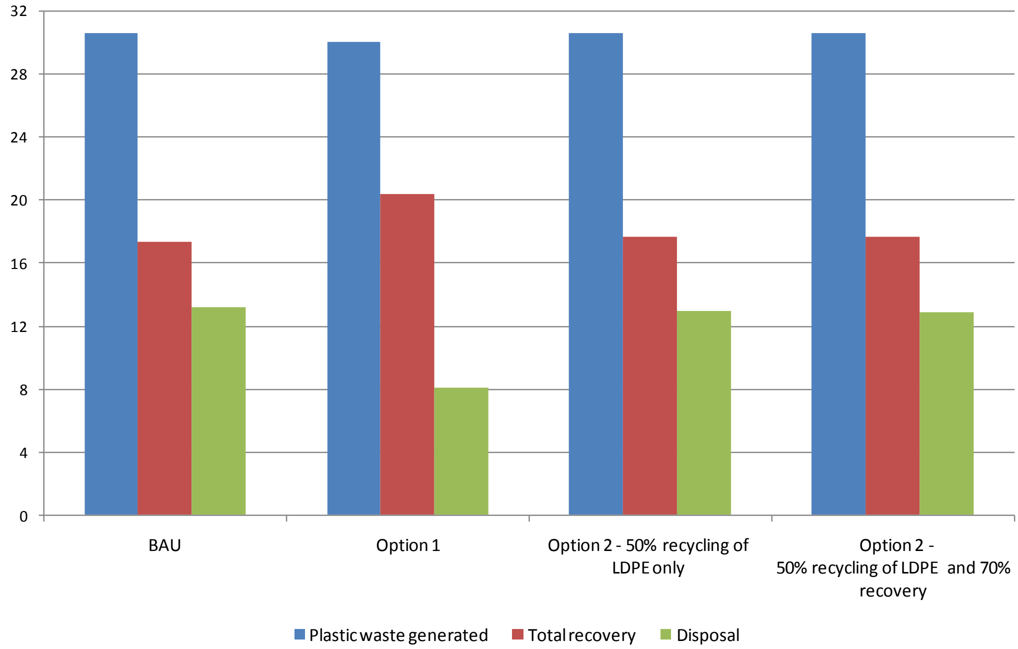
Two of the main goals of each policy option should be to reduce the amount of plastic waste generated and to increase the rate of waste recovery. Based on the figures calculated in section 7.1, it was only possible to directly compare the reduction and recovery potentials of Options 1 (Sustainable packaging guidelines) and 2 (Agricultural plastic recovery and recycling guidelines) in relation to BAU. Table 40 and Figure 7.3

show that of the two options, Option 1 appears to perform best in relation to the potential to both reduce waste and increase recovery.

Table 40: Calculated reduction and recovery potentials of different policy options

Option	Plastic waste generated	Disposal	Mechanical recycling	Energy recovery	Total recovery
Option 1	-1.9%	-38.8%	48.8%	-1.0%	17.4%
Option 2 - 50% recycling of LDPE only	0.0%	-2.0%	3.8%	0.0%	1.5%
Option 2 - 50% recycling of LDPE and 70% recovery	0.0%	-2.4%	4.5%	0.0%	1.8%

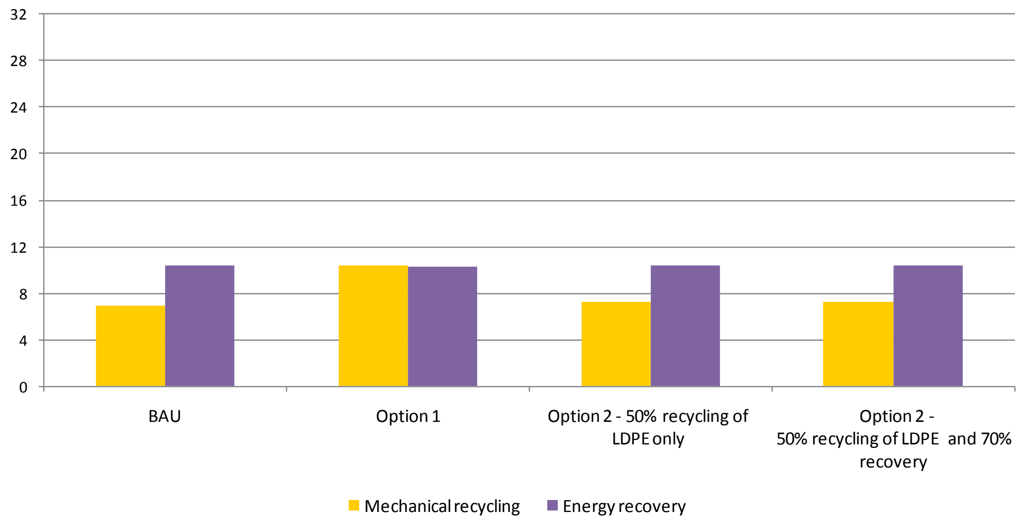
Figure 7-3: Waste generation and recovery potentials of policy options in relation to the BAU scenario (Mt)



Only Option 1 has the potential to reduce plastic waste generated – by 1.9%. Moreover, Option 1 has the potential to reduce disposal by up to 38.8%, which is much more than Option 2 which may result in only a 2-2.4% reduction in disposal. Total recovery is also much higher in the case of Option 1 than in either Option 2 case. In particular, mechanical recycling could be nearly 50% higher than in the base case.

The results imply that the Option 1 might have the greatest impact. However, this must be considered in the context of the materials being addressed, as each option focuses on a very different waste stream. Given the size of the plastic packaging sector, even low percentage reduction targets may have a greater effect than the same targets in other sectors that generate much less plastic waste.

Figure 7-4: Recycling potentials of policy options in relation to the BAU scenario (Mt)



So far the analysis has focused on the introduction of Options 1 and 2 and little has been discussed in relation to Option 4, due mainly to the different target dates for this option. However, it is possible to estimate the effect that displacement of petroplastics could have on plastics disposal if biodegradable plastics were to be introduced. With a target of 10% displacement by bioplastics, it is estimated that disposal can be reduced to as much as much as 56.5% below BAU levels (from 14.95 Mt to 8.45 Mt) (Table 41), assuming bioplastics here consist only of the biodegradable kind.

It is important to note that this assumption does not consider possible impacts of bioplastics on the environment and human health, focusing only on the quantitative reduction potential. It is also important to note that in this case, recycled plastics may not have such a significant effect on the reduction of plastic waste and recovery. This type of waste must be dealt with through the same waste management schemes used for virgin petroplastics and thus their end of life is assumed to be the same or similar. Recycled plastics do, however, have an effect on the consumption of petroplastics, thus having a greater effect at the production phase than the disposal phase. Therefore, although disposal drops significantly in this case, other waste management options are estimated to stay at similar levels (Table 41).

Table 41: Calculated reduction and recovery potentials of Option 4 (Mt)

Option	*Plastic waste generated*	*Disposal*	*Mechanical recycling*	*Energy recovery*	*Total recovery*
BAU	34.60	14.95	7.89	0	11.76
Option 4	34.60	8.45	7.89	0	11.76

7.3.2. SOCIO-ECONOMIC IMPACTS AND BENEFITS

7.3.2.1 Economic impacts

Determining the direct costs of each option is not possible at present due to the incompleteness of quantitative data in this area. Such calculations would also depend on the structure, responsible entity and implementation of each policy option.

In the case of Option 1, the cost of change would be dependent on retailer demand. Innovation may be funded by the need to remain competitive, so costs would most likely fall on the side of the producer. This could potentially have a knock-on effect of raising costs for consumers. However, these impacts could be buffered if increased sustainability were to result in a reduction of costs for producers in the long term.

In the case of both Options 1 and 2, if these instruments were to be modelled on extended producer responsibility, costs would have to be borne by plastic producers, although in the case of an increased need for infrastructure to deal with increased influx of recycled materials, as in the case of other EPR mechanisms, market forces driving the recycling capital may provide an incentive for increased capital investment in the sector, thus shifting the burden of cost on private entities.

In the case of Option 4, increased demand may also result in a greater amount of investment. However, the initial cost may be high considering the existing capacity of the bioplastics and recycled plastic industries. However, as targets for this option are defined for 2020, there is more time for the market to adjust to changes than for other options.

For both Options 2 and 4, the administrative burden is much higher than that of Option 1. Although this is not possible to quantify in direct terms, it can be assumed that the need to produce two or potentially three new policy instruments (as Option 4 may be split for bioplastics and recycled plastics) will result in more administrative effort than Option 1, which relies more on the voluntary actions of the private sector.

7.3.2.2 Employment

One of the areas that will potentially be most impacted by policy changes is employment. It is difficult to effect policy changes without having some impact on employment, whether positive or negative. In this case, all policy options will cause some change, but in different sectors and to a varying degrees. All options have the potential to increase green job opportunities, particularly where recovery potential is high. In the case of Option 1, the significant size of the packaging sector may mean that changes in this industry could result in a higher number of employment opportunities, in comparison with other options.

Both Options 1 and 2 will potentially affect employment in the recycling and overall recovery industry. It is difficult to identify a quantitative figure for employment in the recycling sector, especially in relation to specific waste streams. Waste management data collection is often not refined enough to classify employment information according to waste treatment types. However, it can be assumed that Option 1 in particular will have a more significant impact on employment in the plastics recycling industry, given the amount of plastic packaging waste generated, as well as the significant increase in overall recovery potential, as shown in section 7.3.1. However, the true impact of Option 1 will be highly dependent on the participation of key stakeholders (in particular, retailers, who are expected to drive this initiative) and therefore final results and impacts are very uncertain for this option.

The introduction of Options 1 or 3 could have a significant impact on employment opportunities in the plastics production industry. In 2007, it was estimated that the plastics production industry employs approximately 1.3 million people.[238] Although it is not possible to quantify the effect each option will have on this figure, given the magnitude of their petro-plastic reduction potential either one could have a significant effect on employment. In the case of Option 1, this effect may not be felt directly, as it would rely on the reaction of retailers to fuel changes in the industry; in relation to Option 4 however, although the proposed implementation targets stretch as late as 2020, the introduction of rigid targets can have a more definite impact on jobs. Increasing employment opportunities in the plastics recycling and bioplastics production sectors may result in lesser opportunities in the virgin petroplastics production industry. However, the gradual nature of the phasing out of virgin petroplastics may allow for adaptation in the industry, therefore absorbing impacts on employment in the long term.

7.4. SUMMARY OF POLICY ANALYSIS AND CONCLUSIONS

Although direct comparison of the three policy options is not always feasible, the analysis has shown that due to the size of the sector involved in Option 1, if successful this option is likely to have the most significant effect on plastic waste reduction and recovery, and consequently on the environment, employment and the economy. This will largely be dependent on the involvement of producers and retailers, which will drive the success of the instrument.

In the case of Option 2, although its impact may be small, the option deals with a distinct sector and a particular type of material (e.g. LDPE). Although this does facilitate the construction of a network for managing agricultural plastics, the inherent difficulties of collection in rural areas must also be taken into account.

The main effect of Option 4 is to reduce the amount of petroplastics sent to disposal with the ultimate goal of reducing the impacts tied to petroplastics production and disposal. Further study is required to determine whether the impacts of increased bioplastics production outweigh the benefits of the reduction of plastics at the end-of-life phase. In the case of increasing recycled plastics consumption, although the direct reduction potential is not certain, an increase in recycling at the expense of virgin plastics production would in fact have a definite positive impact of the environment.

[238] http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-BW-09-001-07/EN/KS-BW-09-001-07-EN.PDF

One aspect that must be considered is the potential to link these three options together. Considering that Options 1 and 2 address different sectors, and potentially rely on different instruments and methods of implementation, it is highly likely that these two options can be implemented in parallel at the EU level. Although plastic waste generation would still only see a modest 1.9% reduction, disposal could be reduced by as much as 41.2% and total recovery could be increased by 19.2%. However, the introduction of Option 4 would inevitably have an effect on the feasibility of Options 1 and 2, as the replacement of materials further upstream can affect the viability of product design (in the case of Option 1), and the recycling and recovery rate of certain materials (in the case of either option). It would potentially be possible to introduce all three policy instruments simultaneously, as for the most part they can work independently from each other, thus further increasing environmental and economic benefits.

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ANNEX A: ACKNOWLEDGEMENTS

The following organisations and individuals provided useful information for this report and we acknowledge their valued contribution.

- **Industry associations / Other organisations**

  EU - EPRO (European Association of Plastics Recycling and Recovery Organisations)

  EU - European Bioplastics

  EU - EuPC (European Plastics Converters)

  EU - EuPR (European Plastic Recyclers)

  EU - EUROPEN (European Organisation for Packaging and the Environment)

  EU - PlasticsEurope

  EU - ProEurope (Packaging Recovery Organisation Europe)

  Belgium - Bureau of International Recycling

  Finland - Finnish Plastics Recycling Ltd

  France - FEDEREC

  France - PAPREC

  France - Syndicat français des enducteurs, calandreurs et fabricants de revêtements de sols et murs (SFEC)

  Germany - Bundesverban Sekundarrohstoffe und entsorgung (BVSE)

  Hungary - Hulladékhasznosítók Országos Egyesulete (HOE)

  Ireland - Repak

  Ireland - Rx3 Market Development Programme for Waste Resources 2007-2011

  Italy - ASSORIMAP

  Norway - Grønt Punkt Norge AS ("Green Dot Norway plc")

  UK - British Plastics Federation, Recycling Council

- **Plastic recycling industry**

  France - Eco Emballages

  France - Golden Line Recycling

  France - Valorplast

  Netherlands - Morssinkhof Plastics b.v.

UK - Axion Recycling

- **National waste authorities**

Austria - Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft

Belgium - Environmental Inspectorate

Czech Republic - Environmental Inspectorate

Finland - Finnish Environment Institute

France - Ministry of Ecology, Sustainable Development and Town and Country Planning

Germany - Federal Ministry for the Environment

Germany - Umweltbundesamt

Hungary - Ministry of Environment

Ireland - Department of the Environment, Heritage and Local Government

Ireland - Environmental Protection Agency

Italy - Institute for Environmental Protection and Research

Luxembourg - Administration de l'environnement

Netherlands - Ministry of Housing, Spatial Planning and the Environment

Norway - Norwegian Pollution Control Authority (SFT)

Poland - Chief Inspectorate for Environmental Protection

Poland - Ministry of Environment

Portugal - IGAOT - Inspecção - Geral do Ambiente e do Ordenamento do Território

Sweden - Environmental Protection Agency

United Kingdom - Department for Environment, Food and Rural Affairs

United Kingdom - WRAP

- **Packaging industry**

EU - Brewers of Europe

EU - European Federation of Bottled Waters (EFBW)

France - Euro Pool System France

- **Academic experts**

  Tokyo University of Agriculture and Technology - Hideshige Takada

  University of Hamburg - Walter Kaminsky

  University of Plymouth - Richard Thompson

  University of Wisconsin-Superior - Lorena M. Rios