Comparison of Carton and Plastic Packaging Sustainability

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May 2018

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About Truffula

Truffula Ltd is a UK-based sustainability consultancy with extensive experience of print, paper and related industries. Services include policy and strategy development, research and analysis, supply chain due diligence, green marketing and communications, guidance and support.

www.truffula.co.uk

About Pro Carton

Pro Carton is the European Association of Carton and Cartonboard manufacturers. Its main purpose is to promote the use of cartons and cartonboard as an economically and ecologically balanced packaging medium.

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This Report

Pro Carton commissioned Truffula to research and write this independent report. Its information sources are all in the public domain and are individually referenced. The report is intentionally transparent, analysing the advantages and disadvantages of plastic and cartonboard from a technical and environmental standpoint. Any opinions stated in this document are that of the author.

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1. Executive Summary

This report looks at two types of packaging materials: cartonboard and its potential plastic alternatives. It considers the most prominent life cycle impacts of each (both positive and negative) and the views of interested parties that can influence the choice of material. It then looks more closely at some applications where either plastic or cartons could fulfil the functional need and examines to what extent sustainability should be a deciding factor.

In recent times, the primary sustainability strategy of brand owners and retailers has been to reduce and lightweight the packaging materials they use. However, a more holistic approach is now emerging, which recognises that it is not just about the amount of packaging materials used but also the life cycle of those materials, from the nature of the resources needed to make them, to the potential for their value to be recovered at the end of their life.

One of the most prominent consumer issues that brands are facing currently is related to the amount of packaging waste (particularly plastic bottles) that ends up in the world's oceans. This is one of the flagship issues driving interest in circular economy thinking and has been the subject of high-profile campaigns by environmental activists. Consumer brands can be vulnerable to such negative publicity, which help to shape customer preferences, including that for packaging materials.

Cartonboard is largely based on a renewable raw material (wood) with about a third derived from recycled fibre, thus extending the useful life (and retaining the value) of the raw material. The use of renewable resources is a fundamental principle of the circular economy and so is a significant benefit of cartons.

Plastic packaging is almost entirely based on finite fossil resources, with very little derived from renewable raw materials or recycled feedstock.

One potential advantage of plastic is its durability, which may be important for some applications. However, as much consumer packaging is single-use it is likely to remain in the supply chain for less than a year, negating the benefits of durability and potentially exacerbating the end of life impacts.

The potential for plastic to perform a function with less weight of material is also an important and attractive attribute. However, it is not without some drawbacks. The lighter individual packaging items are, the less value the materials may have, which means there is less incentive to ensure they are collected and recycled at the end of their life.

When considering how packaging waste is treated, it can be seen that paper and cardboard performs significantly better in relation to the waste hierarchy. Based on data from Eurostat, more than double the proportion of paper and cardboard packaging is sent for recycling (82.6%) compared to the recycling rate for plastic packaging (39.8%).

While technically most plastics can be recycled, in practice it is often difficult to ensure it is properly segregated in volumes sufficient to make it economically attractive to collect. So, while some items like PET drinks bottles are widely recycled, others may be more difficult for consumers to deal with.

It is difficult to be certain exactly how much packaging ends up in landfill but it could be as much as 4.6 million tonnes for plastic and 3.3 million tonnes for paper and cardboard (according to Eurostat). Therefore, it is more likely for plastic packaging to be sent to landfill than it is for paper and cardboard. Leakage into the environment also appears to be a much more substantial

1. Executive Summary - continued

problem for plastic packaging than for paper-based packaging. According to the European Environment Agency, 82% of the litter collected on European beaches is plastic, while only 2% is paper or cardboard. Once in the environment, paper-based packaging can break down within months but plastics can take decades or even centuries to degrade. Much of this finds its way into the sea.

As well as the cost associated with trying to clean up ocean plastics, there are serious concerns about the impact on marine life and, ultimately, human health. Plastics are ingested by sea birds, fish and other organisms, and experts warn that some of it is already finding its way into the human food chain. Even some of the so called 'bioplastics' that are intended to degrade, do not fully address the issue of plastic pollution at present. For example, oxo-degradable plastics, which are treated with additives so they break-up after a period of time, do not degrade fully but rather fragment into 'microplastics' smaller than 5mm, which can actually exacerbate the problem.

It can be very difficult to reliably compare the carbon footprint of different packaging items as there are so many variables involved. While the carbon footprint per tonne may be lower for cartonboard, the amount of plastic required to package the same item may be less. Therefore, the carbon footprint should always be evaluated with regards to the specific application.

In conclusion, cartons are already an appropriate alternative to plastic packaging for a wide range of applications because of their technical and aesthetic qualities. In some examples, such as for confectionery, tea and small beverage multipacks, it can be demonstrated that cartons have, on balance, clear environmental benefits too. Principally, these benefits relate to the use of renewable raw materials and ease of recycling, which make cartons a positive packaging choice for the circular economy of the future. Plastics packaging of course has its own advantages but, for certain applications, the key benefits of durability and lightweight can be redundant or insufficient overall for it to be considered an automatic choice. Furthermore, plastic's reliance on non-renewable resources and its waste-related environmental impacts can be anticipated to pose an increasing risk to brands, through potential tightening of waste legislation and negative public perception. Anyone specifying packaging should carefully consider these issues when making their choice of packaging material.

2. Introduction

Packaging performs multiple functions. It protects and promotes products, makes distribution and use easier, delivers important information and can potentially minimise the environmental impacts of the product.

The choice of packaging materials depends on many factors - functional, economic, marketing and environmental drivers all play a part. Some packaging materials have particular properties, such as durability, impermeability, flexibility or transparency that may be essential for some applications. Others may appeal more because of their sustainability credentials, for example using renewable raw materials or being easy for consumers to recycle.

This report looks at two types of packaging materials: cartonboard and its potential plastic alternatives. It considers the most prominent life cycle impacts of each (both positive and negative) and the views of interested parties that can influence the choice of material. It then looks more closely at some applications where either plastic or cartons could fulfil the functional need and examines to what extent sustainability should be a deciding factor.

3. Life Cycle Overview

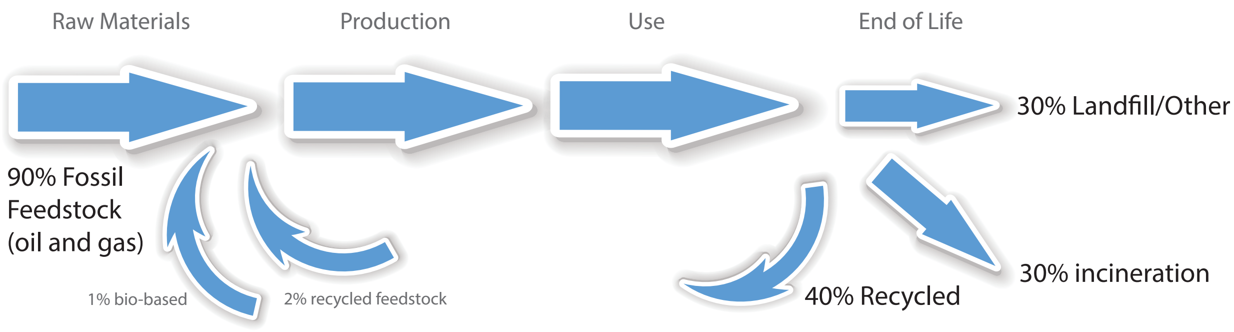

Figure 1: Simplified life cycle overview of plastic packaging materials.

The primary raw material for plastic manufacture is oil and gas, which makes up 90% of the feedstock.[1] This is processed through a distillation process into different fractions such as Naphtha, which is further processed, or 'cracked' into simpler compounds such as ethylene and propylene. These hydrocarbons are then linked together in a chemical reaction called polymerisation to form a polymer chain. Different plastics have different polymer chains, which is what determines their particular properties.[2]

The most common plastics used for packaging are 'thermoset' plastics (which soften on heating and harden again on cooling), particularly polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET) and to a lesser extent polystyrene (PS) and poly vinyl chloride (PVC). Packaging accounts for nearly 40% of all plastic demand in Europe.[3]

Bioplastics, which can be bio-based (derived from plants) or degradable (they biodegrade or fragment and may be plant or fossil-based) currently only account for about 1% of global plastic production.[4]

When used as packaging, plastic is claimed to have several benefits, such as flexibility, strength, lightness and impermeability.[5]

While many plastics can technically be recycled, in practice about 40% of plastic packaging is collected for re-cycling in Europe (most significantly PET bottles) and a further 31% is recovered by other means such as incineration.[6]

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[1] Ellen MacArthur Foundation, *The New Plastics Economy: Rethinking the Future of Plastics,* 2016.

[2] PlasticsEurope, *How Plastic is Made* (http://www.plasticseurope.org/what-is-plastic/how-plastic-is-made.aspx), accessed October 2017.

[3] PlasticsEurope, *Plastics – the Facts 2016,* 2016.

[4] European Bioplastics, *Bioplastics Facts and Figures,* 2016.

[5] PlasticsEurope, *Packaging* (http://www.plasticseurope.org/use-of-plastics/packaging.aspx), accessed October 2017.

[6] Eurostat, 2016.

3.2 Paper and Board

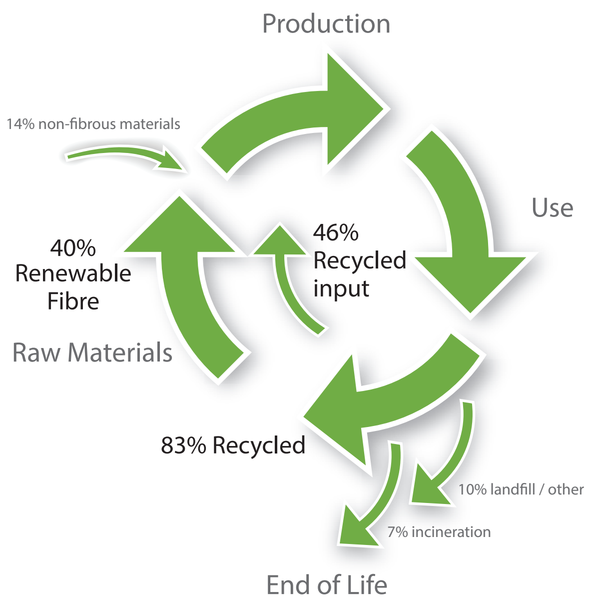

Figure 2: Simplified life cycle overview of paper and board packaging materials.

The primary raw material for paper and board is cellulose fibre, which can either be virgin fibre from trees or recovered fibre obtained from recycling paper products. The European paper industry as a whole uses 86% renewable raw materials – about 46% is fibre from paper for recycling and 40% is virgin woodpulp – plus about 14% non-fibrous material such as calcium carbonate.[7] 90% of the wood used by the European industry comes from within the European Union and 60% of it is third-party certified as coming from well-managed forests.[8]

The wood or recycled fibre pulp is mixed with water and dispersed on a mesh, through which water drains away, and the fibres begin to form a continuous sheet. Several sheets are brought together to make cartonboard which is then squeezed and heated through rollers before having a coating applied and finally being cut to size.

The most common types of cartonboards are White Lined Chipboard (WLC) which is mostly made from recycled fibre, Folding Box Board (FBB) which is mostly made from virgin fibre, Solid Bleached Board (SBB) and Solid Unbleached Board (SUB), both of which use virgin fibre.[9]

Cartonboard is claimed to have several benefits, such as design versatility, consumer appeal, renewable raw materials and ease of recycling.[10]

In Europe, 83% of paper and board packaging (including cartons) is recycled, with a further 7% collected for recovery of some of its value through other means such as incineration.[11]

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[7] CEPI, *Key Statistics 2016,* 2016.

[8] CEPI website http://www.cepi.org/topics/forest, accessed October 2017.

[9] CEPI cartonboard website http://www.cepicartonboard.com/?section=different_types_of_cartonboard, accessed October 2017.

[10] Pro Carton, *Why Choose Cartons?* (http://www.procarton.com), accessed October 2017.

4. Stakeholder Concerns

In recent times, the primary sustainability strategy of brand owners and retailers has been to reduce and lightweight the packaging materials they use.[12] This is understandable, given that reduction is an important first step towards both waste and carbon footprint minimisation. There are also legal drivers in the form of the Packaging Waste Directive (which in effect places a weight-based fee on those putting packaging onto the market, to fund the recovery of packaging waste) and the desire to reduce transport costs.

'Reducing the weight and thickness of packaging is the best way to both minimise impact on the environment and keep costs down.'
Carlsberg Group Sustainability Report 2016.

'Using less packaging provides an economic benefit, not only in material costs, but also in transportation and disposal. This helps us to reduce our overall CO2 emissions and operate more efficiently.'
Mondelez International, Impact for Growth 2016 Progress Report.

However, a more holistic approach is now emerging, which recognises that it is not just about optimising the amount of packaging materials used but also the life cycle of those materials, from the nature of the resources needed to make them, to the potential for their value to be recovered at the end of their life. This means a move away from the traditional linear 'take, make, dispose' model of consumption towards a 'circular economy' where waste is designed-out of the system, renewable energy is used, toxic chemicals are eliminated, metals and most plastics are reserved for durable applications and consumables are largely made obiological, renewable resources.[13]

'The Commission adopted an ambitious new Circular Economy Package to stimulate Europe's transition towards a circular economy which will boost global competitiveness, foster sustainable economic growth and generate new jobs... In a circular economy the value of products and materials is maintained for as long as possible; waste and resource use are minimised, and resources are kept within the economy when product has reached the end of its life, to be used again and again to create further value.'
European Commission, Circular Economy Package, 2015.

Companies in the Fast Moving Consumer Goods (FMCG) sector are amongst the most active in adopting life cycle and circular economy approaches towards the products they sell and their packaging. Packaging can be one of the most significant contributors to a brand's environmental impact and so it is no surprise that, as well as material reduction, there is a drive for increased use of recycled content, better recyclability of materials and, where feasible, increasing the use of renewable raw materials.

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[11] Eurostat 2015.

[12] Pro Carton / Smithers PIRA, *The Importance of Sustainability in Packaging,* 2017.

[13] Ellen MacArthur Foundation, *Towards the Circular Economy,* 2013.

“Preventing packaging ending up in landfill requires a new approach. This is why we have embraced circular economy thinking in our approach to tackling waste.”
Gavin Warner, Director, Sustainable Business, Unilever.

‘We optimise the weight and volume of our packaging; lead the development and use of materials from sustainably-managed renewable resources considering packaging and product performance requirements; support initiatives to recycle or recover energy from used packaging; use recycled materials where there is an environmental benefit and it is appropriate.’
The Nestlé Policy on Environmental Sustainability, February 2013.

One of the most prominent consumer issues that brands are facing currently is related to the amount of packaging waste (particularly plastic bottles) and microplastics that ends up in the world’s oceans. This is one of the flagship issues driving interest in circular economy thinking and has been the subject of high-profile campaigns by environmental activists, such as that by Greenpeace targeting Coca-Cola.[14]

Consumer brands can be vulnerable to such negative publicity, which help to shape customer preferences, including that for packaging materials. There are now grassroots organisations calling for plastic-free aisles in supermarkets[15], a proposal that appears to have widespread support, with one survey finding that 91% of UK respondents support the idea.[16] Another found that 64% of Swedish consumers perceive plastic as the least environmentally friendly packaging material (compared to only 4% for paper/cardboard).[17]

‘Paper offers inspiration - a widely used and recycled packaging material that is relatively benign if leaked into natural systems.’
Ellen MacArthur Foundation, The New Plastics Economy, 2016.

[14] https://www.greenpeace.org.uk/coke-campaign-goes-global/, accessed October 2017.

[15] http://aplasticplanet.com/, accessed October 2017.

[16] Populus, *Plastic Packaging Survey,* July 2017.

[17] Innventia, *Global Outlook Packaging 2020,* 2013.

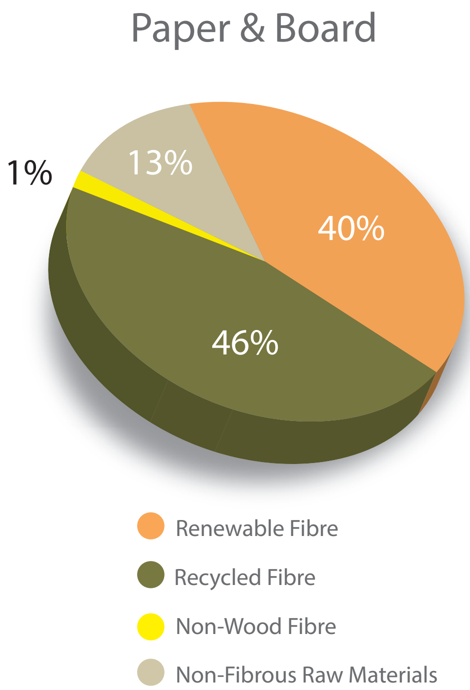
5. Material Comparisons: Cartonboard and Plastic

5.1 Raw Materials

Cellulose fibre accounts for over 86% of the raw materials consumed by the European paper industry. The source of this fibre is primarily from previously-made paper sent for recycling (46%) and 'virgin' woodpulp that comes from trees (almost 40%), with a small amount of non-wood fibre such as cotton (less than 1%). The remaining non-fibrous raw materials are mostly coatings and fillers such as calcium carbonate and clay. Specifically for cartonboard, the use of recycled fibre is slightly lower at about 37%, which mostly goes into White Lined Chipboard, for applications such as breakfast cereal cartons.[18]

Around 90% of the wood used by the European pulp and paper industry originates from within Europe. Between 2005 and 2015, European forests grew by 44,000 Square Kilometres, which amounts to over 1,500 football pitches of forest growth every day.[19] 60% of the wood used by the industry is third-party certified (FSC or PEFC) as coming from well-managed forests.

Cartonboard is therefore largely based on a renewable raw material (wood) with about a third derived from recycled fibre, thus extending the useful life (and retaining the value) of the raw material.[20]



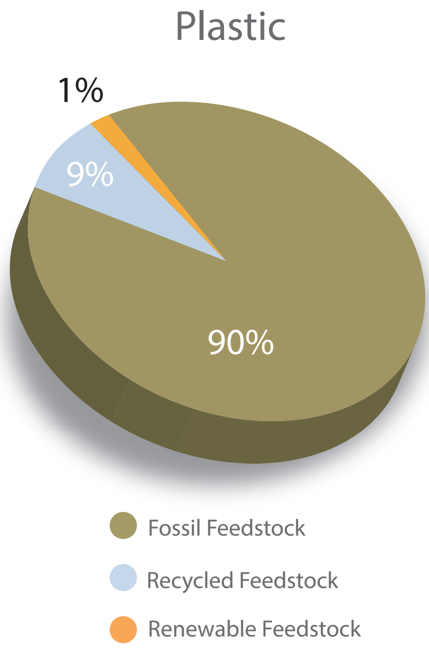


Table 1: Key raw materials used for paper & board and plastic production.

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[18] CEPI, *Key Statistics 2016,* 2016.

[19] Two Sides, *Print and Paper Myths and Facts,* 2017.

[20] CEPI website, http://www.cepi.org/topics/forest, accessed October 2017.

Currently, plastics are mostly derived from non-renewable fossil feedstocks (oil and gas) which accounts for over 90% of the plastic industry's raw materials.[21] The plastics industry in Europe accounts for 5% of oil and gas consumption (compared to transport at 45% and energy production at 42%[22]) and globally this is estimated to grow to about 20% of oil consumption globally by 2050.

Biobased plastics, derived from renewable feedstocks such as corn or sugar cane, currently account for less than 1% of all plastic production.[23] This has potential to grow and, in the longer term, alternative feedstocks such as cellulose or even captured greenhouse gases could be utilised.[24]

Recycled plastic is thought to contribute about 9% of the raw materials used in plastic production. However, as much of this is used for lower-value applications, the contribution to plastic packaging is currently around 2%.[25] Some consumer brands are attempting to improve this situation, for example Proctor & Gamble is making shampoo bottles using 25% post-consumer plastic and even washing-up liquid bottles from 100% recycled waste, including 10% plastic litter collected from the ocean.[26]

Nevertheless, plastic packaging is almost entirely based on finite fossil resources, with very little derived from renewable raw materials or recycled feedstock.

5.2 Energy

The pulp and paper industry in Europe transparently reports on energy consumption and its energy mix. Biomass (typically wood by-products incinerated to produce heat and steam) is the largest direct fuel source at nearly 58%, followed by gas (almost 35%). About half of all electricity is produced on-site, nearly all of that (96%) using highly efficient Combined Heat and Power (CHP) plants.[27] Of course, the specific energy consumption and mix for cartonboard products will depend on the producing mill. Likewise, the energy consumption and mix for onward processing will depend on local conditions but can be assumed to follow the national energy mix of the country of production.

About half of the plastics industry's oil and gas consumption is for production energy (the other half used as feedstock).[28] However, more detailed industry reporting of the energy mix is not publicly available. It is likely that the major energy source is electricity, and in the absence of other evidence, it can be assumed that this is typically bought-in and so is dependent on the relevant national energy mix. The European average energy mix is 43% from fossil fuels, 30% renewable energy (including biofuels) and 27% nuclear.[29]

There is not the consistent data available with which to make a reliable comparison between the energy consumption of carton production and that of plastic packaging. In any case, given the many variables involved, any generalised assertion would be largely meaningless. What can be said is that both industries are significant users of energy but that pulp and paper appears to utilise renewable energy (biomass) to a much greater degree.

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[21] Ellen MacArthur Foundation, *The New Plastics Economy: Rethinking the Future of Plastics,* 2016.

[22] PlasticsEurope, *Plastics – the Facts 2016,* 2016.

[23] European Bioplastics, http://www.european-bioplastics.org/market/, accessed October 2017.

[24] Ellen MacArthur Foundation, *The New Plastics Economy: Rethinking the Future of Plastics,* 2016.

[25] ibid

[26] Edie.net, *How P&G formed a new supply chain to combat ocean plastics,* 9th October 2017.

[27] CEPI, *Key Statistics 2016,* 2016.

[28] Ellen MacArthur Foundation, *The New Plastics Economy: Rethinking the Future of Plastics,* 2016.

[29] Eurostat, *EU Production of Electricity by Source,* 2015.

5.3 Water

The pulp and paper industry uses a large amount of water, through evaporation during the production process as well as secondary waste treatment, water in solid residues and water in the products themselves. However, only a relatively small part of this is actually 'consumed' (i.e. bound up in the products or waste). More than 90% is returned to the source and the total intake volume of fresh water has dropped by 20% over the last twenty years.[30]

The production of polyolefin (PE and PP) resin uses water for processing, boilers and most notably, cooling. Like the paper industry, much of this water is returned to source; what is lost is mostly through evaporation.

As with energy, it is difficult to find reliable data on water consumption with which to compare cartons and plastic packaging. Furthermore, any consideration of water consumption, or water footprint, needs to consider the specific, local water risks, such as scarcity - that is, where there is ample water availability, the issue will be less significant than where there is drought or high demand. Therefore, any comparison needs to be on a case by case basis.

5.4 In-Use Aspects

One of the primary purposes of packaging is to protect the product it contains, to prevent the product and all the resources that went to make it from being wasted. For perishable goods such as food, the packaging can also extend the life of the product. It has been estimated that the resources preserved by packaging can be ten times as much as those used to make the packaging itself.[31]

There are many applications where cartons provide the versatility, strength and rigidity to ensure appropriate product protection, as well as appealing aesthetic qualities – cereals, frozen foods, perfume, pharmaceuticals, homewares and clothing are just a few. However, for applications involving direct contact with wet foodstuffs, or requiring impermeability, flexibility or transparency, cartons may not be suitable. In these areas plastic may be a preferred choice or may compete with alternative materials such as metal or glass and, in practice, there is often a combination of different materials used to provide optimal functional (as well as aesthetic) aspects. Nevertheless, there are applications where either cartons or plastic could be chosen as the primary packaging material and some of these are explored further in chapter six.

However, from an environmental perspective, there are two areas where plastic may have a potential advantage during the use phase of packaging:

One is the durability of plastics. For applications requiring the packaging to withstand especially rough handling or to serve its purpose over a long period of time this may be important. However, as much consumer packaging is single-use, it is likely to remain in the supply chain for less than a year,[32] negating the benefits of durability while potentially exacerbating the end of life impacts (see overleaf).

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[30] CEPI, Water: *Used only with care,* 2014.

[31] Food & Drink Federation / INCPEN, *Packaging for people, planet and profit - a sustainability checklist,* 2017.

[32] Ellen MacArthur Foundation, *The New Plastics Economy: Rethinking the Future of Plastics,* 2016.

Another potential advantage of plastic is its relatively lightweight nature, which is particularly the case with flexible plastics. It is claimed that plastic packaging accounts for only 17% of the weight of packaging on the market despite being used on over 50% of European goods. Many consumer goods brands have focused on 'lightweighting' of packaging (to reduce lorry loads and associated fuel use, costs and emissions), which has helped to drive a 28% reduction in the weight of plastic packaging over ten years.[33]

In the case of food, transport from the factory has been estimated to account for 3.5% of the energy required throughout a product's lifecycle, which is a relatively minor but still significant impact (by comparison, primary packaging itself accounts for 6.5%).[34] Therefore, the potential for plastic to perform a function with less weight of material is an important and attractive attribute. However, it is not without some drawbacks. The lighter individual packaging items are, the less value the materials may have, which means there is less incentive to ensure they are collected and recycled at the end of their life. This tension between efficiency savings in production and use, and the potential to retain the value of the material after use, has been dubbed the 'lightweighting paradox'.[35] In addition, there is evidence (in the case of shredded PET bottles) that thinner flakes have more probability to get discarded during the recycling process, which has been cited as a contributing factor in decreased recycling yields.[36]

Nevertheless, plastic's relative light weight has appeal for brands and retailers interested in reducing transport costs and impacts. The plastic industry promotes what it sees as a clear benefit in this area because it has been estimated that alternative materials have a mass 3.6 times greater than plastic, on average, for the same functional units.[37] However, this claim relies on a study that compares plastic packaging to a theoretical mix of alternative materials (including glass, metal, wood and paper-based materials) which seems unlikely to reflect real-world packaging options. Therefore, it is important to judge the benefit of light weight with comparison between actual material options and in consideration of the broader life cycle impacts.

5.5 End of Life

The waste hierarchy is a concept widely used by governments, businesses and non-governmental organisations when considering how to tackle the problem of waste disposal. The principle is that it is better to prevent waste altogether by, for example, avoiding the use of unnecessary materials. If that is not feasible then at least minimise the waste by reducing the amount of materials used. Next, can the item or its components be reused for the same purpose? If not, recycling the raw materials into new products is the preferred disposal option – this reduces the amount of waste going to landfill sites while cutting down on the need for new raw materials, typically with a significant energy saving too. All of these options fit well with the notion of the circular economy, as waste is minimised and the value (both economic and environmental) of products is retained.

[33] Plastics Europe, http://www.plasticseurope.org/use-of-plastics/packaging.aspx, accessed October 2017.

[34] INCPEN, *Table for one - the energy cost to feed one person,* 2009.

[35] Ellen MacArthur Foundation, *The New Plastics Economy: Rethinking the Future of Plastics,* 2016.

[36] Plastics Recyclers Europe, *PET recyclers suffer lower input qualities [press release],* July 2017.

[37] Denkstatt / PlasticsEurope, *The impact of plastic packaging on life cycle energy consumption and greenhouse gas emissions in Europe,* 2011.

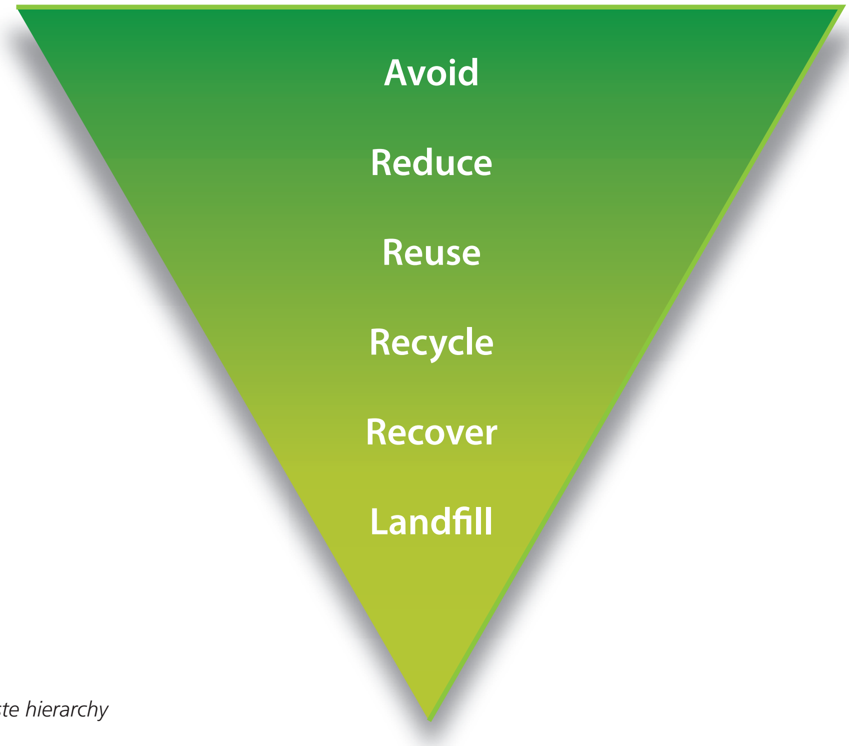

Figure 3: The waste hierarchy

If it is not possible to retain the value of resources through reuse or recycling it may at least be possible to recover some of it. For organic waste this may be through composting or anaerobic digestion (to produce biogas) but more typically is through energy recovery by the incineration of waste to produce heat, steam and electricity. Finally, the least preferable option is to send waste to landfill, as its value is then entirely lost.

In Europe, legislation has driven a reduction in municipal waste going to landfill over the past twenty years (to 120kg per capita or 25% of all EU28 municipal waste in 2015), while recycling (29% in 2015), incineration (27%) and composting (17%) has grown.[38] One of these legal drivers is the packaging waste directive and its amending acts, which 'provides for measures aimed at limiting the production of packaging waste and promoting recycling, re-use and other forms of waste recovery. Their final disposal [to landfill] should be considered as a last resort solution'.[39] To achieve this, targets have been set to reuse, recycle or recover minimum amounts of packaging waste depending on the material used – the latest proposed targets are for 75% of paper and cardboard and 55% of plastic to be prepared for reuse or recycled by the end of 2025.[40]

In 2014, an average of nearly 163kg of packaging waste was generated per inhabitant in the EU28, with most of the large economies exceeding this (Germany for example generated 220kg per inhabitant). 41% of this

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[38] Eurostat, http://ec.europa.eu/eurostat/statistics-explained/index.php/Municipal_waste_statistics, accessed October 2017.

[39] European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste.

[40] Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Directive 94/62/EC on packaging and packaging waste. COM/2015/0596 final - 2015/0276 (COD).

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was paper and cardboard, while 19% was plastic (also 19% glass, 16% wood and 6% metal).[41] This indicates that paper and cardboard is the most significant type of packaging waste when measured by weight.

However, when considering how that packaging waste is treated, it can be seen that paper and cardboard performs significantly better in relation to the waste hierarchy. While 34.6 million tonnes of paper and cardboard packaging waste was generated across the EU28 in 2015, over 90% of it was recovered in some way (including recycling). By comparison, 15.8 million tonnes of plastic packaging waste was generated, with a recovery rate of 71%. Therefore, the quantity of packaging waste that was not recovered, and could potentially have gone to landfill,[42] was 3.3 million tonnes for paper and cardboard and 4.6 million tonnes for plastic.[43]

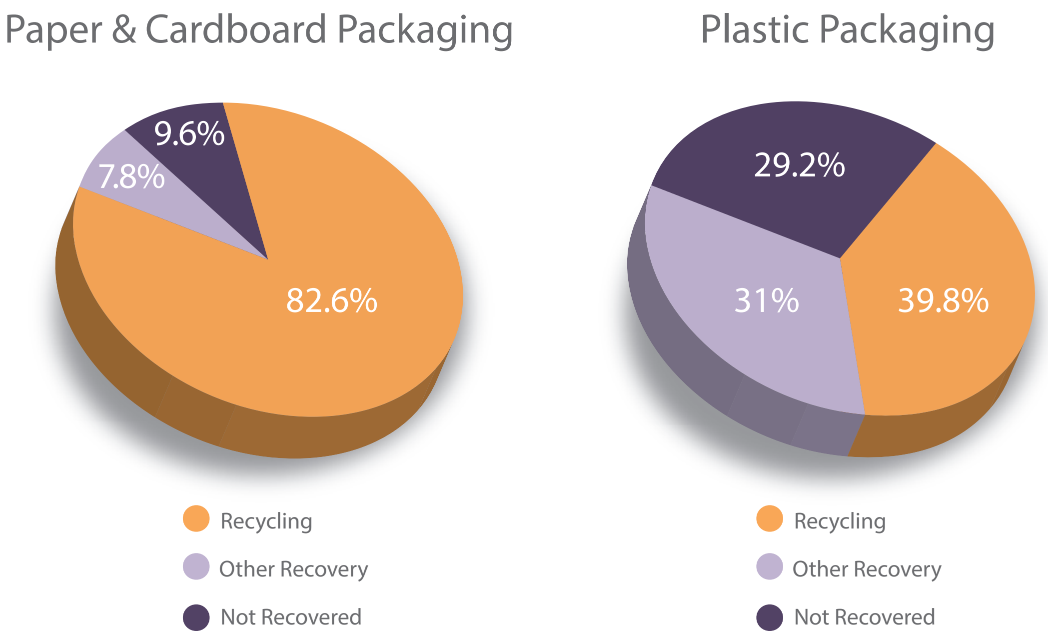

Figure 4: Recycling and recovery rates for paper & cardboard packaging and plastic packaging. Source: Eurostat.

Furthermore, more than double the proportion of paper and cardboard packaging is sent for recycling (82.6%) compared to the recycling rate for plastic packaging (39.8%).[44]

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[41] Eurostat, http://ec.europa.eu/eurostat/statistics-explained/index.php/Packaging_waste_statistics, accessed October 2017.

[42] The rules for recording packaging waste regard 'generated packaging waste' as packaging that becomes waste. However, they also allow that this 'may be deemed to be equal to the amount of packaging placed on the market'. Therefore, it is possible that the amount not recovered may also include that which is still in circulation, i.e. still serving its purpose in the market.

[43] Based on Eurostat, *Packaging waste by waste operations and waste flow (env_waspac),* query run October 2017.

[44] ibid

The recycling of paper starts with collecting used paper or board from industry (e.g. printing companies), offices and homes. It may be sorted and graded depending on the requirement of the papermaker. The used paper is mixed with water and then large contaminants (e.g. staples or paper clips) are removed, the fibre is cleaned and may be de-inked and bleached depending on the end use. The paper for recycling has now been turned into pulp, from which paper can be made again, either using 100% recycled pulp or mixed with 'virgin' pulp derived directly from trees.[45]

Individual cellulose fibres can typically be recycled several times before they become too short and degraded to be of use in papermaking. At that point they are screened out of the recycling process, with the resultant sludge having a variety of secondary uses such as incineration for energy production, production of construction boards or spreading on farm land.[46]

It is thought that there is a theoretical upper limit to the recycling rate of the paper industry (not just packaging) of about 78%.[47] This is because around 19% of the paper used is not possible to collect or recycle – it may be destroyed or contaminated in use (e.g. hygiene products) or kept for the long term such as with books, photographs or archived documents.[48] In addition, some used paper is collected but goes for other, non-papermaking uses such as insulation.

Nevertheless, paper and cardboard packaging has the highest recycling rate of any packaging material, at 82.6%, followed by metal (76.2%), glass (73.1%), plastic (39.8%) and wood (39.3%).[49]

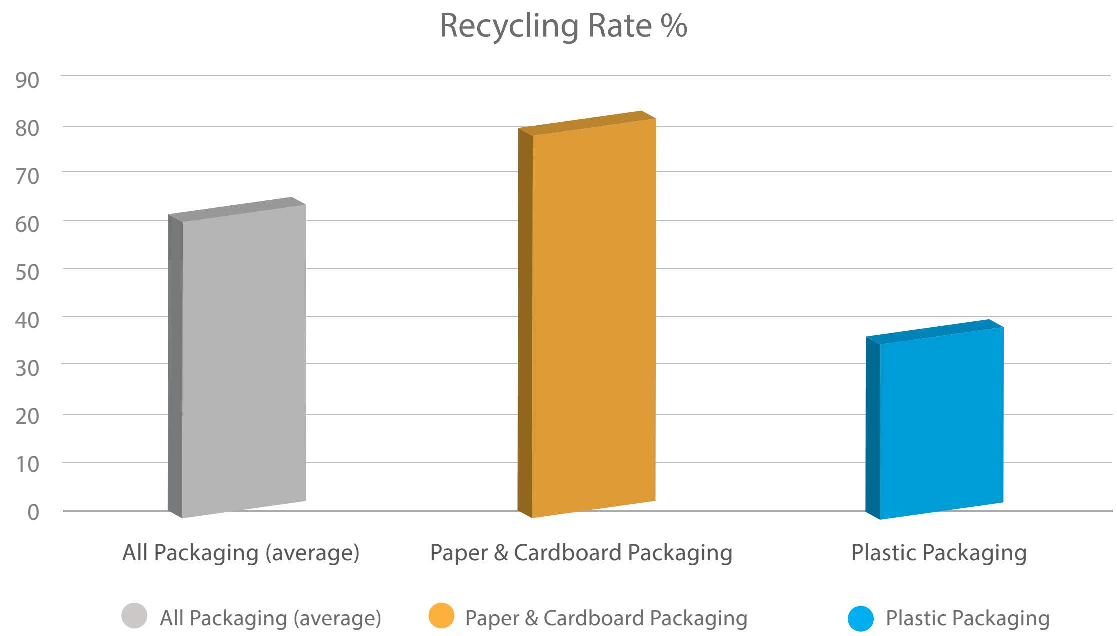

Figure 5: Average packaging recycling rate in 2015 against that for paper & cardboard and plastic packaging. Source: Eurostat.

[45] European Paper Recycling Council, http://www.paperforrecycling.eu/the-recycling-process, accessed October 2017.[45]

[46] CEPI, *Maximum value from paper for recycling,* 2011.

[47] European Paper Recycling Council, European Declaration on Paper Recycling 2016-2020, 2017.

[48] European Paper Recycling Council, http://www.paperforrecycling.eu/questions-answers, accessed October 2017.

[49] Based on Eurostat, *Packaging waste by waste operations and waste flow (env_waspac),* query run October 2017.

It should also be noted that recycling rates are currently based on the weight of materials sent for recycling. Despite good segregation this will inevitably contain incorrect materials or those detrimental to production, such as multi-material laminates or packaging contaminated with food. The share of unusable materials depends on the effectiveness of sorting and recycling and also the end-use requirements and it means that the volume of material actually recycled is lower than that sent for recycling. It has been estimated that the net loss from household collections is about 14% for paper and board and 40% for plastics.[50]

The biggest source of plastic for recycling currently come from packaging[51] and these thermoplastics are recycled through a process known as 'mechanical recycling'. Because different plastic, or polymer, types have different properties, it is important that single-polymer streams are segregated (e.g. only PET or only LDPE) otherwise the recyclates can have inferior mechanical properties and so be unsuitable for many uses.[52] Once sorted, the used plastic is cleaned, ground or shredded and heated so that it melts into a homogenous mixture, typically made into pellets that can feed back into the production of new plastic.

Globally it is estimated that only 14% of plastic packaging is recycled (mostly into lower-value applications) and that, after sorting and reprocessing losses, only about 5% of the material value is actually retained. Of the nearly 40% recycling rate for plastic packaging in Europe, much of this is likely to relate to PET and HDPE bottles, which can have recycling rates of up to 90% in some areas.[53]

While technically most plastics can be recycled, in practice it can be difficult to ensure it is properly segregated in volumes sufficient to make it economically attractive to collect. So, while some items like PET drinks bottles may be recycled, others are more difficult for consumers to deal with. Flexible films for example are only fully compatible with recycling if certain conditions are met (for specific material types, largely colourless or transparent, with limited labels[54]). Multi-material packaging, such as laminates of different materials, or of different types of plastic (as with stand-up pouches) cannot currently be effectively recycled, though efforts to develop suitable technology are ongoing[55]. This difficulty in identifying recyclable plastics can lead to consumer confusion, with one UK survey finding the most frequently cited barrier to plastics recycling is uncertainty about which plastics can and can't be recycled (34% of respondents)[56].

Ease of disposal for consumers is also dependent on local collection regimes, which vary by country and sometimes by municipality or even type of dwelling (for example, there may be fewer facilities in apartment blocks). Paper and board is almost universally collected. Several countries, such as Germany, Sweden, Bulgaria, the Netherlands and the Czech Republic also take most plastics, with the possible exception of films. Yet others take a different approach. Spain limits collections to PET, HDPE and film, while Belgium collects plastic bottles only.[57] In the UK, some local authorities accept polystyrene pots and tubs while others do not and only about 20% of local authorities will recycle flexible packaging made of LDPE film[58] (though taking it to a local supermarket for collection may be an option).

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[50] Expra, *The effects of the proposed EU packaging waste policy on waste management practice,* October 2014.

[51] Plastics Recyclers Europe, http://www.plasticsrecyclers.eu/plastic-recycling-industry-europe, accessed October 2017.

[52] Plastics Recyclers Europe, http://www.plasticsrecyclers.eu/mechanical-recycling, accessed October 2017.

[53] Ellen MacArthur Foundation, *The New Plastics Economy: Rethinking the Future of Plastics,* 2016.

[54] Plastic Recyclers Europe, *PRE flexible film in PE LLDPE LDPPPE HDPET Guidelines,* October 2014.

[55] Ellen MacArthur Foundation, *The New Plastics Economy: Rethinking the Future of Plastics,* 2016.

[56] Pledge4Plastics, *Plastics Packaging and Recycling: Consumer Attitudes & Behaviour,* August 2016.

[57] For further information: Germany (www.gruener-punkt.de), Sweden (www.ftiab.se), Bulgaria (www.ecopack.bg), Netherlands (www.nedvang.nl), Czech Republic (www.jaktridit.cz), Spain (www.ecoembes.com), Belgium (www.pack4recycling.be).

[58] *Polypouch (UK) Ltd,* http://www.polypouch.co.uk/about-us/green-policy, accessed October 2017.

As has been seen, the recyclability of both plastic and paper can suffer due to contamination (e.g. from food contact) or when materials are combined to improve functionality. Conversely, both waste streams benefit from being well segregated (either by the consumer or subsequent sorting) because the material recyclers need to have confidence in the quality of their input. However, the recycling of plastic packaging come with the additional technical difficulty of dealing with mixed polymers, the lack of economic viability for recycling uncommon plastics and sometimes the consumer's uncertainty about what plastics can be recycled. This means that, even if a rate of reuse and recycling of 55% for plastic packaging (as proposed by the European Commission[59]) were to be met, it will in practice remain a far less recyclable material than paper-based packaging such as cartons.

5.5.2 Incineration for Energy Recovery

As efforts to divert waste away from landfill have increased, so has the use of incineration. This has the benefit of recovering some of the energy by producing electricity, steam and heat for buildings. Waste can also be used as a fuel in certain industrial processes. In Europe, there are strict requirements governing waste incineration, to ensure that any harmful emissions are minimised, though this may not be the case in other parts of the world.[60]

There are also concerns that over-deployment of incineration can distort the waste hierarchy, by creating an ongoing demand for such waste (a so-called 'lock-in' effect) that in some cases could have been better utilised through recycling.[61]

For plastics as a whole, more waste is incinerated than is recycled[62] but, for plastic packaging specifically, the opposite is true – according to Eurostat, 31% of plastic packaging was recovered in 2015 (most likely through incineration for energy), whereas nearly 40% was recycled. However, no more than 8% of paper and cardboard packaging was incinerated in the same period, compared to nearly 83% recycled.[63] Therefore, considering the waste hierarchy, it can be argued that more effective use is made of paper and cardboard at the end of its life.

5.5.3 Landfill & Leakage

Landfill is the least beneficial waste disposal option because all of the resources used to make the item is lost. Furthermore, biodegradable wastes (including paper) sent to landfill, may not decompose fully and, in the absence of oxygen, give off methane, an undesirable greenhouse gas. They can also create a potentially toxic liquid run-off called leachate.[64] In Europe, legislation has reduced biodegradable waste going to landfill and there are strict requirements for controlling methane and leachate. Some countries have even banned waste going directly to landfill, mostly with a corresponding increase in incineration.[65]

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[59] European Commission, *Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Directive 94/62/EC on packaging and packaging waste*, December 2015.

[60] European Commission, *Being wise with waste: the EU's approach to waste management,* 2010.

[61] Ellen MacArthur Foundation, *The New Plastics Economy: Rethinking the Future of Plastics,* 2016.

[62] PlasticsEurope, *Plastics – the Facts 2016,* 2016.

[63] Based on Eurostat, *Packaging waste by waste operations and waste flow (env_waspac),* query run October 2017.

[64] European Commission, *Being wise with waste: the EU's approach to waste management,* 2010.

[65] Zero Waste Europe, *ZERO WASTE TO LANDFILL AND/OR LANDFILL BANS: false paths to a Circular Economy,* November 2015.

It is difficult to be certain how much paper and cardboard or plastic packaging ends up in landfill. According to Eurostat, only 0.4% (130,000 tonnes) of all paper and cardboard waste went to landfill in 2014 (across the EU28). For all plastic waste, the figure was 5.7% (730,000 tonnes). However, this only includes waste streams where the material is clearly identifiable and not mixed. It seems likely that a lot of post-consumer material is hidden within broader categories such as household waste, of which 42% went to landfill.[66] The plastics industry itself reports that in 2014, nearly 31% of post-consumer plastics (not just packaging) went to landfill.[67] For packaging specifically, 29.2% of plastic and 9.6% of paper and cardboard is not recovered in some way and so potentially could go to landfill (though a proportion may remain in the market). This equates to a maximum of 3.3 million tonnes for paper and cardboard and 4.6 million tonnes for plastic.[68] While the data needs to be treated with a certain amount of caution, what is clear is that it is more likely for plastic packaging to be sent to landfill than it is for paper and cardboard packaging.

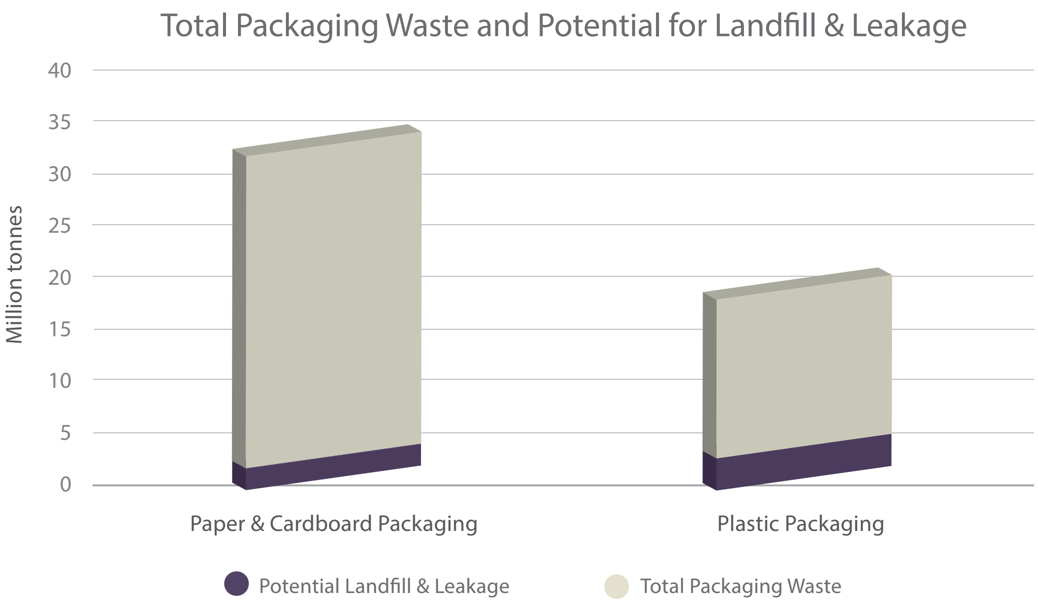

Figure 6: Total packaging waste and amount not recovered, therefore potentially going to landfill or leaking outside of the waste system, 2014. Source: Eurostat.

Licenced landfill sites in Europe are generally well managed and subject to controls that minimise waste escaping into the environment. However, this may not be the case in other regions, particularly developing countries. In addition, not all waste is disposed of responsibly; some is littered, fly-tipped or goes to illegal waste sites without proper controls. This is a nuisance in the local environment and causes serious problems when washed down water courses into the sea.

[66] Based on Eurostat, *Treatment of waste by waste category, hazardousness and waste operations*, query run October 2017.

[67] PlasticsEurope, *Plastics – the Facts 2016*, 2016.

[68] Based on Eurostat, *Packaging waste by waste operations and waste flow (env_waspac)*, query run October 2017.

Leakage appears to be a much more substantial problem for plastic packaging than for paper-based packaging. It is likely that, if littered, paper-based packaging breaks down within months, before it becomes an issue, whereas the durability of plastic means it can stay in the environment for centuries.[69] This helps to explain why, between 2013 and 2017, 82% of the litter collected on European beaches was plastic, while only 2% was paper or cardboard.[70]

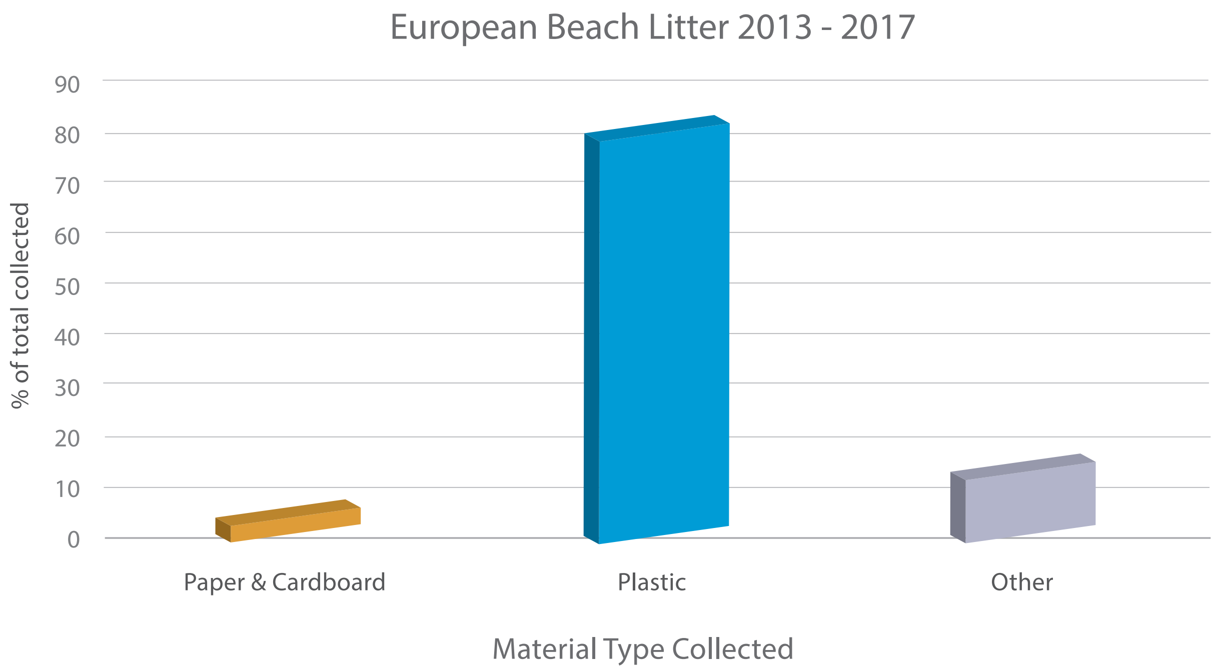

Figure 7: Litter collected from European beaches 2013 - 2017. Source: European Environment Agency.

According to the Ellen MacArthur Foundation, it is thought that globally up to 32% of plastic packaging (notably drinks bottles) leaks out of the waste management system and that at least 8 million tonnes of plastics find their way into the ocean each year (equivalent to dumping the contents of one garbage truck into the ocean per minute), with the majority of this being packaging. Because plastics last so long, there are fears that without action it will continue to accumulate so that, by 2050, there may be more plastic than fish in the ocean, by weight.[72]

As well as the cost associated with trying to clean up ocean plastics, there are serious concerns about the impact on marine life and, ultimately, human health. Plastics are ingested by sea birds, fish and other organisms, and experts warn that some of it is already finding its way into the human food chain. Plastic has been found in a third of UK-caught fish,[73] sea salt around the world[74] and 72% of European drinking water.[75]

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[69] A paper bag is estimated to take one month to break down, whereas a plastic bag takes 10-20 years and a plastic bottle takes 450 years – source: Keep Britain Tidy, *The Little Book of Litter,* 2012.

[70] European Environment Agency, *Marine LitterWatch Data Viewer* (https://www.eea.europa.eu/data-and-maps/dashboards/marine-litter watch-data-viewer), accessed October 2017.

[71] Ellen MacArthur Foundation, *The New Plastics Economy: Rethinking the Future of Plastics,* 2016.

[72] The Guardian, *A million bottles a minute: world's plastic binge 'as dangerous as climate change',* June 2017.

[73] The Guardian, *Sea salt around the world is contaminated by plastic, studies show,* September 2017.

[74] The Guardian, *Plastic fibres found in tap water around the world, study reveals,* September 2017.

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Even some of the so called 'bioplastics' (see Appendix) that are intended to degrade, do not fully address the issue of plastic pollution at present. For example, oxo-degradable plastics, which are treated with additives so they break-up after a period of time, do not degrade fully but rather fragment, which can actually increase the likelihood of microplastics (smaller than 5mm) entering the environment.[75]

5.6 Carbon Footprint

A 'carbon footprint' is a measure of the greenhouse gas emissions related to a product, service or activity and, therefore, its contribution to climate change. A carbon footprint can have various uses (such as tackling reductions or comparing alternative materials) and calculating it can involve different methodologies, boundaries and levels of accuracy.

It can be very difficult to reliably compare the carbon footprint of different packaging items as there are so many variables involved. The material (or multiple materials) used, the mix of energy needed to produce them, the packaging design, the production methods, transportation, use and end of life disposal options all influence the actual contribution to climate change. In addition, how the footprint is calculated and reported, particularly the scope of what is included, may vary from one organisation to another.

The paper industry has developed a framework for developing the carbon footprint of paper and board products. This provides extensive guidance to ensure that carbon footprints produced by the industry are as reliable as possible and are aligned with other internationally-recognised approaches. Following this framework, it is typical for a 'cradle to gate' carbon footprint to be calculated. This will include all the important stages of a paper or board products, from forestry, through pulp and paper manufacture and including all the energy and transport related emissions. Sometimes, additional issues such as product use, end of life and avoided emissions (for example, by replacing a more carbon-intensive alternative) may also be included.[76]

A particular feature of the forest products industry (including paper and board products such as cartons) is that its use of wood fibre provides an incentive to keep land as forest where it can absorb, or sequester, carbon from the atmosphere. Sustainable forest management helps to ensure that the stocks of carbon in forests remain stable or even improve over time.[77] This means that in principle, assuming there is no significant change in land use, the specific emissions related to the use of wood[78] – so called biogenic carbon – can be considered equal to the amount of carbon originally removed from the atmosphere by the trees.

Using the industry framework, it has been calculated that the 'cradle to gate' carbon footprint of a tonne of converted cartonboard (excluding final product delivery, use and disposal) is typically 885kg of CO2 equivalent per tonne. Furthermore, biogenic carbon (that removed from the atmosphere by

[75] Ellen MacArthur Foundation, *The New Plastics Economy: Rethinking the Future of Plastics,* 2016.

[76] CEPI, *Framework for Carbon Footprints for paper and board products,* April 2017.

[77] ibid

[78] The biogenic carbon in wood used a raw material (cellulose fibre) is stored within the product, albeit for a relatively short time in packaging applications (extended through recycling of the fibre) and eventually will be released if the product de grades or is burnt. The biogenic carbon from biomass used as fuel will be released directly.

tree growth) is calculated as -730 kg per tonne of cartons.[79] Some of this removed carbon will be re-emitted when biomass is burnt for energy, but some will also be locked up in the carton, at least for a while, compensating somewhat for the fossil CO_2.

Plastics come in many types, for many applications and comparable public data for alternatives to cartonboard is difficult to find. The plastics industry has claimed that for packaging applications, if plastics were to be substituted by alternative materials, greenhouse gas emissions would increase by a factor of 2.7, or by 61 million tonnes of CO_2 equivalents per year. However, the underlying study (Denkstatt 2011[80]) does not compare plastic against specific alternatives but against a theoretical mix of all alternative materials and so should be treated with a great deal of caution. More reliably, eco profiles for PE and PP resins show a cradle to gate carbon footprint of between 1,630 and 1,870kg of CO_2e per tonne[81], suggesting that even at an earlier stage of production, plastic has a considerably higher carbon footprint per tonne than converted cartonboard. This is supported by older research by WRAP, which indicated that the average carbon footprint of plastic packaging is around 3,000kg of CO_2e per tonne, with cardboard (including corrugated and cartonboard) being about 1,000kg of CO_2e per tonne[81]. However, it should be noted that this data does not provide an accurate comparison (nor was it intended to). Furthermore, while the carbon footprint per tonne may be lower for cartonboard, the amount of plastic required to package the same item may be less. Therefore, any carbon footprint should be evaluated with regards to the specific application (and with consideration for wider life cycle impacts).

[79] Pro Carton, *The Carbon Cycle: Role of cartonboard's natural raw material,* 2015.

[80] Denkstatt / PlasticsEurope, *The impact of plastic packaging on life cycle energy consumption and greenhouse gas emissions in Europe,* 2011.

[81] PlasticsEurope, *Eco-profiles and Environmental Product Declarations of the European Plastics Manufacturers – HDPE, LDPE & LLDPE and PP,* December 2016.

[82] WRAP, *Methodology for assessing the climate change impacts of packaging optimisation under the Courtauld Commitment Phase 2,* December 2010.

6. Conclusions

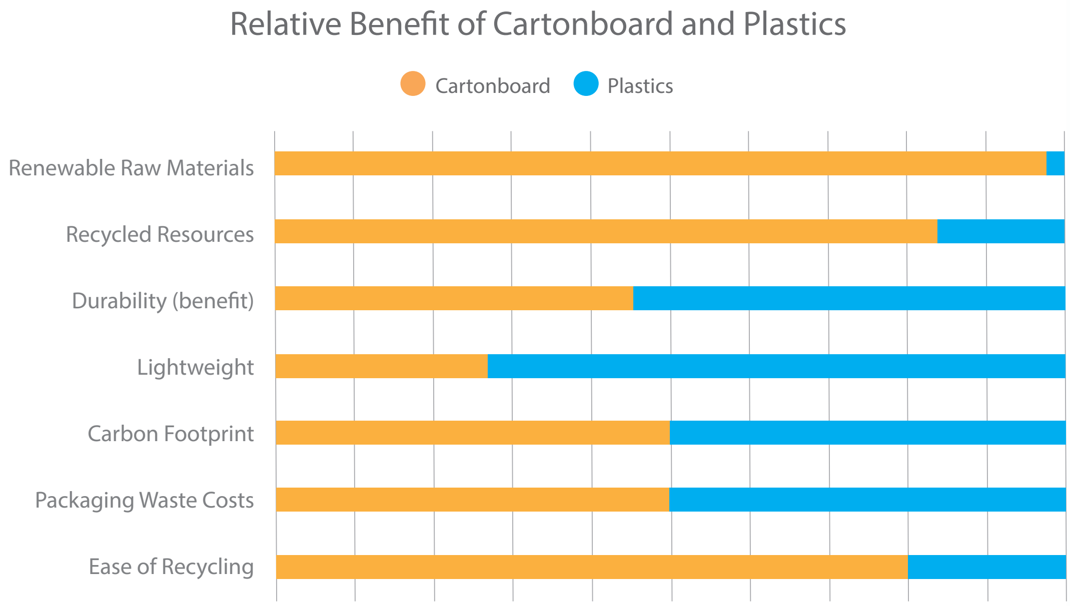

Figure 8: Estimated relative environmental benefit of cartonboard and plastics in applications where either could fulfil the functional need.

Cartons are already an appropriate alternative to plastic packaging for a wide range of applications because of their technical and aesthetic qualities. In some examples, such as for confectionery, tea and small beverage multipacks, it can be demonstrated that cartons have, on balance, clear environmental benefits too. Principally, these benefits relate to the use of renewable raw materials and ease of recycling, which make cartons a positive packaging choice for the circular economy of the future. Plastics packaging of course has its own advantages but, for certain applications, the key benefits of durability and lightweight can be redundant or insufficient overall for it to be considered an automatic choice. Furthermore, plastic's reliance on non-renewable resources and its waste-related environmental impacts can be anticipated to pose an increasing risk to brands, through potential tightening of waste legislation and negative public perception. Anyone specifying packaging should carefully consider these issues when making their choice of packaging material.

Appendix: Types of Plastic

I. Polyethylene (PE)[83]

Example Uses: (HDPE) milk bottles, freezer bags, shampoo bottles, food tubs; (LDPE) squeeze bottles, shrink wrap, rubbish bags.

PE, or Polyethylene, is a chemically resistant thermoplastic that can be very durable. Polyethylene is derived from either modifying natural gas or from the catalytic cracking of crude oil producing ethylene. Manufacturing processes are usually categorized into 'high pressure' and 'low pressure' operations. The former produces low density polyethylene (LDPE) while the latter makes high density (HDPE) and linear low density (LLDPE) polyethylenes.

Properties:

- Easily processed by most methods. It is capable of being moulded, extruded and cast into many various shapes.
- Can be flexible or rigid.
- Strong and a dimensionally stable material that absorbs very little water.
- Good gas barrier properties.
- Good chemical resistance against acids, greases and oils.
- Can be highly transparent and colourless but thicker sections are usually opaque and off-white.
- Good self-extinguishing properties.
- Resistance against ultra violet.

Recycled PE is made by collecting, sorting and regrinding it into usable resin. It can be blended with virgin polyethylene, extruded into film and converted into bags and tubing. PE present in mixed plastic waste streams can also be recovered for its energy content.

II. Polypropylene (PP)[84]

Example Uses: Microwaveable dishes, food tubs, bags, textiles, stationery, reusable containers, polymer banknotes.

Polypropylene (PP) is a thermoplastic polymer mainly derived from the catalytic cracking of crude oil. Melt processing of polypropylene can be achieved via extrusion and moulding. The large number of end-use applications for polypropylene are often possible because of the ability to tailor grades with specific molecular properties and additives during its manufacture.

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[83] Source: http://www.plasticseurope.org/what-is-plastic/types-of-plastics-11148/polyolefins/polyethylene.aspx

[84] Source: http://www.plasticseurope.org/what-is-plastic/types-of-plastics-11148/polyolefins/polypropylene.aspx

Properties:

- Can be flexible or rigid
- Opaque
- Good dimensional stability at high temperature and humidity conditions
- Tough
- Lightweight
- Excellent chemical resistance.

Recycled PP is made by collecting, sorting and regrinding it into usable resin. PP present in mixed plastic waste streams can also be recovered for its energy content.

III. Polyethylene Terepthalate (PET)[85]

Example Uses: Water and soft drink bottles, salad domes, biscuit trays, fibres for clothing.

Polyethylene terephthalate, commonly abbreviated PET, is the most common thermoplastic polymer-resin of the polyester family. It is produced from ethylene glycol and dimethyl terephthalate (DMT) or terephthalic acid.

Properties:

- Can be semi-rigid to rigid.
- Very lightweight.
- Good gas and fair moisture barrier.
- High mechanical strength.
- Transparent

Because of the recyclability of PET and the relative abundance of post-consumer waste in the form of bottles, PET is rapidly gaining market share as a carpet fibre.

IV. Poly Vinyl Chloride (PVC)[86]

Example Uses: Cosmetic containers, cling film, trays.

PVC, or Polyvinyl chloride is one of the earliest plastics. It is made from chlorine – produced when salt water is decomposed by electrolysis – with ethylene, which is obtained from oil or gas via a 'cracking' process. By varying the use of additives (stabilisers and/or plasticizers) in the manufacturing of PVC products, features such as strength, rigidity, colour and transparency can be adjusted to meet most applications.

Properties:

- Durable
- Light
- Strong
- Fire resistant
- Excellent insulating properties
- Low permeability

[85] Source: https://en.wikipedia.org/wiki/Polyethylene_terephthalate

[86] Source: http://www.plasticseurope.org/what-is-plastic/types-of-plastics-11148/polyvinyl-chloride.aspx

V. Polystyrene (PS)[87]

Example Uses: CD 'jewel cases', disposable cups, yoghurt pots, foamed meat trays, electronics, toys.

Polystyrene is a thermoplastic polymer which softens when heated and can be converted into semi-finished products like films and sheets, as well as a wide range of finished articles. The building block - monomer - of-polystyrene is styrene, which is obtained from crude oil through a range of processes such as distillation, steam-cracking. In order to get the final articles, polystyrene pellets are extruded, thermoformed or injection moulded. Applications of thermoformed articles include disposables such as cups, plates, pots and food trays. Typical injection moulding applications are housing of televisions, jewel boxes for compact discs, toys and innumerable other uses.

Properties:

- Can be rigid or foamed
- Inexpensive resin per unit weight
- Poor barrier to oxygen and water vapour
- Relatively low melting point
- Transparent but can be coloured

Polystyrene is generally not recycled.

VI. Bioplastics [88]

Example Uses: potentially anything made from conventional plastics.

Currently, bioplastics represent about one per cent of the about 300 million tonnes of plastic produced annually[89]. Bioplastics – plastics that are biobased, biodegradable, or both – have the same properties as conventional plastics and offer additional advantages, such as a reduced carbon footprint or additional waste management options such as composting. Bioplastics are a diverse family of materials with differing properties. There are three main groups:

Properties:

- Biobased or partially biobased non-biodegradable plastics such as biobased PE, PP, or PET (so-called drop-ins) and biobased technical performance polymers such as PTT or TPC-ET
- Plastics that are both biobased and biodegradable, such as PLA and PHA or PBS
- Plastics that are based on fossil resources and are biodegradable, such as PBAT.

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[87] Source: http://www.plasticseurope.org/what-is-plastic/types-of-plastics-11148/polystyrene.aspx

[88] Source: http://www.european-bioplastics.org/bioplastics/materials/

[89] http://www.european-bioplastics.org/market/

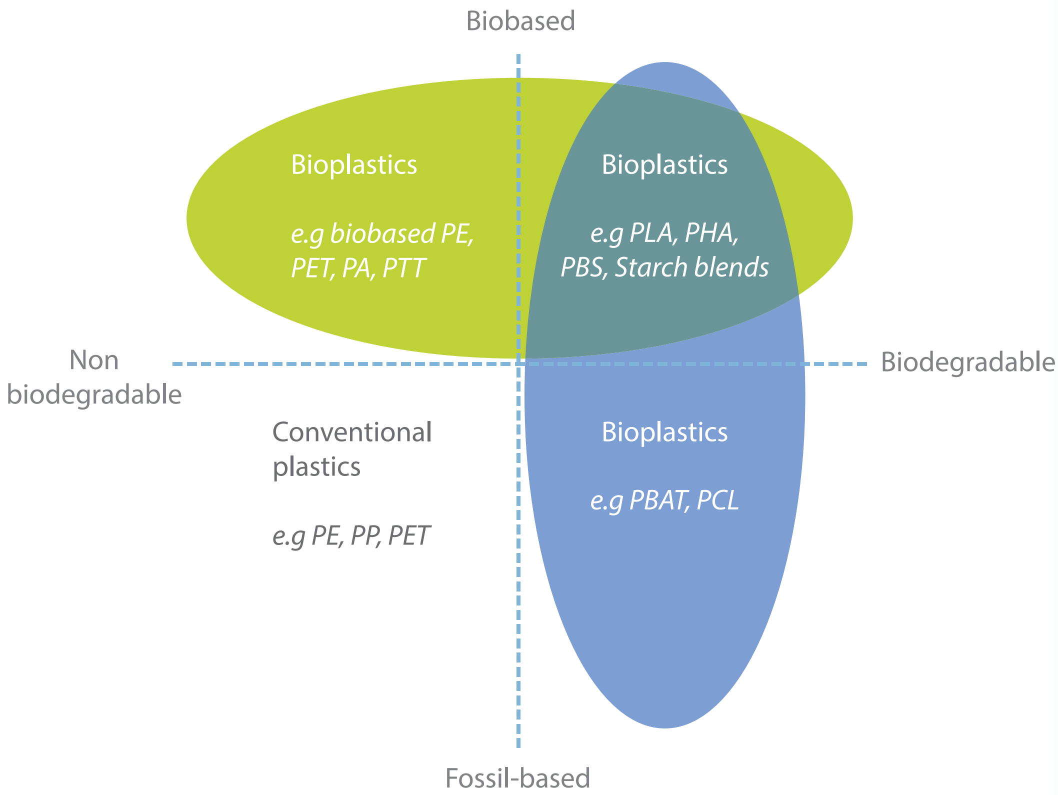

Figure 9: Bioplastics Overview. Source: European Bioplastics

Note: While bioplastics promise to be more sustainable than conventional plastics, currently some stakeholders have concerns about their use:

- *Most of the feedstock for biobased plastics currently comes from food crops, so their increased use could impact food prices and availability.*
- *There are concerns that the 'biodegradable' message could exacerbate consumer negligence, leading to plastic pollution (e.g. ocean plastics), especially in the case of oxo-degradable plastics that fragment rather than truly degrade.*
- *Some degradable plastics that end up in traditional waste streams can have a significant, negative effect on plastics recycling.*

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Published 2018 by:
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