Options to improve the biodegradability requirements in the Packaging Directive

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Table of Contents

List of Tables

List of Figures

Report summary

Objectives

This report contributes to the impact assessment of policy options on the need for reinforcement of the requirements for biodegradability in Annex II of the Packaging Directive (Directive 94/62/EC) and improvement of the visibility of biodegradable packaging products for consumers. This analysis is part of a broader policy review of the Packaging Directive and takes into account the results of a stakeholder consultation on policy options related to plastic bags that was launched by the European Commission in May 2011. The study followed the Commission's Impact Assessment Guidelines in assessing the impacts of specific policy options.

The purpose of the report is to define the problem, develop a baseline scenario at the EU level and carry out a comparative analysis of selected policy options.

Context

With society's growing concern for sustainable consumption, production, and waste management, biodegradable packaging may appear as an environmentally friendly option and could rapidly become an attractive commercial feature. The scientific community has been developing new biodegradable products that could be used in packaging applications. As the market uptake and commercial success of biodegradable products relies on the understanding and proper functioning of the biodegradation process, well-defined normative instruments could help to contribute to a more transparent exchange of information between consumers, companies and public authorities.

The term "biodegradable" has to be carefully used when promoted by manufacturers or directed at consumers. In this respect, two issues may require precision:

- how the relevant concepts ("biodegradable", "compostable", etc.) are defined and understood from a technical perspective, with implications for manufacturers bringing certain products to market; and
- how the concepts are communicated to and understood by consumers, with implications for product labelling and consumer purchasing choices, product use, and end-of-life decisions.

Some Member States have implemented measures to reduce the use of non-biodegradable packaging. However, while existing EU policies provide strong drivers to make the EU a resource-efficient society, there is no legislation specifically targeting biodegradable packaging at the EU level.

Options analysed

This study analyses the following policy options and their relative costs and benefits from environmental, social, and economic perspectives:

- Baseline scenario (business as usual)

- Reinforcing existing requirements by making a clear distinction between compostability and biodegradability [P1a]
- Introducing a requirement for compostable packaging to be fit for biodegradation in natural conditions in the environment [P1b]
- Implementing a mandatory positive labelling or marking system for biodegradable and compostable packaging products (with the distinction between industrial composting and home composting) [P2a]
- Implementing a mandatory negative labelling or marking system for biodegradable and compostable packaging products (with the distinction between industrial composting and home composting) [P2b]

Quantifying the impacts

In order to estimate the environmental, economic, and social impacts of the policy options, it is necessary to estimate — with as much precision as is possible — what quantity of which material will find its way into which end-of-life treatment options.

To do this, a simplified model was created that starts with a breakdown of the market share of different types of packaging. The portions of the different types of the materials that are considered biodegradable and non-biodegradable (according to the definition in the Packaging Directive) are distinguished to allow a complete analysis of the policy options. Where the availability of data permitted, the same approach was used to estimate the impacts for each material and each end-of-life option.

Starting from the baseline scenario, the analysis of the impact of the policy options was accomplished by modifying the shares of the different packaging materials put on the market, the quantity of each material that will be treated in each of the different end-of-life options. In some cases, the impact indicators were modified as well, depending on the expected impact of the option.

These modifications have been based on hypotheses of the impacts of each option, which are, in turn, based on existing literature and input from experts. Where necessary and possible, these hypotheses were validated by relevant experts.

As a general principle of the analysis, the minimum number of variables was modified for each policy option, relative to the baseline. Only when there is clear justification has any modification been made.

Conclusions

The implementation of stricter requirements (policy options P1a and P1b) regarding biodegradability and compostability would result in many packaging producers not being able to comply with such standardisation. Many would not find it to be economically viable to enter such a market niche, even by 2020. The positive environmental impacts are mainly due to a part of the current biodegradable packaging being shifted to non-biodegradable packaging with the new requirements, resulting in environmental gains from recycling.

The implementation of labelling (positive P2a or negative P2b) will increase the consumption and production of biodegradable packaging products and contribute to the creation of jobs. However, it would also lead to higher packaging costs compared to the baseline scenario.

Biodegradable packaging has many positive aspects due to the possibility for disposal in composting facilities. However, from the consumer's point-of-view, it is expected that fostering composting habits will directly impact the recycling rates for packaging, leading to a loss of the benefits from recycling (deriving additional value from the materials, related energy savings, reduced resource depletion, etc.).

Looking at environmental impacts, the overall benefits of biodegradable products are less significant than the environmental benefits stemming from recyclable products. Currently, the industry is more focused on developing the bio-based packaging market, without consideration of the biodegradability of the final product, as benefits from the origin of the resource prevail over the benefits from the end-of-life management.

To compare the policy options, a semi-quantitative score matrix approach is adopted, as shown in the table below. The level of detail in the analysis depends on the amount of information gathered as well as their quality.

Semi-quantitative score matrix

Legend	Environmental impact indicators	Social and economic impact indicators
++	> 10,000 inhabitant-eq	Substantial beneficial effect
+	between 1,000 and 10,000 inhabitant-eq	Slight beneficial effect
0	No effect (the baseline)	No effect (the baseline)
≈	Between 1 and 1,000 inhabitant-eq)	Marginal/Neutral impact
-	between 1,000 and 10,000 inhabitant-eq	Slight negative effect
--	> 10,000 inhabitant-eq)	Negative effect
?	Unknown effect	Unknown effect

The following table summarises the potential environmental, economic, and social impacts for the implementation of the different policy options. In each cell of the matrix a qualitative score is given.

Qualitative comparison of environmental, economic and social impacts of policy options to improve the biodegradability requirements in the Packaging Directive

Policy Option Impact Indicator	Option P1a	Option P1b	Option P2a	Option P2b
Environmental impact indicators				
Energy Use	≈	+	-	-
GHG emissions	≈	-	++	++
Resource Depletion	≈	++	--	--
Human Toxicity	≈	++	--	--
Aquatic Toxicity	≈	+	-	-
Acidification	≈	++	--	--
Eutrophication	≈	≈	≈	≈
Economic impact indicators				
Biodegradable packaging production	0	--	+	+
Biodegradable packaging consumption	0	--	++	++
Packaging costs	0	≈	-	-
Impact on producers and industries	-	--	-	--
Packaging waste management sector	≈	--	-	--
Internal Market	+	-	+	+
Administrative burden	+	+	++	++
Research and Development	++	++	+	+
Social impact indicators				
Consumer behaviour and awareness	≈	≈	+	++
Employment	0	≈	++	++

Main Definitions

Technical terms

In order to make a consistent use of different technical terms in the report, some basic definitions[1] are presented here. In addition, potential misunderstandings or confusions are highlighted.

Biodegradable materials: Materials that can be degraded by living organisms - in particular microorganisms - into water, CO_2, methane (CH_4) and possibly non-toxic residues (i.e. biomass).[2] **In this report, the term "biodegradable" refers to the capacity of a product to degrade under specific environmental conditions. It is defined as "(technically) biodegradable"** and it includes "naturally biodegradable" materials whose biodegradation processes can occur in natural environmental conditions (as opposed to the controlled conditions in home or industrial composting facilities) (Figure 1).

Biomaterials: Compounds that are naturally synthesised in the environment (fauna and flora).

Bio-based products: Products that are produced from renewable resources (e.g. starch extracted from potatoes or maize), in contrast with petroleum-based products[3]. Bio-based products can be either biodegradable or non-biodegradable.

Bioplastics: According to the European Bioplastics Association, bioplastics can either refer to:

- bio-based plastics (i.e. bioproducts) (not necessarily biodegradable), or
- biodegradable plastics (bio-based, petroleum-based or a combination of both).

This non-differentiation can be confusing as the use of the prefix "bio" could imply the origin of the resource and/or its end-of-life pathway. Most of the publications do not further distinguish between these two categories, a situation that could lead to misunderstanding by consumers and other stakeholders. **In this report, the use of the term "bioplastics" is avoided and a distinction is made between "bio-based plastics" and "biodegradable plastics".** When sufficient information is not available in the evidence, this uncertainty is highlighted and discussed.

Biopolymers: Paper and plastic materials that are manufactured with renewable resources (i.e. biomaterials). Cellulose (for paper) is a polymer of glucose whereas plastic polymers mainly use starch. For more information, please see section 2.1.3.

[1] Adapted from Conseil National de l'Emballage, 2009.

[2] This definition excludes oxo-degradable compounds which degradation process does not only rely on microbial activity and whose residues may have unclear impacts.

[3] Regarding more specifically bio-based plastics, three main categories exist: natural polymers from renewable sources such as cellulose, starch and plant-based proteins; polymers synthesised from renewable sources, e.g. polylactic acid (PLA); polymers produced by microorganisms, e.g. polyhydroxyalkanoates (PHA).

Compostable materials: Products that can be decomposed by living organisms into water, CO_2, methane (CH_4) and possibly non-toxic residues under controlled conditions (industrial composting or home composting). What is compostable is technically biodegradable. However, what is technically biodegradable is not necessarily compostable, depending on the specific controlled conditions. **As controlled conditions may vary significantly, it is consistently specified in this report whether evidence refers to home or industrial composting.**

Degradation or Decomposition: Molecular unbinding of a compound due to physical, chemical or biological actions (e.g. UV exposure, temperature, microbial activity) that may lead to the loss of the initial properties of the compound. For instance, photodegradation is caused by the absorption of photons from infrared radiation, visible light, and ultraviolet light.

Fragmentation: Unbinding of a compound into multiple particles (i.e. fragments), which may be invisible to the eye and keep some properties of the initial compound[4].

Organic recycling: Generic term that includes both composting and biodegradation processes.

Conceptual relationship between key terms

Figure 1 presents a graphical overview of the different definitions that are considered under the "biodegradability" concept. Although some compounds may technically show some levels of biodegradation, this study addresses packaging materials that allow biodegradation in a defined condition (industrial composting, home composting, or natural environment).

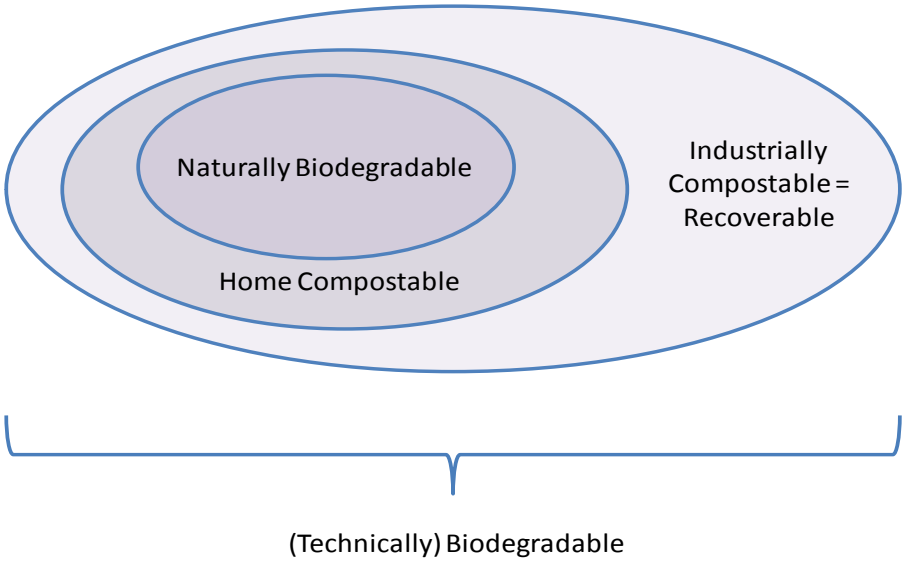

Figure 1 – Biodegradability and compostability

[4] That includes oxo-degradation which occurs with conventional products to which an oxidising agent (usually a metal compound) was added in order to increase the instability of the material and thereby foster fragmentation under specific conditions. Indeed, in presence of oxygen and under the action of heat and UV, some structural carbon bonds of the oxo-degradable packaging will be broken and the system will be visually altered but may keep some inherent properties. Therefore, oxo-degradation is not a biodegradation process.

Chapter 1: Introduction

Many different materials or combinations of materials are used for packaging, a great majority of which enter the municipal waste stream at the end of their use phase. For example, in the EU-27, just over 17 million tonnes of packaging were disposed off in 2008. This has caused increasing environmental concern, resulting in the strengthening of various regulations—such as Directive 94/62/EC1 (the Packaging Directive)—aimed at improving to resource efficiency, moving towards a "recycling society" while ensuring the functioning of the internal market. Such regulations could lead to the use of biodegradable materials that can degrade under natural or artificial conditions into compounds that are not hazardous to the environment.

As shown in Figure 3, for different OECD countries, packaging waste represents a significant share of total household waste. In the EU-27, for the last years, the packaging waste generation per inhabitant has generally increased (see Figure 4).

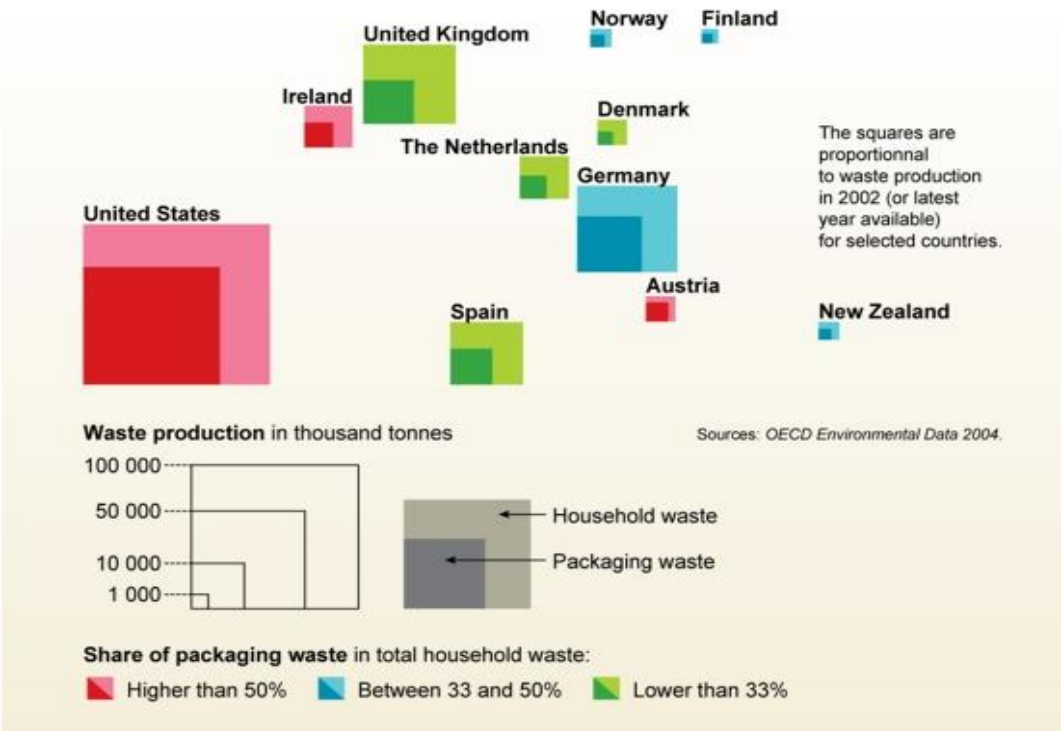

Figure 2 – Share of packaging waste in total household waste[5]

[5] OECD, 2006.

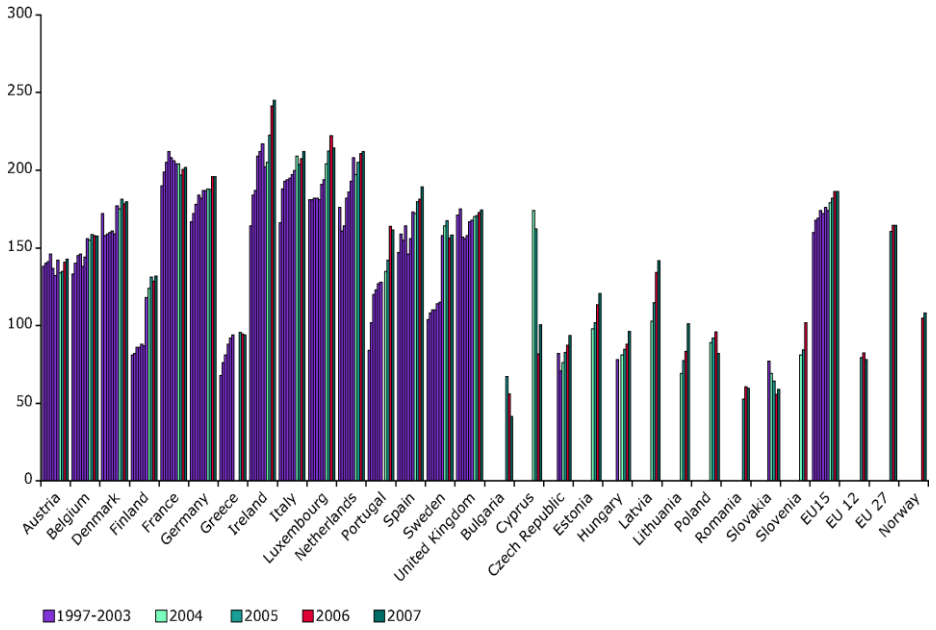

Figure 3 – EU Packaging waste production (kg/capita/year)[6]

With society's growing concern for sustainable consumption, production, and waste management, biodegradable packaging may appear as an environmentally friendly option and could rapidly become an attractive commercial feature. The scientific community has been developing new biodegradable products that could be used in packaging applications. As the market uptake and commercial success of biodegradable products relies on the understanding and proper functioning of the biodegradation process, well-defined normative instruments could help to contribute to a more transparent exchange of information between consumers, companies and public authorities.

The term "biodegradable" has to be carefully used when promoted by manufacturers or directed at consumers. In this respect, two issues may require precision:

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Some Member States have implemented measures to reduce the use of non-biodegradable packaging. However, while existing EU policies provide strong drivers to make the EU a resource-efficient society, there is no legislation specifically targeting biodegradable packaging at the EU level.

This report contributes to the impact assessment of policy options on the need for reinforcement of the requirements for biodegradability in Annex II of the Packaging Directive and improvement of the visibility of biodegradable packaging products for consumers. This analysis is part of a

[6] EEA, 2007.

broader policy review of the Packaging Directive and takes into account the results of a stakeholder consultation on policy options related to plastic bags that was launched by the European Commission in May 2011.

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This study follows the Commission's Impact Assessment Guidelines[7] in assessing the impacts of specific policy options. In addition to this introductory chapter, the report includes the following chapters:

- Chapter 2: Problem definition
- Chapter 3: Identification of policy options
- Chapter 4: Analysis of impacts
- Chapter 5: Comparing the options

[7] European Commission, 2009.

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Chapter 2: Problem definition

This chapter describes the nature of the problem being addressed. First, it presents the different types of biodegradable packaging materials, their associated end-of-life options as well as their share in the European packaging market. Next, the sources of misinterpretation and underlying drivers of the problem are thoroughly discussed. Finally, the main environmental, economic and social aspects of the problem and their expected changes to 2020 are described.

2.1 Types of biodegradable packaging materials

2.1.1 Paper and cardboard

Examples of paper and cardboard or other pulp-based packaging includes wrapping paper, carton boxes, disposable plates and cups, and corrugated cardboard, among others. A large proportion of such material is recycled in dedicated industrial facilities but the public may perceive biodegradation and composting (home or industrial) as a viable alternative.

Paper is composed of lignocellulose, which consists of three kinds of polymers: cellulose, hemicelluloses and lignin. Lignin is a highly resistant substance that protects cellulose and hemicellulose against microbial attack and thereby makes paper difficult to degrade. Only a few species of microorganisms[8] are in fact able to decompose lignin. In the scientific literature, little is known about the extent of the mineralisation of lignin and, thereby the potential for biodegradability for paper packaging products[9]. Moreover, in typical writing and printing paper, some inorganic material (e.g. ink) may inhibit complete biodegradation.

2.1.2 Wood

Wood packaging is mainly used for the transport of goods. Crates and boxes are often built to suit a particular commodity and wood pallets are used to facilitate the shipping and handling of a wide variety of goods. Like for paper, wood is mainly made of cellulose (up to 45%), hemicellulose (20-30%) and lignin (25-30%)[10]. Certain microorganisms such as fungi contribute to the deterioration of wood by causing decay. In addition, insects feed on the sapwood and heart wood to accelerate the degradation process.

Although fungal spores are common, they need favourable conditions to develop and attack wood. Those conditions include:

- an adequate supply of oxygen,

[8] Among which the white-rot fungi (basidiomycetes) are the most efficient degraders.

[9] Imperial College, 2006.

[10] Rajendra, 2007.

- a favourable temperature (15 to 40°c),
- sufficient moisture (25 to 30%), and
- absence of other fungi.

2.1.3 Plastics

Plastics are used extensively in packaging of products such as food, pharmaceuticals, cosmetics, detergents and chemicals because of their suitable physical and chemical properties (e.g. strength, light weight, water resistance, etc.). Around 30% of the plastics used worldwide are for packaging purposes[11]. The most common plastic compounds are petroleum-based polymers such as polyethylene (PE)— either with low density (LDPE), medium density (MDPE), high density (HDPE) or linear low-density (LLDPE)— polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC) and polyurethane (PUR). However, a significant increase in plastic use has drawn more attention on the potential environmental issues related to the littering of plastics including accumulation[12], pollution[13], and persistence[14]. As a result, biodegradable plastics have recently gained attention as possible sustainable packaging solutions.

The first plastics using the term "biodegradable" date from the end of 1980s. They were made from polyethylene to which small amounts of biodegradable compounds were added (approximately 5% starch). Since then, significant development with regard to the biodegradability of packaging materials has been made in the EU.

In order to provide a competitive alternative to conventional plastics, biodegradable plastics need to ensure proper functionality in terms of strength and impermeability, while also ensuring adequate degradation (i.e. unbinding) in response to specific environmental conditions that they would encounter in appropriate end-of-life environments. These conditions include appropriate temperature, light, hydration and/or microbial presence.

Bioplastics (both biodegradable and bio-based) can be classified into biopolymers, biodegradable polymers and polymer blends depending on the origin of their primary material as well as their biodegradability potential (See Table 1 and Figure 4).

- **Biopolymers (Bio-based)**

Biopolymers are naturally occurring polymers such as cellulose and polysaccharides (starch). Most of them can be decomposed by fungal and bacterial activity. However, some bio-based polymers exist that are not biodegradable (such as polyethylene (PE), which results from bioethanol). Therefore, not all bio-based plastics are biodegradable.

[11] Shah et al., 2008.

[12] Accumulation is defined as the capacity to collect and/or concentrate a compound in a specific space-limited environment.

[13] Pollution is defined as the introduction of contaminants into a natural environment that causes instability, disorder, harm or discomfort to the surrounding ecosystems.

[14] Persistence is defined as the resistance to environmental degradation through chemical, biological, and photolytic processes.

- **Biodegradable polymers**

This includes both bio-based and synthetic petroleum-based polymers that have certain degrees of inherent biodegradability or are chemically enhanced with an organic additive to foster biodegradation (representing a type of polymer blend)[15].

- **Polymer blends**

Polymer blends are conceived in order to combine different physical and chemical properties, including biodegradability under different environmental conditions. Polymer blends that are usually synthesised from bio-based monomers include polylactate (PLA), polyesters and bio polyethylene. When used alone in packaging applications, starch shows a poor performance because of its brittle and hydrophilic nature. To address these issues, starch is often modified and combined with a plastic agent and/or another type of polymer additive. This additive may not be biodegradable itself but enhance the resistance of the final product while maintaining its overall biodegradability. The concentrations of starch in biodegradable polymer blends may vary from 5% to 90% by weight.[16]

Table 1 gives some examples of the main bioplastic compounds while Figure 4 provides an illustrative approach to the classification. Different technologies that are used to manufacture bioplastics are presented in Annex 1.

Table 1 – Examples of bioplastics and their biodegradability properties

Type of bioplastics	Main compounds	Biodegradable properties
Synthetic (petroleum-based)	Polyethylene (PE), Polyurethane (PUR), Polyvinyl chloride (PVC), BTA-copolyester, polycaprolactone (PCL), Polyethersulfone (PES)	Biodegradable
Bio-based / Biopolymers	Polysaccharides, Thermoplastic Starch (TPS), Cellulose, Polylactate (PLA), PLA blends, Polyhydroxyalkoates (PHA)	Biodegradable
Blends	PE produced from Bioethanol, PVC produced from Bioethanol, polyamides (PA), Bio-propanediol (PDO)	Non-Biodegradable

[15] With respect to that definition, oxo-degradable products are not considered biodegradable as they contain a metal oxide additive.

[16] Imperial College, 2006.

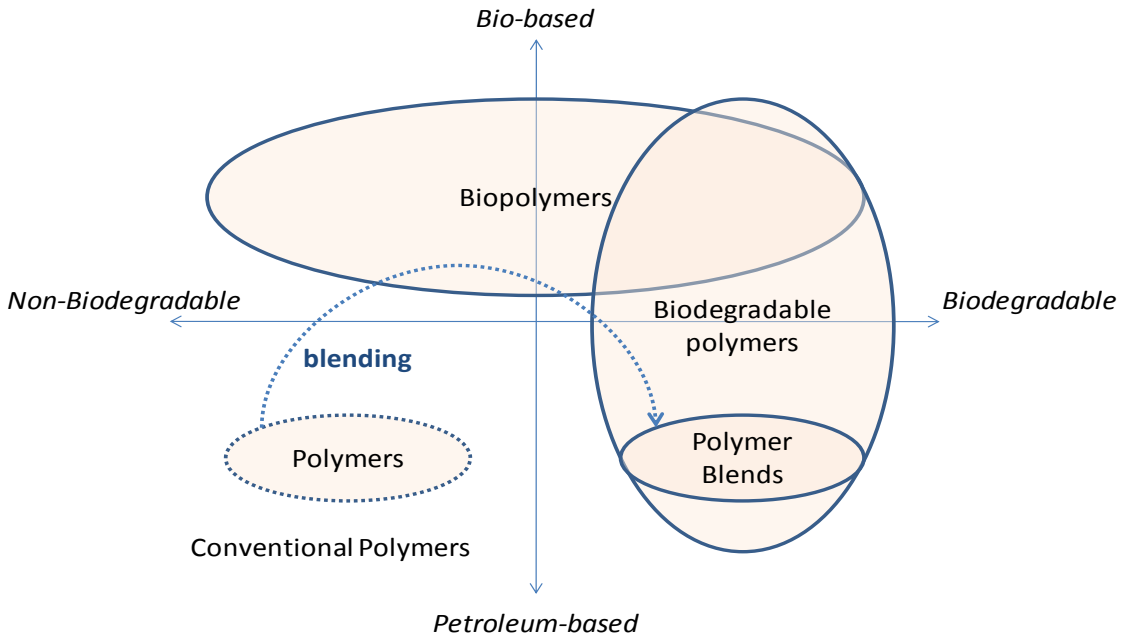


Figure 4 – Classification of bioplastics (based on European Bioplastics, 2011)[17]

**The curved arrow indicates the blending process, which can combine a petroleum-based polymer and a bio-based polymer*

2.2 End-of-life options

The biodegradation rate of a biodegradable material depends on the end-of-life options and the physico-chemical conditions (e.g. presence of oxygen, temperature, presence of light, presence of specific microorganisms). The main end-of-life options for biodegradable packaging include:

- composting,
- recycling (and reprocessing),
- incineration (and other recovery options),
- landfill, and
- natural environment (as a result of littering or the accidental escape from the waste management chain).

In most cases, the nature of the biodegradable materials would determine suitable end-of-life management practice(s). Composting is generally the most appropriate option for biodegradable packaging, but the other end-of-life options are also presented (for both biodegradable and non-biodegradable packaging) in the following section as they have a significant role in the modelling approach of the study (see section 2.7.2.3).

[17] European Bioplastics, 2011a.

2.2.1 Composting

Description

Composting (in home or industrial facilities) is the common end-of-life option for many types of biodegradable waste[18], especially garden and food wastes, municipal solid waste and sewage sludge.

Biodegradation in composting is mainly due to hydrolysis[19] and aerobic and anaerobic microbial activity. When conducted in compliance with the EN13432 standard (in line with the Packaging Directive, see section 2.5.1), composting usually takes 10 to 12 weeks and the degradation products are compost (humus) and CO_2.

The following pre-treatment steps are required before beginning the composting process:

- removal of bulky, non-compostable items,
- particle size reduction,
- moisture addition,
- general mixing, and
- attaining an adequate temperature (55 to 60°C).

The key differences between an industrial composting facility compared to home composting is the fact that there is regular mixing and the key conditions—moisture and temperature—are monitored and maintained during the composting process. This allows certain materials to decompose more quickly and/or completely.

Some of the key factors to be considered when assessing the suitability of the waste for composting are:

- Physical persistence

Packaging waste can be suitable for composting if the disappearance of the material can be totally achieved by disintegration, dissolving or melting. The original material must not be physically recognisable in the final compost.

- Chemical persistence and toxicity

Composting is possible for packaging materials that can be decomposed through mineralisation, a process during which carbon is incorporated into the microbial biomass and then oxidised into CO_2. Biodegradable compounds avoid the accumulation of synthetic materials in the soil. Additionally, the release of toxic compounds into the final compost is not allowed.

- Quality of compost

Composting can be considered as a viable option so long as the biodegraded materials do not adversely affect the fertilising properties of the final compost.

[18] Nolan-ITUPty Ltd., 2002.

[19] Process of splitting a compound into fragments with the addition of water.

- **Current situation in EU for composting with regard to packaging waste**

The available capacity of composting facilities in the EU is limited. In 2006, around 1,900 industrial composting plants in the EU represented an annual capacity of more than 19 million tonnes of waste (around 0.79% of the total treated waste in the EU[20]). However, 40% of those facilities only address garden waste[21].

Many of the existing composting facilities are not adapted to processing compostable packaging. For instance, in Belgium, it is estimated that around half of existing facilities would have to undergo technical modifications to ensure an efficient packaging composting process[22]. In particular, technical problems are numerous at the level of pre-processing[23]. Co-mingled collection of biodegradable plastic and conventional plastic will not be feasible so long as investment into sophisticated separation equipment is not economically viable. From a purely technical perspective, separating biodegradable and compostable plastics from conventional plastics is possible using near infrared (NIR) detection technology. In practice, however, this technology is not widely available in Europe and may be costly to put into operation. Moreover, in facilities already using NIR detection, the technology still needs to be adapted to allow sorting biodegradable packaging in addition to existing sort lines[24].

Given these factors, the shares of home and industrial composting in the distribution of packaging disposal options are considered negligible in the current EU situation, with respect to the other disposal options.

2.2.2 Recycling and reprocessing

- **Description**

Recycling is an end-of-life option where packaging materials can be recovered and transformed into materials with market value. Packaging to be recycled is sorted according to the type of material (e.g. glass, paper, plastics), separated from unrecyclable items, cleaned, and finally reprocessed into new materials bound for manufacturing.

One of the challenges faced by the recycling sector in recent years has been to build confidence in the technical integrity of the recycled and reprocessed materials and to demonstrate its ability to perform as a reliable alternative to virgin materials. Biodegradable materials in the recycling waste stream may bring new treatment and quality issues to recycling. Stakeholders from the recycling industry have raised the concern that the proportion of reprocessed materials will contain biodegradable parts and thereby the technical characteristics (e.g. strength, durability, etc.) of the final product would be compromised. Thus, the sorting and separation steps have an important role to enable the production of quality end-products. For instance, multilayer

[20] Considering 2.39 billion of waste in the EU in 2008, based on Eurostat data. Available at: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_wastrt&lang=en

[21] Gibert J., 2007.

[22] Fost Plus, 2009.

[23] Organic waste Systems, 2006.

[24] California Integrated Waste Management Board, 2009.

lamination of different biopolymers may be necessary to enhance biodegradable plastics properties[25]. However, multilayer packaging can compromise recyclability of both the scrap during the production process and packaging waste stemming from goods and services consumption.[26] Similarly, the addition of natural fibres to conventional polymers may complicate recycling processes.[26]

This issue is particularly relevant for plastics as biodegradable and conventional plastics cannot be distinguished by the optical systems used for waste separation. In addition, both types of products have similar weights and densities, which prevent any easy mechanical separation. That said, new technologies[27] are being introduced that better allow plastics waste to be automatically sorted. For instance, the biodegradable compound PLA could be identified with new infrared systems, though these systems currently face considerable technical and economic challenges, as presented in the previous section.

In order to avoid potential alteration of the properties of conventional materials in products manufactured with recycled materials, biodegradable materials would require their own waste-collection streams. However, the lack of sufficient supplies for the different types of biodegradable packaging waste (in particular for plastics) to feed pure biodegradable recycling chains is likely to make separate collection economically less attractive than conventional packaging.[26] As previously stated, composting is the most suitable end-of-life option for biodegradable packaging and therefore, it is more appropriate to ensure that biodegradable packaging remains out of the recycling schemes than to develop related waste collection streams for recycling purposes.

- **Current situation in EU for recycling with regard to packaging waste**

For each of the considered packaging materials, the recycling rates in 2011—presented in Table 2—were calculated from the available EUROPEN[28] data[29] with projections being made based on EU-15 (2001-2008) and EU-New (2005-2008) information. It can be seen that recycling schemes are rather well-implemented for paper and cardboard with more than 80%. This is significantly higher than the shares for wood (42%) and plastics (32.1%).

[25] Multilayer lamination of different films is a conventional method used for instance to produce high-barrier films for packaging of food in protective atmosphere. It consists in laminating different types of plastics in order to obtain the required properties (gas barrier, water vapour barrier properties, etc.) (Weber J., 2000).

[26] Song et al., 2009.

[27] Such as X-ray, fluorescence, infrared (IR) and near infrared spectroscopy, electrostatics and flotation.

[28] The European Organization for Packaging and the Environment (EUROPEN) is an industry and trade organization representing companies with an economic interest in packaging and packaged products. It presents the opinion of the packaging value chain on topics related to packaging and the environment.

[29] EUROPEN, 2011.

Table 2 – Recycling rates per type of materials

	Paper and Cardboard*	Wood*	Plastics*
Share of material sent to recycling	80.7%	42%	32.1%

*No distinction between biodegradable and non-biodegradable materials is made as the available information is related to the packaging material itself with no specification of its biodegradability potential.

2.2.3 Incineration (and other recovery options)

Description

While energy recovery by incineration may be a technically viable option for biodegradable packaging, it negates many of the potential benefits from the material's biodegradability potential. In technical terms, natural cellulose fibre and starch have relatively lower energy potential (expressed as gross calorific value, or GCV) compared coal but are similar to wood and thus still have significant value for incineration.[30] Regarding the other biodegradable materials, little data is currently available to accurately determine their value for energy recovery by incineration, and thereby the relevance of this end-of-life management option.

Current situation in EU for incineration with regard to packaging waste

The current share of packaging materials that is sent for incineration can be extrapolated from the recovery rates that are available on Eurostat[31] for the 2005-2008 period. The distribution between incineration and other energy recovery options is derived from complementary Eurostat information[32] and is presented in Table 3. It can be seen that incineration is a significant end-of-life option for wood waste, accounting for 24.5% of its treatment. For plastics, other energy recovery schemes such as gasification, anaerobic digestion (biogas), pyrolysis, etc. represent a more significant share of the end-of-life treatment at 17.9% than incineration at 11.5%.

[30] Song et al., 2009.

[31] Recovery rates are available at: epp.eurostat.ec.europa.eu/tgm/refreshTableAction.do?tab=table&plugin=1&pcode=tenooo62&language=en

[32] Eurostat, 2008.

Table 3 – Share of incineration and other energy recovery options in the disposal management for packaging, in 2011.

Packaging materials	Paper and Cardboard*	Wood*	Plastics*
Share of material sent to incineration	10.2%	24.5%	11.5%
Share of material sent to other energy recovery schemes	1.5%	6.1%	17.9%

*No distinction between biodegradable and non-biodegradable materials is made as the available information is related to the packaging material itself with no specification of its biodegradability potential.

2.2.4 Landfill

- **Description**

Landfill is the least favoured option in the waste hierarchy as defined by the Waste Framework Directive, as this leads to a permanent loss of resources in addition to land use and landfill management issues. That explains why a target for 0% landfilling has been set out in the EU's Resource Efficiency Roadmap.[33] Indeed, the EU is running out of suitable landfill sites and the risk of contamination/leakage is problematic for waste managers.

The landfill decomposition cycle for packaging waste usually takes place in four successive phases[34]:

- **Aerobic phase** (few days): During this period, aerobic microorganisms spread and the moisture content increases. In such conditions, molecular bonds in biodegradable compounds are weakened and more exposed to microbial activity. Oxygen is then replaced with CO_2.
- **Anaerobic, non-methanogenic phase** (up to 6 months): After the depletion of oxygen, the anaerobic processes take place, starting with a hydrolysis of large polymers into simpler monomers. Microbe colonies spread and CO_2 production increases rapidly. With time, monomers are converted into fatty acids.
- **Anaerobic, methanogenic unsteady phase** (up to 18 months): The microbial colonies continue their growths. Fatty acids evolve into acetic acids, CO_2, and H_2. With time, CO_2 rates decrease and H_2 production stops.

[33] European Commission – COM(2011) 571 final – Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Roadmap to a Resource Efficient Europe. Available at: http://ec.europa.eu/environment/resource_efficiency/pdf/com2011_571.pdf

[34] Adams et al., 2009.

- **Anaerobic, methanogenic steady phase** (up to 5 years): H_2 is consumed and CH_4 and CO_2 are produced. The process continues until the only remaining element is humus, where the final stage of decomposition takes place.

The decomposition process contributes to landfill gas production. Collection of this gas is mandatory under the Landfill Directive. Typical landfill gas contains 50% CH_4 and 45% CO_2. However, many landfills in new MS, but also in certain cases in the EU-15, do not have any gas collection systems in practice. That is also the case for several thousand illegal dumps. The presence of biodegradable packaging may then increase the greenhouse gas emissions from these sites that operate outside of the requirements of the Landfill Directive. According to Art. 5 of the Landfill Directive, MS shall set up a national strategy to reduce the biodegradable waste going to landfill.

Current situation in EU for landfill with regard to packaging waste

No direct information on the share of packaging waste that goes to landfills could be found. Relative estimations can be made from "non-recovery" rates, which are assessed from Eurostat data and cover both landfill and litter. Currently, it is assumed that landfill is used for 85% of non-recovered packaging waste and litter 15%. Table 4 presents the share of landfill in the end-of-life management of packaging, based on these assumptions.

Table 4 – Share of landfill in the disposal management for packaging

	Paper and Cardboard*	Wood*	Plastics*
Share of material sent to landfill	6.5%	24.3%	31.7%

*No distinction between biodegradable and non-biodegradable materials is made as the available information is related to the packaging material itself with no specification of its biodegradability potential.

2.2.5 Litter

Current EU situation for littering with regard to packaging waste

The largest fraction of the overall litter stream consists of cigarette butts, organic waste, and non-packaging waste.[35] At EU level, the average share of packaging waste in the overall litter stream is around 6%. In England, packaging accounts for just 1.3% of the number of littered items dropped in the streets and in the countryside.[36]

It is assessed that 15% of the share of all packaging types that are not sent to other recovery options are littered. Table 5 further details the shares of each type of material that is littered.

[35] Pro Europe, 2007.

[36] Industry Council for Packaging and the Environment, 2009.

Table 5 – Share of litter in the disposal management for packaging

	Paper and Cardboard*	Wood*	Plastics*
Litter	1.1%	4.3%	5.6%

*No distinction could be made between biodegradable and non-biodegradable materials as the available information is related to the packaging material itself with no indication of the biodegradability potential.

- **Litter and the impact on marine and freshwater environments**

Litter in marine and freshwater environments leads to aesthetic problems and can damage the health of wildlife (e.g. entanglement and ingestion of materials). While non-biodegradable packaging is of particular concern, biodegradable packaging may not be the most appropriate solution. The rate of biodegradation in marine environments is dependent on:

- the type of product (structure, presence of additives, etc.);
- the water temperature (in cold waters, plastic materials may remain in a form that could damage marine life);
- the density of the product. Density will affect sunlight availability and whether the waste item floats or sinks. For instance, many plastics—independent of their biodegradability potential—can photodegrade in the marine environment. This means that they break down into smaller pieces as a result of UV exposure.

Many biodegradable plastics were created to biodegrade in a compost pile and will not biodegrade in marine environments. In some trials, a starch-PCL blend was found to degrade in 20 to 30 weeks in Australian waters while being able to degrade in 20-30 days in compost.[37] Moreover, many biodegradable plastics may not degrade in the intestines of marine species and injury is likely to remain an issue. European Bioplastics promotes PHA as a suitable compound for biodegradation in the marine environment.[38] While this is confirmed by other studies showing some biodegradation levels for PHA and PHB, the rate of bedegradation in 25°C sea water was measured to be 0.6 µg per week.[39] Keeping in mind that a typical plastic bag weighs 6 grams, this rate of biodegradation is not particularly significant.

[37] Nolan-ITUPty Ltd., 2002.

[38] European BioPlastics, 2011a.

[39] California State University, 2007.

2.3 The market for biodegradable packaging

2.3.1 Overall packaging market

Types of packaging materials

European packaging consumption is largely dominated by paper, cardboard, and plastics. With a market share of 18% and an annual growth rate of 2.9% in the EU-15, plastic packaging was the fastest growing sector between 1998 and 2008. Paper and board packaging alone accounted for 38% of the market volume. Together, paper, cardboard, and plastics accounted for more than half of European packaging put on the market in 2008 (Figure 5).

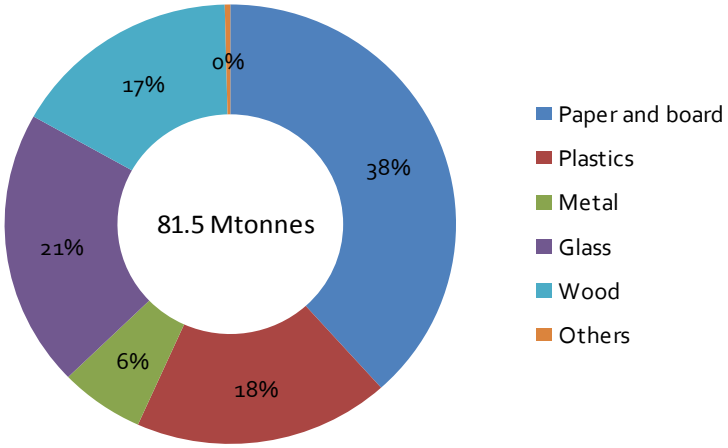


Figure 5 – European packaging consumption by sector (in tonnes, EU-27[40], 2008)[41]

Market growth

In EU-15, the overall amount of packaging placed on the market grew by 15.1% from 1998 to 2008, with an average annual growth rate of 1.5%. In the new Member States (Malta excluded), packaging consumption followed the same trend, increasing by 10.9% from 2005 to 2008.

European packaging consumption is characterised by per capita packaging consumption growing for plastics (+27%) and paper and board (+7%) while declining for glass (-7%) and remaining stable for metal over the period 1998-2008 (see Figure 6 for the EU-15 and Figure 7 for the new Member States). Overall, the amount of packaging placed on the market increased continuously until 2007. The economic downturn in 2008 resulted in a small reduction (-0.6%) in the packaging placed on the market.

[40] Omitting Malta that has not yet reported data to the Commission for 2008.

[41] EUROPEN, 2011.

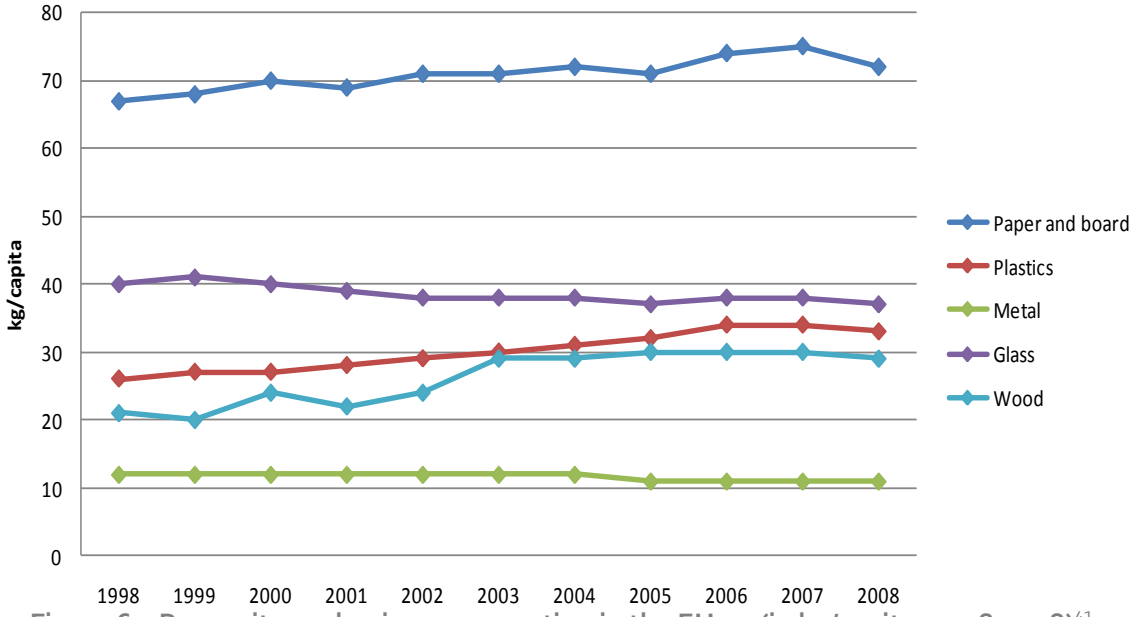


Figure 6 – Per capita packaging consumption in the EU-15 (in kg/capita, 1998-2008)[41]

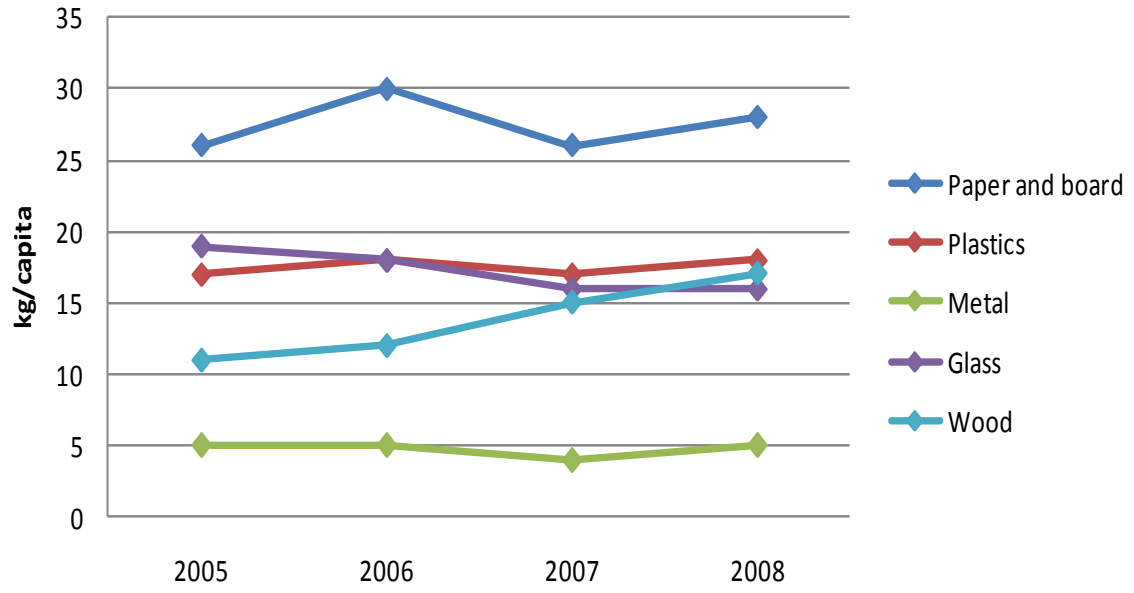


Figure 7 – Per capita packaging consumption, in new MS (in kg/capita, 2005-2008)[41]

2.3.2 Market for biodegradable plastic[42]

Biodegradable plastics production

With a worldwide production of biodegradable plastic packaging estimated at about 167,000 tonnes in 2010[43] and an average annual growth rate of roughly 60% for the period 2008-2010 (Figure 9), the worldwide market for biodegradable plastic packaging is currently functioning at industrial-scale capacity.

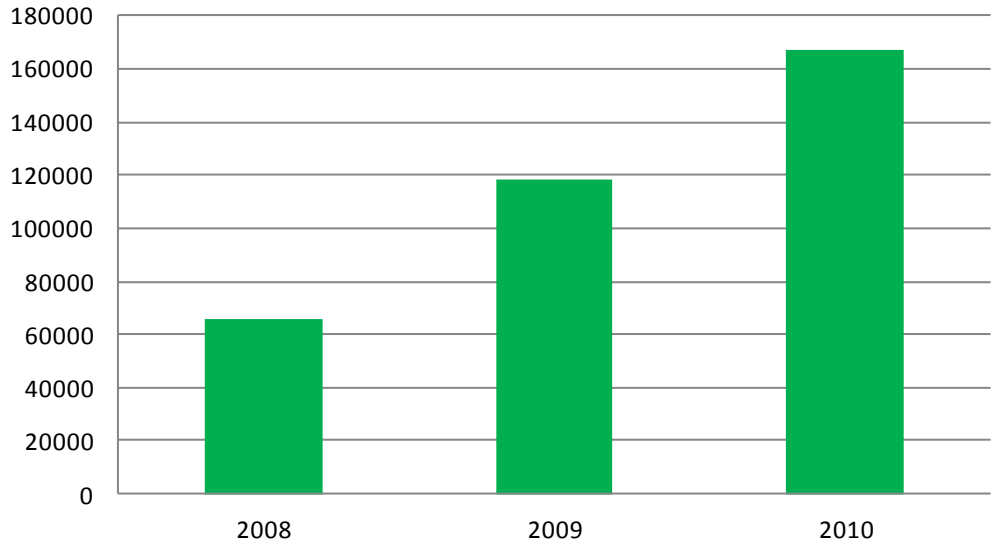


Figure 8 – Worldwide production capacity of biodegradable plastic packaging (tonnes)

The worldwide market for biodegradable plastics is witnessing increasing diversification with a growing numbers of materials, applications and companies developing biodegradable packaging (Table 6). Packaging applications contributed around 39% of the European biodegradable plastics market in 2010[44], with Europe producing 26.7% of worldwide tonnage.[45]

Based on these figures, European biodegradable plastic packaging production is estimated to 45,000 tonnes of biodegradable plastic packaging in 2010, representing 0.2% of European plastic packaging production.

With regard to the different types of biodegradable plastics, the available data show very small market shares for petroleum-based (synthetic) biodegradable plastic packaging within European production. European production of petroleum-based biodegradable plastic packaging is

[42] Due to small market shares, available data on the market for biodegradable plastics is very scarce. The main source of data on biodegradable plastics consumption and production in the EU-27 is European Bioplastics, the association representing the interests of the European bioplastics industry. Market data provided by European Bioplastics are not perfectly in line with the definitions adopted in the study as it encompasses either or both bio-based plastics and biodegradable plastics.

[43] This estimate was computed from data provided by European Bioplastics on the global production of biodegradable plastics (428,000 tonnes in 2010). The share of plastics production used in packaging (39% in 2010) stems from Plastics Europe.

[44] Hans van der Pol, 2011..

[45] European Bioplastics, 2011a.

estimated to be about 6,000 tonnes in 2010, accounting for 13% of the biodegradable plastic packaging produced in the EU-27.[46] Moreover, only about 22% of the plastic packaging considered as biodegradable in 2011 is actually fit for biodegradation in natural conditions.[46]

Table 6 – Worldwide production capacity of bioplastics by type (in thousands tonnes, 2010)

Bioplastics	Production capacity in 2010	Bio-based and non-biodegradable	Petroleum-based and biodegradable	Bio-based and Biodegradable	Biodegradable in natural conditions
Bio-PE	200,000	x			
Biodegradable Starch Blends	117,800	Not necessarily		x	Not necessarily
PLA	112,500	x		x	
PHA	88,100	x		x	x
Biodegradable Polyesters	56,500		x	x	
Bio-PET	50,000	x			
Regenerated Cellulose	36,000	x		x	
BIO-PA	35,000	x			
Cellulose Derivatives	8,000	x		x	x
PLA-Blends	8,000	x		x	
Durable Starch Blends	5,100	Not necessarily			
Others (PEA, PBSA, PBAT, PCL, etc.)	7,500	n.a	x	n.a	
Total bioplastics	724,500	296,000		428,000	
Total conventional plastics	265,000,000		x		

Source: European Bioplastics, University of Applied Sciences and Arts Hanover (2011)

[46] Computed from European Bioplastics , 2011a.

- **Biodegradable plastics consumption**

There is no close monitoring of the consumption of biodegradable plastic packaging either worldwide or at the EU level. Available data from the literature suggests that biodegradable plastic packaging consumption in the EU-27 reached about 73,000 tonnes in 2008 and increased to 91,000 tonnes in 2010.[47] In comparison, overall plastic packaging consumption amounted to 18.5 million tonnes in 2008 in EU-27, plus Norway and Switzerland.[48]

From 2008 to 2010, average annual market growth of biodegradable plastic packaging consumption was in the range of 12% in the EU-27. This is significantly higher than other types of materials. Over the same period, the European plastic packaging market (including all types of plastic materials) decreased by about 1%.

The market drivers for biodegradable plastic packaging vary across different countries:

- **Europe**: legislation, depleting landfill capacity, support for biodegradable packaging from retailers, growing consumer interest in sustainable plastic packaging solutions, petroleum and gas independence and greenhouse gas emissions reduction; [49]
- **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 related to packaging waste and improvements in the properties of biodegradable polymers used in packaging;
- **Japan**: promotion of the use of biodegradable packaging by the government and industry, and increased cost-competitiveness of biodegradable polymers used for product packaging;
- **China**: high growth is expected in the coming years because of an increase in biodegradable packaging production capacity, higher demand for greener packaging products, and plastic waste control legislation[50].

2.3.3 Market for biodegradable paper and board packaging

Interactions with relevant stakeholders revealed insignificant market shares for biodegradable paper and cardboard in 2011. Based on data that was provided by Member States on the different types of packaging material placed on their markets each year[51], it is estimated that

[47] These estimates were computed from data provided by European Bioplastics on the European demand for bioplastics (260,000 tonnes in 2008). The share of biodegradable plastics in European bioplastics consumption is set to 80% based on the shares of biodegradable plastics production in global bioplastics production prevailing from 2008 to 2010. The share of biodegradable plastics consumption used in packaging applications is set to 35% according to stakeholders' consultations.

[48] Plastics Europe, 2010.

[49] Framework Program 6 Project « GRU S UP » and Visiongain, 2011.

[50] BIOIS, 2011.

51 EUROPEN, 2011.

about 65,000 tonnes of biodegradable paper and board packaging is consumed in the EU-27 in 2011, representing 0.2% of the European paper and board packaging market.

European production is estimated to amount to 85,000 tonnes in 2007.

2.3.4 Market for biodegradable wood packaging

As for paper and cardboard, data availability is also an issue in the field of wood and stakeholder feedback revealed insignificant market shares for biodegradable wood in 2011.

Based on EUROPEN data, it is estimated that about 28,000 tonnes of biodegradable wood packaging are placed on the market in the EU-27 in 2011, representing 0.2% of the European wood packaging market.

2.4 Sources of confusion for the consumer

Given the diverse terminology—biodegradation, bioplastics, bio-based, compostable, home compostable, industrial compostable—it is expected that the concept of biodegradability may not be clearly understood by common users as highlighted by different stakeholders, ultimately leading to misinformed purchasing decisions or improper choices for disposal. Therefore, even environmentally conscious consumers may misinterpret the conditions for biodegradation and contribute to additional environmental impacts if they do not select an appropriate end-of-life treatment option for packaging that is marked "biodegradable" or "compostable".

2.4.1 Origin of the resource / end-of-life management

To common users, the term "bioplastics" could refer to either bio-based plastics or biodegradable plastics. This could lead to misinterpretation and then to the misuse of such materials. Some stakeholders suggest having two compulsory criteria in order to use the term "bioplastic":

- minimum share (e.g. 50%) of primary resources coming from naturally occurring products, and
- compliance with the EN13432 definitions of biodegradability.

2.4.2 Oxo-degradation

Oxo-degradation is a specific process that uses two methods to start the degradation of plastic compounds: photodegradation and oxidation. Photodegradation uses UV light to degrade the end product, whereas the oxidation process uses time and heat to break down the plastic. Both methods reduce the molecular weight of the plastic and therefore refer to fragmentation rather than biodegradation. The resulting fragments will remain in the environment although they may no longer be visible and they may still keep some properties of the initial compound, as opposed to residues from biodegradation.

2.4.3 Disposal conditions

Many consumers are confused with regard to the sorting behaviour they should adopt when dealing with biodegradable packaging. Distinguishing between compostable, biodegradable and bio-based packaging is crucial to prevent consumers from wrongly assuming that any product that is labelled as biodegradable, compostable or bio-based can simply be discarded in the environment and will degrade with no additional measures taken.[52] Similarly, there are growing concerns about consumers' misunderstanding of the compostable feature of packaging. Many packaging materials that are compostable in industrial facilities (as defined in EN 13432) do not meet the requirements necessary to degrade into compost in home or garden compost bins. In the UK, an experiment carried out in 2009 on 12 bio-based, compostable materials over a 24-week period showed that a number of packaging materials that typically biodegrade well in industrial composting facilities fail to biodegrade in home composting environments operating at lower temperatures.[52] These results confirm the high importance for households to be able to differentiate clearly between home-compostable and industrial-compostable packaging. Otherwise, both unfounded claims of biodegradability and misunderstanding of the concept of compostability may lead to inappropriate waste sorting behaviour that is, in turn, likely to have significant impacts on the quality of the compost or the quantity of packaging waste littered in the environment.

In order to take the best advantage of their features, biodegradable and compostable packaging would ideally be separated from other wastes at the household level. Then, they would be collected with organic waste in order to be treated in appropriate facilities and ultimately used to generate compost. This would allow waste to be diverted from landfills while reducing the need to use chemical fertilisers to improve the quality of soils.

2.5 Underlying drivers of the problem

2.5.1 Lack of a clear regulatory framework and harmonised standards

The concept of biodegradability has different interpretations among the authors of different standards. In particular, the time scale required for a material to degrade is a key issue. On a scientific level, conventional plastics can, in fact, show a certain level of biodegradation over a very long period. However, such products would not be useful with regard to improving the waste management system as the disposal rate far exceeds the degradation rate, leading to accumulation of the material over time. This illustrates a relevant gap between technical feasibility and common understanding.

The current legislative provisions set that packaging materials that are placed on the EU market must comply with the European Directive on Packaging and Packaging Waste (94/62/EC).

[52] Song et al., 2009.

Requirements with regard to organic recycling are defined in Annex II, §3 (c) Packaging recoverable in the form of composting and (d) Biodegradable packaging. According to the European Directive on Packaging and Packaging Waste, biodegradable packaging waste shall be of such a nature that it is capable of undergoing physical, chemical, thermal or biological decomposition such that most of the finished compost ultimately decomposes into carbon dioxide, biomass and water.

The following sections present different standards addressing the biodegradability and compostability of materials.

- **Harmonised Standard EN13432**

The European Committee for Standardization (CEN) developed a standard intended to ensure the conformity to the requirements on biodegradability set by the European Packaging Directive, namely EN 13432 "Requirements for packaging recoverable through composting and biodegradation – Test scheme and evaluation criteria for the final acceptance of packaging". Although the use of this standard is voluntary, it ensures conformity with the essential requirements provided by the European Packaging Directive.

- Requirements

Biodegradable-compostable packaging must fulfil each of the following features:

	Test Method	Minimum level	Duration
Biodegradability	ISO 14855	90%	Less than 6 months
Compostability (disintegration)	EN 14045 / ISO 16929	The mass of the material residues larger than 2mm must be less than 10% of initial mass.	3 months
Levels of heavy metals	An adjusted OECD 208 and other analytical tests.	Below predefined maximum limits and absence of negative effects on composting process and quality.	

- Limits

In the standard EN 13432 description, composting, biodegradation and organic recycling are used synonymously when applied to packaging. Thus, the standard does not allow for a clear distinction between biodegradability and compostability.

Moreover, "home composting" which takes place at a low temperature and may not always operate under optimal conditions for biodegradation, is out of the scope of both the standard and the Packaging Directive.

- **EN 14995 Plastic materials - Assessment of compostability – Test and specification system**

This standard is complementary to EN 13432, as it includes compostable plastic materials not used for packaging (e.g. compostable cutlery, compostable bags for waste collection).

- **ISO 17088 - Specifications for Compostable Plastics**

This international standard applies to plastic materials that are suitable for recovery by aerobic composting and addresses four aspects: biodegradation, disintegration during composting, negative effects on composting and negative effects on the resulting compost quality. The standard claims to have the conformity to all international, regional, national and local regulations (e.g. European Directive 94/62/EC)

- **ASTM D6400 – Standard Specification for Compostable Plastics**

Implemented in the United States, this standard covers plastics and products made from plastics that are designed to be composted in municipal and industrial aerobic composting facilities. It was the first standard to specify whether plastics can be composted satisfactorily at a rate that is comparable to known materials (e.g. cellulose). Contrary to EN 13432, (1) the limit level of biodegradation is reduced to 60% (2) the test duration is extended to 365 days if the test is concluded with radioactive material in order to measure the evolution of radioactive CO_2.

2.5.2 Labelling

Currently, no harmonised labelling or marking system is implemented at the EU level. However, different national-level schemes exist within and outside the EU. These schemes refer to different types of biodegradability/compostability, which could lead to confusion for consumers. Feedback from stakeholders in the bioplastics industry indicates that nearly all biodegradable plastics are identified as such, using either a standardised label or some other voluntary marking.

Table 7 presents different schemes that are currently implemented in the market and the paragraphs that follow describe them in detail.

Table 7 – Labels and certifications for biodegradability and compostability

Organisation	Country	Logo	Standard
DIN Certco	Germany		EN13462, ASTM D6400
Vinçotte	Belgium		EN 13432
AfOR	UK		EN 13432
BPI	US		ASTM D6400 and / or ASTM D6868
Australasian Bioplastics Association	Australia, New Zealand		EN13432, AS4736

- **DIN Certco**

DIN Certco is the certification organisation of TÜV Rheinland Group in Germany. They developed a certification scheme for compostable products made of biodegradable materials.

Depending on the properties and composition of the materials, intermediates, biodegradable additives or final products, different types of tests may be necessary. These tests may include the following:

- chemical testing,
- laboratory testing of total biodegradability,
- disintegration under composting conditions, and/or
- ecological non-toxicity.

Additionally, the tests ensure that no heavy metals enter the soil and the compost quality is not adversely affected.

- **Vinçotte**

Vinçotte is an independent, Belgian certification provider that has developed several labels targeting biodegradability and compostability:

- OK compost (since 1995, based on the compliance with EN 13432)
- OK compost HOME

The OK compost HOME test is similar to those in EN 13432, though the test temperatures and durations are adapted to a home-composting setting, as presented in Table 8.

Table 8 – Test conditions for OK Compost and OK Compost HOME labels

	OK compost	OK compost HOME
Biodegradability	55-60°C, 6 months	<30° , 12 months
Compostability	55-60°C, 3 months	Between 20 and 30°C, 6 months

- OK biobased (since September 2009)

Depending on the percentage of bio-based, renewable materials in the product, the product can be certified as one-star-bio-based, two-star-bio-based, three-star-bio-based or four-star-bio-based.

- OK biodegradable SOIL

Vinçotte has developed a specific OK biodegradable SOIL certification as soil biodegradability represents a benefit for agricultural products (such as plastic ground coverings) by allowing on-field disposal. The criteria level in soil conditions remains a 90% biodegradation within 2 years at ambient temperature (20-25°C).

- OK biodegradable WATER

Vinçotte has also developed a specific OK biodegradable WATER certification for fresh water (seawater is not addressed). The criteria level in freshwater conditions remains a 90% biodegradation within 2 years at ambient temperature (20-25°C).

- **AfOR - Association for organic recycling**

The Association for Organics Recycling (AfOR) is the United Kingdom's membership organisation dedicated to the sustainable management of biodegradable resources. Due to the increasing number of "compostable" packaging and plastics products in the UK market, AfOR established in February 2011 a "home compostable" certification scheme and certification logo, under a partnership arrangement with Vinçotte.

- **BPI**

The Biodegradable Products Institute (BPI) is a non-profit association of multi-stakeholders from government, industry, and academia, which promotes the use and recycling of biodegradable polymeric materials. In 1999, they created a certification program to ensure that the products are truly compostable based on their compliance with ASTM D6400 and / or ASTM D6868. ASTM

D6400 is designed to cover plastic films and bags. ASTM D6868 is for packaging that is designed to be composted, including plastic coated paper and board.

2.6 Who is affected, in what ways, and to what extent?

2.6.1 Environmental Impacts

In this section, environmental impacts related to the use of biodegradable packaging are presented. Where data are available, a life-cycle approach (as shown in Figure 9) to environmental assessment is provided. It enables some general conclusions to be drawn as to which products and life-cycle phases are responsible for the most significant environmental impacts. It can also be used as basis for possible future policy discussions.

In the study, the environmental impacts of packaging are linked to three main criteria:

- Type of packaging material
- Quantity produced and consumed
- Disposal option used to treat the packaging at the end of its useful life.

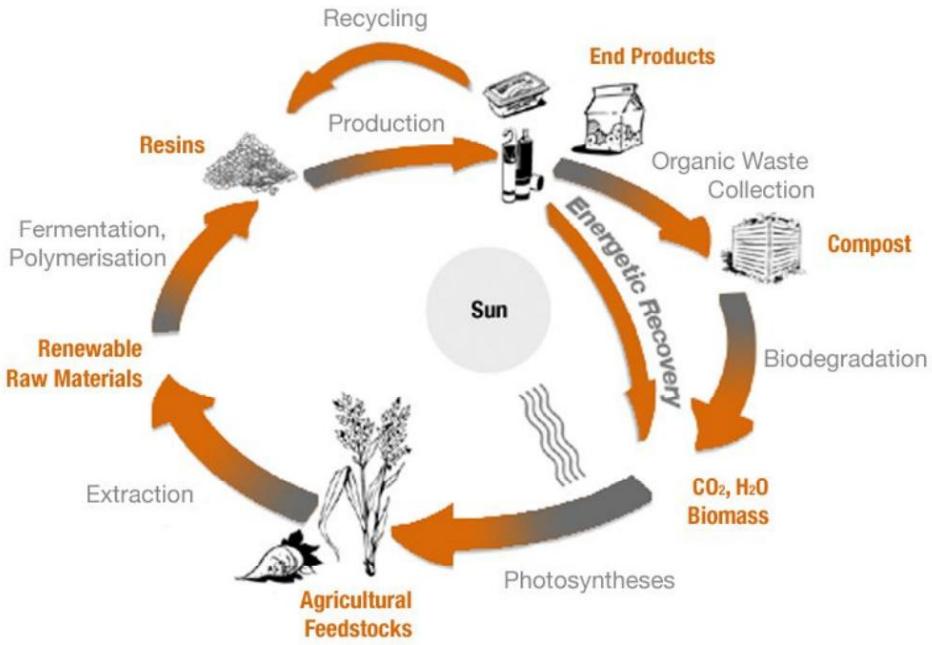


Figure 9 – Life-cycle approach to biodegradable packaging[53]

[53] European Bioplastics, 2008.

Land use

In recent decades, increasing conflicts have arisen between society's need for resources and space, and the capacity of land to support and absorb these needs, thereby threatening ecosystems.[54] Largely to meet the rapidly growing demands of society, humans have changed ecosystems extensively and often undermined the capacity of ecosystems to sustain food production, maintain freshwater and forest resources, and regulate climate and air quality[55]. According to the FAO projections of world agriculture in 2050, cropland area is forecasted to grow by 9% from 2000 to 2050.[56]

The concept of land use is important to bear in mind when discussing potential policy development in the EU biodegradable packaging sector. Currently, a production ratio of 300,000 ha per million of tonnes of biodegradable plastic material is estimated, based on worldwide averages.[57] Based on this ratio, it is estimated that agricultural land used for bio-based plastics was less than 0.1% of total arable land in 2009.[58]

Stakeholders from the bioplastics industry argue that crops used to produce bio-based plastics (including both biodegradable and non-biodegradable types) would not necessarily displace food crops, as there is existing land available—17% of the naturally irrigated arable land on the planet in 2006, i.e. 570 million ha—that could conceivably be used for energy and industrial raw material production. Taking into account the expected increase in the food demand until 2020, European Bioplastics estimates that if half the world's plastics were produced from cultivated crops, the industry would only need 3% of the total cultivated area and 360 million ha of naturally irrigated arable lands would remain unexploited on the planet (including 8 million ha in the EU).[59]

This preliminary estimation does not account for the environmental impacts related to land use changes both within and outside of the EU. Negative effects associated with land use changes include an increased release of green house gases to the atmosphere through the disturbance of soils and vegetation caused by deforestation.[60] Furthermore, any habitat disturbance leads to changes or degradation of biodiversity. In turn, any loss of biodiversity generally leads to a reduction or loss of ecosystem functions.

Moreover, transferring consumption away from production may displace rather than reduce pressure on the environment because of the close interdependencies between agricultural production and land use, and the globalisation of food commodities markets.[61] With regard to packaging, EU consumption of biodegradable plastics is not only dependent on land in EU countries, but also indirectly responsible for large areas of land use for agricultural production

[54] Bates et al., 2008.

[55] Foley et al., 2005.

[56] Erb et al., 2009.

[57] European Bioplastics, 2011d.

[58] Bioplastics Magazine, 2009.

[59] Biome Bioplastics, 2011.

[60] EEA, 2010.

[61] Audsley et al., 2009.

outside the EU's borders. Such overseas land requirements are referred to as "virtual land use". Virtual land use is potentially problematic since the spatial separation of material production (including resource exploitation) from consumption eliminates the direct negative feedback that normally occurs when people dependent on local ecosystems degrade those ecosystems[62], and may lead to food scarcity at the source of production.

Therefore, it can be noticed that increasing demand for biodegradable plastics may drive an increasing need for agricultural land, which can lead to ongoing land use change in countries where pristine forests are cleared or other land use types are pushed into forests, as has been seen in Brazil and Malaysia.[63] The land use changes overseas due to European consumption of biodegradable packaging might entail carbon emissions while increasing land used for certain crops and compete with food production in the future.

Another cause of concern lies in the effect that fostering bio-based biodegradable plastics might have on intensive agricultural practices and their impacts on ecosystems and biodiversity. More intensive land-use practices and increased greenhouse gas emissions might arise in response to expanding global markets for bio-based biodegradable packaging.[64]

- **Energy use**

Energy requirements in the manufacturing phase depend on the type of plastics. As shown in Table 9, biodegradable plastics can result in relatively low energy requirements compared to some conventional plastic like polyethylenes (PE). This is particularly relevant for starch-based plastics, whose use may then lead to energy savings.

However, for some fermentation-based materials, considerable amounts of energy are used in the process of converting renewable biomass into an equivalent alternative to petrochemical polymers.[65] The environmental benefits of using bio-based biodegradable plastics are significantly reduced if the energy required for this conversion comes from fossil sources.

[62] Kissinger, 2010.

[63] Gavrilova et al., 2010.

64 European Commission, 2011a.

65 Bier et al., 2011.

Table 9 – Energy requirements for the manufacture of different plastics[66]

Polymer	Energy (MJ/kg)
Low density polyethylene (LDPE)	81
Polyhydroxyalkoates –(PHA)	81
High density polyethylene HDPE	80
Polycaprolactone - PCL	77
Polyvinyl alcohol - PVOH	58
Polylactate - PLA	57
Starch (TPS) + 60% PCL	52
Starch (TPS) + 52,5% PCL	48
Starch (TPS)	25
Starch (TPS) + 15% PVOH	25

- **GHG emissions**

GHG emissions mainly result from the production of the energy required for the manufacturing process. In the case of bio-based packaging, carbon is also stored within the growing plants that are then used in the production of bio-based biodegradable polymers. This carbon is then returned to the air while the polymers degrade contributing to GHG emissions.

The greenhouse gas emissions resulting from the manufacturing processes as well as end-of-life treatment of different plastics are shown in Table 10, which reveals that biodegradable plastics, in particular starch blends, have relatively low GHG emissions compared to some polyethylenes.

66 Utrecht University, 2001.

Table 10 – Life cycle Greenhouse Gas Emissions from Biodegradable Plastics[66]

Polymer	GHG Emissions ($kgCO_2eq/kg$)
PCL	53
LDPE	50
HDPE	49
PVOH	42
TPS + 60% PCL	36
TPS + 52,5% PCL	33
TPS + 15% PVOH	17
Mater-Bi film grade	12
TPS	11
Mater-Bi foam grade	9
PLA	Not available
PHA - ferment	Not available

- **Pollution of aquatic environments**

In addition to the problems caused by packaging made from conventional plastics in aquatic environments (e.g. persistence, accumulation, contamination, etc.), biodegradable plastic packaging can have significant effects as well. This section is focused on those issues.

- Increased aquatic biological oxygen demand

The breakdown of starch-based biodegradable plastic materials can result in increased biological oxygen demand (BOD). In turn, pollution from high nutrient levels in waterways, determined by high BOD and chemical oxygen demand, lead to the degradation of aquatic ecosystems and algal blooms.

- Water transportable degradation products

Non-biodegradable by-products from the biodegradable packaging - such as dyes, plasticisers, catalyst residues that accumulate in landfills or compost can potentially leach to groundwater and surface water bodies. Organisms living in these water compartments could thereby be exposed to toxic compounds. A risk of accumulation can also appear.

- Risk to marine species

Marine species could ingest marine pollution given its resemblance to jellyfishes, squids or other translucent, amorphous organisms. In the animal guts, biodegradable products will not degrade rapidly and will affect the health of the species. It has been seen that turtles can die of starvation when plastic bags block their digestive tract.[67]

- **Litter**

Consumers are more likely to litter biodegradable packaging, presumably based on a mistaken belief that such products will disappear quickly in the natural environment. Figure 10 shows that an item being biodegradable is an important driver for littering, especially for young generations.

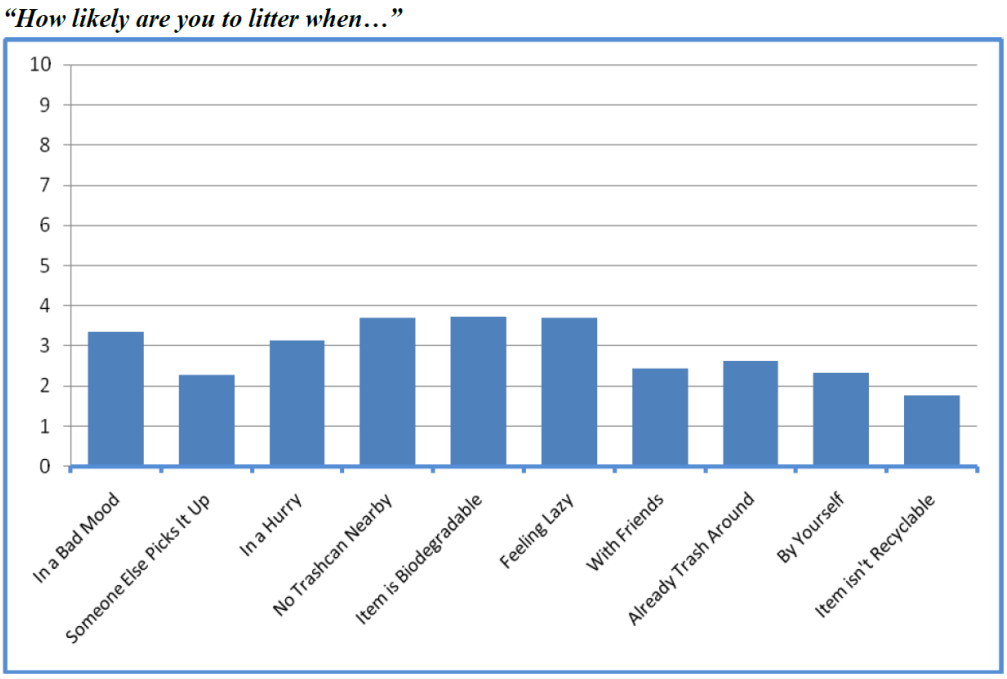


Figure 10 – Motives for littering based on youth panel (16-24 year-old)[68]*

*The response categories are scaled from 0 (not likely to litter) to 10 (very likely to litter)

This situation, where littering is induced by a misunderstanding or misuse of the term "biodegradable", could worsen the littering problem. In many cases, biodegradable materials are only technically biodegradable and not naturally biodegradable (see main definitions), resulting in the littered packaging persisting in the environment for a long period.

Focusing on marine litter, the impacts of marine debris are far-reaching, with serious consequences for marine habitats, biodiversity, human health, and the global economy[69]:

- At least 267 marine species worldwide are affected by either entanglement or ingestion of marine debris. That includes 86% of all sea turtles species, 44% of all seabird species and 43% of all marine mammal species.

67 Wabnitz et al. 2010.

68 Keep LA beautiful Initiative, 2009.

[69] UNEP, 2009.

- There is a potential risk on human health of toxic substances released by plastic waste in the ocean. Small particles—known as "microplastics"—made up of disintegrating plastic items or lost plastic pellets used by industry, may accumulate contaminants that may be responsible for cancer, reproductive problems and other health risks. Scientists are studying whether these plastics could also desorb these contaminants to biota and thereby the food chain at a later stage.
- Accumulated debris on beaches and shorelines can have a serious economic impact on communities that are dependent on tourism.
- Marine debris may house communities of invasive species that can disrupt marine habitats and ecosystems. Heavy pieces of marine debris can damage habitats such as coral reefs and affect the foraging and feeding habits of marine animals.

Composting

Composting has a positive environmental impact as it produces compost that increases organic soil matter and water and nutrient retention, while reducing fertiliser inputs and providing a better protection against plant disease. It contributes to cycles of matter (e.g. carbon cycle, nitrogen cycle, etc.) instead of locking these useful compounds in materials that will not degrade over time.

However, composting plastics will also expose plants, soil dwelling organisms (such as worms) and aquatic organisms to polymer degradation by-products such as manufacturing residues or potential additives used in their formulation. Due to the complex nature of polymer breakdown and the variety of biodegradable compounds, it is currently uncertain if toxic compounds may leach in the matrix of decomposed products.

Recalcitrant residues

Recalcitrant residues refer to fragments that are resistant to complete degradation. Their fate and potential effects in the environment are not fully known though some results suggest that some polymeric compounds may function as valuable components to humus.[70]

2.6.2 Economic impacts

2.6.2.1 Production costs

Biodegradable packaging production costs are characterised by:

- high research and development costs;
- high production costs resulting from the current small scale of production;
- optimisation potential of production facilities that are not fully exploited; and

[70] Nolan-ITUPty Ltd., 2002.

- price difference relative to conventional commodity products.

Due to these factors, biodegradable and compostable packaging is more expensive than conventional packaging. For instance, production costs of biodegradable plastic packaging range from €2 per kg for PLA to €5 per kg for starch blend and cellulosic bioplastic grades compared to the €1.2 per kilo of conventional polymers.[71]

Some examples of prices differentials can be found in the literature for 2009:

- "Mirel" biodegradable plastics produced by Metabolix (both bio-based and biodegradable in natural soil and water environments, in home composting systems, and in industrial composting facilities) have about twice the price of an equivalent conventional plastic;[72]
- "Inego", a biodegradable plastic made by NatureWorks LLC (compostable in industrial facilities) is slightly more expensive than conventional equivalents.[72]

High production costs are a major barrier for increasing market penetration and more widespread use of biodegradable packaging. However, production costs have dropped in the past decade and would continue to do so as the industry grows and technological improvements become available.[73]

In the long term, the main factors likely to influence the production costs of biodegradable packaging include:

- **Crude oil prices** – Crude oil prices have a strong influence on the production costs of petroleum-based plastic packaging. Therefore, increases in oil prices tend to foster the competitiveness of bio-based biodegradable plastic packaging.[74], [75]
- **Crop prices** – Highly variable in recent years, crop prices may increase the production costs of bio-based materials and thereby hamper the development of the market for biodegradable packaging.[76]
- **Processing costs** – In order to keep up with increasing demand, companies are undergoing rapid expansion. For most types of biodegradable packaging, the first industrial plants were recently set up and are now entering an optimisation process. However, average plants capacities are still smaller than petrochemical plants and manufacturers are still at the early stage of the learning curve.[77]

[71] Song et al., 2009.

[72] Momani, 2009.

[73] IBAW, 2005.

[74] Barker et al., 2009.

[75] Byrne, 2008.

[76] BIOIS, 2011.

[77] Shen et al., 2009.

Therefore, the biodegradable packaging industry has not yet reached production levels allowing economies of scale to be realised. [78]

2.6.2.2 *Trade*

There is no close monitoring of biodegradable packaging trade either worldwide, or at the EU level. With regard to plastics in general, the EU is traditionally a net exporter of plastics products with a trade surplus increasing by 105% since 2000.[79] In 2010, North America, South America and Europe produced each about 27% of the bioplastics produced worldwide, closely followed by Asia which contributed to about 18.5%.[80]

2.6.2.3 *Market barriers*

- **Limited applications**

Although biodegradable packaging materials have functionalities and process features that are generally similar to conventional plastics[81], they cannot replace all types of traditional materials in all applications. These limitations are the result of technical factors such as resistance and durability as well as economic factors such as production costs and capital availability.[82] In particular, material used in food packaging can have stringent requirements for certain properties—such as gas permeability—in order to ensure product freshness. It is possible that biodegradable plastics will not be able to replace many types of food packaging for such technical reasons (gas permeability, resistance, durability, etc.).[83]

- **Compatibility with existing manufacturing equipment**

When biodegradable packaging can match the performance of conventional packaging, the next barrier is the manufacturing chain, which may require adaptation and investment. For instance, in order to produce rigid parts from biodegradable plastics, some investments may be necessary to adapt existing equipment.[84]

- **Competition with food production**

Competition with food production is of particular importance to biodegradable plastic packaging, of which 95% are bio-based[85] and therefore require crops or combination of crops to be produced.

[78] Song et al., 2009.

[79] European Plastics Converters, 2009.

[80] European Bioplastics, 2011c.

[81] Hans van der Pol, 2011.

[82] Shen et al., 2009.

[83] BIOIS, 2011.

[84] Bioplastics Magazine, 2010.

[85] European Bioplastics, 2008.

It is often claimed that increasing biodegradable plastic packaging production would have two effects:

- A direct effect consisting in **increasing raw materials prices** through increasing demand for crops used to produce biodegradable plastics such as potatoes, maize, rice, etc.
- An indirect effect arising from the limited land availability that might lead to **competition with food production**, although it is highly debatable (see the part on land use in section 2.6.1 and the discussion below).

Concerning raw materials prices, the rise in agricultural commodity prices following the rise in ethanol production illustrates the extent to which an increase in biodegradable plastic packaging production could affect prices of agricultural products. Depending on the studies, biofuel demand is estimated to have accounted for 15 to 70% of the 2007-2008 food price increases.[86] [87]

An increase in biodegradable and compostable plastics demand would have an effect on the prices of the raw materials required for their production such as plant sugar or starch prices.[88] However, the extent to which crop prices are forecasted to increase is likely to be limited due to the relatively small share of the total crop dedicated to bio-based plastics.

With regard to food supply, the impact of biodegradable plastic packaging expansion on the world's food supply depends on the availability of cropland for food. Bio-based biodegradable plastics are made from raw materials harvested from crops that otherwise might be used for food production.

Currently, the biodegradable plastic packaging market is in its infancy. Therefore, it does not require a significant proportion of land for feedstock supply. The area of cropland used to satisfy EU consumption of biodegradable plastic packaging amount to only 26,443 ha in 2011 (see section 2.7.5). However, in the medium to long run, an increase in the European consumption of biodegradable plastic packaging could require significant areas of land for feedstock, decreasing thereby the land available for food production while increasing the incentive to cut down forested areas.

Given the relative small share of biodegradable materials used in the packaging market, there is no evidence yet in the literature showing that biodegradable packaging would decrease land availability in the future. Several parameters have to be taken into account when estimating the impact of bio-based products on food security (increase in yields, changes in food consumption patterns, investments in research and development of alternative non-food biomass such as algae, land required for urban development, etc.), which leaves any assumption on that matter open to debate.

[86] United Nations, 2011.

[87] Fortenbery et al., 2008.

[88] Momani, 2009.

- **Consumer awareness**

With regard to consumption, biodegradable packaging still face significant barriers in penetrating the consumer market due to misunderstanding about the difference between biodegradable, compostable, bio-based and conventional packaging (see section 2.4). Moreover, biodegradable packaging products are often seen as more expensive and of inferior quality. Ultimately, purchasing decisions seem to be more driven by prices than by environmental concerns.[89]

- **Contamination of the recycling streams**

Integration of biodegradable packaging into current end-of-life management systems (collection, sorting, recycling, etc.) will also be an important factor in the development of biodegradable packaging. When introduced into a recycling stream that is lacking the appropriate technical capacity, biodegradable plastics may potentially lead to the contamination of recycled plastics, affecting the quality and physical integrity of the resulting material[90] as discussed in section 2.2.2. The addition of biodegradable packaging into the existing waste stream will increase separation costs because equipment that is more sophisticated is required. In 2011, production of bioplastic packaging is not sufficient to cover the investments required to allow their treatment in existing recycling streams without damaging the quality of the recycled materials.[91] In the future, investment will have to be made in processing sites so that they can handle the new amounts and types of biodegradable plastics.

- **Lack of separate bio-waste collection system**

As discussed in section 2.2.2, it is necessary to introduce separate collection streams for biodegradable packaging products if their market share increases, as the contamination of the conventional recycling chains may render other recycled materials unusable. However, cost efficiency in the development of new waste treatment facilities depends on the ability to extract large volumes of homogenous materials from waste streams that have a significant value. Today's biodegradable packaging production capacity is still small relative to conventional packaging. Therefore, collected volumes of biodegradable packaging are too small to ensure the cost efficiency of biodegradable waste treatment facilities.

2.6.2.4 Economic cost of packaging litter

The wide diversity of impacts caused by litter makes measuring the full economic cost a very complex task. In theory, direct impacts such as litter cleansing costs would be easier to estimate than indirect economic impacts such as reduced ecosystem values or decreased quality of life that require controversial ecosystem valuation methods in order to be estimated. Discarded packaging represents a cost to maritime activities such as fishing based on time and money spent cleaning, disentangling etc. and because they may damage fish stocks. In some European regions, tourism may also be affected when discarded packaging visually affect landscapes and

[89] Kurka et al., 2009.

[90] Hopewell et al., 2009.

[91] European Bioplastics, 2011d.

decrease the recreational potential and the attractiveness of both inland and coastal sites. Unfortunately, relatively few data on the economic costs of packaging litter are reported in practice.

- **Costs of cleaning marine litter**

According to the UNEP, sectors that can potentially be economically affected by marine litter include tourism and recreational activities, shipping, fishing, agriculture by the coast, marinas and recreational boats, aquaculture and rescue services. However, the main cost related to marine litter consists in costal cleaning. Costs of cleaning packaging litter on coasts can be significant and often fall to local authorities rather than national governments.[92] For instance, UK local authorities, industry and coastal communities spent approximately €17.7 million in 2004 cleaning up marine litter in England and Wales.

More data on the costs of cleaning both marine and inland litter are presented in Annex 2.

- **Costs of cleaning inland litter**

Inland litter induces both direct costs to local communities in charge of cleaning discarded packaging and indirect costs encompassing decreasing property values, decreasing recreational attractiveness of sites, decreasing amenity value of landscapes, etc.[93] The literature gives very little specific information on the clean-up costs of packaging inland litter for EU Member States. However, some information has been found, including in third countries, which can be used to make an estimate. In particular, a study carried out in 2011 estimated the cost of litter in Switzerland and its distribution among the different litter components (take-way food packaging, drinks containers, newspapers and flyers, cigarettes). In towns and villages, more than 50% of the litter-costs were estimated to be caused by food and drink packaging and other objects associated with fast food.[94] (See Annex 2 for more data on the costs of cleaning inland litter).

Overall, assuming that 50% of the costs of cleaning litter are attributable to packaging litter[94] and that about 4% of packaging placed on the market end up in the environment, cleaning-up marine packaging litter cost approximately €22 per tonne of packaging littered in the UK in 2004.

2.6.3 Social impacts

2.6.3.1 Employment

- **Employment generated by biodegradable packaging production**

Based on extrapolations from data provided by Plastics Europe, as explained below, biodegradable packaging production in Europe is estimated to employ directly and indirectly

[92] UNEP et al., 2009.

[93] Keep America beautiful, 2010.

[94] Switzerland Federal Office for the Environment, 2011.

2,060 persons in 2011. In comparison, non-biodegradable plastic production is estimated to support directly and indirectly about 660,000 jobs in 2011.

According to European Bioplastics, estimates of the direct and indirect employment related to biodegradable plastics range from 3,000 to 6,000 jobs for a production capacity of 100,000 tonnes of biopolymers. This includes all stages of the value chain and all products: from agriculture and related activities, through to engineering, plant construction, conversion, sales, etc. Bio-resins are manufactured by very large, multi-national companies, while small- and medium-sized companies are involved the manufacture of end products.

No information is available for biodegradable plastic packaging as such. However, stakeholders confirmed that there is no reason to assume that biodegradable bioplastic production would be more labour-intensive than non-biodegradable bioplastics. In comparison, Plastics Europe calculated that 1.6 million people worked in the European plastics industry in 2009, producing 55 million tonnes of plastics.[95] Based on these data, it can be estimated that direct and indirect employment generated by the overall European plastic industry is around 3,000 jobs for each 100,000 tonnes of plastics produced.

- **Employment generated by the biodegradable packaging waste management sector**

In the EU-27, employment generated by the management of biodegradable plastics, wood and paper and board packaging waste is estimated to amount to about 1,400 jobs in 2011.[96] By comparison, the overall employment generated by packaging waste management (both biodegradable and non-biodegradable) is estimated to amount to about 600,000 jobs in 2011.

Data on employment generated by packaging waste management in either the EU-27 or Member States is very scarce. Some general data on waste recycling are available. For instance, a recent study by Friends of the Earth estimates that recycling creates about 10 times more jobs per tonne than sending waste to landfill or incineration.[97]

In conclusion, the employment effect related to biodegradable packaging can be estimated as being marginal compared to the overall employment generated by the plastic packaging industry.

2.6.3.2 Affected stakeholders

- **Public authorities**

National waste authorities are often responsible for ensuring that EU-wide regulations are implemented at the Member State level. They are also responsible for implementing waste collection, treatment schemes and cleanup operations. They are therefore affected by the

[95] Plastics Europe, 2010.

[96] It is assumed that waste management has the same labour-intensity for both biodegradable and non-biodegradable packaging waste.

[97] Friends of the Earth, 2010.

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.

increasing costs and environmental impacts of packaging waste. Moreover, in line with the EU Resource Efficiency Roadmap that was published in September 2011, more efforts to reduce the weight and volume of packaging waste[98] and to eliminate landfilling by 2020 could be supported by the increased of biodegradable packaging.

- **Retailers**

The majority of retailers usually seek cost-reducing or cost-neutral sustainable packaging solutions. A shift from conventional to biodegradable packaging would need to be motivated by consumer demand and/or regulations. Currently, retailers rely on standardisation of certain technical parameters so that suppliers and customers across the industry have a common understanding of the properties of a product labelled "biodegradable" or some variant thereof. As such, well-defined standards with a consistent coverage of the biodegradability and compostability requirements would contribute to the market development of biodegradable packaging.

- **Packaging companies**

Despite the lack of consensus on the biodegradability of packaging, packaging companies seem adamant that it represents a commercial opportunity and many are mobilising to take advantage of this.[98]

- **Consumers**

European consumers have an interest for biodegradable packaging. However, a shift to biodegradable packaging could lead to additional costs for the end-users. Studies have shown that consumers express a willingness to pay slightly more for biodegradable plastics than for alternatives made of conventional plastics. Therefore, favouring the development of biodegradable packaging appears to face no strong behavioural obstacle.

According to a survey conducted by the BIOPOL – Project in 2009 in six European countries (Germany, Greece, UK, the Netherlands, Sweden and Poland), consumers' motivation to be more "eco-friendly" is the most important driver behind consumers' selection of bioplastic products, coming before their desire to conserve resources for future generations, as well as before health-related reasons.[99] In 2009, consumers seemed to be willing to pay, on average, 0.40€ more for orange juice packed in a bioplastic bottle than for orange juice packed in a traditional Tetra Pak carton and 0.32€ more for orange juice packed in a bioplastic bottle than the same product packed in a glass bottle. In 2005, over 50% of European citizens declared they would accept to pay more for bioplastics than for conventional plastics.[100] However, the same study showed that Europeans would prefer to rely on government incentives (e.g. tax incentives) and free markets for supporting the use of biodegradable plastics than investing in them through their own consumer choices (Figure 11).

[98] Pricewaterhouse Coopers, 2010.

[99] Kurka et al. , 2009.

[100] Gaskell et al., 2006.

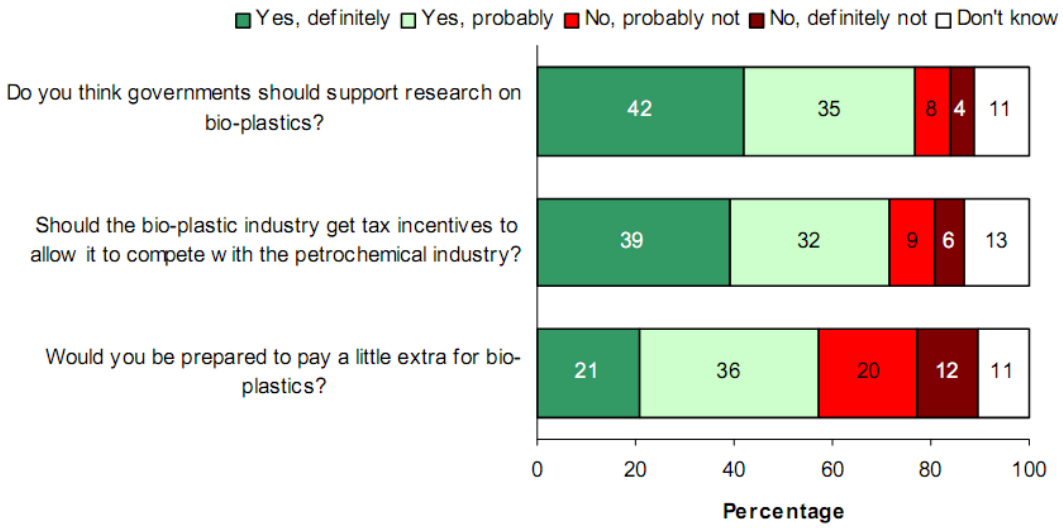


Figure 11 – European citizens' opinion on bio-plastics[101] (2005, EU-25)

Consumer interest in biodegradable plastics is further addressed in a survey on consumer reaction to compostable packaging made from biodegradable polymers carried out in the city of Kassel (Germany) in 2001 and 2002.[102] Out of 600 respondents, about 90% supported the idea of replacing conventional plastic packaging by their biodegradable equivalents and 75% confirmed that they would consider or definitely be willing to pay a higher price for such products. Consumers particularly appreciated the fact that biodegradable bags could be reused as hygienic containers for collecting organic kitchen scraps. Moreover, respondents declared that its compostable character (23%) drove buying compostable packaging slightly more than its renewable origin (18%). However, a survey carried out on Belgium consumers showed that in 2007, Belgium consumers ranked renewable sourcing of packaging as a higher priority than compostability.[103]

Additionally, as mentioned in section 2.2.5, compostable packaging is often interpreted as fit for home composting, while in fact, many packaging materials will not completely degrade in home composting environments. A similar misunderstanding exists regarding the biodegradable character of packaging. Biodegradable is often understood as able to disintegrate in nature without human interventions (21% of respondents in Belgium).[103] Such confusions increase the risk of littering, as consumers may believe that they simply disintegrate and disappear after disposal in the environment.

[101] Here bioplastics are defined as "Another industrial use of crop plants is the manufacture of bio-plastics. These, it is claimed, will be less environmentally damaging as they can be easily recycled and are bio-degradable." EuroBarometer – Gaskell et al., 2006.

[102] Kassel Project, 2003.

[103] Fost Plus, 2009.

2.7 Baseline scenario

The EC guidelines on Impact Assessments require that the problem definition includes a clear baseline scenario as the basis for comparing policy options. The baseline scenario aims to provide information and insights as to how the problem would evolve should no further EU action be implemented.

This section therefore describes how the problem is expected to evolve based on trends and policies in place as of late 2011. The scenario is subject to significant uncertainty due to the complexity of the issue and the low quality and completeness of the available data.

2.7.1 Overview of current and possible future requirements and standards related to biodegradable packaging products

- **European Union**

Annex II of the Packaging and Packaging Waste Directive 94/62/EC provides essential requirements that packaging products must fulfil in order to be placed on the EU market. With regard to the biodegradability of packaging, the Directive states that biodegradable packaging waste shall be of such a nature that it is capable of undergoing physical, chemical, thermal and biological decomposition such that most of the finished compost decomposes into carbon dioxide, biomass and water. The technical criteria to fulfil the requirement on biodegradability are set in harmonised standard EN 13432. The use of this standard is voluntary but it gives a presumption of conformity with the essential requirements provided by the Packaging Directive. By setting specific targets in terms of recycling and recovery for a set of packaging materials, the Packaging Directive favoured the development of the biodegradable packaging market and the introduction of separate collection schemes for biodegradable packaging.

In addition to the Packaging Directive, several other policies could affect biodegradable packaging. The Landfill Directive 99/31/EC sets a combination of intermediate and long-term targets for the phased reduction and pre-treatment of biodegradable municipal waste going to landfill (Table 11), as well as banning the disposal in landfill of certain materials. Member States that landfilled more than 80% of their municipal waste in 1995 (such as Greece and the UK) were allowed to postpone each of the targets by a maximum of four years.

Table 11 – Targets set in the Packaging Directive for reduction of biodegradable municipal waste going to landfills (in % of 1995 levels)

Year	Target
2006	75%
2009	50%
2016	35%

Source: Article 5 of the Landfill Directive 99/31/EC

In order to reach these targets, most national strategies included the promotion of composting, recycling of paper and energy recovery. However, the level of detail of the strategies and the measures to achieve the targets varied considerably. For instance, some Member States chose legally binding measures, while others chose voluntary measures and incentives.[104]

Another relevant EU policy influencing future development of biodegradable packaging is the European Commission's Roadmap for a Resource Efficient Europe. Adopted on 20 September 2011, this Roadmap provides a framework in which future actions related to resource efficiency can be designed and implemented coherently up to 2050. It proposes ways to increase resource productivity and decouple economic growth from resource use and its environmental impact. With regard to waste treatment, one of the milestones that the Roadmap sets for 2020 is the limitation of energy recovery to non recyclable materials, the elimination of landfilling, and the provision of high quality recycling.

- **Member States**

Some Member States' actions are also likely to influence future trends regarding the production, collection and treatment of biodegradable packaging. These actions to reduce or ban the use of conventional packaging in different Member States illustrate a non-harmonised approach, which could also have impacts on the functioning of the internal market.

- In 1993, **Germany** introduced a ban on landfilling waste with an organic content of more than 3%. However, due to several loopholes, the ban was not properly implemented before 2001 and the adoption of the Waste Landfilling Ordinance postponed the implementation of the ban to 2005 and introduced new criteria for the organic content of waste that has undergone mechanical-biological treatment. Since then, the amount of municipal waste for landfill has dropped to only 1%.[105]
- In the **Netherlands**, since 1 January 2008, packaging importers, producers and purchasers pay a packaging tax, with different tariffs for each type of material. For conventional plastic packaging, the tariff is currently €0.47/kg. To encourage the use of biodegradable plastics, these have a tariff of €0.08/kg.

The main focus of most Member States with regard to plastic packaging wastes concerns plastics bags. Thus, several Member States have implemented actions to phase out the use of disposable plastic bags through taxation (e.g. in Belgium, Ireland and Denmark), agreements with the retail sector (e.g. UK), or through the outright ban of non-biodegradable carrier bags (Italy).

- **Italy** announced in 2010 the progressive introduction of a ban on plastic shopping bags that do not meet biodegradability requirements, with the exception of reusable plastic bags. Since 1 January 2011, the marketing of such bags has been forbidden in Italy. Shops and supermarkets were only able to provide customers with the plastic bags remaining in their stockrooms, giving them to customers free of charge; and only until 31 August 2011 in

[104] European Commission, 2005.

[105] EEA, 2009.

supermarkets and 31 December in smaller shops.[106] The goals are to reduce CO_2 emissions, protect the environment and support the agricultural sector with the commercialisation of bio-based materials. However, this kind of ban is a breach of the Packaging and Packaging Waste Directive, as well as internal market rules.

- In 2005, **France** adopted a law banning the sale of non-biodegradable plastic bags by 2010 but the text was never applied since it was deemed to be in breach of certain provisions of the Packaging Directive. The 2010 budget, *Loi de finances rectificative pour 2010, article 47,* instead set up a tax on non-biodegradable plastic bags of €10/kg, which will be applied from 2014. In addition, Corsica banned plastic bags in 2003. A referendum was organised that proposed three options for the replacement of conventional plastic carrier bags: large reusable plastic bags costing €1, paper bags sold for €0.08, or bio-based bags sold between €0.05 and €0.14 depending on their size. Of the 30,448 persons who voted, the majority (61%) opted for the reusable plastic bag sold for €1.
- In 2008, **Cyprus** rejected a proposal to make all bags biodegradable.
- **Greece** has no legislation in place regarding biodegradable plastics. However, some municipalities (e.g. Athens), districts (e.g. Samos) and large supermarkets have introduced biodegradable shopping bags.
- **Malta** introduced a €0.16 charge per conventional plastic bag in 2005 while no charges are set for biodegradable plastic bags.
- **Romania** introduced a tax of €0.5 for each non-biodegradable plastic carrier bag placed on the market. In 2010, the tax was cut to €0.25 and applies to bags from non-renewable sources.
- In **Slovenia** there are proposals to introduce a tax on plastic bags that would be passed on to customers and that would amount to €0.50 for bags made from at least 5% plastic; €0.40 for bags made from more than 95% biodegradable material; €0.20 for bags made from more than 95% textiles.

Third countries

Many other countries around the world have implemented policies to reduce the use of non-biodegradable packaging, focusing especially on plastic shopping bags.

- **China** announced a nationwide ban on shops distributing free LDPE plastic bags from 1 June 2008. The price that consumers would pay per bag is not defined; therefore, retail outlets are free to set their own prices for plastic bags. Nonetheless, the selling price set by retailers would be higher than the operating costs. According to one study, Chinese consumers use at least 24 billions less plastic bags each year since the ban of free plastic bags.[107] Despite the reduction

[106] Legge finanziaria 20071.

[107] Strange, 2011.

in plastic bag use, some implementation problems have been observed. There is a lack of effective substitutes for plastic bags and there are cases of double charging consumers.[107] China also banned the production, distribution and use of HDPE ultra-thin bags less than 0.025 mm thick.

- In **India,** there are local and regional bans on the use of non-biodegradable plastic bags that are thinner than 0.030 to 0.070 mm, depending on the region. The Government of Delhi is currently pushing for a complete ban on the production and use of non-biodegradable plastic bags nationwide, whereas the Environment Ministry supports only a partial ban. The justification for a partial ban is that there is no cheaper alternative to plastic bags.
- **Bangladesh** banned non-biodegradable plastic bags in 2002, after being found to be responsible for the 1988 and 1998 floods that submerged most of the country. A ban was first placed in Dhaka city only, and due to its success, a nation-wide ban was proposed and implemented in 2002. The Bangladesh ban was the first nationwide ban on plastic bags in the world. It has successfully cleaned up the streets and drains of the country, while stimulating a re-birth of the jute bag industry as well as other sustainable and biodegradable alternatives.[108]
- In **Thailand**, the government has committed itself to derive 5% of plastics from bio-based sources by 2012. To do so, an incentive program including research funding and favourable tax policies was introduced. Supported by the National Innovation Agency, this five-year plan called the *National Bioplastics Road Map* encompasses policy measures such as increases in import tariffs for non-biodegradable raw materials, tax-free policies for importing bioplastics, foam compounds, raw materials and biodegradable products which can substitute for conventional plastic bags and foam trays or land ownership rights for foreign investors.[109] Thus, Thailand aims at positioning itself as one of the world-leading producers of biodegradable plastics.
- In the **United States**, there is no regulation at federal level but local authorities can decide whether and how to intervene. San Francisco was the first city to ban non-biodegradable plastic bags from large supermarkets and pharmacies in 2007. Washington D.C. introduced a $0.05 fee for "single-use" paper and plastic shopping bags, resulting in a drop in monthly use from 22.5 million bags in 2009 to 3 million in 2010. The money collected goes to a dedicated river clean-up fund.[110] A $0.10 fee for plastic bags has been introduced in Los Angeles. With regard to labelling, two recent laws in California are also worth mentioning:
  - Assembly Bill 1972 – Truthful Environmental Advertising for Plastics – was passed into law in 2008 prohibiting the sale of plastic food

[108] Plastic Free Times website: plasticfreetimes.com/bangladesh-plastic-bag-ban.

[109] National Innovation Agency, 2008.

[110] ICC, 2011.

and beverage containers labelled "compostable" or "marine degradable" unless the container meets the applicable ASTM standard specification (ASTM D-6400 and D-7081 for plastic bags, and ASTM D-6400, D-7081 and D-6868 for food or beverage containers). The law also prohibits the sale of plastic food and beverage containers that are labelled "biodegradable," "degradable," or "decomposable," or any form of those terms, or in any way imply that the food or beverage container will break down, fragment, biodegrade, or decompose in a landfill or other environment.[111]

- Assembly Bill 2071 – Plastic Labelling Enforcement – was passed into law in 2009 giving local governments authority to fine companies that mislabel their products, as "compostable" or "biodegradable" even though they do not meet American Society for Testing and Materials (ASTM) standards.[112]

- **Mexico City** approved a law to ban the use of non-biodegradable plastic bags in 2009. However, confusion caused by unsubstantiated claims of biodegradability led the Mexico City Government to amend the law several times since its passage. In particular, plastic bags that use additives to accelerate their degradation have now to declare the additives and ensure they are accredited by the Ministry of the environment.
- In **Argentina**, the province of Buenos Aires (representing 37% of the country's population) and cities in the Patagonia region placed a ban on non-biodegradable plastic bags in 2008. A 2-year period was allowed prior to enforcement in order for all shops to convert to paper or biodegradable-plastic bags. At national level, a similar law banning conventional bags in all supermarkets and shops was presented in 2007.
- In **Brazil**, a bill was introduced (but not passed) in the Brazilian Chamber of Deputies in March 2007 in order to promote the replacement of conventional bags with biodegradable bags in retail outlets throughout Brazil. More recently, in Rio de Janeiro, a law was passed to decrease the use of polyethylene, polypropylene and similar plastic bags in retail outlets. Implemented with a phase out of over 3 years, the law requires stores to stop using that kind of plastic bags while providing alternative bags (such as biodegradable or reusable bags). Moreover, the stores that do not provide an alternative to conventional plastic bags are required to compensate their customers by giving them a discount if they decline to use a plastic bag or, for every 50 bags brought back to a store, customers are entitled to a kilogram of rice, beans or any other staple

[111] AB 1972, Legislative Counsel's Digest, Plastic bags – Plastic food and beverage containers . Available at: http://www.leginfo.ca.gov/pub/07-08/bill/asm/ab_1951-2000/ab_1972_bill_20080815_enrolled.html

[112] AB 2071, Legislative Counsel's Digest, Plastic bags – Plastic food and beverage containers – Enforcement. Available at: http://www.leginfo.ca.gov/pub/07-08/bill/asm/ab_2051-2100/ab_2071_bill_20080929_chaptered.html

food item. Thus, the law is designed to impose additional costs on stores that continue to use conventional plastic bags such that it is likely to have the practical effect of a ban. Numerous other municipalities in Brazil have passed similar laws intended to reduce the use of plastic bags in retail stores.[113]

- In **Australia**, an ex-ante impact assessment carried out by the Australian government indicated that a charge of 0.25 AUD (approximately €0.20, which is similar to the level of the plastic bag levy in Ireland) was likely to achieve the best environmental outcomes in terms of energy use and reduction litter. Rather than implement this charge as a mandatory levy, the Australian government responded to retail pressure and agreed to see what could be achieved through a voluntary retailer Code of Practice. The approach was implemented from 2003 to 2005. Supermarkets reduced HDPE plastic carrier bag provision by about 41-44% during this period and overall plastic bag use was reduced by about 34%.[114] According to the Australian Retail Association, the recycling rate increased to 14% as well. The initiative has also increased use of alternative forms of shopping bags such as biodegradable bags, reusable shopping bags and to some extent kitchen tidy bags. More recently, the Northern Territory government passed a law entered into force in September 2011 and forbidding retailers from supplying lightweight, single use, non-biodegradable plastic bags. To avoid the ban, biodegradable bags must meet the Australian Standard (AS4736-2006) and biodegrade within 180 days under industrial composting conditions. Paper bags are excluded from the ban as, according to the law, they are biodegradable in nature and have less impact on the environment.[115]
- In 2003, **South Africa** banned the manufacture, trade and commercial distribution of HDPE plastic bags thinner than 30 microns and introduced a plastics levy of around 1.20 €/kg on the thicker non-biodegradable plastics, which manufacturers are expected to pass on to consumers. The government wants to promote thicker and easier to recycle plastic bags, which would also stimulate the recycling industry.
- **Macedonia** (candidate for EU membership) intends to introduce a total ban on non-biodegradable plastic shopping bags, prompting a switch to biodegradable bags by 2013. The distribution of free plastic bags by retailers has been banned since January 2009. Consumers are charged one Macedonian denar (€0.016) per plastic bag. In the past two years, the use of plastic bags in Macedonia has fallen by 40-50%.[116]

[113] Lei N°5502, de 15 de julho de 2009 do Rio de Janeiro. Available at : www.bdlaw.com/assets/attachments/Rio%20de%20Janeiro%20Law%20No.%205502.pdf

[114] Australian Environment Protection and Heritage Council website. www.ephc.gov.au/taxonomy/term/54.

[115] Northern Territory Government, 2011.

[116] Strange,2011.

2.7.2 Model Description

A simplified model is developed in order to integrate projections until 2020 on both market developments and end-of-life management practices.

2.7.2.1 Model Structure

In order to calculate the environmental, economic, and social impacts of the policy options, it is necessary to estimate — with as much precision as is possible — what **quantity** of which **material** will find its way into which **end-of-life treatment** options.

The model (see Figure 12) starts with a breakdown of the market share of different types of packaging.[117] The portions of the different types of the materials that are considered biodegradable and non-biodegradable (according to the definition in the Packaging Directive) are distinguished to allow a complete analysis of the policy options. Figure 12 provides an example of the structure of the model for biodegradable plastics discarded in home composting. Where the availability of data permitted, the same approach was used to estimate the impacts for each material and each end-of-life option.

The total quantities of each of the different types of packaging are then distributed amongst the different end-of-life treatment options[118]. The result is a quantity of each material in each of the end-of-life options.

Based on these values, economic, social and environmental impacts can be calculated and aggregated for the baseline and the policy options.

[117] The material categories are as follows: Wood, Wood – BD (biodegradable), Wood – nBD (non-biodegradable), Paper and board, Paper and board – BD, Paper and board – nBD, Plastic, Plastic – BD, Plastic – nBD, Glass, Metal, Others.

[118] The end-of-life options are as follows: Landfill, Recycle, Composting (Home), Litter, Incineration, Industrial Composting, Other Recovery Options.

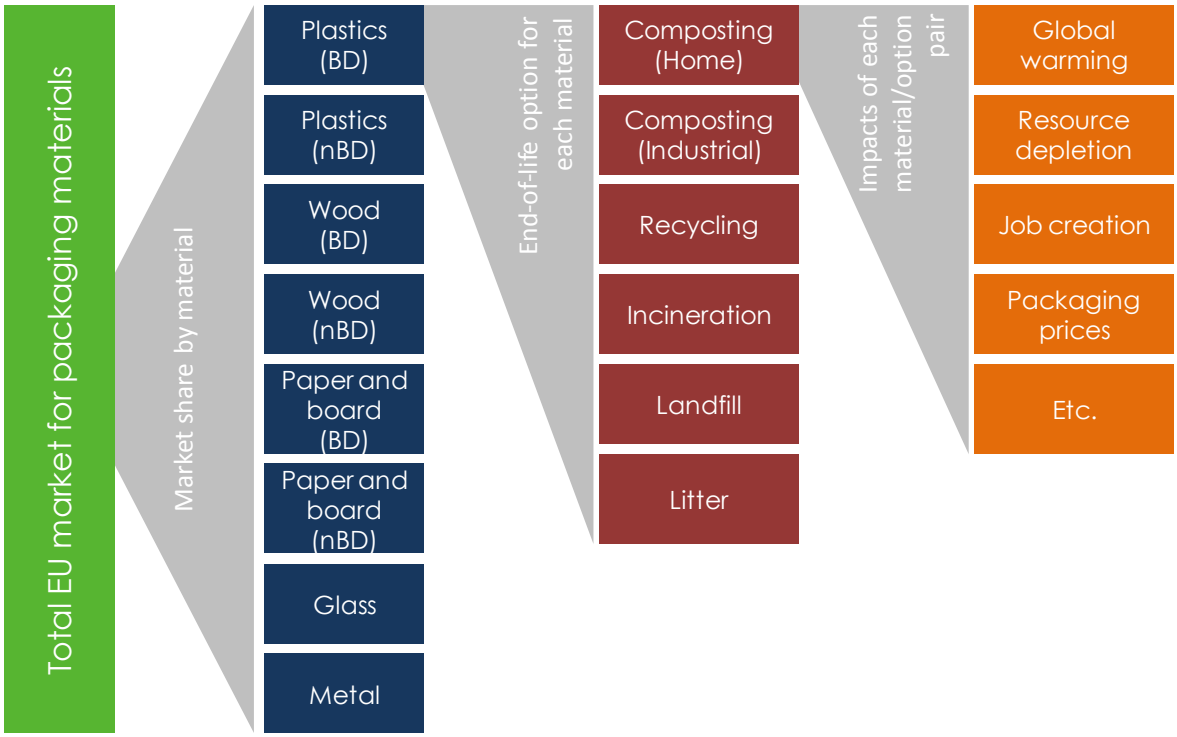


Figure 12 – Model structure for the baseline scenario

2.7.2.2 *Limitations of the methodology*

As packaging is a horizontal product, used as one component of many other products, the usual statistical and market databases such as PRODCOM are inadequate to provide specific data on the size of the market. Depending on the type of material and the availability of information, data collection on packaging materials relies on sources such as professional organisations (for data related to packaging production) or Member States declarations (for data related to the end of life management of packaging). Given that they come from different sources and do not systematically account for the same scope, these data are often difficult to compare.

This lack of frequent, consistent and reliable data on packaging is a serious obstacle to the projection of quantities of packaging production, consumption and end of life treatment by type of material. Market projections are based on data from studies on the European packaging market 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.

Moreover, although the projections were made at EU-27 level, there will be considerable variation across Member States due to differing economic and demographic trends, current regulations, etc. Therefore, because of the complexity involved and the incompleteness of the available historical data, it is not possible to make projections at the individual Member State level.

Scrutiny is warranted and further research would be needed to improve the estimates and in particular to establish the extent of regional variation.

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 packaging production and consumption would allow for more robust estimations and projections.

2.7.2.3 *Construction of the baseline*

As previously indicated, the construction of the baseline scenario aims to provide information and insights as to how the problem would evolve should no further EU action be implemented. The baseline is constructed out to 2020 and will serve as a reference scenario against which the impacts of potential policy options will be compared.

2.7.3 Packaging market projections to 2020

This section discusses first all packaging materials (biodegradable and non-biodegradable) and focuses then on projected market trends for specific materials (plastics, paper and board, wood, glass and metal).

As mentioned previously, demand for biodegradable and compostable packaging materials is growing rapidly, though the absolute quantities remain small. Several drivers can explain this fast rise, including:

- technology breakthroughs enabling a much wider range of application;
- limited landfill capacity;
- pressure from retailers;
- consumer pressure; and
- environmental legislation focused on limiting fossil-fuel dependence in order to limit greenhouse gas emissions and energy security.

In the subsequent sections, packaging consumption and production are projected to 2020 for the EU-27 for the following types of packaging materials:

- Wood (biodegradable and non-biodegradable)
- Paper and board (biodegradable and non-biodegradable)
- Plastics (biodegradable and non-biodegradable)
- Glass[119]
- Metal

Based on past trends, overall packaging production is projected to grow on average by 1.1% per year from 2011 to 2020. Over the period, growth of biodegradable packaging consumption is expected to exceed growth of non-biodegradable packaging consumption, with biodegradable

[119] Non-biodegradable packaging such as glass and metal are included in the baseline scenario in order to analyse the substitution effects that the different policy options could potentially induce.

packaging consumption growing at an average annual rate of 7.7% and non-biodegradable packaging consumption growing at an average annual rate of 1.1%.

Figure 13 and Figure 14 present respectively the projected trends in European consumption for non-biodegradable and biodegradable packaging up to 2020.

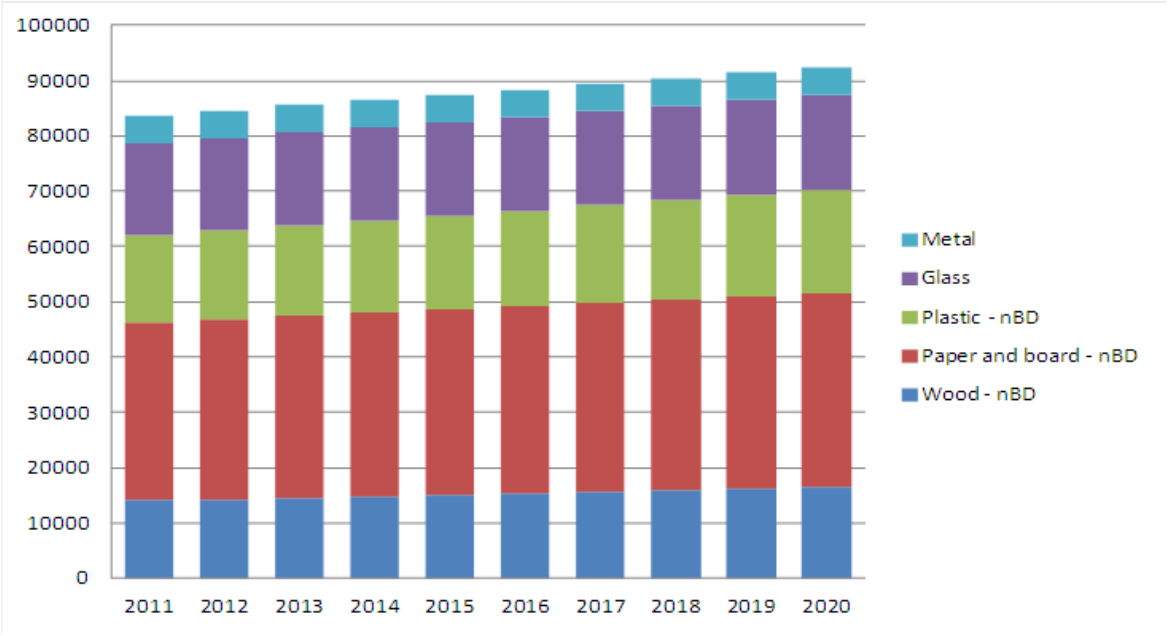


Figure 13 – Projection of the consumption of non-biodegradable packaging in the EU-27 (2011-2020, '000 tonnes)

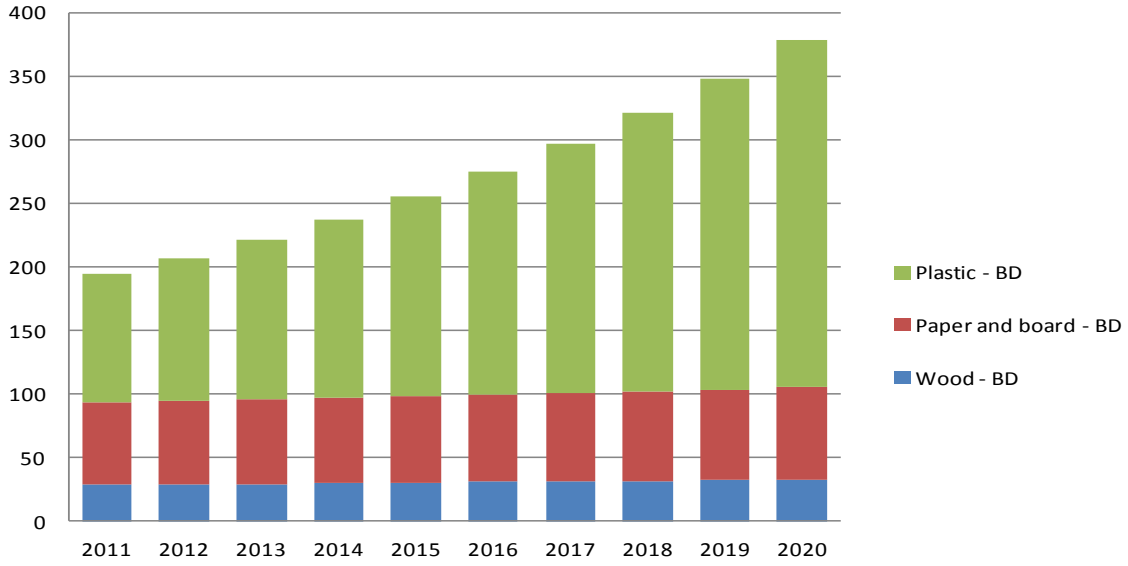


Figure 14 – Projection of the consumption of biodegradable wood, plastics and paper and board packaging in the EU-27 (2011-2020, '000 tonnes)

Similar trends are expected with regard to production. While non-biodegradable packaging production is projected to grow on average by 1.4% over the period 2011-2020, growth of

biodegradable packaging production would amount to about 11% in the EU-27. Figure 14 and Figure 15 present respectively the projected trends in European production for biodegradable and non-biodegradable packaging up to 2020. Data have been gathered for paper and board, plastics and glass packaging only.

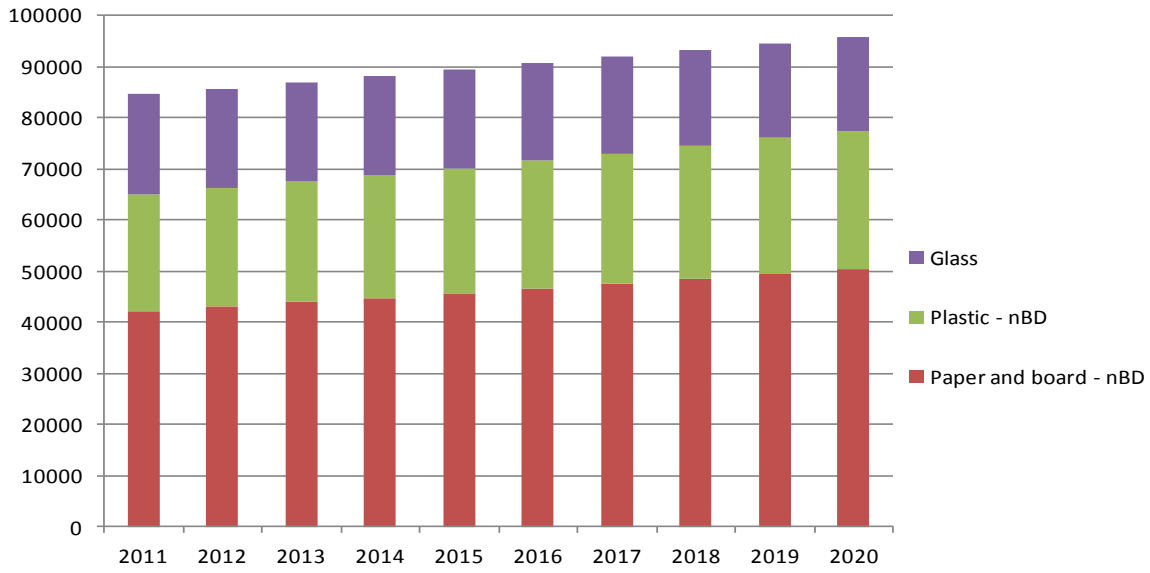


Figure 15 – Projection of the production of non-biodegradable glass, plastics and paper and board packaging in the EU-27 (2011-2020, '000 tonnes)

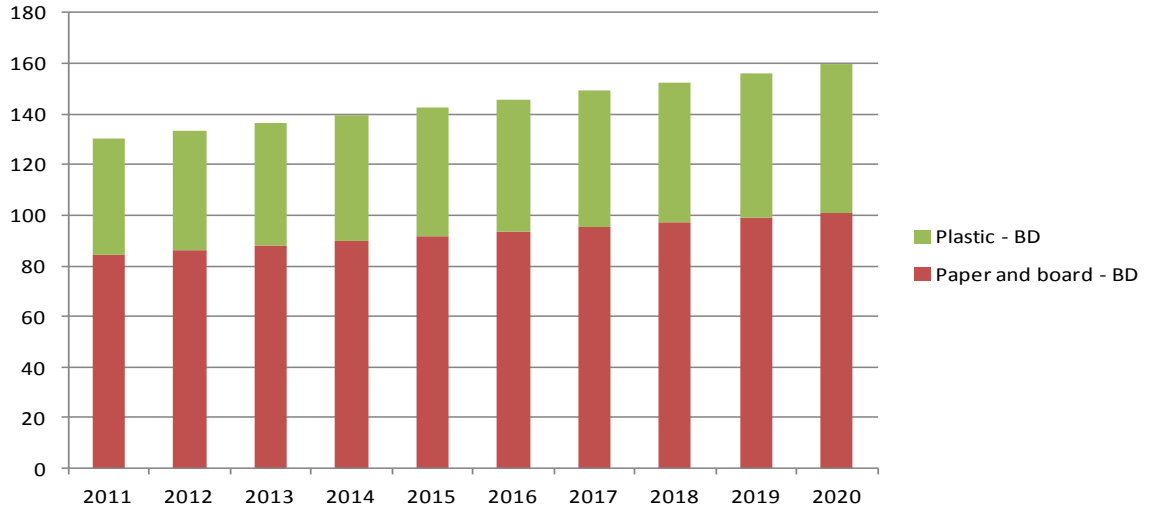


Figure 16 – Projection of the production of biodegradable plastics and paper and board packaging in the EU-27 (2011-2020, '000 tonnes)

Despite the rapid growth rate of biodegradable packaging, it will remain only a small fraction of the overall packaging market at the 2020 horizon (Figure 17).

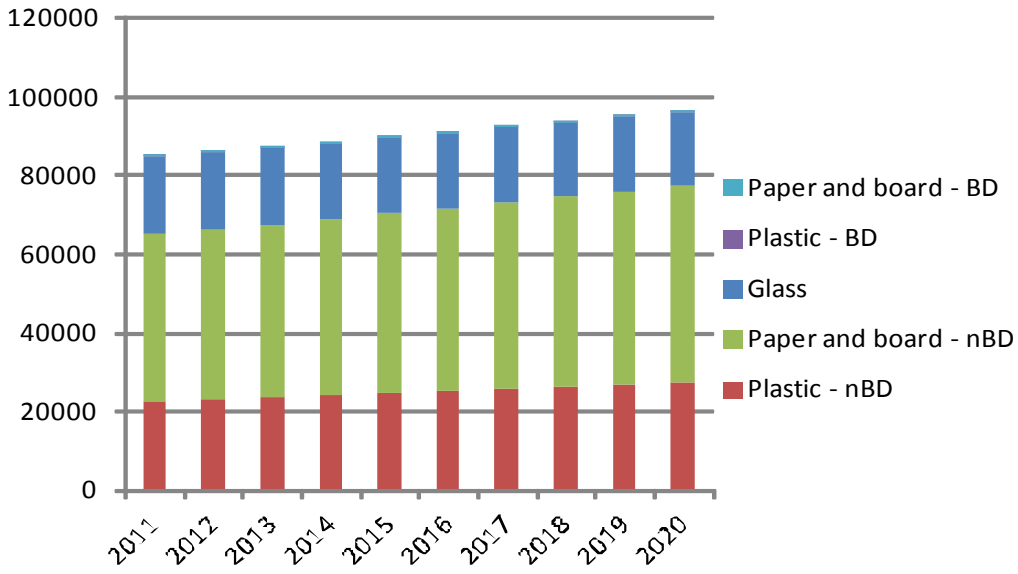


Figure 17 – Projection of the production of biodegradable and non-biodegradable plastics, paper and board and glass packaging in the EU-27 (2011-2020, '000 tonnes)

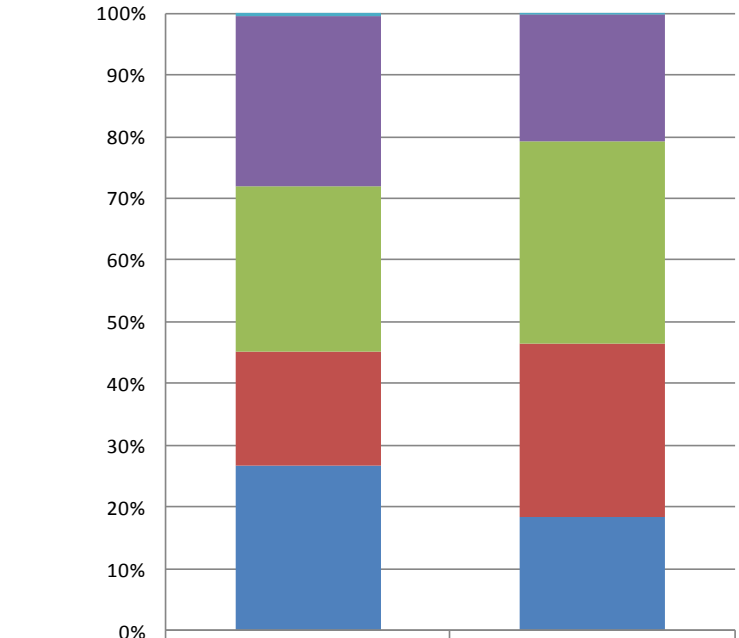
- **Plastic packaging**

European consumption of biodegradable plastic packaging is estimated at about 101,000 tonnes in 2011, increasing by 12% each year to reach 273,000 tonnes in 2020. [120]

Although about 40% of the global biodegradable plastic packaging demand arose from Western Europe in 2008, more rapid growth in demand is forecasted from the Asia-Pacific region whose market should equal the West European market by 2013. The Asian market will be stimulated by strong demand in Japan whose legislation favours the replacement of petroleum-based plastics in the packaging sector.

With regard to biodegradable plastic packaging production, the main producers of biodegradable plastics are currently North America, Western Europe and Japan. However, several bio-based plastics plants are expected to open in China and Brazil in the coming years, which should make them the world's leading producers of bio-based plastics by 2018 (Figure 18).

120 These estimates were computed from data provided by European Bioplastics on the European demand for bioplastics (260,000 tonnes in 2008). The share of biodegradable plastics in European bioplastics consumption is set to 80% based on the shares of biodegradable plastics production in global bioplastics production prevailing from 2008 to 2010. The share of biodegradable plastics consumption used in packaging applications is set to 35% according to stakeholders' consultations.



	2010	2015
Australia	0,50%	0,20%
South America	27,60%	20,50%
North America	26,70%	32,90%
Asia	18,50%	28,10%
Europe	26,70%	18,30%

Source: Adapted from European Bioplastics (2011)

Figure 18 – Biodegradable plastics production capacity by region (2010, 2015)

European production of biodegradable plastic packaging is estimated at 47,000 tonnes in 2011. Using the same annual growth rate of 2.7% for 2010-2015 and 2015-2020, the European production of biodegradable plastic packaging is projected to reach 52,000 in 2015 and 60,000 tonnes in 2020.[121]

With regard to materials, while starch-based materials dominated the European biodegradable plastic packaging market in 2006 (accounting for over 60% of the market), bio-PET and PHA are expected to increase significantly their market share thanks to the introduction of lower-cost technologies and additional resin capacity. Overall, bio-PE should continue to dominate the biodegradable plastic packaging market, with market shares expected to remain around 27% by 2015 (Figure 19).[122]

[121] European Bioplastics estimates that global biodegradable plastic production will increase from 428,000 tonnes in 2010 to 714,000 tonnes in 2015. Based on these data, production trends to 2020 were estimated considering 26.70% of global production arising from Europe in 2010 (European Bioplastics) and 40.01% of European plastics used in packaging in 2009 (Plastics Europe).

[122] Frost & Sullivan Research Service, 2007.

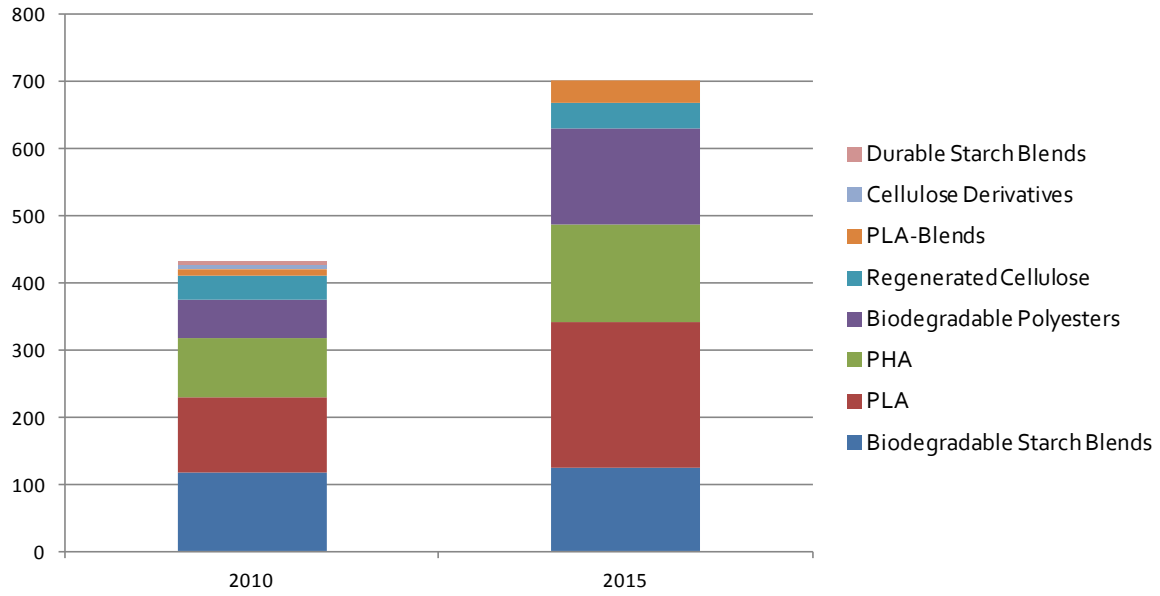


Figure 19 – Projection of the global production capacity of biodegradable plastics by type (in thousands tonnes per year, 2010-2015)[123]

As for exclusively bio-based plastics, of which over 85% are biodegradable, according to company announcements, the global capacity will increase from 0.36 million tonnes in 2007 to 2.33 million tonnes in 2013 and 3.45 million tonnes in 2020, i.e. at an average annual growth rate of 37% from 2007 to 2013 and 6% from 2013 to 2020. Based on expected influencing factors such as technical barriers, bulk applications, cost and raw material supply security, three scenarios describing the world production capacity of bio-based plastics until 2020 were developed by Shen et al. (2009) within PRO-BIP 2009. In particular, the BAU scenario reflects a steady growth of starch plastics, PLA, bio-based PE and bio-based epoxy resin and only a modest growth for cellulose films, PHA and bio-based PUR.

The use of biodegradable plastics is also expected to change in the future:

- In the coming years, **bio-based plastics** will be mainly used in medium to long life span applications.[124] Therefore, although packaging currently constitutes the main domain of application for bio-based biodegradable plastics, the largest growth rates are forecasted in the electronics and automotive industries.
- The largest end-use for **biodegradable polymers** should remain the food packaging, dish and cutlery markets until at least 2015[125] because of the large brand producers placing packaging made from biodegradable plastics on the market. Moreover, according to experts from the biodegradable plastics industry, due to their small individual volume and short life span, packaging products are particularly relevant for composting. Biodegradable packaging

[123] Adapted from European Bioplastics, 2011a.

[124] Stakeholders' consultation.

[125] European Bioplastics, 2011c.

materials are also particularly suitable for single-use disposable applications where the post consumer waste can be locally composted.[126]

- **Paper and board packaging**

Production of biodegradable packaging is expected to grow from 85,000 tonnes in 2011 to 101,000 tonnes in 2020 while consumption is projected to grow from 65,000 tonnes in 2011 to 72,000 tonnes in 2020. Data on biodegradable paper and board packaging consumption and production in the EU-27 are based on inputs received from experts in the fields of paper and board. They are assumed to account for about 0.2% of the market in 2011 and increase at a small rate up to 2020.

Overall (biodegradable and non-biodegradable) paper and board packaging consumption in the EU-27 is based on the data submitted by Member States to the European Commission. In particular, data on the amount of paper and board packaging placed on the European market from 1998 to 2008 is presented and analysed in EUROPEN (2011).[127]

In 2008, over 31 million tonnes of paper and board packaging were placed on European markets. Assuming a constant annual growth rate of about 1%,[128] paper and board packaging consumption is estimated to reach 35.2 million tonnes in 2020.

With regard to production, the amount of paper and board packaging produced in the EU-27 comes from CEPI (2011).[129] According to CEPI, the trend in paper and board production in Europe is around 2% growth. Based on these figures, paper and board packaging production is expected to increase from 42.3 million tonnes in 2011 to 50.5 million tonnes in 2020.

- **Wood packaging**

With a stable market share of 0.2% over the period, biodegradable wood packaging European consumption is projected to grow from 28,000 tonnes in 2011 to 33,000 tonnes in 2020.

Similar to the approach adopted for paper and board packaging, overall (biodegradable and non-biodegradable) wood packaging consumption in the EU-27 is based on EUROPEN (2011). Projections to 2020 set wood packaging consumption at about 14 million of tonnes in 2011 and 16 million of tonnes in 2020.

The share of biodegradable wood packaging consumption in overall wood packaging consumption is estimated based on inputs received from a wood industry association.

- **Glass and metal packaging**

The remaining shares of glass and metal packaging are considered as non-biodegradable. Consumption projections are based on EUROPEN (2011).

[126] Song et al., 2009.

[127] EUROPEN, 2011.

[128] 1.02% corresponds to the average annual growth rate of paper and board packaging consumption in the EU-27 from 2005 to 2008.

[129] CEPI, 2011.

2.7.4 End-of life management to 2020

The distribution of the different types of packaging into the different waste streams is characterised until 2020 in the baseline scenario.

As for 2011, no distinction between biodegradable and non-biodegradable materials is made as the available information is related to the packaging material itself with no specification of its biodegradability potential.

- **Recycling and recovery rates**

For each type of the packaging material, the recycling and recovery rates until 2020 were extrapolated from the available EUROPEN[130] and Eurostat data. Results for recycling are presented in Figure 20, which illustrates—in green—a steady increase for plastic and paper and cardboard recycling until 2020 whereas wood recycling will stabilise around 42-43%. Based on the EU Resource Efficiency Roadmap, which targets the elimination of landfilling by 2020, some adjustments on this preliminary baseline have been implemented from 2012—shown in blue in Figure 20—in order to take into consideration the redistribution of landfilled packaging into other waste streams. It is this baseline, assuming that the Resource Efficiency Roadmap target is reached, that is used in the modelling that follows.

[130] EUROPEN, 2011.

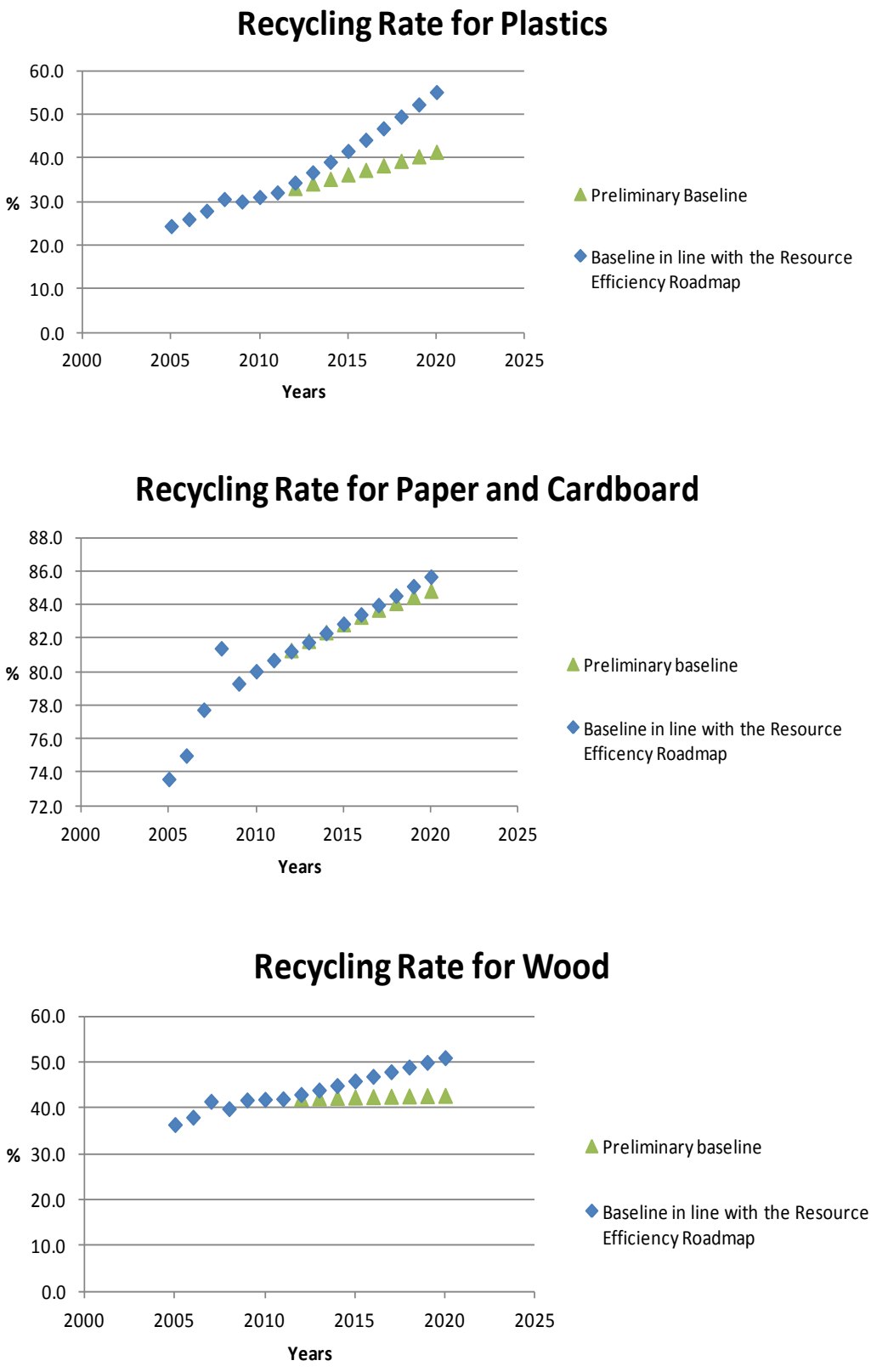


Figure 20 – Projections recycling rates for plastic, paper and cardboard, wood packaging.

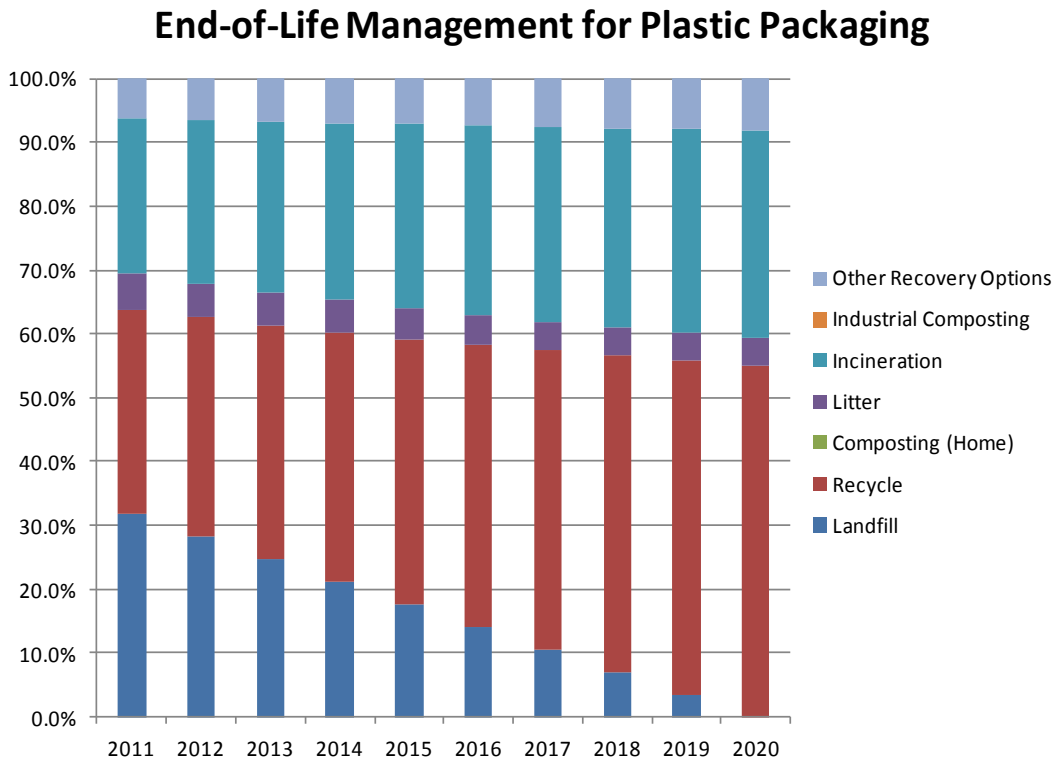
Complete distribution of packaging waste in disposal options

The full distribution of packaging waste among the different disposal options was modelled to 2020.

The following assumptions were considered:

- For plastics, paper and cardboard, and wood, it is assumed that packaging composting (home and industrial) remains at 0% in the baseline scenario. Although consumers will be more sensitive to organic recycling, they would preferably apply it to garden and organic waste. The distribution between incineration and other energy recovery options is similar to the 2011 one (see section 2.2.3).
- Landfill share is set to 0% of the packaging waste in 2020 assuming that the objective from the EU Resource Efficiency Roadmap will have been achieved. The landfill shares that would have been expected based on current trends (i.e. 28% for plastics, 1% for paper and cardboard and 15.7% for wood in 2020) are then proportionally redistributed into the remaining waste streams.
- Litter share follows the current trends to reach 4.2% for plastics, 0.2% for paper and cardboard and 4.8% for wood.

The three charts of Figure 21 illustrate the projections for each disposal option under the baseline scenario.



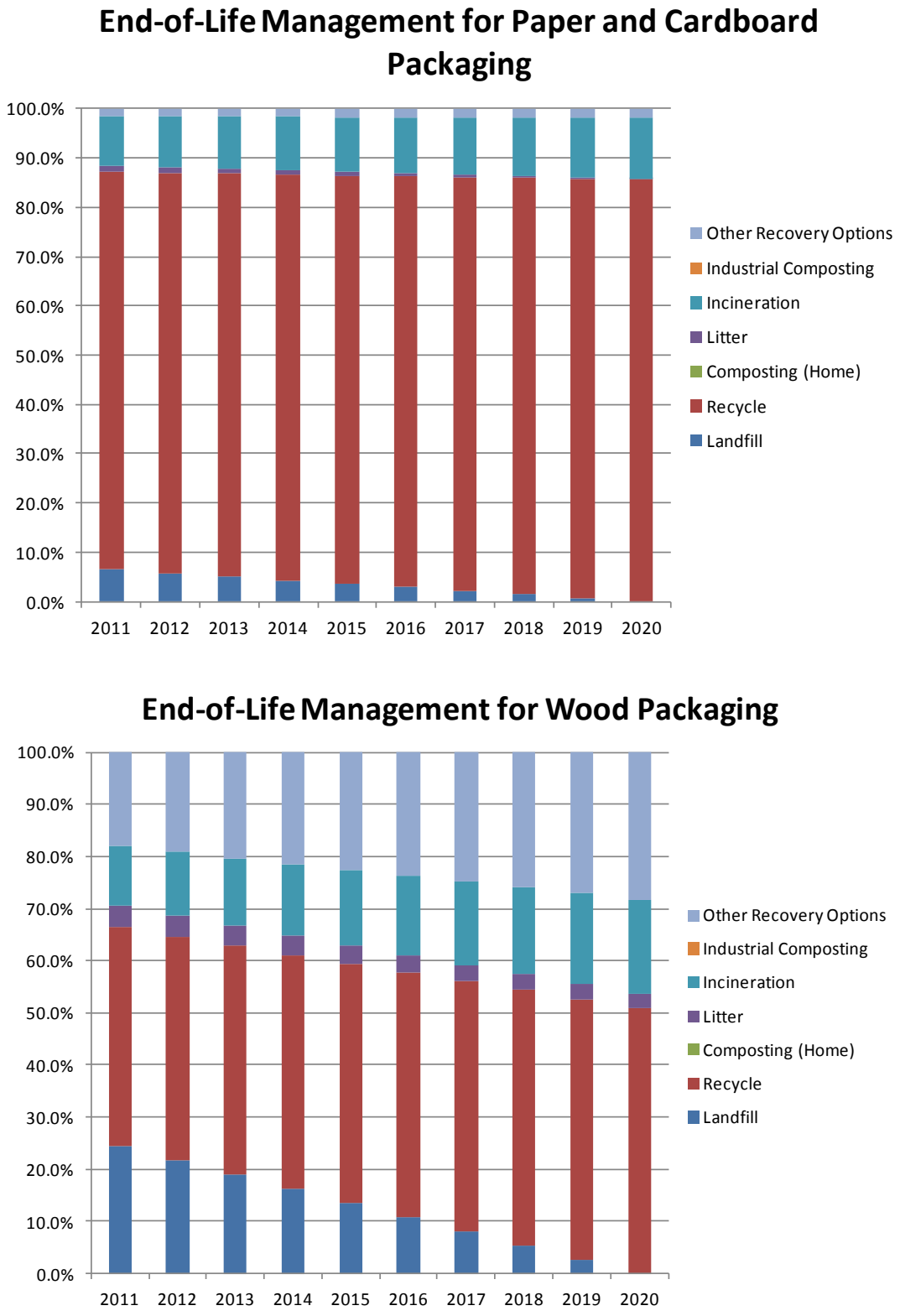


Figure 21 – Distribution in disposal options for packaging waste (plastics, wood and paper and cardboard) until 2020.

2.7.5 Environmental impacts

When biodegradable plastics are treated in appropriate end-of-life streams (such as composting facilities), most research shows environmental benefits coming from the use of biodegradable plastics compared with conventional plastics. This benefit, however, is also dependant on the production phase of the life cycle, with experts pointing out that biodegradable plastics can lead to negative impacts on the environment stemming from fertiliser and pesticide use, land use change required for increased agricultural production, as well as fermentation and other chemical processing steps.[131]

The following section aims to clarify these facts by quantifying environmental impacts related to both the production and end-of-life phases by 2020. It is assumed that during the period of projection, the environmental indicators (e.g. the greenhouse-gas emissions associated with the production of one tonne of biodegradable plastic) will remain stable. Therefore, most forecasted environmental impacts to 2020 do not take into account potential technological change.[132]

- **Environmental impacts related to the production of biodegradable packaging**
  - Land use

The area of cropland used to satisfy EU consumption of biodegradable plastic packaging (around 101,300 tonnes) amounts to 26,443 ha in 2011. This is estimated from the production ratio of 300,000 ha of cropland required to produce 1 million tonnes of biodegradable plastics material[133] and considering that more than 85% of the EU biodegradable plastic packaging market is made of bio-based polymers. Since less than half of biodegradable plastic packaging consumed in the EU are produced in the EU, it is likely that in 2011 most of the land use required to satisfy EU consumption is outside the EU.

The scenario to 2020 is built assuming that (Figure 22):

- The share of petroleum-based polymers within the biodegradable plastic packaging market will remain stable over the period at its 2010 level, namely 13%;
- Agricultural yields will increase on average by 0.87% per year. This estimate is based on the FAO projections of world agriculture in 2050 where crop yields are forecasted to grow by 54% on average from 2000 to 2050.[134]
- The difference between production and consumption figures will increase with time, meaning that more imports will be required.

[131] Tabone et al., 2010.

[132] An exception is made for the likely increase in yields that is forecasted by the FAO in its projections of world agriculture in 2050.

[133] European Bioplastics, 2011d.

[134] FAO, 2006.

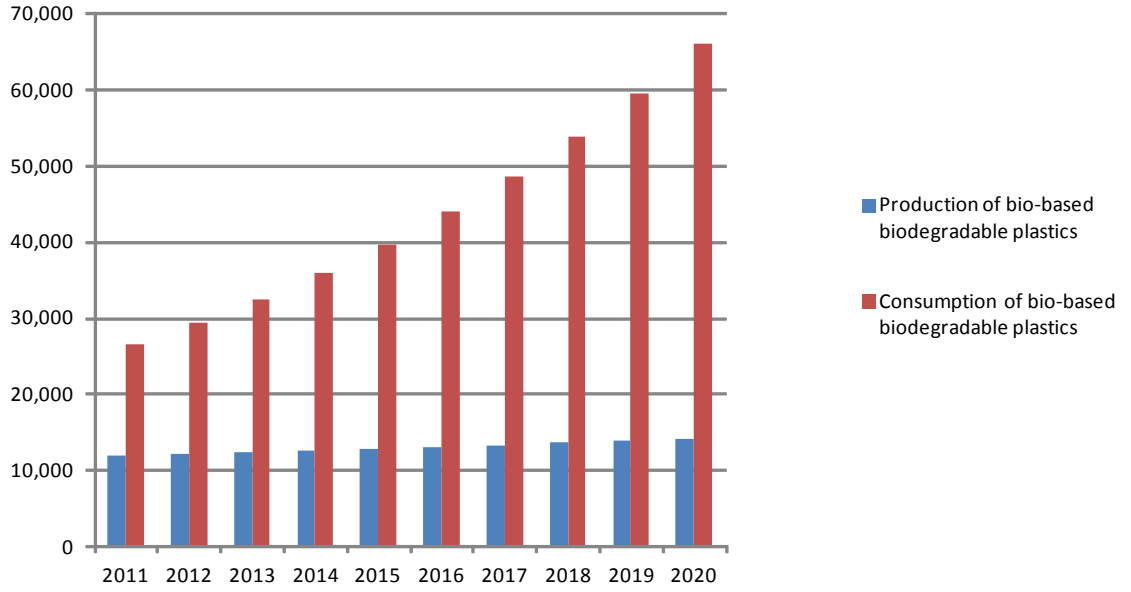


Figure 22 – Forecast of land demand induced by EU consumption and production of biodegradable plastics used in the packaging sector to 2020 (EU-27, in ha)

With regard to the impact of this increase in land use on the environment, it should be noted that feedstock crops would likely require the use of fertilisers, pesticides and water leading to further negative effects on the environment.[135]

- Energy use

The energy used in converting crops into plastics is generally much lower than the energy required to produce oil-based plastics because biological materials need lower pressures and temperatures in the manufacturing process. On average, bio-based plastics are processed at about 140-180 degrees Celsius compared to temperatures of over 300 degrees Celsius for conversion of petrochemicals to plastics.[136]

In the baseline scenario, the energy used to satisfy EU consumption of both conventional and biodegradable plastic packaging was computed from different LCA studies carried out between 1998 and 2005.[137] Indicators are averages of various types of plastics weighted according to their relative shares on the market in 2010. Considered technologies are state-of-the-art technologies in 2005.

Overall, indicators show that biodegradable plastics use on average 34% less energy during the production phase than non-biodegradable plastics, as shown in Table 12.

[135] European Commission, 2011.

[136] Biome bioplastics, 2011.

[137] JRC, 2005.

Table 12 – Average energy use during the production of conventional and biodegradable plastic packaging (EU-27, in GJ)

	Average energy use (GJ/t)
Biodegradable plastic packaging	55
Non-biodegradable plastic packaging	83

- GHG emissions

Biodegradable plastics made from biomass do not require petroleum feedstocks. The plants from which they are made absorb and sequester CO_2 as they grow and release it in the environment when they degrade. Therefore, the carbon emissions associated with their production only result from the materials and equipments used to cultivate the crops, and the energy used to run the manufacturing process and the treatment of the resulting wastes.[138]

In the baseline scenario, CO_2-eq emissions related to the production phase of both conventional and biodegradable plastic packaging were computed from different LCA studies carried out between 2003 and 2007.[139] Indicators are averages of various types of plastics weighted according to their relative shares on the market in 2010. The plastics taken into account are:

- Biodegradable plastics: PHA, PHB, PLA and TPS, with PHB generating significantly higher CO_2 emissions than PLA, PHA and TPS that require less processing;
- Non-biodegradable plastics: LDPE, PP and HDPE, with PP emitting slightly more CO_2 than LDPE and HDPE.

Overall, indicators show that CO_2-eq emissions generated during the production phase are on average 60% less for biodegradable plastics than for non-biodegradable plastics, as shown in Table 13.

[138] Vink et al., 2003.

[139] Harding et al., 2007 ; Yu et al., 2008 ; Vink et al. 2003.

Table 13 – Average CO_2-eq emissions generated during the production of conventional and biodegradable plastic packaging (in tCO_2-eq)

	Average CO_2-eq emissions (tCO_2/t)
Biodegradable plastic packaging	1.19
Non-biodegradable plastic packaging	2.97

- **Environmental impacts related to the end-of-life of biodegradable packaging**

Most environmental impacts related to the end-of-life of biodegradable packaging depend directly to the choice of waste management options. Environmental indicators presented in Table 14 are based mainly on a study carried out in 2006 by Eco-Emballages (a French packaging-recovery organisation) that compares polymers from different origins and assesses the end-of-life impacts of plastic packaging.[140] Indicators are averages of various types of plastics, weighted according to their relative shares on the market in 2010. The technologies considered are state-of-the-art technologies in 2006 in France. As the original study used GHG emissions based on the energy mix in France[141], the GHG emission factors are adjusted based on comparative and proportional analysis from the Ecoreport tool that is currently used by the European Commission (DG ENER) in preparatory studies regarding the Ecodesign Directive.

Polymers used to estimate environmental impacts associated with the end-of-life of biodegradable packaging are:

- Biodegradable plastics: PLA and PBAT;
- Non-biodegradable plastics: PE and PET.

For each type of plastic, three end-of-life options are assessed:

- Biodegradable plastics: Incineration, composting and landfilling;
- Non-biodegradable plastics: Incineration, recycling and landfilling.

[140] Eco-Emballages, 2006.

[141] Using these indicators to estimate environmental impacts at the European level would likely lead to underestimated GHG emissions as nuclear energy accounts for over 40% of France's primary energy supply.

Table 14 – Environmental indicators associated with the end-of-life of plastic packaging (France, 2006), (*) adjusted to represent the EU energy mix

Environmental indicators	GHG emissions (*)	Resource depletion	Acidification	Eutrophication	Human toxicity	Aquatic ecotoxicity
Units	$kgCO_2$-eq/t	Kg Sb-eq /t	kg SO2-eq/t	Kg Po42-eq/t	kg 1-4DB-eq/t	kg 1-4DB-eq/t
Biodegradable plastic packaging						
Incineration	-681.18	-3.36	-0.67	0.54	-15.93	-11.24
Composting	-748.16	0.05	0.05	0.01	0.9	0.15
Landfilling	-301.49	0.04	0.04	0.01	0.5	0.09
Non- biodegradable plastic packaging						
Incineration	887.83	-6.16	-0.93	1	-32.14	-21
Recycling	-1555.06	20.08	-8.39	-0.44	-369.59	-3
Landfilling	11.73	0.04	0.01	0.01	0.5	0.09

To allow for a meaningful comparison between the different environmental impacts, each policy option's value for each impact indicator was normalised to its 'inhabitant equivalent'. This is equivalent to the average impact associated with one inhabitant of the EU and allows impacts presented in different units to be compared more easily. The values used for normalisation factors are presented in Table 15 and the results of the normalisation are presented in the following sections.

Table 15 – Normalisation factors used to calculate 'inhabitant-equivalent'[142]

Environmental impact indicator	Normalisation factor (per inhabitant)
GHG emissions	11,232 kgCO2 eq
Resource Depletion	36.4 kg Sb eq
Acidification	36.3 kgSO2 eq
Eutrophication	40 kg $PO4^{2-}$eq
Human Toxicity	1,078 kg1-4DBeq
Aquatic Ecotoxicity	450 kg1-4DBeq

For instance, the GHG emissions generated by plastic packaging by 2020 can be measured in tCO2-eq and inhabitant-eq as shown in Table 16.

Table 16 – Forecast of GHG emissions generated by both conventional and biodegradable plastic packaging consumption to 2020 (EU-27)

	2011	2020
Biodegradable plastic packaging	240,115 tCO_2-eq *21,380 inhabitant-eq*	647,196 tCO_2-eq *57,620 inhabitant-eq*
Non-biodegradable plastic packaging	80,563,844 tCO_2-eq *7,173,000 inhabitant-eq*	95,505,469 tCO_2-eq *8,503,000 inhabitant-eq*

2.7.6 Economic impacts to 2020

Production costs

Lower relative production costs are expected for biodegradable plastic packaging in the future compared to other materials due to higher oil prices and increase in production capacities. Furthermore, legislative support outside of the EU and increasing restrictions on the use of plastic products at the Member State level would decrease production prices abroad. It is not possible to quantify such costs related to biodegradable packaging. To a larger extent, profits from bioplastics on the European market are expected to grow to 475.5 million€ in 2016, compared to 146.8 million€ in 2006.[143]

[142] These values were developed taking into account EU 25 +3 (EU25+ Iceland +Norway+ Switzerland) level in 2000 based on the values presented in:

1: *"Instititute of Environmental Sciences (CML) database (2010)"* for GHG emissions, acidification, eutrophication, human toxicity and aquatic toxicity.

2: *"Instititute of Environmental Sciences (CML) database (2008)"* for resource depletion

[143] Frost & Sullivan Research Service, 2007.

Knock-on effects on other sectors of the economy

The high market growth projected for biodegradable plastics is likely to have knock-on effects on other sectors of the economy.

Concerning employment along the production chain, compared to petroleum-based chemicals, bio-based chemicals use some raw materials whose production is more labour intensive than petroleum-production (see section 2.6.3.1 for a detailed analysis of the impacts of biodegradable packaging in terms of employment).

As for other sectors of the economy, from 2007 to 2017, the bio-based chemicals market[144] is projected to grow by tenfold compared to the conventional chemical market (Table 17). Although only a part of this growth is derived from the expansion of the biodegradable plastics market as such (other applications for bio-based chemicals include pharmaceuticals, cosmetics, food additives, non-biodegradable bio-based plastics, etc.), note that progress and discoveries in the field of biochemistry is likely to spur again the development of improved types of bio-based biodegradable plastics.[145]

Table 17 – Development of the bio-based chemicals market (2007-2017)

Market	2007	2012	2017
Chemical market (€ billions)	1,384	1,750	2,212
Bio-based Chemicals market (€billions)	49	135	340
Share of bio-based chemicals in total chemicals market	3%	8%	15%

Source: G. Festel (EFIB, Lisbon, October 2009; OECD Workshop, Vienna, January 2010).

Packaging prices

Overall, the projected increase in biodegradable materials in European plastic packaging consumption would likely lead to a rise in the cost of overall packaging in the short to medium term.

On the long run, the change in plastic packaging average prices is expected to result from two trends:

- On one hand, due to their dependency to fossil products, petroleum-based plastic packaging prices are expected to closely follow the increasing trend of oil prices. Based on the International Energy Agency's *World Energy Outlook for 2009*, oil prices are projected to increase annually by over 6% from 2011 to 2015 and by around 3% from 2015-2020. Assuming that non-biodegradable plastic packaging prices will follow a similar trend over the period, it is estimated that the average price of non-biodegradable plastic packaging will increase from 1.2€/kg in 2010 to 1.88€/kg in 2020.

[144] Bio-based chemicals include a wide range of products, such as biodegradable and non-biodegradable bioplastics, soy-based inks, biofuels, biocatalysts, and other chemicals and materials derived from renewable biomass.

[145] Heintz et al., 2011.

- On the other hand, assuming that the share of petroleum-based biodegradable plastics within biodegradable plastics remains relatively low until 2020, prices of biodegradable plastic packaging are likely to follow the prices trends of the raw materials used to produce them. Based on the projected changes in prices of raw materials provided by *OECD-FAO Agricultural Outlook 2011-2020*, the average price of biodegradable plastic packaging items are expected to decrease slightly from 4€/kg in 2010 to 3.76€/kg in 2020.

Costs of cleaning-up packaging litter

The increase in packaging placed on the European market will lead to higher public spending on clean-up activities. At the EU level, this means that clean-up costs associated with marine packaging litter are approximately 72 million € in 2011 and that, given the projected increase in packaging consumption, it is estimated that clean-up costs will increase to 80.5 million € in 2020.

The share of plastics in marine litter is expected to continue to grow in the future.[146] According to the project presented in section 2.6.2.4, UK local authorities, industry and coastal communities spent approximately 17.7 million € cleaning up marine litter in 2004 in England and Wales. Assuming that 50% of these costs are attributable to packaging litter[147] and about 4% of packaging placed on the market end up in the environment, cleaning-up marine packaging litter was approximately 22€/tonne of packaging littered in the UK in 2004. Estimated cleaning-up costs at the EU level are based on these figures.

Waste management cost

On the one hand, in the medium to long run, as consumption of biodegradable packaging increases, revenues of recyclers are likely to decrease due to the decreasing amount and quality of recycled materials.

On the other hand, stakeholders from the bioplastics industry claim that increases in commercial volumes and biodegradable packaging sales will cover the investments required to allow recycling of biodegradable plastics in existing facilities.[148]

[146] Thompson et al., 2009.

[147] Switzerland Federal Office for the Environment, 2011.

[148] European Bioplastics, 2011d.

- **Administrative burden and impacts on SMEs**

Unilateral measures in different Member States might hinder trade, and impose a cost for industry to cope with the different rules and administrative burden for public authorities. Impacts may be more severe for SMEs who do not benefit from the same economies of scale as larger companies.

2.7.7 Social impacts

- **Employment**

In the baseline scenario, changes in employment generated by packaging production over the period 2011-2020 is closely related to changes in the amount of packaging produced in the EU for each type of material. Thus, biodegradable packaging production is forecasted to increase by about 800 full-time equivalents (FTE) from 2011 to 2020, a small figure at the scale of the EU-27.

With on average 700 workers employed in the waste management sector for every 100,000 tonnes of packaging consumed in the EU-27, employment generated by the management of biodegradable plastics, wood and paper and board packaging waste is projected to amount to about 2,700 jobs in 2020.[149] By comparison, the overall employment generated by packaging waste management (both biodegradable and non-biodegradable) is expected to amount to about 655,000 jobs in 2020 (see Figure 23).

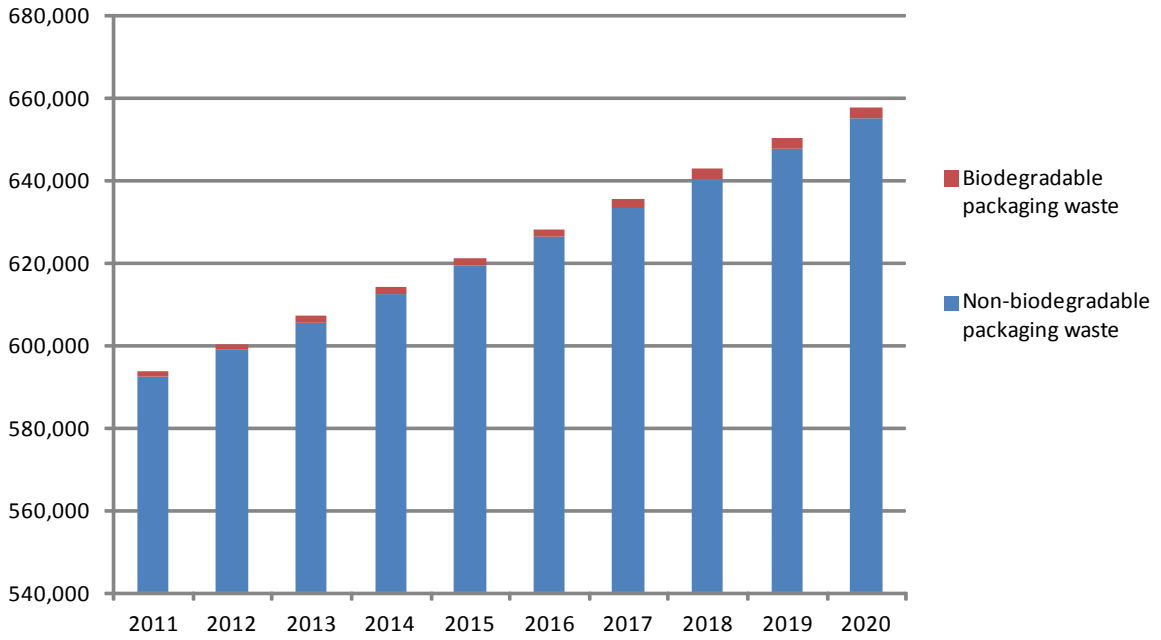


Figure 23 – Forecast of employment generated by packaging waste (EU-27, in FTE)

[149] It is assumed that waste management has the same labour-intensity for both biodegradable and non-biodegradable packaging waste.

Consumer awareness

As the use of biodegradable plastics continues to expand, there are growing concerns among consumers regarding the way they are expected to handle such packaging products. In many countries, consumers' confusion has lead to the development of voluntary labelling schemes. However, since the only harmonised standard applied to biodegradable and compostable packaging is EN 13432, there is a risk that most voluntary labels will be based on claims for biodegradation that are not sufficiently supported by a scientifically-valid standard.

Despite the multiplication of voluntary labels, there is still relatively limited understanding among the public regarding different packaging types on the market, the biodegradability of the materials, and the appropriate end-of-life treatment for such materials. Looking ahead to 2020, and given the increase in packaging use (and especially plastics), concern regarding the environmental impacts associated with the end-of-life treatment will packaging will continue to rise among consumers.[150]

[150] BIOIS, 2011.

Chapter 3: Identification of policy options

The following policy options were developed and will be the subject of the analysis and comparison in the next chapters.

- **Options to reinforce compostability and biodegradability requirements in Annex II of the Packaging Directive**
  - **P1a**: Reinforce existing requirements by making a clear distinction between compostability and biodegradability by means of i) specifying that composting in industrial facilities is to be strictly regarded as a form of packaging recoverability and cannot be labelled as biodegradability, and ii) introducing a new requirement for biodegradability specifying the timeframe and conditions for packaging waste to biodegrade in natural conditions in the environment and in particular in the marine environment;
  - **P1b**: Introduce a requirement for compostable packaging to be fit for biodegradation in natural conditions in the environment and in particular in the marine environment;
- **Options to promote consumer visibility of biodegradable packaging**
  - **P2a**: A mandatory user-friendly labelling or marking system for biodegradable and compostable (with the distinction between industrial composting and home composting) packaging products;
  - **P2b**: A mandatory user-friendly labelling or marking system for biodegradable and compostable (with the distinction between industrial composting and home composting) packaging products.

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Chapter 4: Analysis of policy options

This chapter analyses the potential direct and indirect environmental, social and economic impacts of the policy options given in chapter 4. The aim of this analysis is to provide clear information on the impacts of the policy options as a basis for chapter 5, where they will be compared both against one other and against the baseline scenario.

4.1 Selection of impact categories

One of the first steps required in analysing impacts of the different policy options is to select impact categories and associated measurable indicators where possible. When considering impact categories and indicators, it is important to keep in mind the main life-cycle stages of biodegradable packaging at which impacts occur. Table 18 includes a selection of indicators that will be used to guide the analysis of economic, social and environmental impacts of the proposed policy options. Where data (official or estimates) are unavailable, these indicators will be evaluated on a qualitative basis.

Table 18 – Indicators used in the analysis

Category		Impact
Environmental impacts	Emissions (manufacturing phase)	- Global warming potential (GWP)[151] - GHG emissions
	Littering	- Marine litter - Visible land litter
	Biodiversity and land use	- Area dedicated to biodegradable packaging production
	Waste generation	- Biodegradable packaging waste generation - Energy used to produce and dispose/treat biodegradable packaging
	Water and soil quality (where applicable)	- Eutrophication[152]
	International environmental impacts	- Litter
Economic impacts	Functioning of the internal market and competition	- Impact on the free movement of goods, services, capital and workers. - Reduction in consumer choice, higher prices due to less competition, creation of barriers to new entrants.
	Competitiveness, trade and investment flows	- Impact on the global competitive position of EU firms and their productivity - Trade barriers
	Operating costs and conduct of businesses / SMEs	- Additional adjustment, compliance or transaction costs - Cost and/or availability of essential inputs (raw materials, machinery, labour, energy, etc.) - Stricter regulation of the conduct of a particular business - Number of new businesses - Number of businesses closed
	Administrative burden on businesses and MS	- Implementation and certification costs
	Public authorities	- Budgetary consequences for public authorities at all

[151] Global warming potential is a measure of how much a given mass of a greenhouse gas (for example, CO_2, methane, nitrous oxide) is estimated to contribute to global warming. Global warming potential is measured in terms of CO_2 equivalents.

[152] This is caused by the addition of nutrients to a soil or water system which leads to an increase in biomass, damaging other organisms. Nitrogen and phosphorus are the two nutrients most implicated in eutrophication. Eutrophication is measured in terms of phosphate (PO_4 3-) equivalents.

Category		Impact
		levels of government, both immediate and long run.
	Waste management costs	- Costs of collection - Costs of recycling technologies (investment and operational costs)
Social impacts	Employment and labour markets	- Job loss/creation
	Consumer awareness	- Effect on consumers behaviours in terms of both consumption and disposal of packaging

The following sections provide information on the environmental, social and economic impacts of the identified policy options.

4.2 Modelling of policy scenarios

Starting from the baseline scenario, the analysis of the impact of the policy options was accomplished by modifying the shares of the different packaging materials put on the market, the quantity of each material that will be treated in each of the different end-of-life options). In some cases, the impact indicators were modified as well, depending on the expected impact of the option (see Figure 24).

These modifications have been based on hypotheses of the impacts of each option, which are, in turn, based on existing literature and input from experts. Where necessary and possible, these hypotheses were validated by relevant experts.

For example, policy option P1b, which restricts the definition of "biodegradable" to less persistent materials, sees the share of non-biodegradable plastics increase in the short term, while the share of biodegradable plastics decreases. At the same time, the environmental impact of biodegradable plastics will decrease, as the category no longer includes some of the more damaging materials. Over time, the market shares will change, as producers will likely bring to market more materials that conform to the revised definition.

A general principle of the analysis will be to modify a minimum number of variables for each policy option, relative to the baseline. Only when there is clear justification has any modification been made.

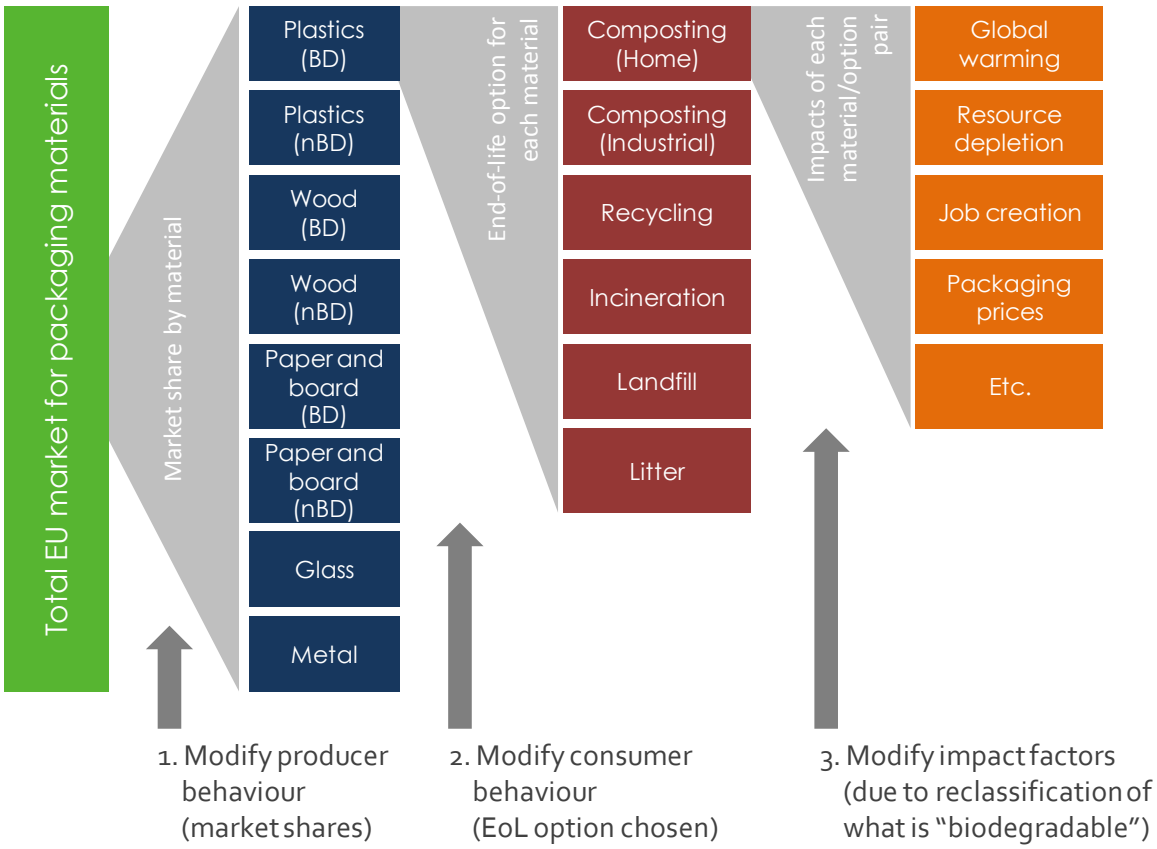


Figure 24 – Analysis of policy scenarios

4.3 Analysis of the impacts

4.3.1 Policy option P1a: Reinforce existing requirements by making a clear distinction between compostability and biodegradability

Following the implementation of the policy option P1a, compostability and biodegradability are clearly differentiated in terms of standards. It is assumed that starting from 2012, composting in industrial facilities is to be strictly regarded as a form of packaging recoverability and cannot be labelled as biodegradability. In parallel, a new requirement is introduced for biodegradability specifying the timeframe and conditions for packaging waste to biodegrade in natural conditions in the environment and in particular in the marine environment.

The main effect of this policy option would be to clarify the definitions for compostable and biodegradable packaging as the following:

- Packaging that is compostable only in industrial facilities would be considered strictly a form of packaging recoverability and could not be labelled as "compostable".
- Packaging that is labelled as "compostable" must be compostable at home ;

- Packaging that is labelled as "biodegradable" must be biodegradable in natural conditions in the environment.[153] Therefore, compostable packaging that does not biodegrade in the environment could not be labelled as "biodegradable".

Considering these aspects, the following paragraphs present the main effects expected from the implementation of this policy option.

- **Expected effects on market projections**

Two opposite effects are expected on market trends:

- On the one hand, as only packaging that is biodegradable in natural conditions will be labelled as biodegradable, consumers will progressively build their trust towards biodegradable packaging as opposed to the current situation where confusion/misuse may exist (see section 2.4). Because of this clarification, in countries where voluntary labels exist or are forecasted to be developed in the coming years, consumers are likely to have greater confidence and to be more receptive to any resulting informative/labelling schemes. This effect will tend to increase the demand for both compostable and biodegradable packaging. In the medium run, policy option P1a is also likely to increase companies' willingness to develop/adopt labelling schemes in countries and/or on markets where no labels are yet implemented.
- On the other hand, higher requirements for biodegradable packaging will constitute a market barrier for new companies willing to enter the market for biodegradable companies. In particular, companies seeking to label their products as "biodegradable" will have to satisfy more stringent requirements in order to do so. For potential new entrants, achieving these new standards will be costly and time-consuming. Therefore, it can be expected that a part of the potential new entrants will postpone, if not cancel, their entry on the biodegradable market. This effect will tend to lead to slower compostable and biodegradable packaging production, compared to the baseline scenario.
- However, a clearer definition for compostability and biodegradability might also attract companies that were previously reluctant to enter the market for compostable and biodegradable packaging as they would not consider it as a promising market given the confusion among the consumers. That could then create an incentive for producing biodegradable and compostable packaging.

The overall impact of this policy option on the packaging market will result from these two opposite effects.

The analysis is based on the following hypothesis: In the absence of additional and accurate information allowing to state which one of these effects will predominate, it is assumed that both effects will compensate and that the ultimate impact on the growth rate for the biodegradable

[153] According to stakeholders from the biodegradable plastics industry, setting a new requirement for biodegradability specifying the timeframe and conditions for packaging waste to biodegrade in natural conditions would be extremely difficult to implement because of the diversity of natural conditions existing in Europe. Therefore, stakeholders state that only the definitions related to the compostability of packaging are relevant to consider.

packaging market will be close to zero. No change from the baseline are expected for the market projections.

- **Expected effects on the projections related to end-of-life management**

As policy option P1a is based on technicality in regulation, little effect on the distribution in waste streams is expected for both compostable and biodegradable packaging compared to the baseline and no effect at all for non-biodegradable packaging. Table 19 summarises the shares of the different disposal options for biodegradable packaging in 2020. Expected changes compared to the baseline scenario are as follows:

- Home and industrial composting are not negligible anymore. With a better definition of compostability in the regulation, the proper and efficient disposal of compostable packaging for composting purposes could be an encouraging sign for consumers that may have been disappointed by a lack of degradation of supposedly compostable packaging in the past. It is suggested that the share of biodegradable packaging sent to each of the composting options would increase from 0% to 2.5% (for plastics) by 2020, relative to the baseline scenario. This value was presented to and accepted by some stakeholders from the plastics industry.
- It is expected that the increase in composting will be counterbalanced by a decreased in recycling, and not the remaining waste streams, as the composting and recycling options would target similarly informed end-users who could then prefer one option to the other.

Table 19 – Expected effects of policy option P1a on the distribution in waste streams by 2020 for biodegradable packaging (green for an increase compared to 2011, red for a decrease)

	Plastics (biodegradable)		Paper and Cardboard (biodegradable)		Wood (biodegradable)	
	2020 baseline	P1a 2020 impact	2020 baseline	P1a 2020 impact	2020 baseline	P1a 2020 impact
Landfill	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Recycling	55.1%	50.1%	85.7%	81.7%	51.0%	47.0%
Composting (Home)	0.0%	2.5%	0.0%	2.0%	0.0%	2.0%
Litter	4.2%	4.2%	0.2%	0.2%	2.8%	2.8%
Incineration	32.6%	32.6%	12.3%	12.3%	18.0%	18.0%
Industrial Composting	0.0%	2.5%	0.0%	2.0%	0.0%	2.0%
Other Recovery Options	8.1%	8.1%	1.8%	1.8%	28.2%	28.2%

Environmental impacts

In this section, environmental impacts are presented as difference compared to the baseline scenario. Therefore, increased impacts relative to the baseline appear as positive values whereas decreased impacts appear as negative ones.

- **Impacts on waste management**

The charts of Figure 25 present the changes in packaging waste amount for each of the waste streams. After the implementation of policy P1a, there is no shift from biodegradable packaging to non-biodegradable packaging due to the stricter definitions. However, for biodegradable packaging, there is progressive shift toward composting streams, with around 14,000 tonnes of plastics, 3,000 tonnes of paper and 1,300 tonnes of wood. No change for the non-biodegradable share of packaging is expected.

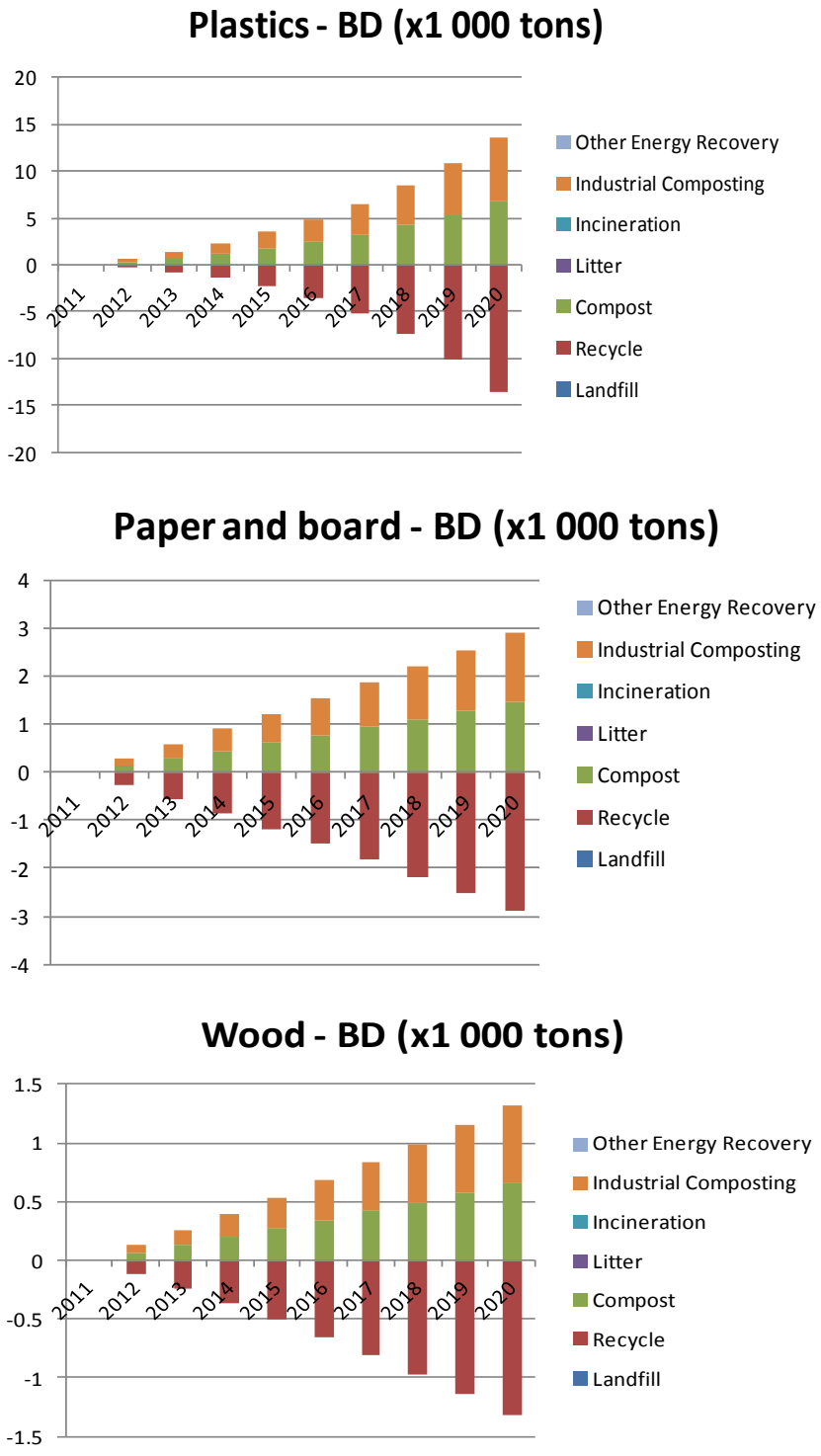


Figure 25 – Difference in biodegradable packaging waste amount for P1a, compared to the baseline scenario until 2020

Energy Use

Figure 26 shows the impact of policy option P1a on the energy use during the production and end-of-life phases in 2020 for all packaging materials, grouped by whether they are

biodegradable (BD) or non-biodegradable (nBD). In this case, the production phase is not impacted by the policy option P1a. However looking only at the end-of-life phase, energy requirements related to the biodegradable share will exceed the baseline scenario with more than 1,400 TJ/year. This is due to the energy savings related to recycling that are not ensured with composting.

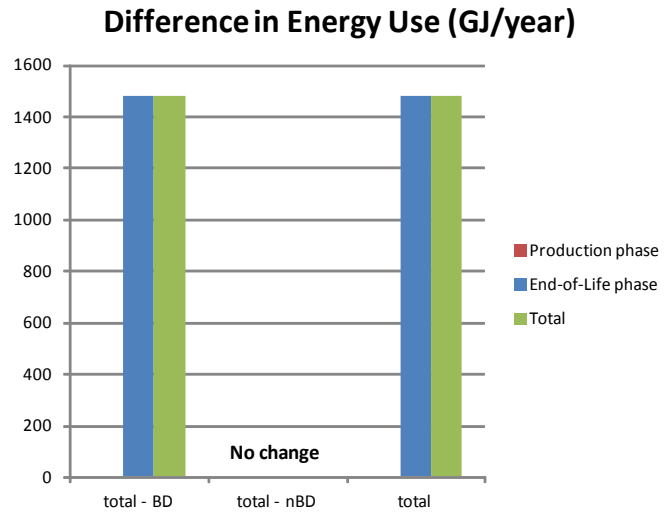


Figure 26 – Difference in Energy Use for plastic packaging waste in 2020 between biodegradable (BD) non-biodegradable (nBD) packaging

- **GHG emissions**

Figure 27 presents the difference in GHG emission compared to the baseline scenario. In this case, the implementation of policy option P1a seems slightly advantageous as up to 5,000 tonnes of CO_2 could be annually saved from 2020. The benefits would remain limited as it only corresponds to the equivalent of 450 inhabitants of the EU. This trend is explained by the less carbon-intensive composting processes, compared to recycling processes.

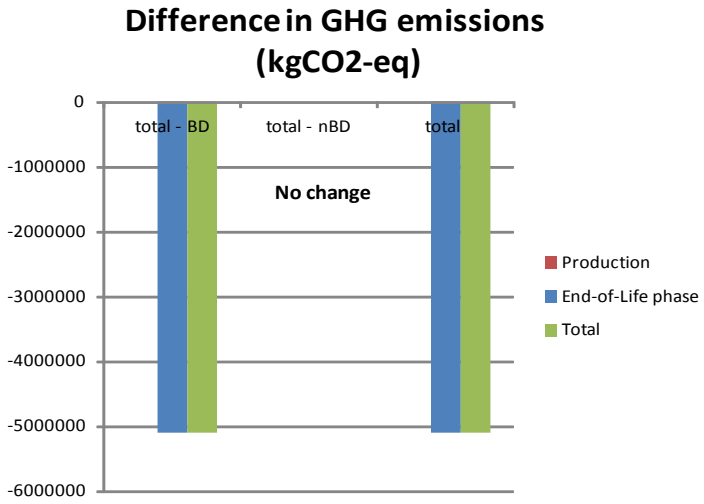


Figure 27 – Difference in GHG emissions for plastic packaging waste in 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

Resource depletion

A negligible increase in resource depletion, equivalent to only 10 inhabitants of the EU, is expected by 2020 with the implementation of policy option P1a (see Figure 28).This slight change is explained by the reduction of recycling in the biodegradable packaging waste by 2020.

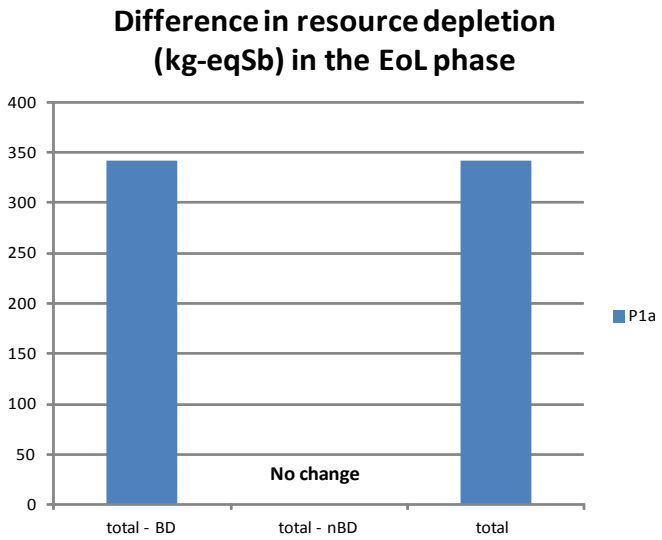


Figure 28 – Difference in resource depletion for plastic packaging waste in 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

Land use

As the production figures for biodegradable packaging are not affected by policy option P1a, there is no impact on the land use.

Eco-toxicity

With regard to toxicity, it can be seen that both human and aquatic toxicities will be negligible with the implementation of policy option P1a (see Figure 29 and Figure 30). For human toxicity, around 6,000 kg-1-4DBeq will be additionally emitted (which correspond to around 6 inhabitants of the EU). For aquatic toxicity, 1,000 kg-1-4DBeq will be emitted (which corresponds to around 2 inhabitants of the EU).

This very limited increase is due to the decrease of the recycling share in biodegradable packaging, and higher risk for toxicity with composting.

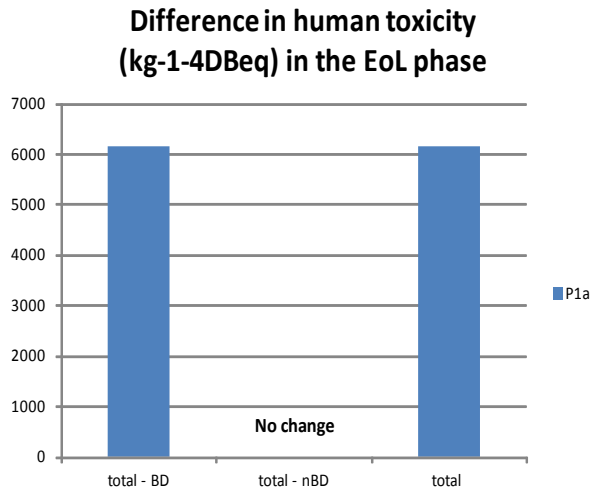


Figure 29 – Difference in human toxicity for plastic packaging waste in 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

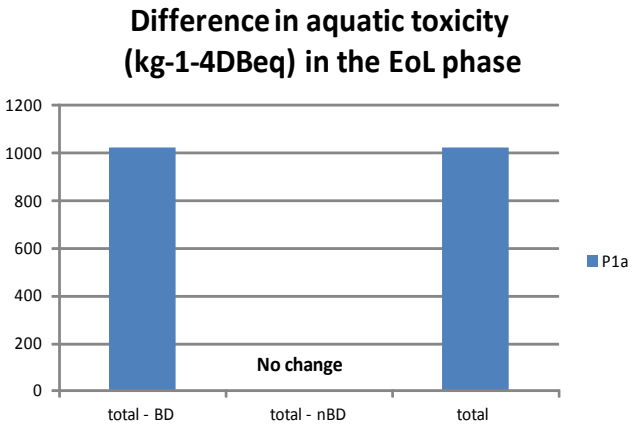


Figure 30 – Difference in aquatic toxicity for plastic packaging waste in 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

- **Air and water quality**

Acidification in the air and eutrophication in water will experience a negligible increase with the implementation of policy option P1a (see Figure 31 and Figure 32), with respectively 350 kg-eqSo_2 (equivalent to around 10 inhabitants of the EU) and 70 kg-eqPO_4(equivalent to around 2 inhabitants of the EU).

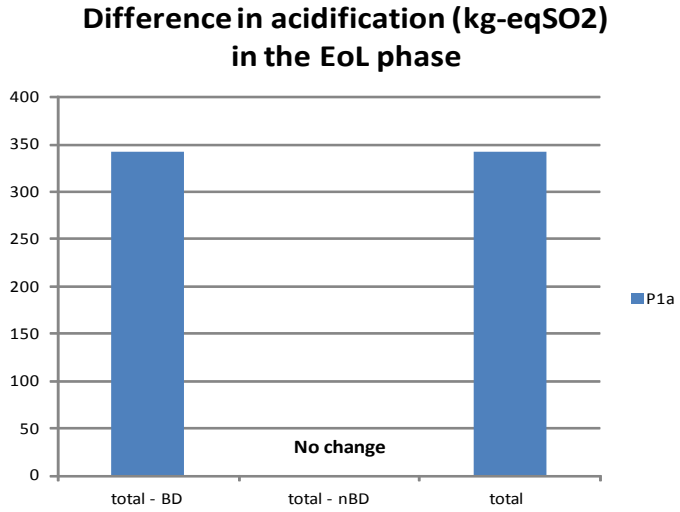


Figure 31 – Difference in acidification (emission to air) for plastic packaging waste in 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

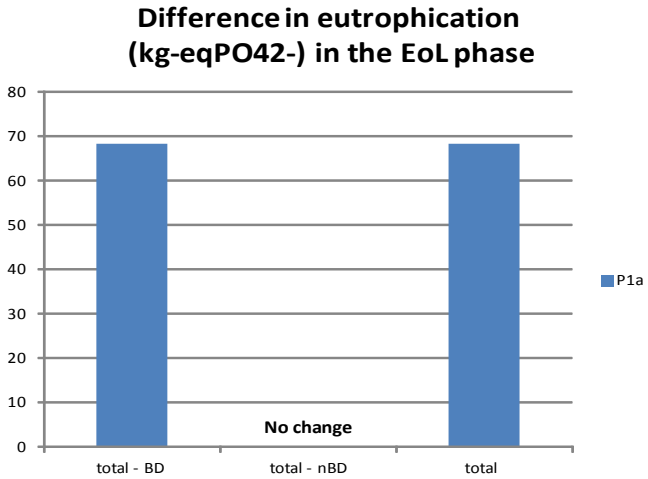


Figure 32 – Difference in eutrophication (emission to water) for plastic packaging waste in 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

Economic impacts

In this section, economic impacts are presented as the difference relative to the baseline scenario.

- **Costs associated with packaging waste management**

Due to clearer definitions of the different types of packaging, consumers will be more likely to trust marketing claims on the packaging. Therefore, it is likely that more consumers will choose the appropriate end-of-life treatment option when dealing with packaging waste. As a result, costs associated with sorting packaging that were put in the wrong bins by mistake will be reduced.

- **Impacts on producers**

Producers willing to remain in the market for biodegradable products are likely to increase their budget in research and development in order to meet the more stringent requirements for biodegrading in natural conditions.

In the short-run, no impact is expected for producers of compostable packaging. However, since option P1a will create a new market for strictly naturally biodegradable products, some producers of compostable packaging are likely to seize this opportunity to improve the degradation potential of their materials in order to satisfy the requirements for biodegradable packaging.

- **Functioning of the internal market**

Competition between compostable and biodegradable packaging will likely increase, in line with the new requirements allowing more precise differentiation between packaging types.

- **Administrative burden**

To complete the reinforced requirements implemented in policy option P1a, companies will have to:

- collect and provide new technical information to public authorities and labelling organisations;
- incur additional costs in order to obtain a certification.

Costs of certification procedure depend on multiple factors (type of packaging, type of certification, etc.). They are closely related to the number and complexity of tests required to assess the extent to which packaging complete requirements associated with certifications, which in turn depends on the type of packaging.

According to the Belgian certification organisation Vinçotte, due to the time required for a packaging to degrade into compost material, it takes about six months for a packaging product to be tested and certified as compostable. To compare, bio-based certification being simpler,[154] it takes only four to six weeks to obtain a bio-based certification.

- **Impacts on innovation and research**

Option P1a will likely encourage companies to invest in research and development for two reasons. First, companies that had previously labelled their packaging "biodegradable" packaging as a marketing tool will be reluctant to lose their competitive advantage and are likely to attempt to regain their position on the market. Therefore, these companies will increase their spending in research and development in order to quickly regain the right to label their packaging as "biodegradable".

A clearer definition for compostability and biodegradability might also attract companies that were previously reluctant to enter the market for compostable and biodegradable packaging

[154] The OK bio-based certification procedure relies on the C-14 method to determine the concentration of young (or renewable) materials in comparison with the concentration of old (or fossil) resources. According to Vinçotte, this method is very simple and the exact value can be precisely and scientifically measured and calculated.

because of consumers' confusion. These new entrants are likely to implement research and development programs in order to offer innovative packaging.

Social impacts

In this section, social impacts are presented as difference compared to the baseline scenario.

- **Effects on consumer awareness/consumption trends/disposal**

Only little change is expected in terms of consumers' behaviour with the implementation of policy option P1a since it focuses on technical requirements and therefore essentially concerns producers. Forbidding companies to claim that a packaging is biodegradable unless it meets the requirements for biodegradation in natural condition will reduce consumers' confusion when discarding waste. Thus, consumers will be more confident when sorting their packaging waste according to what is indicated on packaging products. Improved consumers' understanding of how to dispose of waste packaging will ease the overall end-of-life management of packaging along the different treatment streams.

In terms of public awareness, unless policy option P1a is accompanied by large awareness-raising campaigns, most EU consumers will not be aware of the stricter requirements for biodegradation. Consumers that are already prone to purchase eco-friendly products might appreciate the clarification. These consumers might tend to increase their demand for biodegradable and compostable products. However, in the absence of a common label stating for all products which are biodegradable and which are compostable, individual voluntary initiatives will continue to flourish. There is no evidence to support the conclusion that consumers who were not prone to purchase biodegradable packaging before the introduction of policy option P1a will change their purchasing behaviours as a result of the new requirements.

- **Employment**

No changes are expected in terms of employment compared to the baseline scenario as the amount of biodegradable and compostable packaging placed on the market is not expected to change.

4.3.2 Policy option P1b: Providing for compostable packaging to be fit for biodegradation in natural conditions in the environment and in particular in the marine environment

Option P1b restricts what currently constitutes the market for biodegradable and compostable packaging to only those packaging materials that are biodegradable in natural conditions in the environment.[155]

[155] As already mentioned, according to stakeholders from the biodegradable plastics industry, setting a new requirement for biodegradability specifying the timeframe and conditions for packaging waste to biodegrade in natural conditions would be extremely difficult to implement at the EU level because of the diversity of natural conditions existing in Europe.

However, if policy option P1b were to be implemented, it would restrict the market for biodegradable packaging to only a small share of what it is in 2011. With regard to plastics, it is estimated that only about 22% of the plastic packaging considered as biodegradable in 2011 is really fit for biodegradation in natural conditions (as explained in section 0).

Considering these aspects, the following paragraphs present the main effects expected from the implementation of this policy option.

- **Expected effects on market projections**

Policy option P1b is assumed to affect the market for biodegradable and compostable packaging in the following ways:

- In 2012, both production and consumption of what had previously been reported as compostable (or biodegradable) plastic packaging will drastically drop by 78% relative to their baseline levels, with only 22% being considered "biodegradable" under the new policy. From that point on, no compostable packaging would be considered as biodegradable unless it meets the more stringent criteria for natural biodegradation in the environment. As a result, the production of non-biodegradable packaging increases by 0.2 to 0.6%, depending on the packaging materials considered.
- From 2012 to 2015, producers willing to enter the market for compostable packaging will intensify their investments in research and development in order to produce packaging able to meet the requirements for biodegradation in natural conditions. Given the high production costs associated with compostable packaging production, it is assumed that some of the producers previously offering compostable packaging fit for composting either at home or in industrial facilities will not have the financial resources to enter the market. Instead, it is assumed that they will prefer waiting for production scales to increase (and technologies to spread) before starting producing or using biodegradable packaging. As a result, the production and consumption of non-biodegradable packaging increases by lower rate, relative to the baseline scenario, as more and more businesses enter the market for biodegradable packaging.
- From 2015 to 2020, biodegradable and compostable packaging production has reached a scale large enough to allow a decrease in production costs. Both demand and production for compostable packaging will increase at a fast pace in Europe.
- In 2020, compostable packaging consumption and production reach 50% of their baseline's levels. Non-biodegradable packaging production and consumption in Europe are slightly less than 1% higher than in the baseline scenario.

Figure 33 illustrates the expected changes in consumption of both biodegradable and non-biodegradable packaging compared with the baseline scenario. Data are expressed in quantities ('000 tonnes).

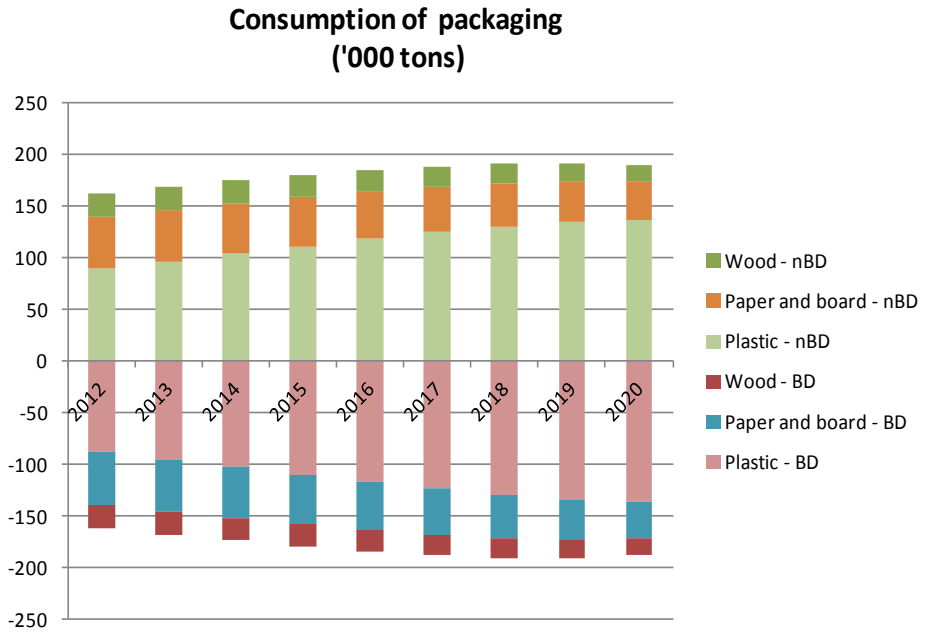


Figure 33 – Difference in consumption of packaging in Policy Option P1b (EU-27, 2012-2012)

Expected effects on the end-of-life management projections

As policy option P1b would change the technical definitions in the Packaging Directive, it would presumably have only a small impact on consumers. As consumers carry the responsibility for selecting an appropriate end-of-life option for packaging waste, it is assumed that this option would result in only a small effect on the distribution in waste streams compared to the baseline, and no effect is expected at all for non-biodegradable packaging.

The main effect of option P1b lies in its ability to reduce environmental impacts related to consumers' littering. Assuring that all compostable packaging is fit for biodegradation in natural conditions will reduce the impact from packaging waste that either is littered or otherwise finds its way into the natural environment. This impact will be better addressed in section 0. Table 20 summarises the shares of the different disposal options for biodegradable packaging in 2020. Changes compared to the baseline scenario are as follows:

- With more stringent requirements on biodegradability, the disposal of any packaging claimed to be biodegradable in composting or natural environments would be in line with consumers' expectations. Composting would see a modest increase. Up to 5% of packaging (for plastics) could be sent to each of the composting options.[156]
- It is expected that littering will slightly increase compared to the share of the baseline scenario, from 4.2 to 5.2% for plastics, as some consumers misinterpret the concept of biodegradability.

[156] This value remains in line with some discussions with stakeholder from the plastic industry, although it is difficult to assess accurately.

- These changes in end-of-life shares will result in corresponding decreases in the recycling waste stream, with no change to the remaining waste streams.

Table 20 – Expected effects on the distribution in waste streams by 2020 for biodegradable packaging (green for an increase compared to 2011, red for a decrease)

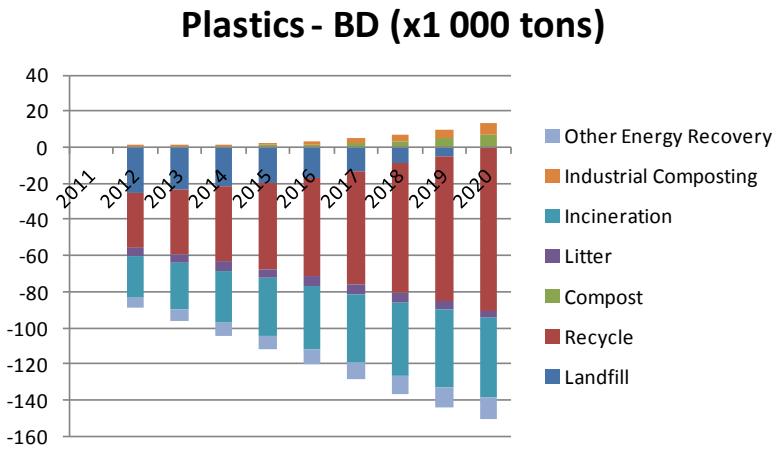
	Plastics (biodegradable)		Paper and Cardboard (biodegradable)		Wood (biodegradable)	
	2020 baseline	P1b 2020 impact	2020 baseline	P1b 2020 impact	2020 baseline	P1b 2020 impact
Landfill	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Recycling	55.1%	44.1%	85.7%	77.5%	51.0%	42.2%
Composting (Home)	0.0%	5.0%	0.0%	4.0%	0.0%	4.0%
Litter	4.2%	5.2%	0.2%	0.3%	2.8%	3.5%
Incineration	32.6%	32.6%	12.3%	12.3%	18.0%	18.0%
Industrial Composting	0.0%	5.0%	0.0%	4.0%	0.0%	4.0%
Other Recovery Options	8.1%	8.1%	1.8%	1.8%	28.2%	28.2%

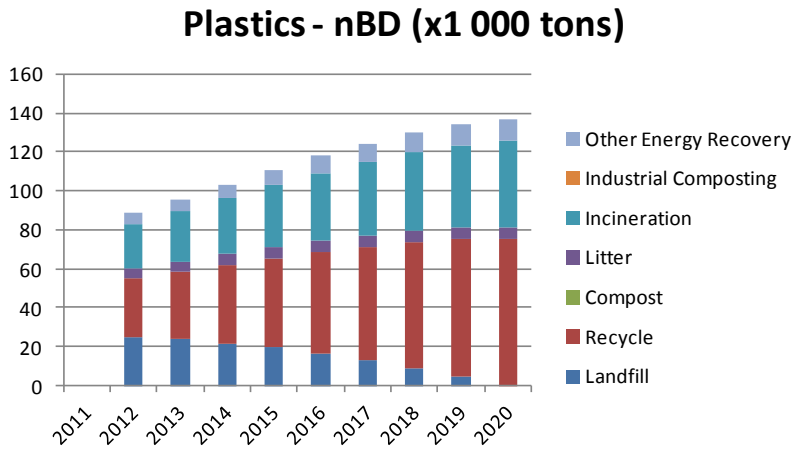
Environmental impacts

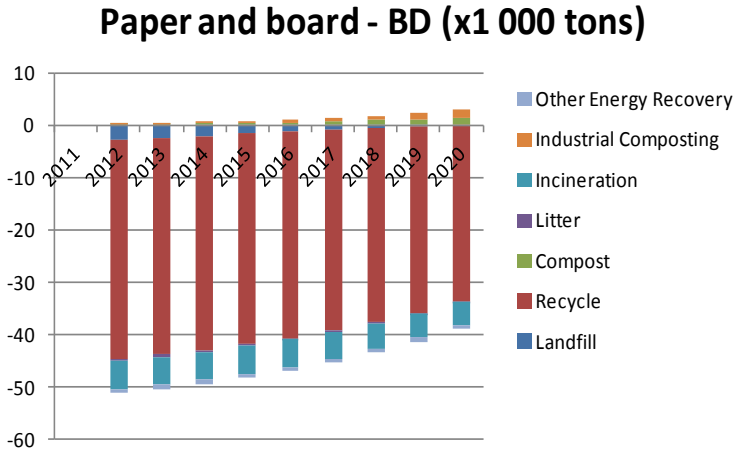
In this section, environmental impacts are presented as difference compared to the baseline scenario. Therefore, increased impacts relative to the baseline appear as positive values whereas decreased impacts appear as negative values.

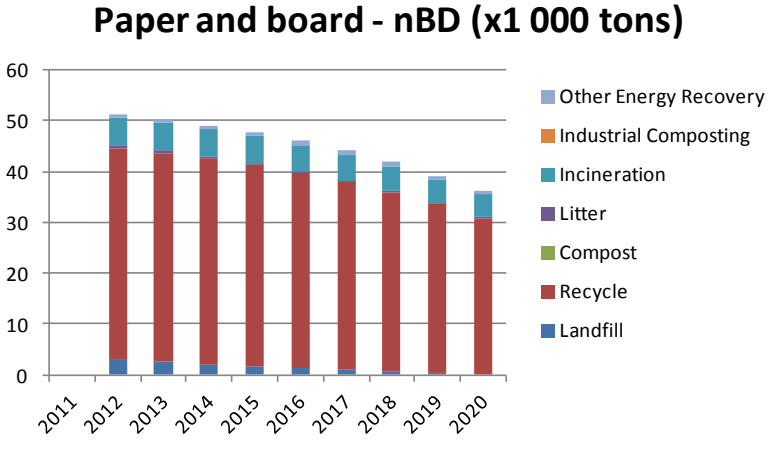
- **Impacts on waste management**

The charts that make up Figure 34 illustrate the changes in packaging waste for each of the waste streams. After the implementation of policy P1b, there is a significant shift from biodegradable packaging to non-biodegradable packaging due to the stricter definitions. This shift corresponds to around 85,000 tonnes of plastics, 50,000 tonnes of paper and cardboard and 22,000 tonnes of wood just after the implementation of the policy. Although this shift is slightly compensated for paper and cardboard and for wood until 2020, the difference in the quantity of biodegradable plastics will increase to 130,000 tonnes. Indeed, the implementation of such strong requirements would likely prevent the market from responding rapidly.


Plastics - BD (x1 000 tons)
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Other Energy Recovery
Industrial Composting
Incineration
Litter
Compost
Recycle
Landfill


Plastics - nBD (x1 000 tons)
160
140
120
100
80
60
40
20
0
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Other Energy Recovery
Industrial Composting
Incineration
Litter
Compost
Recycle
Landfill


Paper and board - BD (x1 000 tons)
10
0
-10
-20
-30
-40
-50
-60
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Other Energy Recovery
Industrial Composting
Incineration
Litter
Compost
Recycle
Landfill


Paper and board - nBD (x1 000 tons)
60
50
40
30
20
10
0
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Other Energy Recovery
Industrial Composting
Incineration
Litter
Compost
Recycle
Landfill

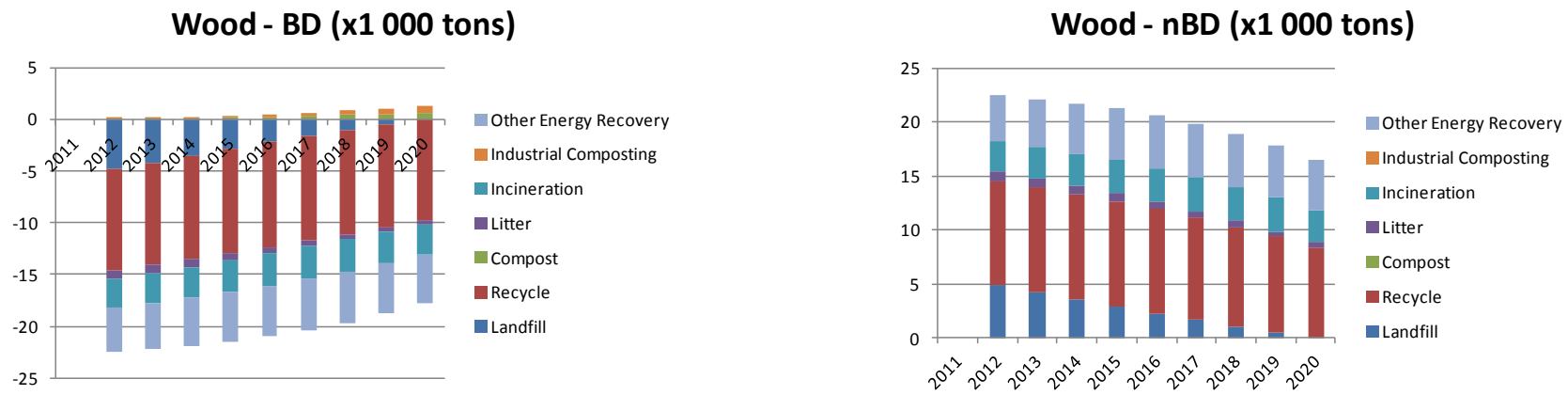


Figure 34 – Difference in packaging waste amount for P1b, compared to the baseline scenario until 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

Energy Use

Figure 35 shows the impact of policy option P1b on the energy use during the production and end-of-life phases in 2020. Considering only these two life-phases, the implementation of such a policy option seems to be slightly positive. This is mainly due to the energy saved from the end-of-life phase as a greater quantity of non-biodegradable material will enable additional energy savings due to the recycling process (see section 2.6.1).

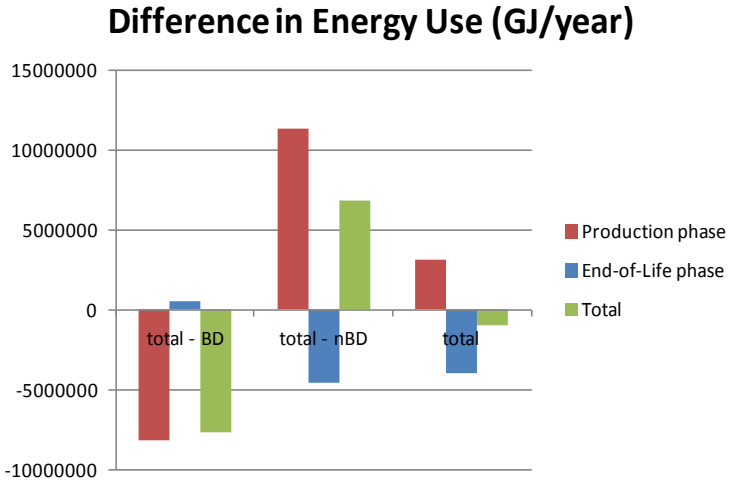


Figure 35 – Difference in Energy Use for plastic packaging waste (for biodegradable (BD) and non-biodegradable (nBD) packaging

GHG emissions

Figure 36 shows that the implementation of policy option P1b would result an increase in the emissions of more than 100,000 tonnes of CO_2 - which corresponds to approximately 9,000 inhabitants of the EU, compared to the baseline. That is mainly due to the increase in manufacturing of non-biodegradable packaging products.

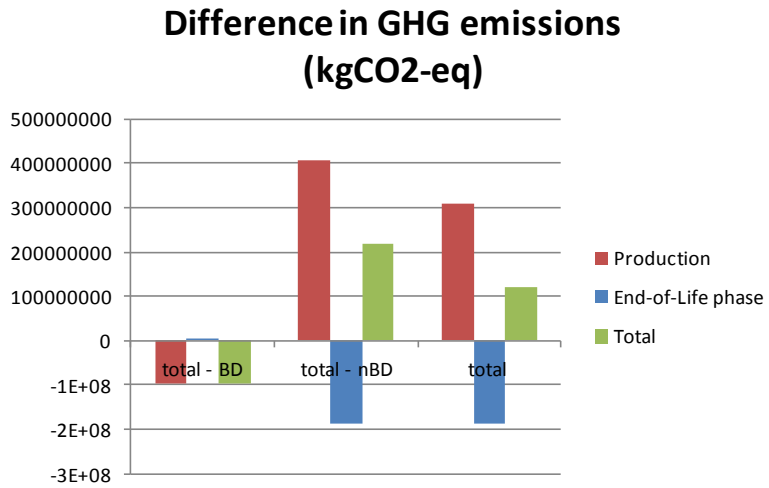


Figure 36 – Difference in GHG emissions for plastic packaging waste in 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

Resource depletion

Resource depletion is expected to decrease by 2020 with the implementation of policy option P1b (see Figure 37), with more than 1,500 tonnes-equivalent Sb (which correspond to 40,000 inhabitants of the EU). This is due to the increase in non-biodegradable packaging by 2020 and thereby the benefits related to the recycling process of these non-biodegradable materials.

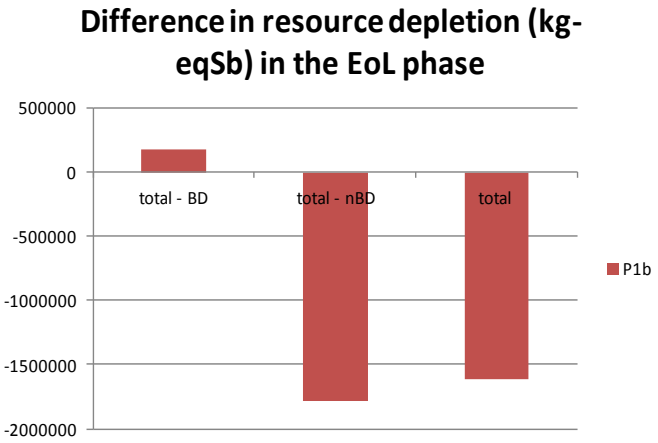


Figure 37 – Difference in resource depletion for plastic packaging waste in 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

Land use

By 2020, it is assessed that almost 500,000ha are no longer required to produce the bio-based biodegradable plastic packaging (see Figure 38).

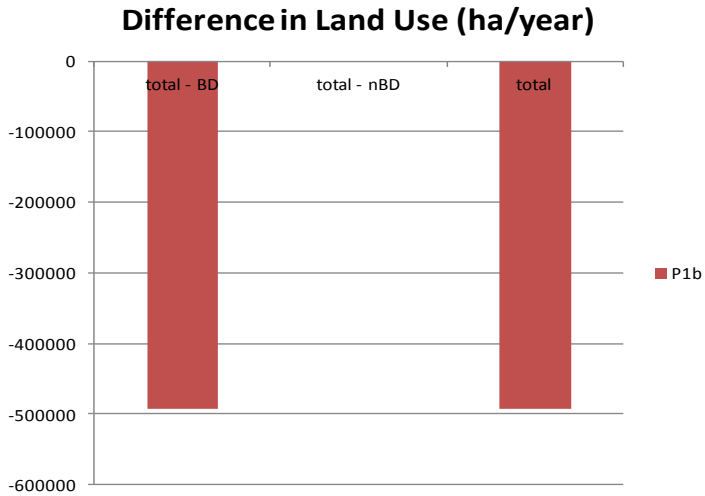


Figure 38 – Difference in Land use for plastic packaging waste in 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

Eco-toxicity

With regard to toxicity, it can be seen that both human and aquatic toxicities will decrease with the implementation of policy option P1b (see Figure 39 and Figure 40). For human toxicity,

around 44,000 tonnes-1-4DBeq will be avoided (which corresponds to around 40,000 inhabitants of the EU). For aquatic toxicity, 600 tonnes-1-4DBeq will be avoided (which correspond to around 1,300 inhabitants of the EU). This trend is due to the increase in non-biodegradable packaging by 2020 and thereby leads to reduced toxicity as a result of increased recycling.

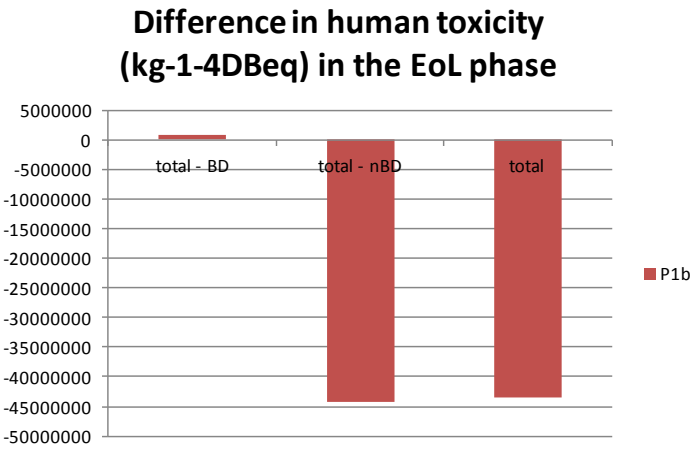


Figure 39 – Difference in human toxicity for plastic packaging waste in 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

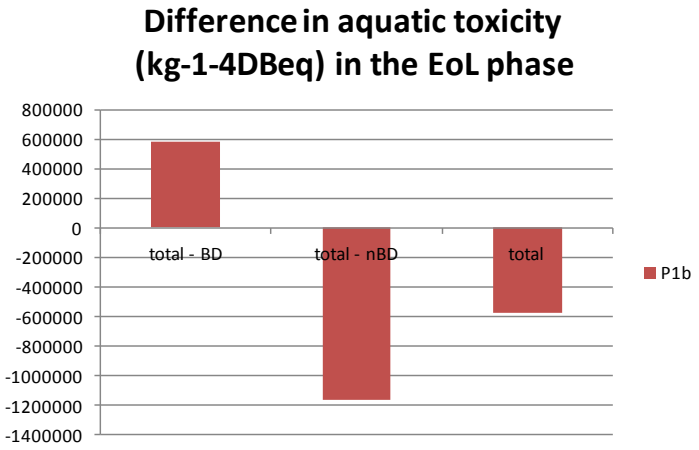


Figure 40 – Difference in aquatic toxicity for plastic packaging waste in 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

- **Air and water quality**

With regard to air quality, it can be seen that acidification in the air will decrease with the implementation of policy option P1b by around 1,000 tonnes-eq SO_2, corresponding to around 27,000 inhabitants of the EU (see Figure 31). That is due to the increase in non-biodegradable packaging by 2020 and thereby it leads to reduced acidification as a result of increased recycling.

With regard to water quality, it can be seen that eutrophication will be decreased with the implementation of policy option P1b by around 16 tonnes-eq PO_4, corresponding to around 400 inhabitants of the EU (see Figure 31). That is due to the decrease in the amount of biodegradable

packaging by 2020 and thereby it reduces the negative eutrophication impacts associated with composting.

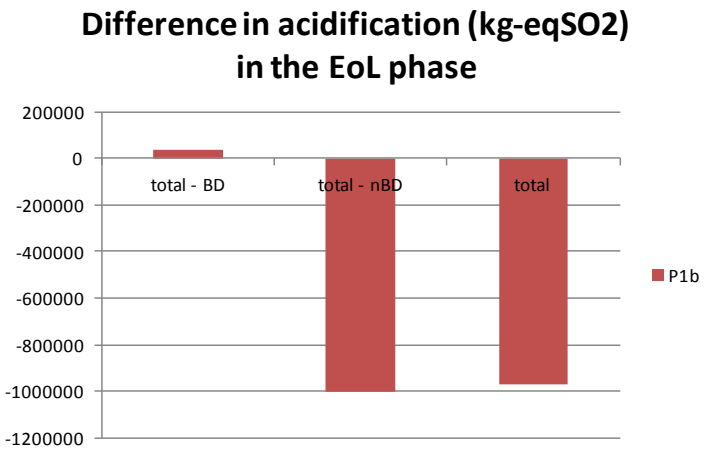


Figure 41 – Difference in acidification (emission to air) for plastic packaging waste in 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

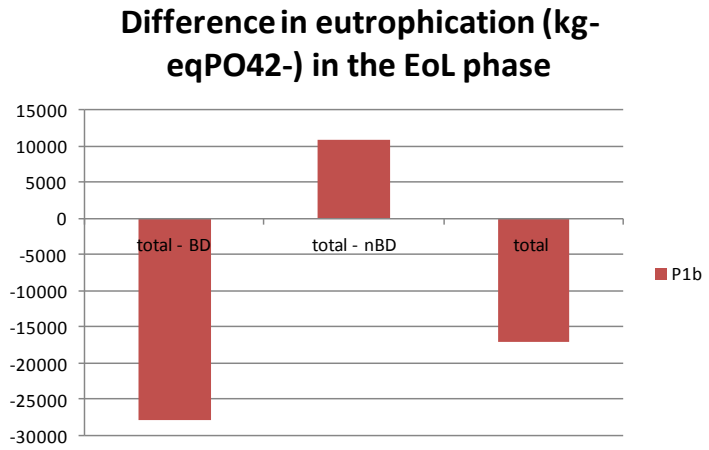


Figure 42 – Difference in eutrophication (emission to water) for plastic packaging waste in 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

Economic impacts

In this section, economic impacts are presented as difference compared to the baseline scenario.

- **Impacts on producers and waste management sector**

Producers that were producing naturally biodegradable packaging products in 2011 will see the demand for their products increasing sharply in the short run. However, since they account for only 22% of the market for biodegradable packaging, the producers of materials that were formerly called "biodegradable" but were only compostable in home or industrial facilities will face significant decrease in demand.

Restricting what currently constitutes the market for biodegradable and compostable packaging to only the materials that are biodegradable in natural conditions in the environment will not prevent bio-based packaging producers from offering their products to consumers. Thus, bio-based packaging consumption will continue to grow. Since bio-based packaging waste that are not biodegradable will not be considered as compostable anymore, they are likely to be treated as any other packaging. As a result, the presence of bio-based packaging waste in recycling streams is likely to grow. One of the main concerns for waste management industries is then the risk of contaminating existing streams with bio-based products. Reduced revenues coming from the reduced quality of the recycled materials will continue to increase until commercial volumes are large enough to cover the investments required to allow recycling of biodegradable plastics in existing facilities.[157] In the end, the waste management sector will adapt to the new market conditions and waste management costs will be similar to the baseline scenario.

- **Impacts on innovation and research**

Producers willing to remain in the market for biodegradable products are likely to increase their spending in research and development in order to meet the more stringent requirements for biodegrading in natural conditions. More precisely, producers of compostable packaging will have to improve the degradation potential of their materials in order to satisfy the requirements for biodegradable packaging.

- **Functioning of the internal market**

It is expected that the competition between compostable and biodegradable packaging will likely decrease. However, non-biodegradable bio-based packaging products are likely to expand as the market for biodegradable packaging shrinks, leading to stronger competition between bio-based and biodegradable packaging.

By 2020, most of the production capacity of bio-based plastics is expected to come from outside of the EU, with Asia and South America forecasted to account for about 50% of global production by 2020.[158] Therefore, imports of bio-based plastics are likely to increase drastically over the period.

- **Administrative burden**

As mentioned and analysed for Policy Option P1a, to complete the reinforced requirements implemented in policy option P1b, companies will have to collect and provide new technical information to public authorities and labelling organisations and therefore incur additional costs in order to obtain a certification.

- **Packaging costs**

By 2020, packaging costs are expected to decrease by about 37 million € per year due to the increased consumption of non-biodegradable packaging and the associated lower production costs (Figure 43).

[157] European Bioplastics, 2011d.

[158] European Bioplastics, 2011c.

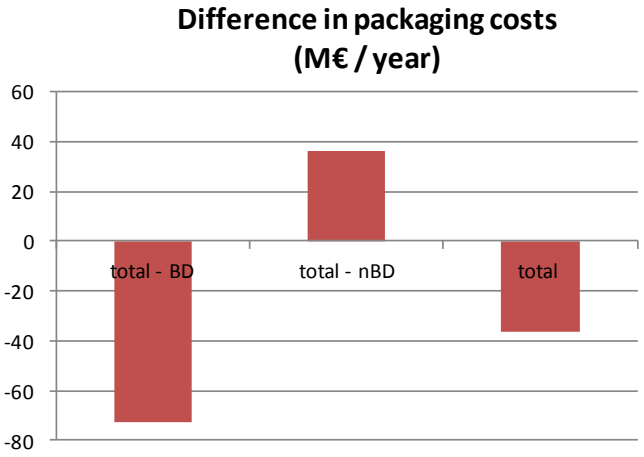


Figure 43 – Difference in packaging costs in Policy Option P1b (EU-27, 2020) for biodegradable (BD) and non-biodegradable (nBD) packaging

Social impacts

In this section, social impacts are presented as difference compared to the baseline scenario.

- **Employment**

Policy option P1b will have negative effects on employment in companies that had previously produced biodegradable packaging that is not fit for biodegradation in natural conditions. That said, in absolute terms, these companies represent only a small fraction of the larger packaging industry.

Restricting the market to only the materials that biodegrade in natural conditions will decrease employment in the biodegradable plastics industry by about 80% in 2012 and 50% in 2020 compared to the baseline scenario. Employment in the non-biodegradable plastic packaging industry will increase by only 0.1% with the implementation of the policy option. Overall employment in the plastic packaging industry will decrease by about 600 FTE shortly after the introduction of the policy. By 2020, jobs lost will amount to roughly 450 FTE in the EU-27.

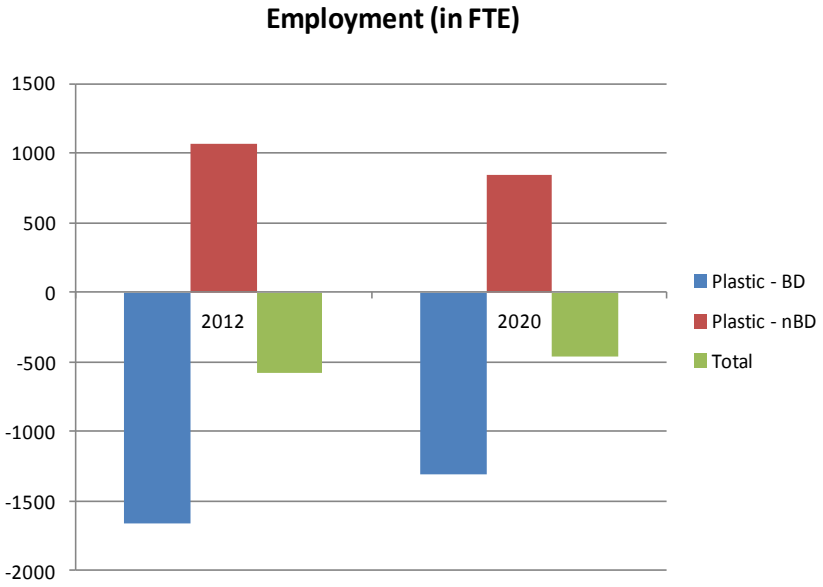


Figure 44 – Employment in the plastic packaging sector (2012-2020, in FTE) for biodegradable (BD) and non-biodegradable (nBD) packaging

- **Consumer behaviour**

In terms of consumer behaviour, the only expected impact is related to the disposal of packaging waste. By only allowing naturally biodegradable packaging to be considered as biodegradable, Policy Option P1b will decrease misinterpretation about the nature of packaging. Consumers will therefore dispose of packaging waste in a more appropriate manner and the share of littering due to misuses of biodegradable packaging will tend to decrease.

- **Social impacts on third countries**

Increasing imports of bio-based products in the EU-27 will tend to increase revenues and employment in countries that are planning to increase their production capacity of bio-based packaging in the coming years such as Brazil or China.

4.3.3 Policy options P2: Promoting consumer visibility of biodegradable packaging by implementing a mandatory user-friendly labelling system for biodegradable and compostable packaging products

Policy option P2 promotes an increase in the demand for biodegradable packaging and better end-of-life sorting as a result of greater visibility of biodegradable packaging. Policy option P2 has two sub-options:

- **Policy option P2a** that consists in implementing a mandatory user-friendly **positive labelling** or marking system for biodegradable and compostable (with the distinction between industrial composting and home composting) packaging

products. Policy option P2a aims at indicating the biodegradable nature of packaging products.

- **Policy option P2b** that consists in implementing a mandatory user-friendly **negative labelling** or marking system for biodegradable and compostable (with the distinction between industrial composting and home composting) packaging products. Policy option P2b aims at indicating the non-biodegradable nature of packaging products.

- **Expected effects on market projections**

With the implementation of a labelling scheme, Policy Option P2 would have a direct impact on consumer behaviour. By increasing the visibility of biodegradable products, a labelling scheme will increase demand for biodegradable and compostable packaging and improve its end-of-life sorting.

However, markets will react differently according to the type of labelling that is implemented. A positive labelling scheme will have a positive influence on consumers' behaviour and purchase intention while negative labelling will play on consumers' sense of guilt. Generally, negative information will have greater overall impact on consumers' behaviours, though consumers express a preference for positive information.[159]

Therefore, it is assumed that both policy option P2a and P2b will tend to increase biodegradable packaging consumption at a faster pace than in the baseline scenario. In both cases, the production of biodegradable packaging will follow the increase in demand in the short-run. However, due to limited production capacity in Europe, this production is likely to stagnate in the medium run while imports will start to increase drastically. In 2020, the production biodegradable packaging in the EU will be similar in policy options P2a and P2b but the consumption will be slightly higher with negative labelling in option P2b than with positive labelling in option P2a.

- **Expected effects on the projections related to end-of-life management**

Policy Options 2a and 2b, which will affect consumers directly, are expected to have a more direct impact on the end-of-life distribution than policy options 1a and 1b. However, as different labels already exist in the market, and most biodegradable packaging already carries some indication of its biodegradable attributes, the implementation of policy options 2a and 2b will mainly have an impact as a result of the harmonisation of the labels at the EU level. Therefore, the change in the consumer behaviour remains modest compared to a scenario where there had previously been no harmonised labelling.

Table 21 summarises the shares of the different disposal options for biodegradable packaging in 2020. Changes compared to the baseline scenario are as follows:

- Home and industrial composting are not negligible anymore. With a clear labelling scheme that is exposed to consumers, the disposal of any biodegradable packaging in composting facilities will be encouraged. **Up to 6% of packaging (for plastics) could be sent to each of the composting options in case of positive labelling and 4% in case of negative labelling.** This value is

[159] Borin et al., 2011.

currently limited by the current state of the composting facilities as the EU is not prepared to handle a large amount of waste for composting. Therefore, even though a harmonised labelling would give more exposure to composting, it would take time so that municipalities could effectively adapt their waste management systems.

- In addition, it is expected that littering will slightly increase to 5% for the positive labelling, compared to the respective share in the baseline scenario (4%) as consumers could misinterpret the biodegradability label as an approval for littering.

Finally, these increases in end-of-life options would result in equivalent decreases from the recycling waste stream and not the remaining waste streams.

Table 21 – Expected effects on the distribution in waste streams by 2020 for biodegradable packaging (green for an increase compared to 2011, red for a decrease)

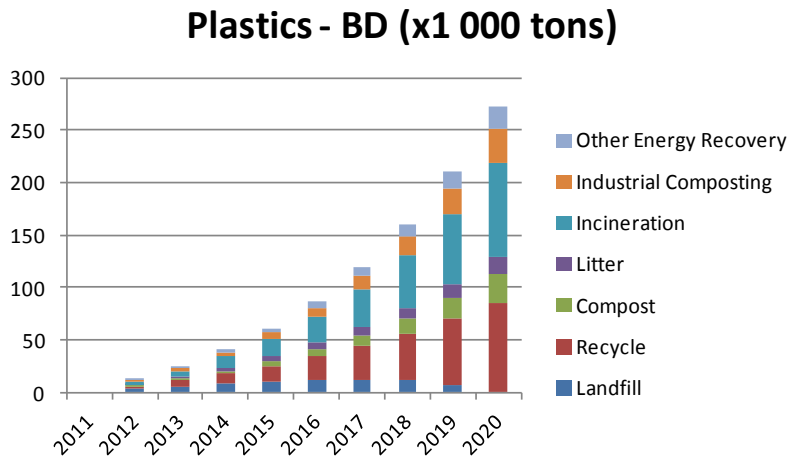
	Plastics (biodegradable)			Paper and Cardboard (biodegradable)			Wood (biodegradable)		
	2020 baseline	P2a 2020 impact	P2b 2020 impact	2020 baseline	P2a 2020 impact	P2b 2020 impact	2020 baseline	P2a 2020 impact	P2b 2020 impact
Landfill	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Recycle	55.1%	43.1%	47.0%	85.7%	76.5%	79.3%	51.0%	41.2%	44.4%
Composting (Home)	0.0%	5.0%	3.0%	0.0%	4.0%	2.5%	0.0%	4.0%	2.5%
Litter	4.2%	5.2%	4.2%	0.2%	0.3%	0.2%	2.8%	3.5%	2.8%
Incineration	32.6%	32.6%	32.6%	12.3%	12.3%	12.3%	18.0%	18.0%	18.0%
Industrial Composting	0.0%	6.0%	4.0%	0.0%	5.0%	3.0%	0.0%	5.0%	3.0%
Other Recovery Options	8.1%	8.1%	8.1%	1.8%	1.8%	1.8%	28.2%	28.2%	28.2%

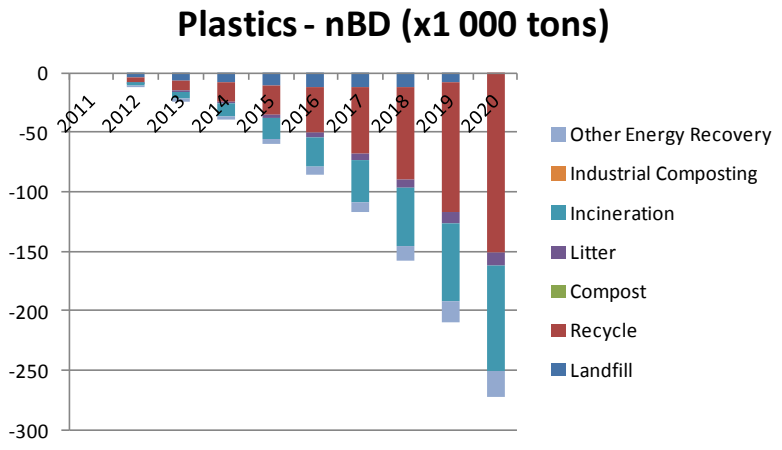
Environmental impacts

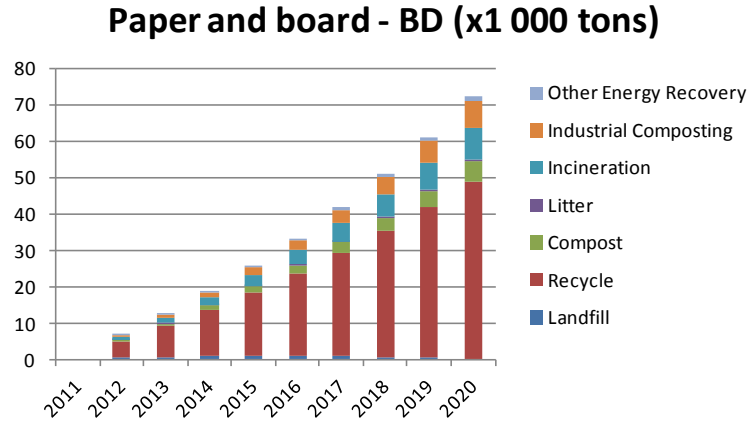
In this section, environmental impacts are presented as the difference relative to the baseline scenario. Therefore, increased impacts relative to the baseline appear as positive values whereas decreased impacts appear as negative ones.

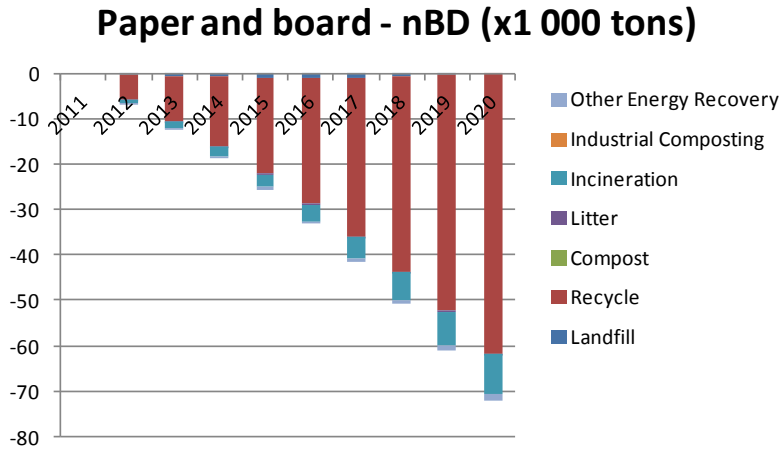
- **Impacts on waste management**

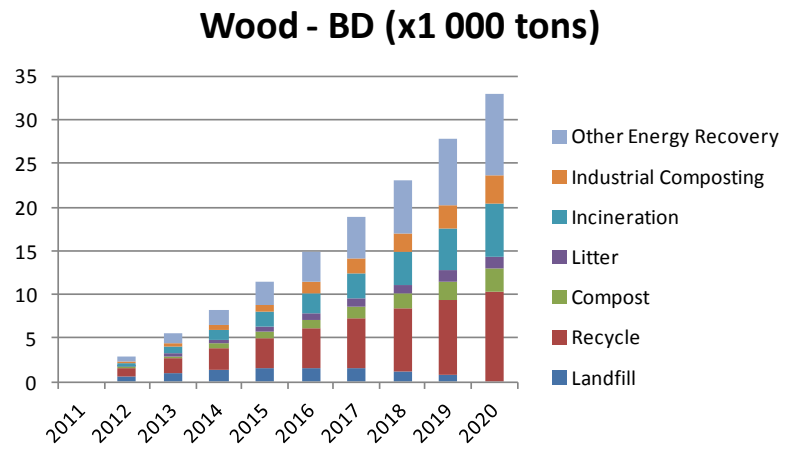
The charts that make up Figure 45 present the changes in packaging waste for each of the waste streams after the implementation of policy P2a. More than 350,000 tonnes of biodegradable packaging are additionally produced in 2020, compared to the baseline scenario with 250,000 tonnes for plastics, 70,000 tonnes for paper and cardboard and 30,000 tonnes for wood. Figure 46 presents the changes in packaging waste for each of the waste streams, after the implementation of policy P2b. Around 416,000 tonnes of biodegradable packaging are additionally produced in 2020, compared to the baseline scenario with respectively 300,000 tonnes for plastics, 80,000 tonnes for paper and cardboard and 36,000 tonnes for wood.


Plastics - BD (x1 000 tons)
300
250
200
150
100
50
0
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Other Energy Recovery
Industrial Composting
Incineration
Litter
Compost
Recycle
Landfill


Plastics - nBD (x1 000 tons)
0
-50
-100
-150
-200
-250
-300
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Other Energy Recovery
Industrial Composting
Incineration
Litter
Compost
Recycle
Landfill


Paper and board - BD (x1 000 tons)
80
70
60
50
40
30
20
10
0
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Other Energy Recovery
Industrial Composting
Incineration
Litter
Compost
Recycle
Landfill


Paper and board - nBD (x1 000 tons)
0
-10
-20
-30
-40
-50
-60
-70
-80
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Other Energy Recovery
Industrial Composting
Incineration
Litter
Compost
Recycle
Landfill



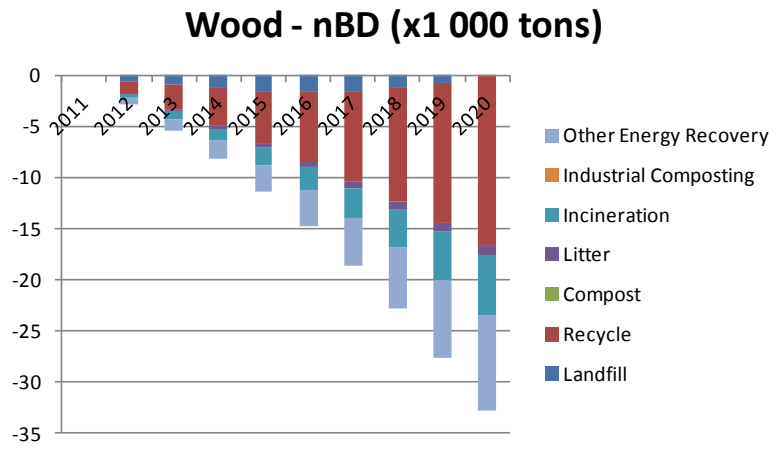
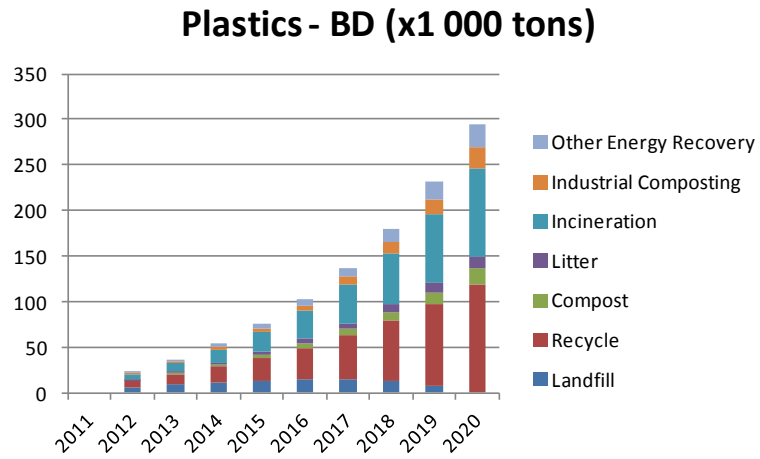
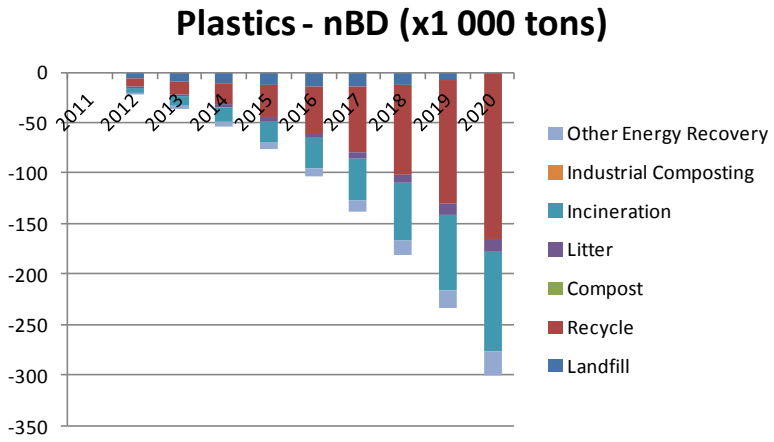


Figure 45 – Difference in packaging waste amount for P2a, compared to the baseline scenario until 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging





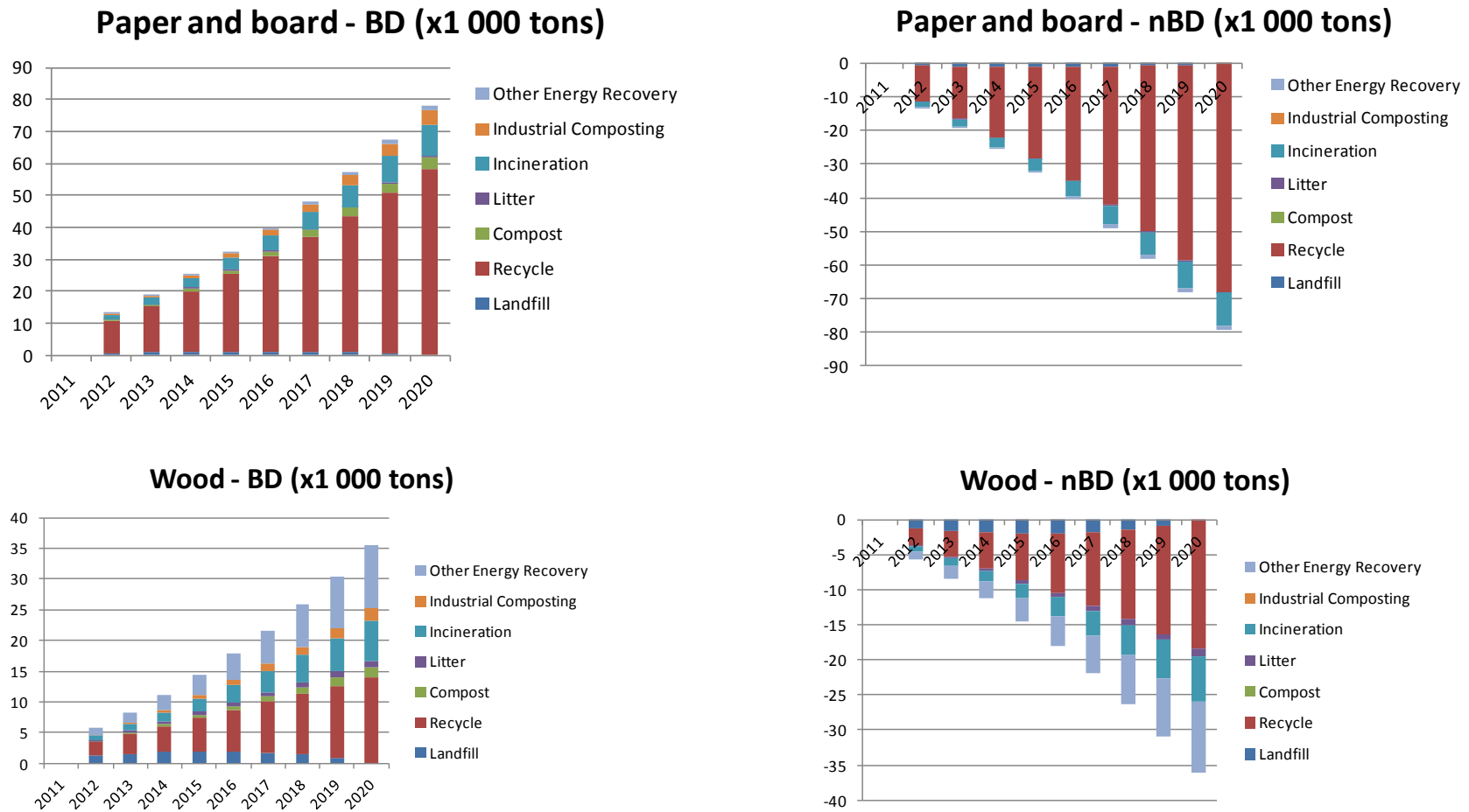


Figure 46 – Difference in packaging waste amount for P2b, compared to the baseline scenario until 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

Energy Use

Figure 47 shows the impact of policy options P2a and P2b on the energy use during the production and end-of-life phases in 2020. Considering only these two life-cycle phases, the implementation of such a policy option seems to be null in terms of energy use for P2a and slightly more energy consuming for P2b. This is mainly due to the energy saved from the production phase, as biodegradable material will require less energy to be produced than non-biodegradable material (see section 2.6.1). However, looking only at the end-of-life phase, energy requirements related to the non-biodegradable share will exceed the baseline scenario with almost 10 000 TJ/year for P2a and about 8,000TJ/year for P2b.

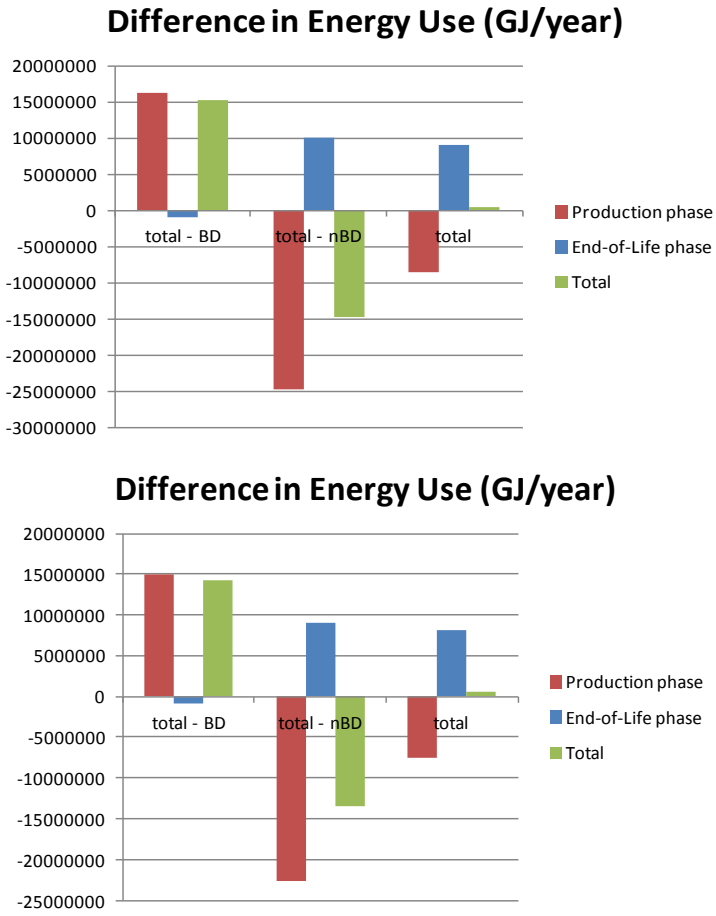


Figure 47 – Difference in Energy Use for plastic packaging waste for P2a (top) and P2b (bottom) for biodegradable (BD) and non-biodegradable (nBD) packaging

GHG emissions

For both options P2a and P2b, it is expected that less GHG emissions will be emitted in 2020, compared to the baseline scenario. It follows a similar trend to energy use. By 2020, GHG emissions are expected to decrease by about 400 000 tonnes of CO_2-eq in both scenarios (which is roughly equivalent to 36,000 inhabitants of the EU).

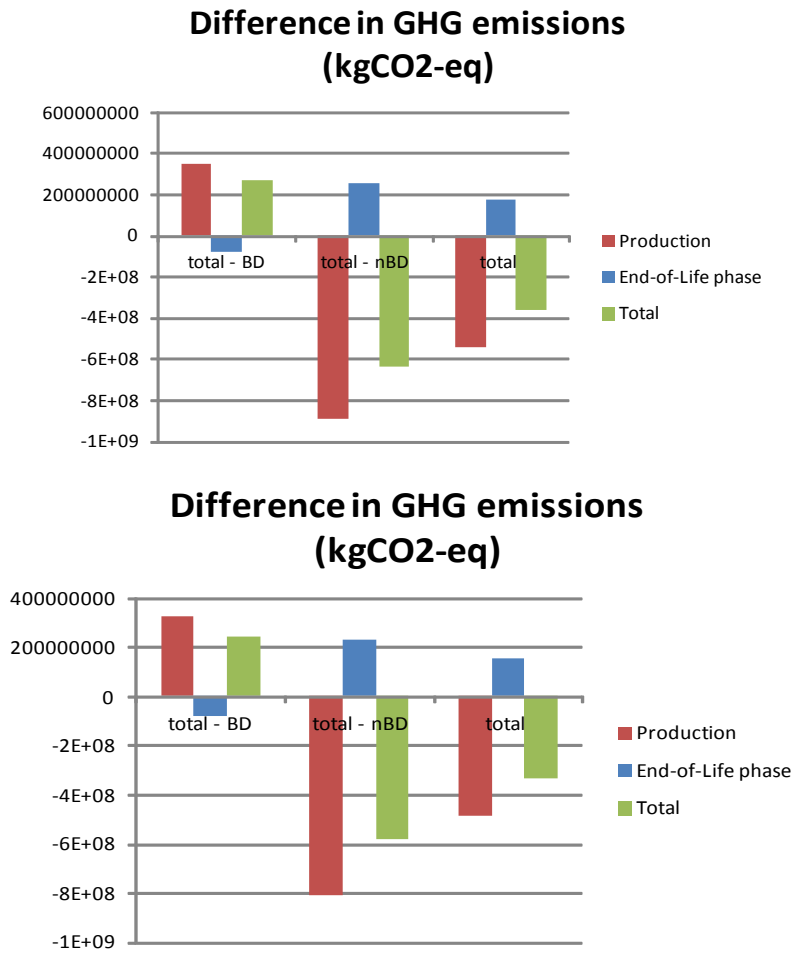


Figure 48 – Difference in GHG emissions for plastic packaging waste for P2a (top) and P2b (bottom) for biodegradable (BD) and non-biodegradable (nBD) packaging

Resource depletion

Resource depletion is expected to significantly increase by 2020 with the implementation of policy option P2 with almost 4,000 tonnes-eq Sb, which correspond to the equivalent of 110,000 inhabitants of the EU (see Figure 49). That is explained by more composting (home and industrial) instead of recycling by 2020 and thereby less benefits from recycling in terms of resource depletion compared to the baseline.

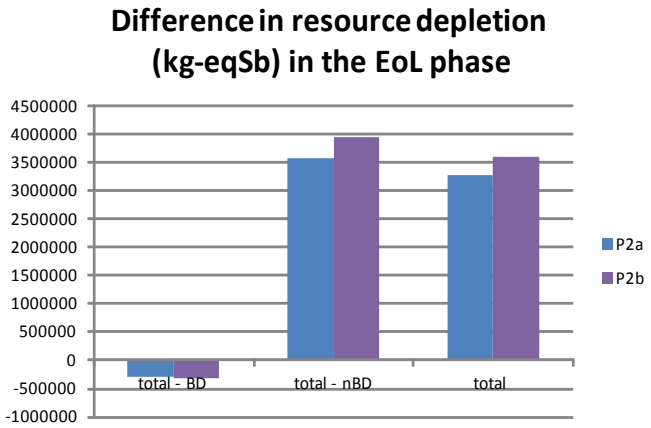


Figure 49 – Difference in resource depletion for plastic packaging waste in 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

Land use

By 2020, it is estimated that almost 1,000,000 ha are additionally required to produce the bio-based biodegradable (plastic) packaging amount with the implementation of P2a or P2b. (see Figure 50).

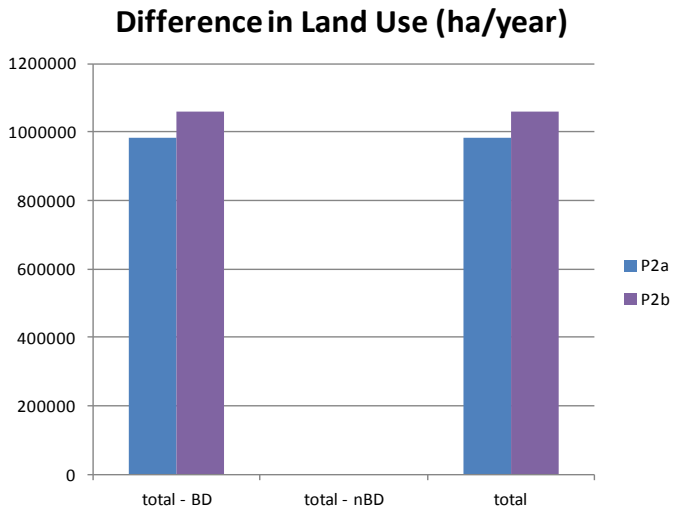


Figure 50 – Difference in Land use for plastic packaging waste in 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

Eco-toxicity

With regard to toxicity, it can be seen that both human and aquatic toxicities will increase significantly with the implementation of policy option P2 (see Figure 51 and Figure 52). The increase could amount to to 60,000 tonnes of 1-4 DBeq for human toxicity (corresponding to the equivalent of 55,000 inhabitants in the EU) and 1,500 tonnes of 1-4 DBeq for aquatic toxicity (corresponding to the equivalent of 3,000 inhabitants in the EU). That is explained by more composting (home and industrial) instead of recycling by 2020 and thereby more toxicity risks related to composting, compared to the baseline scenario.

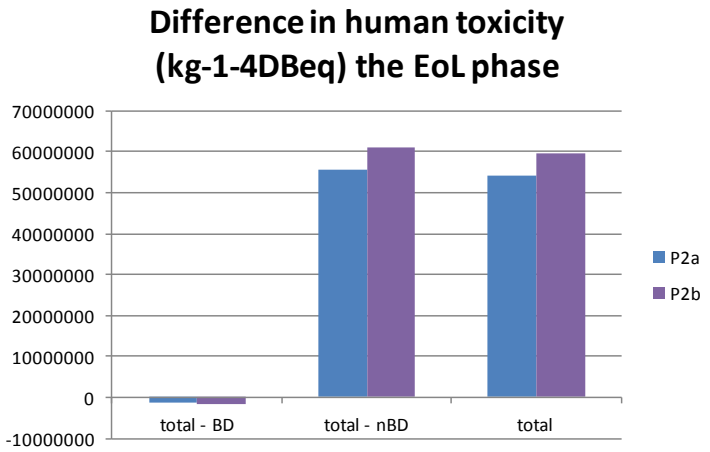


Figure 51 – Difference in human toxicity for plastic packaging waste in 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

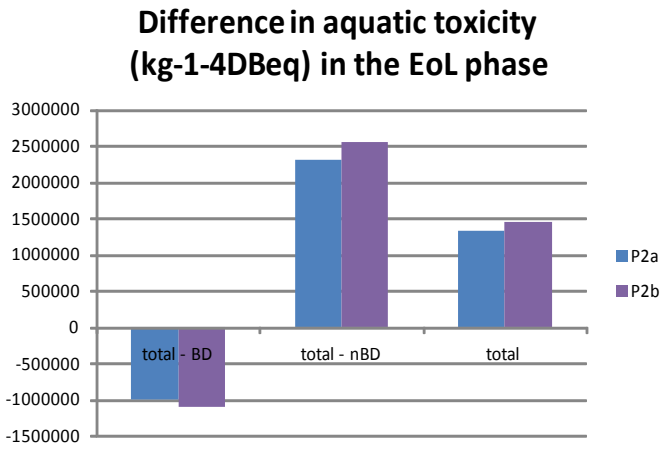


Figure 52 – Difference in aquatic toxicity for plastic packaging waste in 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

Air and water quality

With regard to air quality, it can be seen that acidification in the air will increase with the implementation of policy option P2 (see Figure 53), with up to 1,300 tonnes eq of SO_2 (corresponding to the equivalent of approximately 36,000 inhabitants of the EU). That is explained by more composting (home and industrial) instead of recycling by 2020 and thereby more toxicity risks related to composting, compared to the baseline scenario.

With regard to water quality, it can be seen that eutrophication will be slightly increased with the implementation of policy option P2 (see Figure 54), with up to 30 tonnes eq of PO_4 (corresponding to the equivalent of about 750 inhabitants of the EU). That is due to the increase in the amount of biodegradable packaging amount by 2020 and thereby it fosters the negative impacts of composting to eutrophication.

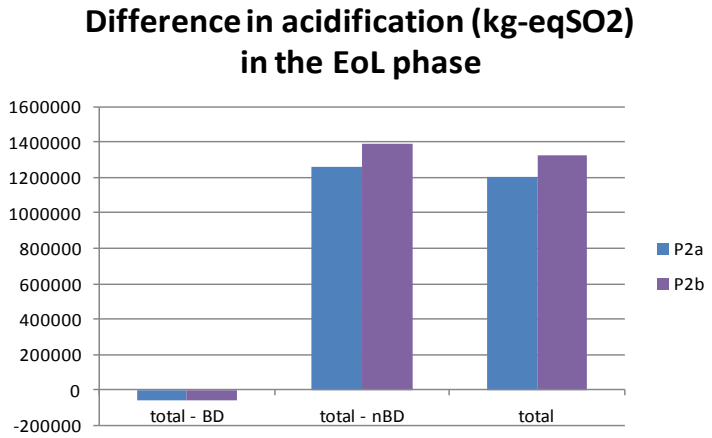


Figure 53 – Difference in acidification (emission to air) for plastic packaging waste in 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

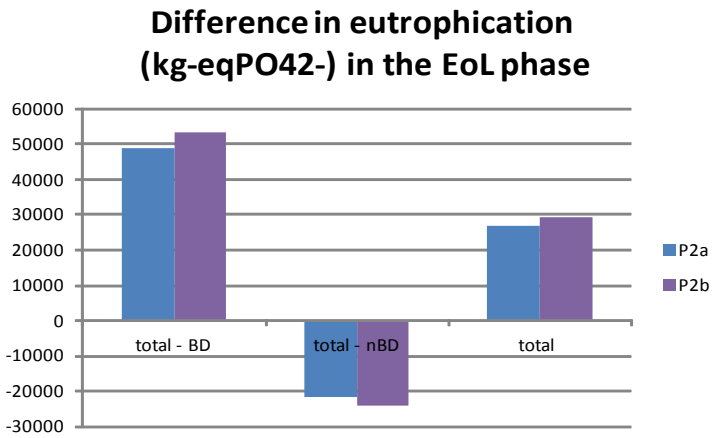


Figure 54 – Difference in eutrophication (emission to water) for plastic packaging waste in 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

Economic impacts

In this section, economic impacts are presented as differences relative to the baseline scenario.

- **Impacts on waste management**

The projected rise in compostable and biodegradable packaging consumption will tend to increase the costs related to separate waste collection schemes and recycling.

- **Impacts on industry and retail sector**

As indicated by stakeholders form the bioplastics industry, although both policy options P2a and P2b are likely to increase the volume of biodegradable packaging consumed in the EU-27, biodegradable packaging will nevertheless remain a relatively small share of the overall European packaging market by 2020. Therefore, implementing a negative labelling on non-biodegradable packaging would result in requiring the large majority of packaging producers to implement this negative labelling. Therefore, the implementation costs of Policy Option P2b are likely to be significant for the packaging industry and the retail sector.

- **Impact on agricultural sector**

Demand for agricultural resources will increase in line with increased consumption of bio-based biodegradable products. This is likely to have an effect on the prices of agricultural products used in the manufacturing process of packaging.

In the long term, pressure on food crops' prices will decrease as producers' reliance on non-food crops is likely to increase. Other biogenic inputs will slowly replace some of the food crops used to produce biodegradable packaging.

- **Packaging costs**

By 2020, packaging costs are expected to increase by more than 60 million € per year due to the relative higher cost of biodegradable packaging compared to non-biodegradable packaging (Figure 55).

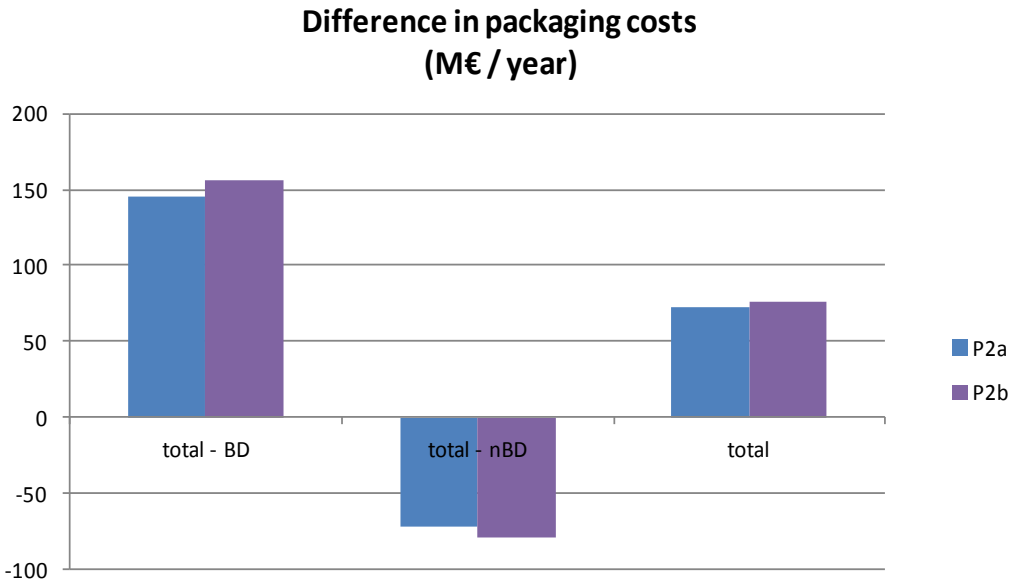


Figure 55 – Difference in packaging costs for Policy Option P2a and P2b (EU-27, 2020) for biodegradable (BD) and non-biodegradable (nBD) packaging

Social impacts

In this section, social impacts are presented as difference compared to the baseline scenario.

- **Consumer awareness**

A labelling scheme will increase the visibility of biodegradable and compostable packaging products. However, consumers will react differently depending on the type of labelling that is implemented. Because most eco-labels aim at identifying the best products within a product group and almost no labels allow identifying the worse products, the analysis of the impacts of policy options P2 on consumer awareness is essentially based on examples taken from the literature.

In a computer-based experiment carried out in 2004, Grankvist, Dahlstrand and Biel suggest that negative labelling may be more effective in reducing environmental impacts related to consumption than positive labelling.[160] Comparing the influence of positive and negative labels on consumers' preferences for some everyday products, their experiment showed that:

- Consumers who had no or little interest in environmental issues were unaffected by either types of labels;

[160] Grankvist et al., 2004.

- Consumers with an intermediate interest in environmental issues were more sensitive to a negative label than a positive label, in other words, they more often choose to purchase environmentally friendly products when faced with the negative label than when faced with the positive one;
- Consumers with a strong interest in environmental issues were affected in a similar way by both labels.

Overall, the "push" force of a negative label seems to be stronger than the "pull" force of a positive label. Some authors explain this result by the fact that negative labels affect consumers' sense of morality by reinforcing the social norms that frown upon actions likely to damage the environment.[161] Moreover, positive labelling can lead to rebound effects (i.e. increases in the overall quantity of packaging purchased) when:

- they encourage consumers to increase their purchase of the labelled products because buying eco-friendly products give them a better image of themselves;
- they project a positive image on the non-labelled products produced by brands offering labelled products.[162]

Researchers tend to conclude that negative information will have greater overall impact on consumers' behaviours, though consumers themselves express a preference for positive information.[163]

161 Lombardini, 2005.

162 Dosi et al., 1999.

163 Borin et al, 2011.

- **Employment**

Increased consumer awareness will lead to a rise in both biodegradable and compostable packaging consumption. Since biodegradable/compostable packaging production is more labour-intensive than conventional packaging production, a switch towards higher demand for biodegradable/compostable packaging will tend to increase employment in the packaging sector.

In 2020, it is assumed that employment will increase by more than 460,000 FTE/year in policy option P2a and P2b.

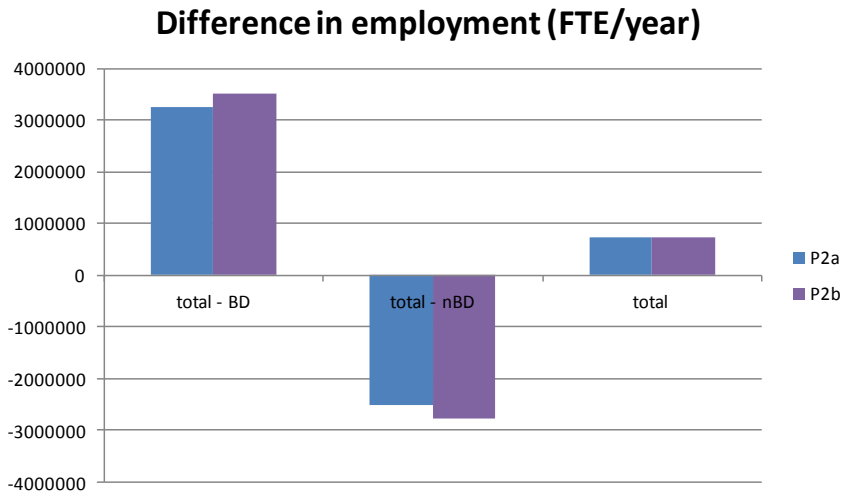


Figure 56 – Difference in employment for Policy Options P2a and P2b (2020, EU-27) for biodegradable (BD) and non-biodegradable (nBD) packaging

- **Risks and controversies surrounding the use of genetically modified organisms (GMOs)**

There are increasing concerns with regard to the genetically modified origin of the biodegradable packaging products. The potential need to increase the use of GMOs to meet the rising demand for bio-based biodegradable packaging is also a recurrent concern in the literature.

As far as producers are concerned, European Bioplastics argues that "the use of GM crops is not a technical requirement for the manufacturing of any bioplastic commercially available today. If GM crops are being used, the reasons lie in the economical or regional feedstock supply situation."[164] Furthermore, according to several producers of biodegradable plastics, even when genetically modified DNA is used, final products present no trace of GMOs. Some companies such as Novamont or Natureworks simply prevent using GM feedstock.[165] However, it can be noted that such approaches involve extra costs to producers since it requires testing and certifying packaging products to ensure they are GM-free.

[164] European Bioplastics, 2011d.

[165] See: http://www.plastemart.com/upload/Literature/Cost-competitiveness-infrastructure-improvements-makes-bioplastics-emerging-sector-in-Europe.asp

Consumers' acceptance of GMOs remains an issue. Every two to three years, the Eurobarometer gauges the changes in public opinion in the EU on a broad range of topics such as biotechnologies and their various applications. If surveys tend to show growing public understanding of biotechnologies-related issues, trust is still lacking in green biotechnologies using GMOs. In 2005, 58% of European citizens believed that the development of GM foods should not be encouraged by governments.[166]

In the future, particular attention would be paid to consumers' attitude towards GMOs because they could potentially affect consumption decisions and reduce the positive impacts of labelling schemes.

[166] Gaskell et al., 2006.

Chapter 5: Comparing the options

In this chapter, the policy options are compared to the baseline scenario and to each other, based on the assessment of the individual policy options in the previous chapter.

5.1 Expected impacts of policy options on drivers

5.1.1 Impacts on packaging market projections over time

It is assumed that the impacts of policy options on packaging consumption and production will change over time. Impacts on glass and metal packaging markets are assumed to be insignificant. Moreover, both impacts on consumption and production are assumed to follow similar trends. The main difference between consumption and production lies in the limited production capacity of European facilities.

Figure 57 presents the changes in non-biodegradable and biodegradable packaging waste, in 2020, compared to the baseline scenario. It can be clearly seen that P1a has no direct effect on the productions of non-biodegradable and biodegradable packaging. For the other policy options, a shift from biodegradable to non-biodegradable (e.g. for P1b) or from non-biodegradable (e.g. P2) is observed. It also shows that the total amount of packaging does not change relative to the baseline, as overall demand for packaging is assumed constant regardless of the policy option. The only change possible is a shift from one type of packaging to another.

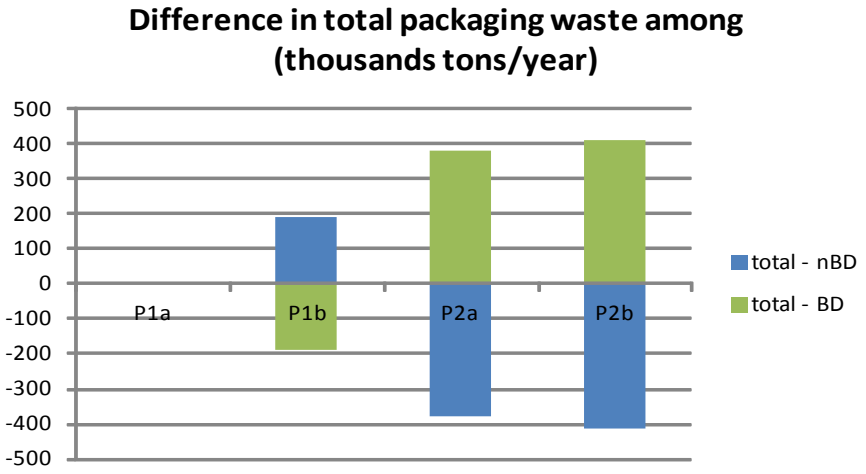
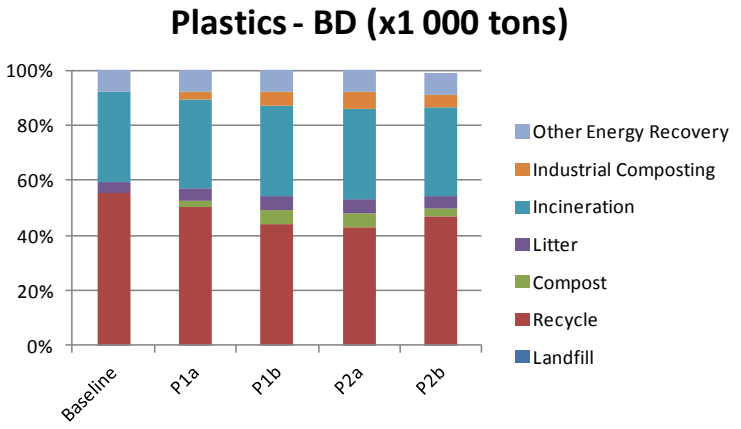


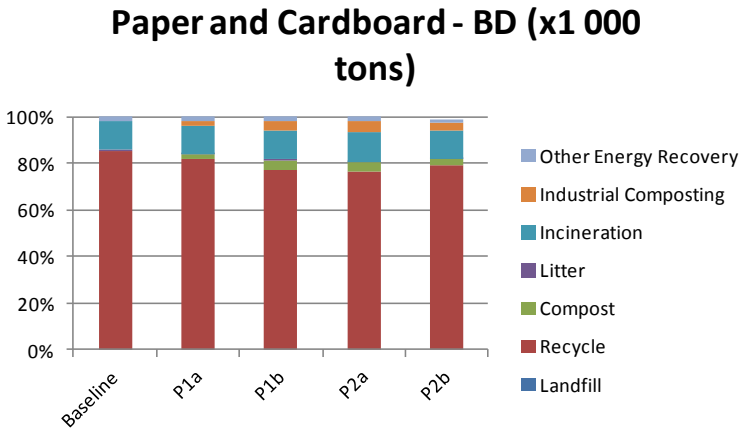
Figure 57 – Difference in total packaging waste amount in 2020 (1 000 tons/year) for biodegradable (BD) and non-biodegradable (nBD) packaging

5.1.2 Impacts on end-of life management

It was assumed that only the distribution of biodegradable (BD) packaging waste will be impacted by the implementation of any suggested policy option. As such, no modification is planned for non-biodegradable (nBD) packaging, meaning that no direct substitution effects are assumed.[167]

The charts that make up Figure 58 present the changes in the amount of biodegradable packaging waste for each of the waste streams. In line with the Resource Efficiency Roadmap, landfill is no longer considered as a suitable disposal management practice by 2020. Compared to the baseline, the recycling shares will decrease in order to foster the use of composting schemes. This is particularly relevant in the case of policy options P1b and P2a where more impacts are expected.





[167] Potential effects on the end-of-life management for non-biodegradable packaging would be negligible as the market share for biodegradable packaging will remain marginal in all the different policy scenarios.

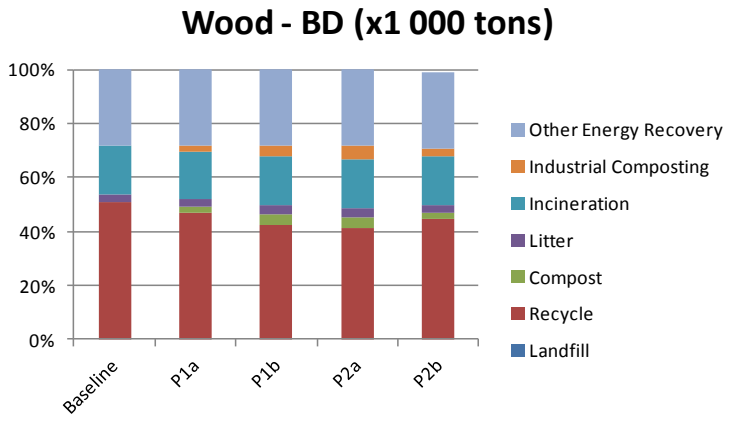


Figure 58 – Distribution in disposal options for packaging waste (plastics, wood and paper and cardboard) in 2020

5.2 Expected environmental, economic and social impacts of policy options

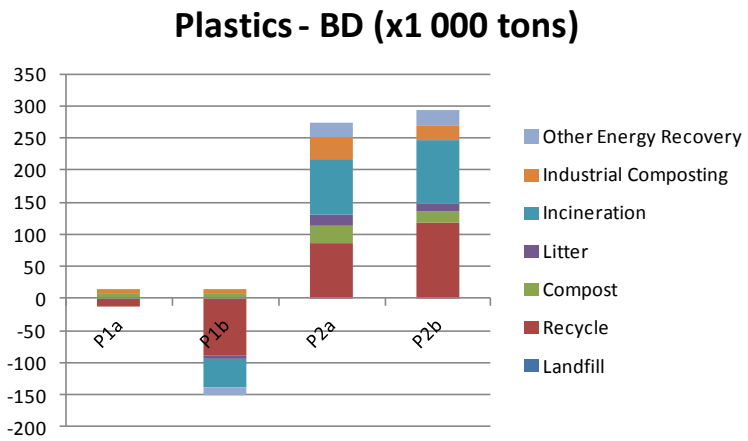
5.2.1 Environmental impacts

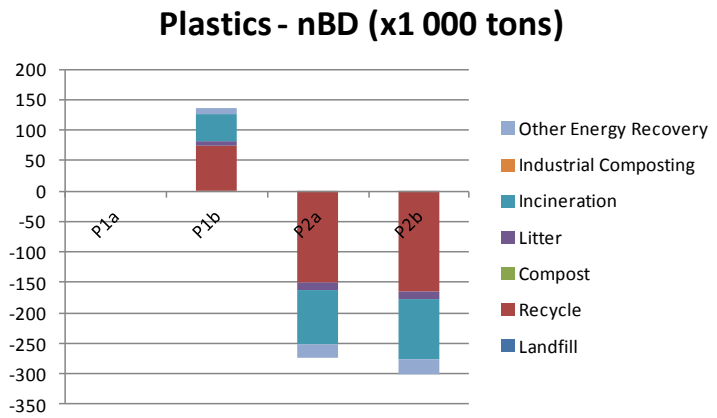
The charts that make up Figure 59 offer a comparative overview of how much packaging waste will be produced in the EU in 2020, compared to the baseline scenario and which disposal option would be used.

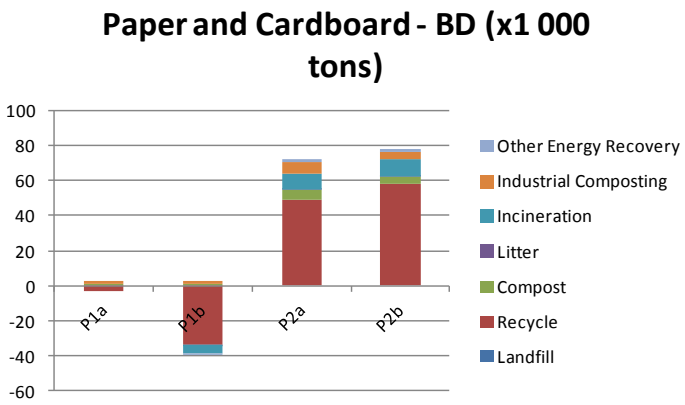
As described earlier, biodegradable packaging will be best promoted with the implementation of a negative labelling (P2b) which offers for each type of material (plastic, paper and wood) the largest shift from non-biodegradable packaging to biodegradable packaging.

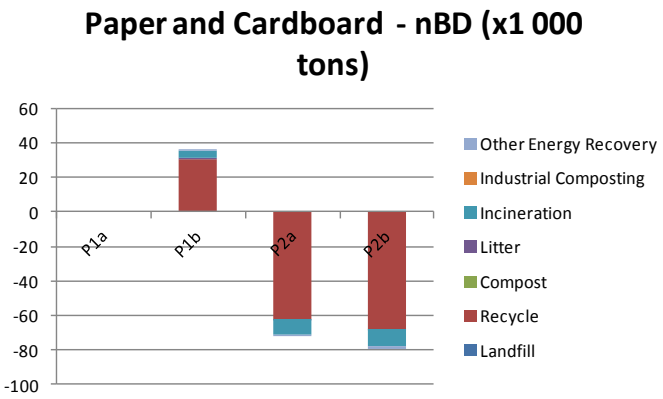
To a slightly smaller extent, the implementation of a positive labelling (P2a) will also bring out a considerable shift from non-biodegradable to biodegradable packaging for all considered materials.

As policy option P1b will induce more stringent requirements towards compostability and biodegradability, the biodegradable market actors will need time to ensure their compliance to the new requirements and thereby make reliable claims of their packaging products. By 2020, it is expected that the production of biodegradable packaging will still be below what is currently produced under the present requirements.


Plastics - BD (x1 000 tons)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
P1a
P1b
P2a
P2b
Other Energy Recovery
Industrial Composting
Incineration
Litter
Compost
Recycle
Landfill


Plastics - nBD (x1 000 tons)
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
P1a
P1b
P2a
P2b
Other Energy Recovery
Industrial Composting
Incineration
Litter
Compost
Recycle
Landfill


Paper and Cardboard - BD (x1 000 tons)
100
80
60
40
20
0
-20
-40
-60
P1a
P1b
P2a
P2b
Other Energy Recovery
Industrial Composting
Incineration
Litter
Compost
Recycle
Landfill


Paper and Cardboard - nBD (x1 000 tons)
60
40
20
0
-20
-40
-60
-80
-100
P1a
P1b
P2a
P2b
Other Energy Recovery
Industrial Composting
Incineration
Litter
Compost
Recycle
Landfill

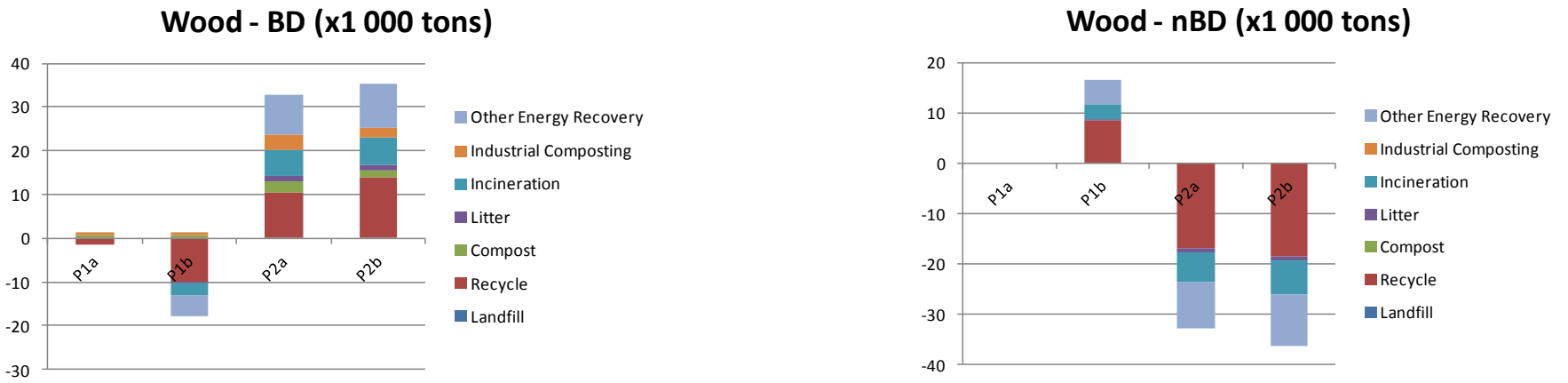


Figure 59 - Difference in packaging waste amount compared to the baseline scenario until 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

Energy use

Figure 60 shows the comparative impact of the envisaged policy options on the energy use during the production and end-of-life phases in 2020.

Considering only these two life-phases, the implementation of such a policy option seems to be slightly beneficial for option P1b. In the four cases, the final energy use reflects balanced energy accounting between the production phase and the end-of-life phase. It is particularly relevant for P2a and P2b where a significant amount of biodegradable packaging is sent to composting facilities instead of recycling. Indeed, the energy savings induced by the production of bio-based biodegradable plastics instead of conventional petroleum-based plastics are in fact outbalanced by the loss in energy benefits that are linked to recycling.

The situation is reversed for P1b where recycling non-biodegradable is more energy-efficient than recycling biodegradable material and thereby compensates the extra-energy needed for production purposes.

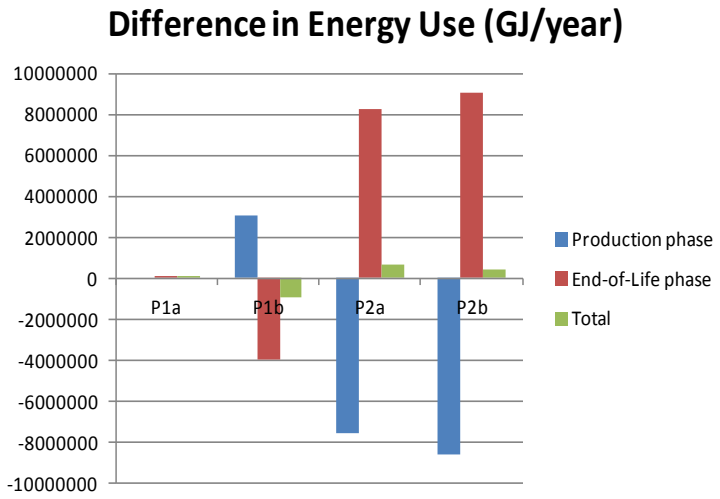


Figure 60 – Difference in Energy Use for plastic packaging waste for biodegradable (BD) and non-biodegradable (nBD) packaging

GHG emissions

Similar to the discussion on energy use, the considered policy options will bring out opposite effects on the production and end-of-life phases with regard to the GHG emissions (see Figure 61). Therefore, both phases tend to compensate each other.

However, in the case of the labelling options (P2a and P2b), less GHG will be emitted by 2020.

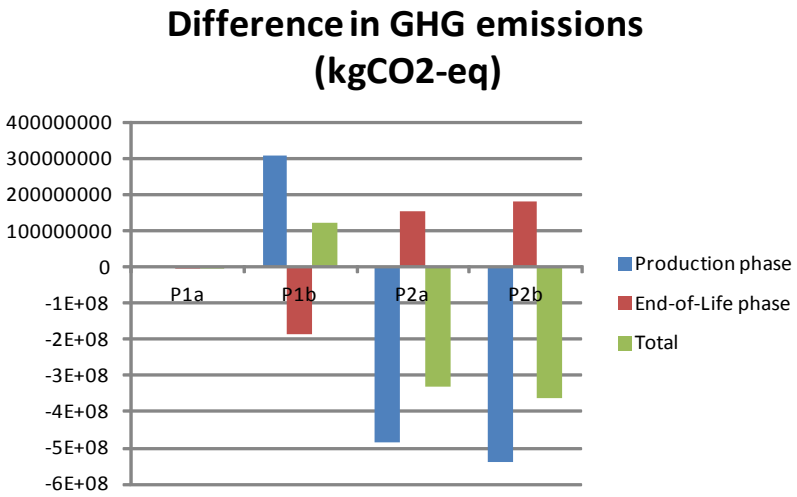


Figure 61 – Difference in GHG emissions for plastic packaging waste for biodegradable (BD) and non-biodegradable (nBD) packaging

Resource depletion

Changes related to resource depletion are strongly linked to the non-biodegradable share of packaging in the overall packaging market.

As policy options P2a and P2b lead to a quantitative shift from non-biodegradable packaging to biodegradable packaging, the biodegradable share of packaging is expected to increase significantly by 2020 with the implementation of policy options P2a and P2b (see Figure 62). Therefore, the benefits related to the recycling process are limited compared to the baseline scenario.

On the other hand, policy option P1b, which leads to more non-biodegradable packaging waste, and thereby more recycling waste, would not contribute to resource depletion.

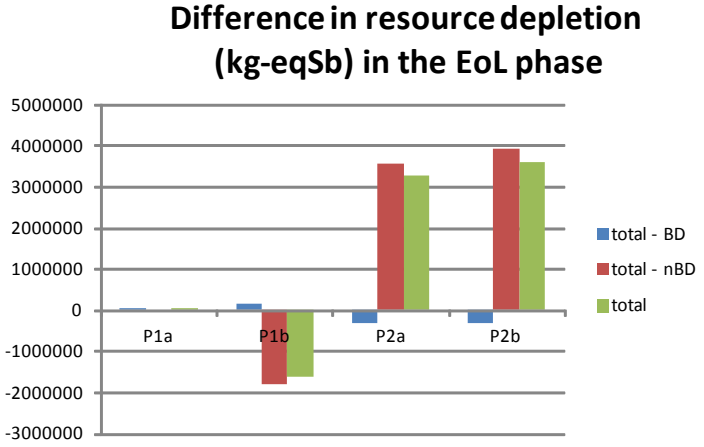


Figure 62– Difference in resource depletion for plastic packaging waste in 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

Land use

In the policy scenarios, only options P2a and P2b actually induce more production of biodegradable packaging and thereby require sufficient land to grow suitable bio-based raw materials. By 2020, it is assessed that almost 1,000,000 additional ha will be needed to respond to the market demand in case a labelling is to be implemented (see Figure 63).

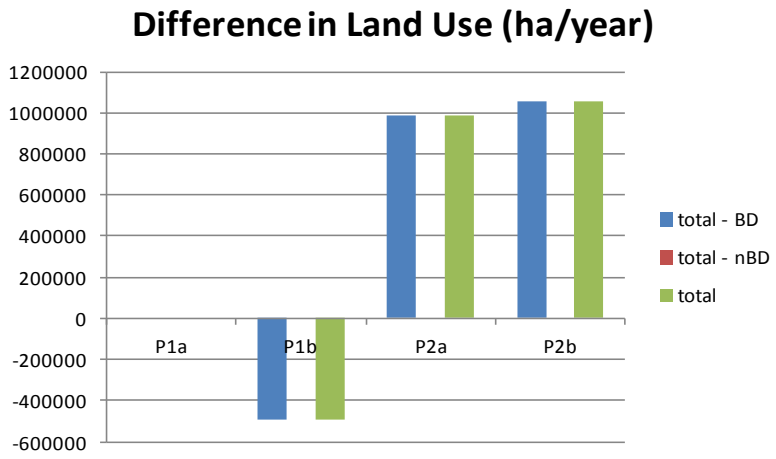


Figure 63 – Difference in land use for plastic packaging waste in 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

Eco-toxicity, air and water quality

With regard to toxicity as well as acidification and eutrophication, policy options P2a and P2b will lead to higher risks of contamination due a shift to biodegradable packaging and thereby to composting uses (as alternative to recycling) compared to the baseline scenario, as can be seen in Figure 64 to Figure 67.

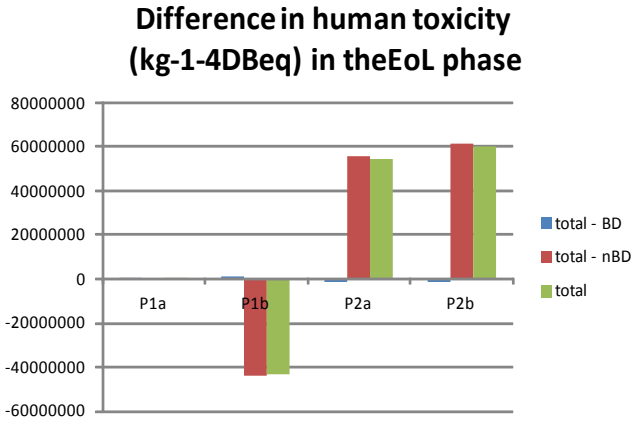


Figure 64 – Difference in human toxicity for plastic packaging waste in 2020 (biodegradable for biodegradable (BD) and non-biodegradable (nBD) packaging

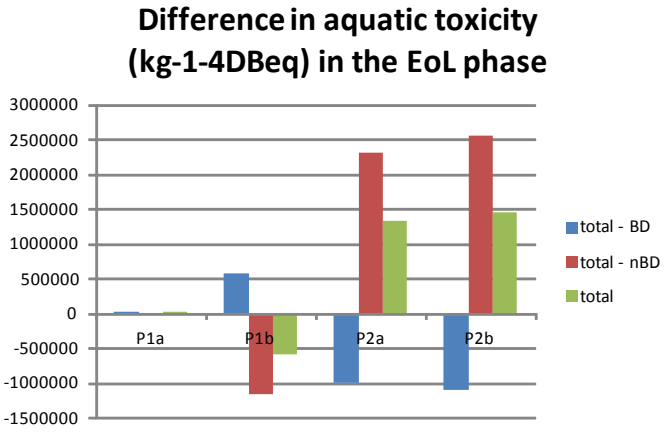


Figure 65 – Difference in aquatic toxicity for plastic packaging waste in 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

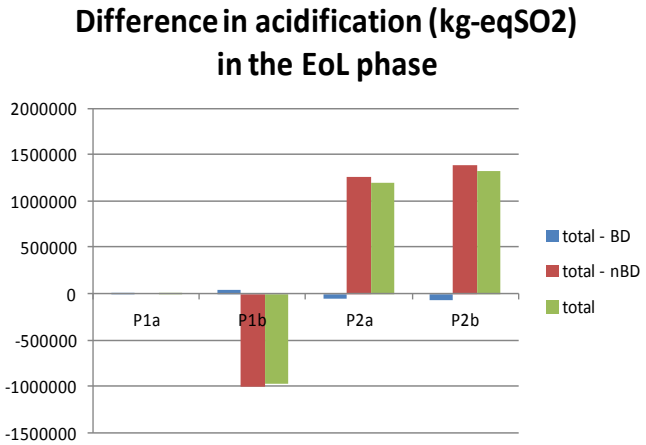


Figure 66 – Difference in acidification (emission to air) for plastic packaging waste in 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

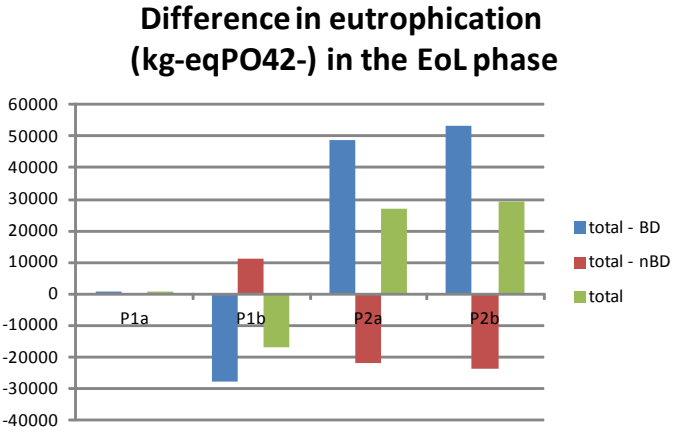


Figure 67 – Difference in eutrophication (emission to water) for plastic packaging waste in 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

5.2.2 Socio-economic impacts

As previously discussed, the implementation of labelling (P2a or P2b) will lead to additional costs in the packaging industry that would exceed the 50 million € per year by 2020. P1b would actually be a cheaper option compared to the baseline scenario as more non-biodegradable packaging will be produced (see Figure 68).

The same trend is observed for the related employment market in Figure 69.

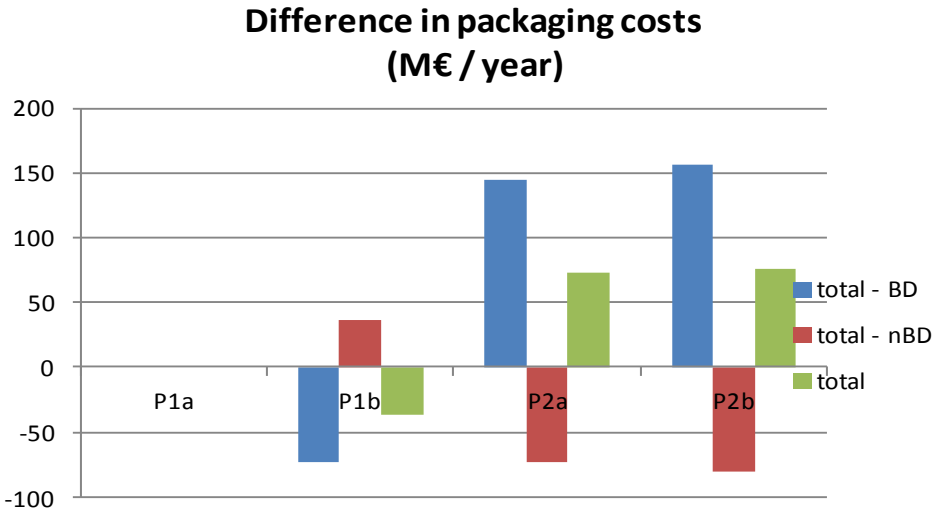


Figure 68 – Difference in packaging costs in 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

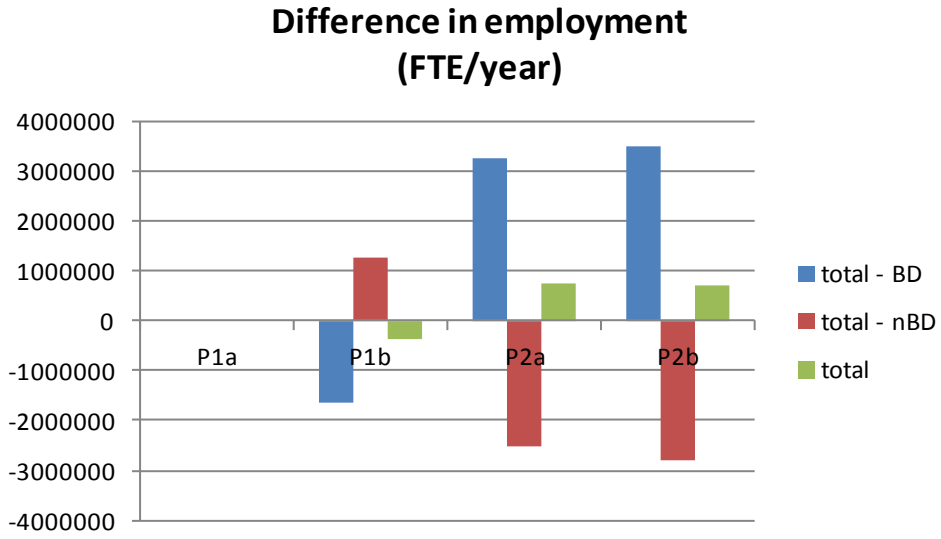


Figure 69 – Difference in employment in 2020 for biodegradable (BD) and non-biodegradable (nBD) packaging

5.3 Conclusions

The comparison made in this section highlights the advantages and disadvantages of the various policy options, across the economic, social and environmental dimensions and identifies potential weaknesses and risks of options. The options are compared from the point of view of effectiveness, efficiency and consistency, including potential trade-offs between competing objectives. The cost-effectiveness of different options is also considered since some of them will have budgetary implications. Table 22 below summarises the pros and cons of the various policy options analysed.

The implementation of stricter requirements (policy options P1a and P1b) regarding biodegradability and compostability would result in many packaging producers not being able to comply with such standardisation. Many would not find it to be economically viable to enter such a market niche, even by 2020. The positive environmental impacts are mainly due to a part of the current biodegradable packaging being shifted to non-biodegradable packaging with the new requirements, resulting in environmental gains from recycling.

The implementation of labelling (positive P2a or negative P2b) will increase the consumption and production of biodegradable packaging products and contribute to the creation of jobs. However, it would also lead to higher packaging costs compared to the baseline scenario.

Biodegradable packaging has many positive aspects due to the possibility for disposal in composting facilities. However, from the consumer's point-of-view, it is expected that fostering composting habits will directly impact the recycling rates for packaging, leading to a loss of the benefits from recycling (deriving additional value from the materials, related energy savings, reduced resource depletion, etc.).

Looking at environmental impacts, the overall benefits of biodegradable products are less significant than the environmental benefits stemming from recyclable products. Currently, the industry is more focused on developing the bio-based packaging market, without consideration of the biodegradability of the final product, as benefits from the origin of the resource prevail over the benefits from the end-of-life management.

Table 22 – Summary of pros and cons of policy options to improve the biodegradability requirements in the Packaging Directive

Policy option	Pros	Cons
Baseline Scenario	– No legal or administrative changes or costs associated with revising the current legislation. – Relative high growth of biodegradable packaging consumption and production in the EU.	– Biodegradable packaging remains a small fraction of the overall European packaging market by 2020. – Increasing misunderstanding regarding the biodegradable character of packaging and increasing costs of cleaning-up packaging litter. – Development of voluntary labels based on claims for biodegradation that are not necessarily supported by a scientifically-valid standard.
Option P1a: Reinforce existing requirements by making a clear distinction between compostability and biodegradability	– Clarification of the definitions for compostable and biodegradable packaging. – Slight increase in the share of packaging discarded in composting facilities.	– High compliance costs for producers (certification costs, research and development investments, etc.). – Unless policy option P1a is accompanied by large awareness-raising campaigns, most EU consumers will not be aware of the stricter requirements for biodegradation.

Policy option	Pros	Cons
Option P1b: Introduce a requirement for compostable packaging to be fit for biodegradation in natural conditions in the environment and in particular in the marine environment	– Decrease in the share of littering due to misuses of biodegradable packaging. – Higher share of recycling for packaging waste due to the increase in non-biodegradable packaging by 2020.	– Drop in compostable packaging consumption and production in the short run. – Risk of contaminating existing streams with bio-based products whose consumption will continue to grow. – High compliance costs for producers (certification costs, research and development investments, etc.). – Rise in imports of bio-based packaging.
Option P2a: Positive labelling	– Better visibility of biodegradable products leads to an increase in demand for biodegradable and compostable packaging. – Improvement in sorting of packaging waste. – Increase in the share of packaging waste discarded in composting facilities. – Rise in employment in the packaging sector.	– Rise in imports of biodegradable packaging. – The share of composting will remain limited by the current state of the composting facilities as the EU is not prepared to handle a large amount of waste for composting. – Increase in the share of littering as consumers could misinterpret the biodegradability label as an approval for littering. – Increase in the cost of separate waste collection schemes and recycling. – Increase in packaging costs. – Risks of rebound effects. – Potential need to increase the use of GMOs to meet the rising demand for bio-based biodegradable packaging.

Policy option	Pros	Cons
Option P2b: Negative labelling	– Better visibility of biodegradable products leads to an increase in demand for biodegradable and compostable packaging. – Slightly higher influence on consumers' behaviour and purchase intention than with policy option P2a. – Improvement in sorting of packaging waste. – Increase in the share of packaging waste discarded in composting facilities. – Rise in employment in the packaging sector.	– Increase in imports of biodegradable packaging. – The share of composting will remain limited by the current state of the composting facilities as the EU is not prepared to handle a large amount of waste for composting. – Increase in the cost of separate waste collection schemes and recycling. – Significant implementation costs for the packaging industry and the retail sector. – Increase in packaging costs. – Potential need to increase the use of GMOs to meet the rising demand for bio-based biodegradable packaging.

To compare the policy options, a semi-quantitative score matrix approach is adopted, as shown in Table 23. The level of detail in the analysis depends on the amount of information gathered as well as their quality.

Table 23 – Semi-quantitative score matrix

Legend	Environmental impact indicators	Social and economic impact indicators
++	> 10,000 inhabitant-eq	Substantial beneficial effect
+	between 1,000 and 10,000 inhabitant-eq	Slight beneficial effect
0	No effect (the baseline)	No effect (the baseline)
≈	Between 1 and 1,000 inhabitant-eq)	Marginal/Neutral impact
-	between 1,000 and 10,000 inhabitant-eq	Slight negative effect
--	> 10,000 inhabitant-eq)	Negative effect
?	Unknown effect	Unknown effect

Table 24 summarises the potential environmental, economic, and social impacts for the implementation of the different policy options. In each cell of the matrix a qualitative score is given, hence, forming the basis for identifying the most workable approach in an efficient and effective manner.

Table 24 – Qualitative comparison of environmental, economic and social impacts of policy options to improve the biodegradability requirements in the Packaging Directive

Policy Option Impact Indicator	Option P1a	Option P1b	Option P2a	Option P2b
Environmental impact indicators				
Energy Use	≈	+	-	-
GHG emissions	≈	-	++	++
Resource Depletion	≈	++	--	--
Human Toxicity	≈	++	--	--
Aquatic Toxicity	≈	+	-	-
Acidification	≈	++	--	--
Eutrophication	≈	≈	≈	≈
Economic impact indicators				
Biodegradable packaging production	0	--	+	+
Biodegradable packaging consumption	0	--	++	++
Packaging costs	0	≈	-	-
Impact on producers and industries	-	--	-	--
Packaging waste management sector	≈	--	-	--
Internal Market	+	-	+	+
Administrative burden	+	+	++	++
Research and Development	++	++	+	+
Social impact indicators				
Consumer behaviour and awareness	≈	≈	+	++
Employment	0	≈	++	++

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Annex 1: Bioplastics manufacturing processes

Figure 70 presents different approaches/technologies that are used to produce bioplastics.

Figure 70 – Technologies for manufacturing bioplastics[168].

Production Technologies	Description	Examples of Manufacturers
Fermentation	Fermentation of natural sugars and fatty acids to produce monomers (PLA) or use bacteria to produce polyesters or intermediates (PHA)	Nature Works, PURAC, Telles, Tianan
Starch / cellulosic	Modified starches and celluloses produced through reactive extrusion and compounding technology	Plantic, Novamont, Cereplast, Stanelco, Innovia.
Blends	Resins compounded to increase renewable content	Novamont, Cereplast, Innovia.
Synthetics	Biodegradable or partially bio-based. Limited renewable content	BASF, DuPont
Bio-based	Produced from bio-based ethylene	Braskem, Dow-Crystalsev, Solvay

[168] Roberts, Ann, Plantic, Presentation on BioPlastics, held during Ausbiotech 2010.

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Annex 2: Economic cost of packaging littering

Discarded packaging represent a cost to fishing and other maritime activities based on time and money wasted cleaning, disentangling etc. and because they may damage fish stocks. In some European regions, tourism may also be affected when discarded packaging destroy landscapes and decrease the recreational potential and the attractiveness of both inland and coastal sites.

The wide diversity of impacts makes measuring the full economic cost resulting from packaging litter a very complex task. In theory, direct impacts such as litter cleansing costs would be easier to estimate than indirect economic impacts such as reduced ecosystem values or decreased quality of life that require controversial ecosystem valuation methods in order to be estimated. Unfortunately, only few data on the economic costs of packaging litter are reported in practice.

- **Costs of cleaning marine litter**

According to the UNEP, sectors that can potentially be economically affected by marine litter encompass tourism and recreational activities, shipping, fishing, agriculture by the coast, marinas and recreational boats, aquaculture and rescue services. However, the main cost related to marine litter consists in costal cleaning. Costs of cleaning packaging litter on coasts can be significant and often fall to local authorities rather than national governments[169]. For instance, UK local authorities, industry and coastal communities spent approximately €17.7 m cleaning up marine litter in 2004 in England and Wales. Moreover, litter cleaning costs increase in high touristic areas. In the Netherlands, the city of Den Haag that receives annually 15 million visitors spend more than €600,000 each year for coastal cleaning.

In the context of a project led by KIMO in 2009, a questionnaire was developed to find out more about beach cleaning activities. This questionnaire was distributed to local government organisations in countries throughout the Northeast Atlantic region. For most municipalities, the potential economic impact of marine litter, particularly in terms of lost tourist revenue, provides the principal motivation for removing beach litter. In this respect, regularly removing beach litter represents a lower cost to municipalities than the potential reduction in revenue that would result from taking no action.

The costs are even higher if, on top of cleaning up costs, overall financial impacts of marine litter are taken into account. Thus, in 2000, KIMO estimated the overall annual cost of marine litter (including costs of beach cleaning but also costs for aquaculture, power generation, farming, fishing, harbours and lifeboat launches) to the Shetland Islands community (Scotland) at €7.1m for 22 000 inhabitants.[170] More precisely, fishermen declared spending on average 1 to 2 hours per week clearing debris from nets while a fouled propeller was estimated to costs about €380 for the hire of a diver to disentangle it.

Some other rough estimates of costs related to marine litter have been found in the literature:

[169] UNEP et al., 2009.

- In 2007-2008, the OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic supported 10 Belgian fishing vessels that participated in a "fishing for litter" project consisting in asking fishermen to voluntary collect marine litter caught up in their nets in large hard-wearing bags. As a reward, fishermen received €5 per bag delivered. The annual cost of the project is estimated at €21 700;[170]
- Cleansing of the Swedish Skagerrak coast in 2006 was estimated to cost about €1.5m and took approximately 100 people and four months to complete;[171]
- Research in Poland found that the cost of removing marine litter from the shoreline of five municipalities and two ports amounted to €570 000;[171]
- In the context of the project led by KIMO in 2010, a questionnaire was developed to find out more about beach cleaning activities and this was distributed to local government organisations in countries throughout the Northeast Atlantic region. For most municipalities, the potential economic impact of marine litter, particularly in terms of lost tourist revenue, provides the principal motivation for removing beach litter. In this respect, regularly removing beach litter represents a lower cost to municipalities than the potential reduction in revenue that would result from taking no action;
- In the French Bay of Biscay, the average annual cost of beach cleaning was around €6,500 per km in 2002.[172]

Costs of cleaning inland litter

Inland litter induces both direct costs to local communities in charge of cleaning up discarded packaging and indirect costs encompassing decreasing property values, decreasing recreational attractiveness of sites, decreasing amenity value of landscapes, etc[173].

The literature gives very little specific information on packaging inland litter clean up costs for EU Member States. However, some information has been found, including in third countries, which can be used to make an estimate:

- A 2011 study estimated the cost of litter in Switzerland and the way this is distributed among the different litter components (take-way food packaging, drinks containers, newspapers and flyers, cigarettes). The emphasis was on litter produced by pedestrians in towns, villages and public transport. In towns and villages, cleaning costs produced by litter-dropping for take-away food packaging and beverage containers were estimated at respectively 19% and 35% of total costs (resp. €22 million and

[170] OSPAR Commission, 2009.

[171] KIMO, 2010.

[172] UNEP et al., 2009.

[173] Keep America beautiful, 2010.

€41 million per year). Thus, more than 50% of the litter-costs were estimated to be caused by food and drink packaging and other objects associated with fast food. Overall, the €118 million associated with cleaning up litter in Swiss towns and villages represent about €15 per head each year. Similar results were obtained for public transport litter related cleaning costs.[174]

- In Great Britain, the estimated cost of street cleaning (including smoking related litter, fast food packaging, confectionery litter and hazardous litter) was roughly €370m in 2005-2006.[175]
- In the Netherlands, it was estimated in 2004 that clearing up beverage packaging inland litter, including the emptying of litter bins and waste processing, cost €5.7 per can or bottle.[176]
- In the United States, researchers have found that cleanup costs for plastic bag litter amounts to approximately 0.17 USD per bag, which means the average taxpayer pays about 90 USD extra per year to clean up plastic bag pollution.177
- Plastic bags cost the city of Austin (United States) taxpayers at least 850,000 USD per year to put in landfills and clean up as litter. [178]

[174] Switzerland Federal Office for the Environment, 2011.

[175] ENCAMS, 2006.

[176] Van Duin et al.2004.

Conversion rate: €1 = 0.81 CHF.

[177] See www.rodale.com/plastic-bag-ban.

[178] See www.statesman.com/news/local/plastic-bags-costly-to-austin-taxpayers-review-says-1181735.html.

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