A Preliminary Assessment of the Economic Impacts of a Potential Ban on Expanded Polystyrene Food and Beverage Containers.

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Contents

Executive summary

Background to the research

The Government's 25 year Plan[1] and Resources and Waste Strategy[2][3] is determining a strategic direction for plastics in the UK. The 25 year plan has a target of working towards eliminating avoidable plastic waste by end of 2042 and significantly reducing and where possible preventing all kinds of marine plastic pollution – in particular, material that came originally from land. An EU Single-Use Plastics (SUP) directive has been passed which must be transposed into member state legislature[4]. The SUP directive proposes a range of measures aimed at reducing the impact of plastic products on the environment. In particular, within the directive 9 categories of single-use plastic products are earmarked for prohibition from the market.

Each of the UK devolved governments are presently considering a range of legislative and voluntary measures aimed at reducing the use of plastics. Department for Environment, Food and Rural Affairs (Defra) wanted to better understand the potential qualitative and quantitative economic, environmental and social impacts of introducing a ban on Expanded Polystyrene (EPS) food and beverage containers in England.

Resource Futures was commissioned to undertake a preliminary impact assessment of a ban on EPS food and beverage containers. The research, which was undertaken between July and September 2019, comprised an evidence review, engagement of a sample of key stakeholders and preliminary impact modelling. The outputs were intended to inform future discussion around whether a potential ban would be advantageous, ahead of further research and impact modelling.

Market failure and the case for intervention

Single-use plastics, including EPS food and beverage containers, are associated with negative effects on the environment if they are littered or discarded incorrectly after their use. There are costs associated with their clean-up and externality costs imposed on public well-being and on the tourism and fishing industries from littering and the transfer of littered plastics into the environment. They can damage terrestrial and marine life and there is widespread and significant public concern regarding plastics and litter. Resources and greenhouse gas emissions are also associated with plastics production and disposal since they depend on finite fossil fuels.

These external costs are not incorporated in the price of the products. Consumers are not sufficiently incentivised to limit the use of these products nor to dispose of these plastic items correctly. The market is failing to deliver an efficient outcome. Consequently, an intervention can be justified to address the market failure – to protect the environment, food supply and other economic sectors from further pollution, and to foster an increased degree of consumer confidence that the products consumers buy will not harm the wildlife and the environment.

[1] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/693158/25-year-environment-plan.pdf
[2] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/765914/resources-waste-strategy-dec-2018.pdf
[3] https://europa.eu/rapid/press-release_IP-18-5_en.htm
[4] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32019L0904&from=EN

Foodservice food and beverage cups are considered for a legislative ban in the research. Namely, beverage cups made from EPS, EPS take-out containers/to go boxes, EPS food tray/chip cones and EPS pots used for foodstuffs.

A qualitative assessment was required by Defra to better understand the range of impacts/risks associated with a potential intervention. A quantitative approach was also requested to provide an indication of the costs and impacts of a ban, and to understand the extent of the empirical evidence and the main data gaps/uncertainties.

Research approach

Resource Futures undertook the research between July and September 2019. The overall research approach taken was:

1. Initial information gathering – an evidence review and initial stakeholder engagement
2. Development of an impact model to estimate quantitative impacts
3. Further information gathering and stakeholder interviews
4. Refinement of the impact model and sensitivity analysis to understand uncertainties
5. Reporting of findings and discussion

Resource Futures has previously undertaken similar research studies to better understand the impact of potential bans on other single items, including plastic straws, plastic drinks stirrers, plastic-stemmed cotton buds[5] and plastic cutlery, plastic plates and plastic balloon sticks[6]. A similar approach to the methodology and impact modelling was taken in this research for EPS food and beverage containers.

A sample of relevant stakeholders across the supply chain were interviewed in the research. These provided opinion on the impacts and risks associated with a ban and directed the researchers to further sources of information for an evidence review.

A bespoke product demand impact model was developed to provide indicative estimates for quantifiable economic, environmental and social impacts.

In general, the evidence base and publicly available market data for each of the four products was found to be limited. Annual product sales were estimated following stakeholder engagement, based on the market data and market understanding provided by leading packaging manufacturers. Assumptions were also compiled and informed by stakeholder discussions regarding the speed and depth of future change in the affected small and medium enterprises (SME) market from EPS to alternative non-EPS product. The trajectory of change (a reduction in the proportion of EPS product in the market) is illustrated in Figure E-1. This shows the change under a **Ban** scenario and that which may possibly happen voluntarily under a **No Ban** scenario over the next 10 years.

[5] Defra (2018) A preliminary assessment of the economic, environmental and social impacts of a potential ban on plastic straws, plastic stem cotton buds and plastics drinks stirrers. Research by Resource Futures, May 2018. http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=20086&FromSearch=Y&Publisher=1&SearchText=eq0115&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description

[6] http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=20144&FromSearch=Y&Status=3&Publisher=1&SearchText=balloon&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description

Figure E-1: Assumptions for EPS product share of total market in the two modelled scenarios: Ban and No Ban scenario. Note: the line indicates the reduction in EPS use (as a percentage of market share) for the products. The modelling also represented a corresponding increase in alternative EPS-free products over the same period.

Qualitative research findings

There is growing public concern over the impact of plastics when littered on land and in the marine environment. Single-use plastic products can be littered in parks and public places, and these can be transferred to the marine environment through sewage and storm drainage. They are also littered directly into the marine environment by marine users and visitors to coastal areas. The Marine Conservation Society's Great British Beach Clean 2018[7] indicates plastic/polystyrene pieces to be the most frequently counted litter item on UK beaches.

Discussions with a sample of stakeholders revealed that the phrasing of the SUP directive covers only *expanded* polystyrene; it may not, technically, cover *extruded* polystyrene. Extruded polystyrene is a similar material in functionality, appearance and use, the main difference is that extruded polystyrene is denser than expanded polystyrene. The research considers both materials in the modelling of a Ban/No Ban scenario. Since both materials pose the same types of environmental risks they have been included in the scope of a ban in this research. The European Commission may wish to consider this issue in further guidance on the directive which is due to be published in July 2020.

Further discussions with a sample of stakeholders revealed strong support from large businesses in the catering and hospitality sectors and high-street foodservice businesses for a ban on EPS. Indeed, many large takeaway retailers have already reportedly switched from EPS to alternative products. The predominant users of EPS are thought to be Small and Medium Enterprises (SMEs) in the foodservice sector, such as chicken takeaways, burger and kebab shops, curry houses and fish and chip shops. Many stakeholders interviewed who represented these businesses supported a ban as a way of engaging these businesses,

[7] https://www.mcsuk.org/media/gbbc-2018-report.pdf

ensuring a reduction in the use of EPS. A ban would serve to level the playing field and strengthen the market for EPS-free alternatives.

Issues were raised from trade association stakeholders and businesses representing plastics production and manufacture. These pointed to potential unintended consequences posed by alternative materials, due to their heavier weight and increased costs placed on the consumer. Further risks identified for a ban on EPS include a potential greater reliance on imported products, as the alternatives that were identified are presently mainly imported. Consequently, there is a risk of losing out from the value that the EPS foodservice supply chain presently provide in the country without ensure its replacement with activity related to packaging alternatives to EPS.

Quantitative research findings

The quantitative research indicates a ban would serve to accelerate the change in the affected SME market and could harmonise the overall market at modest cost. Whilst the ban would not reduce the quantity of relevant foodservice items littered, its effect would be to reduce litter disamenity and associated impacts on the economy, because, where they accumulate, EPS-free items, such as fibre-based single use packaging alternatives would disintegrate within significantly shorter timescales (months rather than tens to hundreds of years). Fossil fuel-based plastic would be reduced so finite material resources would also be saved.

Table E-1 provides the main outputs from the impact model, the results shown reflect central estimates and are summed for all four products researched. Column A indicates the estimated impacts in the Ban scenario, and Column B shows estimated impacts under the No Ban scenario. Column C calculates the difference for the Ban over the No Ban scenario by subtracting column B from column A. Column D expresses the relative difference expected under the Ban scenario relative to No Ban.

Table E-1: All products, impact estimates, central estimate, Net Present Value 2020 to 2029 (£m)

	Ban (Column A)	No Ban (Column B)	Difference - Ban over No Ban (C = A – B)	Difference - % change from No Ban
Financial costs to the economy				
Regulatory implementation cost	1.4	none	1.4	n/a
Business implementation cost	4.2	0.3	3.9	+1363%
One-off capital investment	116.0	none	116.0	n/a
Waste treatment cost	11.1	6.6	4.5	+68%
Local Authority clean-up cost	59.1	60.9	-1.8	-3%
Cost to fishing industry	0.2	1.0	-0.8	-81%
Economic growth impacts				
Sales value	702.0	440.0	262.0	+59%
Revenues to UK manufacturing	370.0	232.0	138.0	+59%
Environmental and social impacts				
UK - Value of traded CO2e	5.8	9.3	-3.5	-38%
UK - Value of non-traded CO2e	1.3	0.7	0.7	+99%
EU - Value of traded CO2e	0.1	0.2	-0.1	-43%
EU - Value of non-traded CO2e	negligible	negligible	negligible	negligible
RoW - Value of CO2e	0.1	0.3	-0.2	-57%
Terrestrial litter visual disamenity	272.0	272.0	none	negligible
Beach litter visual disamenity	9.6	51.5	-42.0	-81%

A range of costs and benefits are indicated by the modelling. The differences between the Ban and No Ban are generally small with the exception of the related factors Sales value, Revenues to UK manufacturing and One-off capital investment. Most notably, based on current prices, Sales value is estimated to increase by ~£262 million in the modelling. This is due to the modelling of the alternatives to EPS products costing from 30% to three times as much as EPS products. This change in sales value, at least in the short term, represents the main cost to internalise the market failure, which itself would be likely to be distributed to consumers. As a consequence, revenues to UK manufacturing would also be affected (increased if EPS-free alternatives were manufactured in the UK). A one-off capital investment would be needed to convert existing EPS packaging manufacturing capacity, or establish new packaging production capacity for EPS-free products in the UK. In time, economies of scale in manufacturing and supply of non-EPS products would likely reduce the unit price difference.

Comparatively small benefits are indicated for the clean-up costs and litter-related costs when monetised. Disamenity costs associated with beach and marine litter are likely to be greater following recent public interest. Extensive sensitivity analysis was conducted in the research which confirmed that costs and benefits and the differences between scenarios are still likely to be modest in scale (and of the same order) when data and model uncertainties are accounted for. A potential lower and upper range for estimated costs and benefits is provided for each of the model's outputs in Section 4.7. Appendix A.3 also provides a list of information gaps and further research to improve the rigour of the assessment.

Next steps

Further consultation on the details of a ban is recommended for all the products, because the research is preliminary, and discussions were only with a sample of stakeholders representing the market. Any legislative ban for these products should be coordinated with other potential bans or measures for different types of single-use plastic products. In the interim ahead of any intervention, complementary and alternative measures to reduce consumer demand can be encouraged - making these products less available (on request only), or where feasible offering reusable alternatives. Communicative actions can also be taken to ensure products are littered less overall, focussing on consumers or practices which result in intentional or accidental littering.

As with the introduction of any ban, care should be taken to mitigate any additional impacts associated with any potential substitution behaviour adopted by consumers and businesses, to ensure both that the overall outcome is sustainable and that unintended consequences are minimised.

1 Introduction

1.1 Research aims

Single-use plastics such as expanded polystyrene (EPS) food and beverage containers can have significant negative impacts on both the terrestrial and marine environment if they are littered or discarded incorrectly.

Despite the level of public concern following media coverage such as the BBC's Blue Planet II, consumers are not incentivised to dispose of single-use plastic items properly, or to limit their use. The market is failing to deliver an efficient outcome.

The Department for Environment, Food and Rural Affairs (Defra) commissioned desk-based research to assess the qualitative and quantitative economic, environmental and social impacts of introducing a legislative ban on EPS food and beverage containers in England. Specifically, the following was required:

- consideration of the impacts on business, covering both the domestic manufacturers of EPS food containers, beverage containers and cups and the businesses that either use, sell or import the products; and
- consideration of the impacts on society, including the cost of substitutes, the life cycle impacts of products and their likely impacts, as well as environmental benefits such as amenity impacts and societal (litter disamenity and social disutility) effects, product health and safety risks.

The research method necessitated an evidence review and a preliminary and high-level indicative impact assessment, which included engagement of a sample of key stakeholders and identification of any evidence gaps/uncertainties. We understand that the outputs of the research are intended to inform the Government over policy implications for a next stage decision by providing an indicative qualitative and quantitative view of the potential impacts. It is not known whether this work will precede a consultation and a full cost-benefit regulatory impact assessment.

1.2 Policy and research context

The Government's 25 year Plan[8] and Resources and Waste Strategy[9] is determining a strategic direction for plastics in the UK. The 25 year plan has a target of working towards eliminating avoidable plastic waste by the end of 2042 and significantly reducing and where possible preventing all kinds of marine plastic pollution – in particular, material that came originally from land. An EU Single-Use Plastics (SUP) directive has been passed which must be transposed into member state legislature[10]. The SUP directive proposes a range of measures aimed at reducing the impact of plastic products on the environment. In particular, within the directive 9 categories of single-use plastic products are earmarked for prohibition from the market.

[8] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/693158/25-year-environment-plan.pdf
[9] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/765914/resources-waste-strategy-dec-2018.pdf
[10] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32019L0904&from=EN

Legislative measures targeting single-use plastics have already been passed by the UK government. For instance, plastic bag charges were introduced for single-use supermarket carrier bags in Wales, Scotland and England to restrict their use. The total quantity of bags used in England has approximately halved in the last three years[11]. Bans for microplastics beads in cosmetics have recently come into force and more bans for single-use products are being considered across the UK.

The Resources and Waste strategy for England[12] commits the government to ban more plastic products where there is a clear case for it and alternatives exist. The Government has announced its intention to ban the sale of plastic straws, drink stirrers and plastic-stemmed cotton buds in England[13] and has undertaken preliminary impact assessment research for bans on the sale of plastic cutlery, plastic plates and plastic balloon sticks[14]. Some jurisdictions are already developing bans for polystyrene food service products. For example, Maryland, USA has just developed a bill to prohibit the sale of expanded polystyrene food service products[15]. The ban will take effect in July 2020 when the state will join several other US cities and counties including Seattle, Washington D.C., San Francisco and New York City which already have similar bans (ibid). Costa Rica is also set to ban the import and sale of all polystyrene packaging products by 2021[16].

The Scottish Government has committed to a Deposit Return Scheme (DRS). Defra consulted on whether disposable cups should be included under an Extended Producer Responsibility scheme or DRS and has stated the Government it is minded to introduce a DRS for drinks containers in England and Wales from 2023[17]. In the analysis of the consultation responses, 66% of respondents believed disposable cups should be included in a DRS[18]. The Scottish government has committed in principle to introducing a charge for single-use cups, the so-called “latte levy”[19] with a 20p to 25p levy mooted to encourage more use of reusable alternatives. Due to full net costs recovery, extended producer responsibility reforms are likely to impact on how street cleansing costs are financed and further consultation is expected next year[20].

A number of voluntary agreements are also concentrating on phasing out “problematic” plastic. Members of the “Plastics Pact”, which includes organisations such as the Food Packaging Association, have pledged to eliminate problematic or unnecessary single-use plastic packaging through redesign, innovation or alternative delivery models (such as reuse) by 2025. In pursuit of this goal, eight items have been identified by WRAP as needing to be eliminated from circulation by 2020 – one of these is polystyrene packaging[21] (expanded and non-expanded). WRAP has also defined the terms ‘problematic’ and ‘unnecessary’ as “single-use plastic items where consumption could be avoided through elimination, reuse or replacement and items that, post-

[11] Single-use plastic carrier bags charge: data in England for 2018 to 2019. https://www.gov.uk/government/publications/carrier-bag-charge-summary-of-data-in-england/single-use-plastic-carrier-bags-charge-data-in-england-for-2018-to-2019#summary
[12] https://www.gov.uk/government/news/gove-launches-landmark-blueprint-for-resources-and-waste
[13] https://www.gov.uk/government/consultations/single-use-plastic-banning-the-distribution-andor-sale-of-plastic-straws-stirrers-and-plastic-stemmed-cotton-buds-in-england
[14] http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=20144&FromSearch=Y&Status=3&Publisher=1&SearchText=balloon&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description
[15] https://www.nationalgeographic.com/environment/2019/04/maryland-styrofoam-food-packaging-ban/
[16] https://www.independent.co.uk/environment/costa-rica-polystyrene-styrofoam-ban-environment-microplastic-law-a9011531.html
[17] https://www.gov.uk/government/consultations/introducing-a-deposit-return-scheme-drs-for-drinks-containers-bottles-and-cans/outcome/introducing-a-deposit-return-scheme-drs-in-england-wales-and-northern-ireland-executive-summary-and-next-steps
[18] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/826853/drs-consult-sum-resp1.pdf
[19] https://www.bbc.co.uk/news/uk-scotland-49024433
[20] https://www.gov.uk/government/consultations/introducing-a-deposit-return-scheme-drs-for-drinks-containers-bottles-and-cans
[21] https://resource.co/article/wrap-publishes-list-plastic-items-be-eliminated-end-2020

consumption, commonly do not enter recycling and composting systems, or where they do, are not recycled due to their format, composition or size."

Amongst its activity, Defra is investigating the impacts of the proposed legislative ban on polystyrene food and drink containers, as one of those product earmarked for prohibition from the market within the SUP directive[22]. This directive notes that "given the high prevalence of EPS in litter and the availability of alternatives, single-use food and beverage containers and cups for beverages made of EPS should be restricted". Article 5 prohibits the placing on the market of a range of different single-use plastic products. The Directive's definition of the relevant EPS products affected by the restriction/ban is as follows:

- Food containers made of expanded polystyrene, i.e. receptacles such as boxes, with or without a cover, used to contain food which:

  a) is intended for immediate consumption, either on-the-spot or take-away;

  b) is typically consumed from the receptacle;

  c) is ready to be consumed without any further preparation, such as cooking, boiling or heating, including food containers used for fast food or other meals ready for immediate consumption, except beverage containers, plates and packets and wrappers containing food;

- Beverage containers (a container intended for the purpose of holding and/or transporting a beverage, either hot or cold), made of expanded polystyrene, including their caps and lids;
- Cups for beverages made of expanded polystyrene, including their covers and lids.

Article 4 of the Directive also requires that member states take necessary measures to achieve an ambitious and sustained reduction in the consumption of single-use plastic products. Cups for beverages and takeaway food containers are highlighted for consumptions reduction measures. It also contains some other relevant context. Namely:

- The Directive promotes circular approaches that give priority to sustainable and non-toxic re-usable products and re-use systems rather than to single-use products, aiming first and foremost to reduce the quantity of waste generated
- a measurable quantitative reduction in the consumption of single-use plastic products
- product design requirements that significantly reduce the dispersal into the environment of beverage container caps and lids

1.3 Market failure and the case for intervention

1.3.1 Littering and the environment

EPS food and beverage containers are commonly used, highly visible, ubiquitous items. They are frequently discarded and littered. Moreover, they are fragile in their physical nature, meaning that once littered these items tend to fragment into smaller pieces and are dispersed into the environment. A route exists for transfer from terrestrial litter to the marine environment (through direct runoff (waterborne and windblown) and through sewage systems).

[22] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32019L0904&from=EN

Among the main pollution costs of single-use plastics is that they are commonly littered on land in private and public places and parks, from which various pathways can transport the littered items into the marine environment. During rainstorms, for instance, sewers can be overwhelmed and discharge directly into rivers and the sea, and for some small types of products (e.g. cotton buds), pre-treatment screens in sewage treatment plants are too coarse to capture them. This is especially so for items that are easily crumbled or fragment into small pieces, such as EPS. Plastic products can also be directly littered into the marine environment, often by being dropped accidently or left behind by visitors to coastal and marine areas. Plastic items do not biodegrade and therefore accumulate in the marine environment where they may be ingested by terrestrial and marine life (with potential cumulative effects further up the food chain via trophic ingestion). Some are captured as marine debris in fishing equipment and need to be disposed of, or are washed up on beaches.

Furthermore, litter can breed more litter, especially if the littered items are large and visible such as EPS food containers and cups. These items often act as “beacons of litter – a social norming cue which encourages further littering”[23].

Polystyrene is resistant to photodegradation and because EPS floats it has accumulated along coastlines and waterways throughout the world and comprises a large component of marine debris. Plastics are thought to represent 50-80% of shoreline debris[24]. Figure 1 presents an excerpt of the findings of the Marine Conservation Society’s Great British Beach Clean undertaken in 2018[25]. It indicates a league table ranking the number of items found on beaches by their prevalence per 100 metres of length of shoreline. Plastic/polystyrene pieces are the most frequently counted litter item. Figure 2 provides a list of the most common recognisable macroplastic items found in beach litter in the UK, suggesting that food containers comprise around 1% of the discernible items.

[23] https://publications.parliament.uk/pa/cm201719/cmselect/cmenvaud/657/65705.htm, paragraphs 12-14.
[24] ISWA (2017) PREVENT MARINE PLASTIC LITTER - NOW! ISWA Marine Task Force. http://marinelitter.iswa.org/marine-task-force-report-2017
[25] https://www.mcsuk.org/media/gbbc-2018-report.pdf

Figure 1 Beach litter items and findings from the Great British Beach Clean 2018 (by item count)

Item	Item count[2]	% by item	Estimated Weight (g)	% by weight[1]
Caps/lids	2,541	13%	2	13%
Crisp/sweet packets and lolly sticks	2,216	11%	2	12%
Cotton bud sticks	2,121	11%	0.16	1%
Drinks bottles	1,016	5%	16	42%
Cutlery/trays/straws	735	4%	5	10%
Cigarette ends	683	3%	1	1%
Foam sponge	636	3%		
Sanitary towels/panty liners/backing strips	635	3%	7	12%
Bags (e.g. shopping)	499	2%	5	6%
Small plastic bags (e.g. freezer bags)	412	2%	2	2%
Toys and party poppers	306	2%		
Food containers incl. fast food containers	257	1%		
Shotgun cartridges	238	1%		
Industrial packaging, plastic sheeting	173	1%		
Plastic cups	165	1%		
Balloons, valves, ribbons, strings	160	1%	2	1%
Pens	131	1%		
Tampons and tampon applicators	121	1%	2	1%
Cigarette lighters	117	1%		
Cosmetics bottles and containers (e.g. sunscreen, shampoo)	109	1%	2	13%

Notes:

1. Proportion by weight is based on items where a reasonable estimate for item weight was possible. Item categories that encompass more varied items (e.g. toys) were not estimated.

2. Source: OSPAR

Figure 2 Most commonly found identifiable macroplastic items in Beach litter in the UK from the OSPAR survey[26]

1.3.2 The costs of litter

The quantitative cost of this litter is not known with any certainty. The negative effects and costs of plastics on marine food supply and associated costs of littering, clean up and waste disposal costs are not incorporated in the price of plastic products. Moreover, adverse effects on the economy from whatever source (e.g. loss of productivity caused by interference with fishing boats and gear, negative impacts on consumer confidence in fish and seafood, negative impacts on the tourism sector, road traffic accidents,

[26] https://cdn.friendsoftheearth.uk/sites/default/files/downloads/reducing-household-plastics_0.pdf

reduced property investment due to visual disamenity, use of finite resources etc) are similarly not reflected in the prices of plastic products. All of this results in negative externalities as the environmental impact created by the polluters (essentially, those responsible for disposing of the litter into the environment) becomes a cost for public organisations, firms and individuals elsewhere.

The direct costs of marine litter to EU fisheries have been estimated at 1% of the total revenue realised from catches by the EU fleet[27]. The annual street cleaning cost to local government in England 2016/17 was £682m[28], a proportion of which can be attributed to plastics litter. Globally it has been estimated marine plastic pollution is costing $2.5tn per year in resource use and environmental damage[29]. The full range of direct and indirect associated costs of discarded plastics is explored in the preliminary impact assessment of a ban on plastic straws, stirrers and plastic-stemmed cotton buds by Resource Futures (2018)[30]. Regardless of any monetised cost estimate, the qualitative impact on the environment and on the well-being of people is rising and as the profile is raised, more people become aware of the issue. The Government's Litter Strategy for England quotes a Populus poll from 2015 which found that 81% of people are angry and frustrated by the amount of litter[31]; two years later, the multi-award-winning documentary series Blue Planet II was broadcast, becoming the most watched TV show of the year[32] and putting the issue of marine litter front and centre in the minds of millions across the general population.

A recent YouGov Omnibus[33] poll of adults in May 2018 indicated overwhelming support for banning a list of single-use plastic items amongst a sample of over 2000 adults (see Figure 3), with disposable coffee cups and clam-shaped takeaway containers as the products receiving the highest level of public support (~80% of responses to the survey) for a ban.

[27] European Commission (2018) A European Strategy for Plastics in a Circular Economy. http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52018DC0028&from=EN

[28] Source: Ministry of Housing, Communities and Local Government, Revenue outturn cultural, environmental, regulatory and planning services (RO5) 2016 to 2017.
https://www.gov.uk/government/statistics/local-authority-revenue-expenditure-and-financing-england-2016-to-2017-individual-local-authority-data-outturn

[29] https://www.theguardian.com/global-development/2019/apr/04/marine-plastic-pollution-costs-the-world-up-to-25bn-a-year-researchers-find?CMP=Share_iOSApp_Other

[30] Defra (2018) A preliminary assessment of the economic, environmental and social impacts of a potential ban on plastic straws, plastic stem cotton buds and plastics drinks stirrers. Research by Resource Futures, May 2018.
http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=20086&FromSearch=Y&Publisher=1&SearchText=eq0115&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description

[31] https://www.gov.uk/government/publications/litter-strategy-for-england

[32] http://www.radiotimes.com/news/tv/2018-01-11/most-watched-tv-shows-2017/

[33] https://yougov.co.uk/news/2018/05/29/yougov-finds-overwhelming-support-banning-problem-/

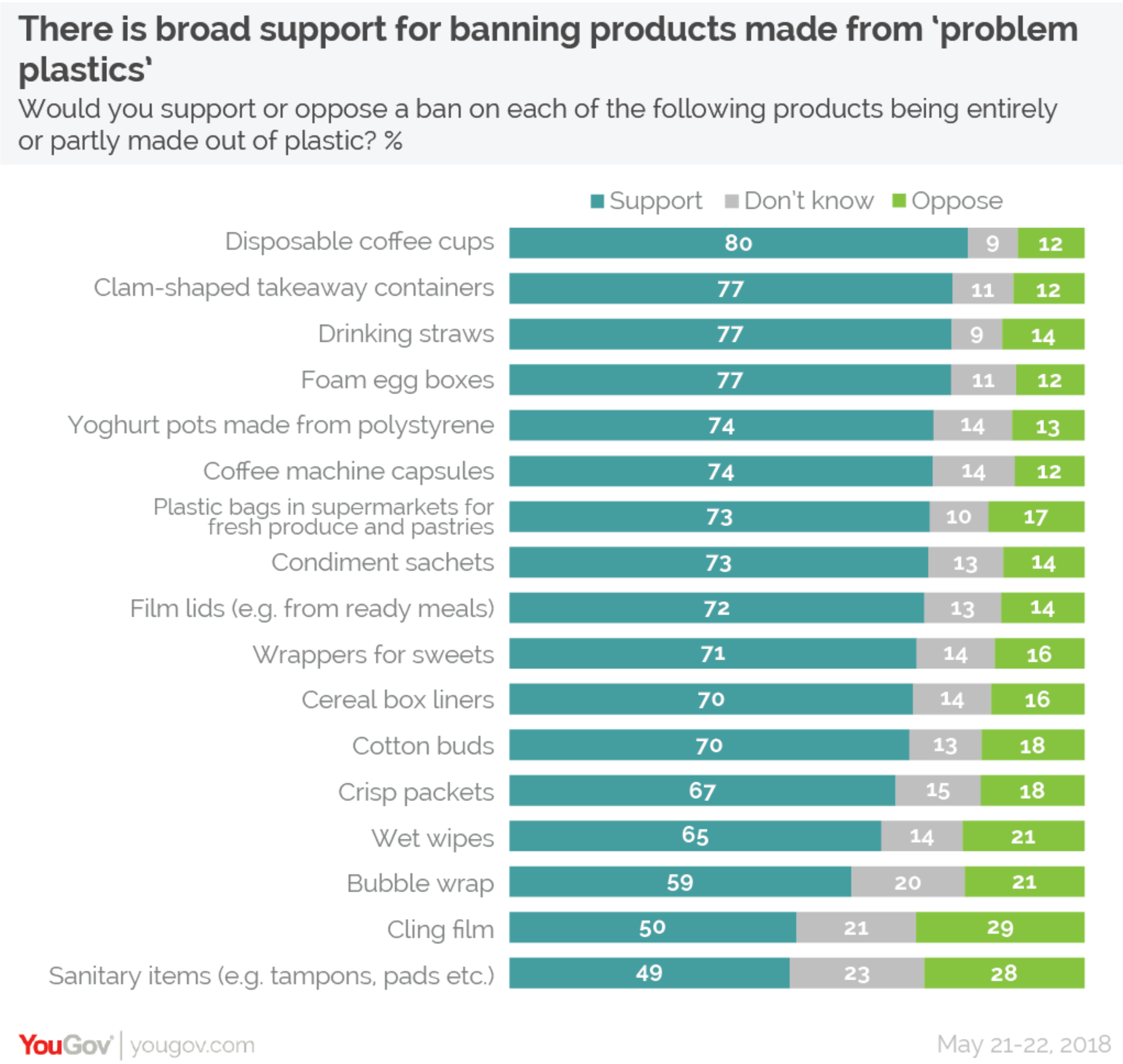

Figure 3 Findings of British public support survey for problem plastics of YouGov Omnibus 2018

As the situation stands, the use of EPS for take away food and beverage purposes contributes to the overall plastic packaging problem and in so doing, is associated with significant economic and environmental externalities. Consumers are not sufficiently incentivised to limit the use and disposal of these plastics and manage them effectively to an acceptable level. The market, left to its own devices, is failing to deliver an economically efficient outcome, and as this constitutes a failure in the market, it justifies a corrective intervention.

1.3.3 Interventions on plastics use

An intervention like a ban can be justified to address such market failures – to protect the environment, food supply, tourism and other economic sectors from further pollution and can help convert attitudes and well-meaning intentions into lasting behaviours. An intervention in the market could reduce littering whilst stimulating innovation and efficiencies among businesses supplying and manufacturing products to the market.

An intervention in the market would also help those businesses which have already acted to address the damage being done, by establishing a level playing field which will ensure that all businesses, including small businesses, budget retailers, online retailers and those handling imported products carry their share of the cost.

However, ensuring that such measures do not cause unintended consequences and impacts of greater scale elsewhere in the life cycle is important. For instance, substitution of EPS with alternative materials that are associated with different impacts needs careful consideration to ensure that net impacts are reduced. Some of these potential concerns are identified and discussed in this research. This report does not undertake a full detailed assessment of the potential impacts of substituting alternative materials for EPS. If the policy is advanced by the government it is expected this would be undertaken following this research.

2 Definitions and scope

For the purposes of this research polystyrene cups and takeaway containers have been defined by Defra, using the same definition as the Single-use Plastics Directive, as:

- Food containers made of expanded polystyrene, i.e. receptacles such as boxes, with or without a cover, used to contain food which:
  - a) is intended for immediate consumption, either on-the-spot or take-away;
  - b) is typically consumed from the receptacle;
  - c) is ready to be consumed without any further preparation, such as cooking, boiling or heating, including food containers used for fast food or other meals ready for immediate consumption, except beverage containers, plates and packets and wrappers containing food;
- Beverage containers (a container intended for the purpose of holding and/or transporting a beverage, either hot or cold), made of expanded polystyrene, including their caps and lids;
- Cups for beverages made of expanded polystyrene, including their covers and lids.

While the directive definition clearly only states *expanded* polystyrene (EPS), for the purposes of this research the definition will also include *extruded* polystyrene (XPS) cups and takeaway containers. XPS is expanded at point of extrusion, then thermoformed. The main difference between the two materials lies in their density: extruded polystyrene is denser than expanded polystyrene (1 kg on average for XPS vs. 0.4 kg for EPS, see Figure 1).

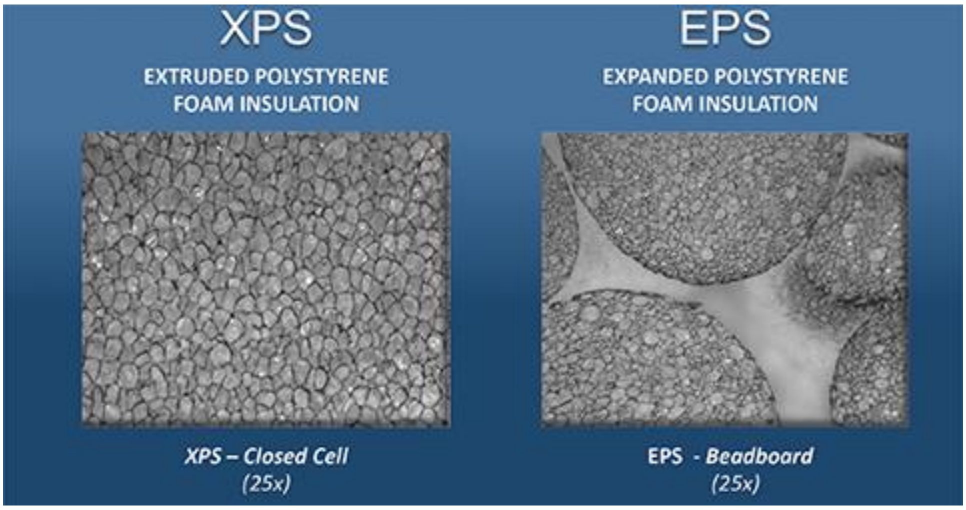

Figure 4. Cellular structure differences between XPS and EPS. Source: Owens Corning, 2015: Technical Bulletin[34].

XPS may be less prone to crumbling than EPS, but it is still a brittle material that can fragment into macro and microplastics when released into the environment. Therefore, taking the precautionary principle, it has been decided that since both materials serve similar purposes and are littered, they will both be considered in-scope in this research.

The purpose of a ban is to cover those products that are associated with environmental damage, not to facilitate loopholes. In this research and throughout this report EPS therefore refers to both expanded and extruded polystyrene. The European Commission may wish to consider this issue in further guidance on the directive which is due to be published in July 2020.

The SUP directive also provides examples of food containers to be considered as single-use plastic products within it: "fast-food containers or meal, sandwich, wrap and salad boxes with cold or hot food, or food containers of fresh or processed food that does not need further preparation, such as fruits, vegetables or desserts." Hence, under the Directive definition we believe there are two main types of single-use 'disposable' take away boxes, on the market[35], which are products

- To contain food that is intended for immediate consumption
- For service – intended for hors d'oeuvres, canapes, appetizers, desserts, takeaways - again available in many shapes and sizes.

In this research, 'take away container' is therefore defined to include containers supplied 'for free' at the point of sale alongside foods in catering and takeaway businesses, as well as ready to consume single portion foods sold in supermarkets. We therefore include EPS **food trays and cones** and small EPS **pots used for foodstuffs** (hot and cold) among the items considered in-scope in this research (more on this in sections 4.1.3 and 4.1.4, respectively).

Notably, EPS disposable plates which are used in takeaways are excluded from the definition used in this research since these have already been considered by Defra in previous research[36].

[34] http://www.owenscorning.com/NetworkShare/EIS/10018681-FOAMULAR-XPS-Performs-Better-EPS-Tech-Bulletin.pdf
[35] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/734837/Plastics_call_for_evidence_summary_of_responses_web.pdf
[36] http://randd.defra.gov.uk/Default.aspx?Module=More&Location=None&ProjectID=20144

3 Methodology

Resource Futures undertook this research for Defra between July and September 2019. The overall research approach that was taken was:

1. Initial information gathering - evidence review
2. Initial information gathering - stakeholder engagement
3. Development of an impact model
4. Further information gathering and stakeholder interviews
5. Refinement of the impact model and sensitivity analysis to understand uncertainties
6. Reporting of findings and discussion

3.1 Initial information gathering – evidence review

A desk-based review of relevant information available in the public domain was undertaken. This focussed on the following:

- **Current product sales** - The contents of market research reports such as the SUP directive's impact assessment technical reports and data sources such as HMRC's UK TradeInfo database were examined for data on annual product sales and sector value. In each case, detailed data was not found to be available at the granular product level or specifically for England, so example data from stakeholders were used in the modelling to represent the market in England. Other literature such as reports from marine litter Non-governmental Organisations (NGOs) were also examined. Inputs to the model were estimated based on data available from large UK manufacturers, based on their understanding of the market and market share. Where UK-wide estimates were determined these were made representative for England by an allocation by relative population.
- **Supply chains** - A sample of retailers, manufacturers and trade associations were contacted and interviewed during the research. Accurate mapping of the supply chains for the products specifically for England was not possible in the timescales of the research.
- **End of life management** - To understand potential pathways for the products, the arising, recycling and disposal behaviours of consumers, and associated costs, research on littering behaviours in the terrestrial and marine litter environment were examined, together with the findings from stakeholder discussions.
- **Non-plastic product alternatives** - Through stakeholder discussions and online searches the most typical market non-EPS product alternatives were identified for the purposes of comparing EPS and non-EPS single-use packaging products. Example material weights and unit prices were compiled from information provided by stakeholders and online research.
- **Environmental and social costs –** Greenhouse gas impacts per material were compiled to indicate the relative production and end of life impacts of materials. A brief review of 'at hand' literature/evidence on life cycle impacts was also examined. A wide body of literature was examined on the 'disamenity impacts' associated with terrestrial and marine litter (disamenity cost is an umbrella measure which can be used to represent a range of societal costs such as wellbeing, health, ingestion/entanglement of wildlife etc).

3.2 Information gathering – stakeholder engagement

Telephone interviews were undertaken with a selection of stakeholders. Table 1 and Table 2 list the interviews that were conducted plus other contributors, showing the range of stakeholders engaged in the research within the timeframe of the research. Contacts with several other trade associations were also made, but these did not engage within the timescales of the research.

A topic guide was adapted to guide each interview and encourage their consistency. This generally covered the organisation’s interest in the subject, opinion on the impact and timing of the ban, changes in use of packaging to date, the evidence-base/significant gaps and impacts and unintended consequences of a ban.

Table 1: Interviews undertaken during the research

Organisation name	Type	Interviewee
EUEMPS	Trade Association - EPS manufacturers	Elisa Setién - Director General
FPA	Trade Association - Food Packaging	Martin Kersh – Executive Director
Large packaging manufacturer	Confidential manufacturer	
National Federation of Fish Friers	Trade Association - Fish and chips shops & takeaways	Andrew Crook - President
Huhtamaki	Manufacturer - Card / fibre food service products	Richard Ali - Sustainability Manager Foodservice
Waitrose	Retailer	Ben Thomas - Sustainability Manager
British Plastics Federation	Trade association - Plastics	Barry Turner - Plastic & Flexible Packaging Group Director
British Plastics Federation - EPS Group	EPS Packaging manufacturer	David Emes - Chair EPS group
NCASS (Nationwide Catering Association)	Trade association - Catering	Mark Laurie - Director
Environmental Packaging Solutions	Independent consultant - packaging	Henry Emblem - Director
Food and Drinks Federation	Trade association - Food and drink manufacturing sector	David Bellamy -Environment Policy Manager
Hubbub	Environmental NGO	Gavin Ellis
Marine Conservation Society	Environmental NGO	Laura Foster
Just Eat	Food delivery service	Robin Clark - Director of Commercial Business Partnerships and Restaurant
UK Hospitality	Trade Association - Pub and restaurant retail	Richard Clifford - Public Affairs and Policy Executive
BioPack	Manufacturer - compostable	Sam Walker
Kockner Pentaplast	Manufacturer - EPS	Helene Roberts - Managing Director

Table 2: Other contributors to the research (by correspondence)

Organisation name	Type
Defra - Policy	Government

Organisation name	Type
Defra - Economics	Government
Defra - Statistics	Government
Office of National Statistics (ONS)	Government
National Outdoor Events Association	Trade Association - Outdoor Events
Confederation of Paper Industries	Trade Association – Paper Recycling
Confederation of European Paper Industries	Trade Association – Paper Recycling

3.3 Overview of the impact model

A product demand impact model was developed in MS Excel to provide a preliminary indication of the quantitative impacts (financial, environmental and social costs and benefits) of two potential product use scenarios each having a time scale of 10 years.

In each scenario, the sales and market share of a 'typical' EPS product relative to the share of alternative non-EPS items is modelled. Figure 5 provides a presentation of the main calculations of the model for a scenario.

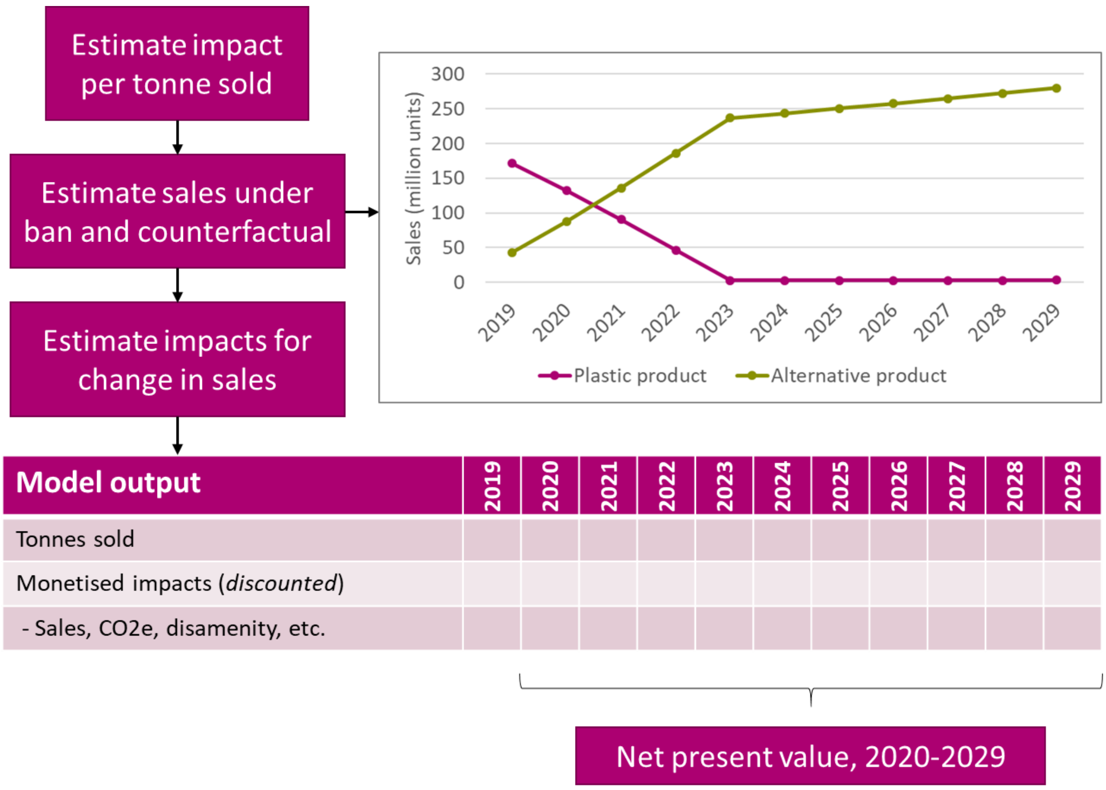

Figure 5: Schematic indicating the main calculations in the impact model for a scenario

The two scenarios that were compared were:

- **No Ban:** Under this scenario the Government would continue to support current voluntary market change towards readily available non-EPS alternatives and an overall reduction in use. Retailers, wholesalers and manufacturers could still produce and sell EPS-based products if they wished to do so in this scenario. This 'do nothing' scenario does not consider the impact of other potential policy measures which may or may not come to fruition in future e.g. changes to the extended producer responsibility system for packaging and potential fiscal measures for reducing the use of single-use plastics proposed by HM Treasury. In short 'business as usual' is assumed unless there is clear evidence that a change in government policy will take place.
- **Ban.** Under this scenario a legislative ban on EPS food packaging and beverage cups would be introduced. EPS would be substituted with alternative materials.

Baseline demand for 2019 was represented and sales were forecast for both EPS and non-EPS products over a 10-year period (from 2020).

An array of different impacts were estimated and monetised in the modelling. The majority of impacts are estimated from the number and nature of each product and the resulting waste tonnage.

Impacts were discounted over the modelling period according to HM Treasury's Green Book[37] e.g. costs were kept at constant prices applying the standard Treasury discount rate of 3.5%.

Transfers of resources between people (e.g. gifts, taxes, grants, subsidies or social security payments) were excluded from the analysis. These types of transfers pass purchasing power from one person to another and do not involve the consumption of resources or make society better or worse off as a whole, hence their exclusion. Since VAT collection and payments are entirely of a distributional nature, VAT was a key transfer excluded from the assessment. In the model the assumed headline product sale price is including VAT and VAT at 20% is removed to calculate the subsequent impacts.

Tariffs are received by HMRC for some imported products[38]. These tariffs are ultimately paid for by UK consumers within the sales price of products. So, they are considered as a transfer and their redistribution is not separately calculated in this assessment.

A central estimate for the impacts of the Ban relative to the No Ban scenario was calculated using the impact model. Sensitivity analysis was also undertaken to investigate the significance of data uncertainties and assumptions, providing a range (lower and upper impact values) from the central estimate.

Regards litter impacts, there is not sufficient evidence available on littering behaviours for these products to estimate with any accuracy what percentage of items are transferred to become terrestrial litter or beach litter, or indeed what the total tonnage may currently be lost each year through these various pathways. The picture is further complicated by the difference between the volume of items littered each year vs. the stock of items accumulating as litter, particular in the marine environment and on beaches.

Hence, an allocation approach was taken in the research to estimating litter disamenity impacts, as illustrated in Figure 6. To calculate litter impacts, the total impact from all items of observed litter in the terrestrial and marine environments was estimated from the research. The best data for relative abundance of different products comes from litter surveys. The survey data was used to allocate a proportion of the total disamenity costs to the products in question. There is no established method for

[37] https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent

[38] A duty of 6.5% is presently applied to plastic imports from outside the EU, not for paper https://www.gov.uk/trade-tariff

allocating these impacts. Litter surveys are reported by item count but relying solely on item count is likely to produce unrealistic impact estimates.

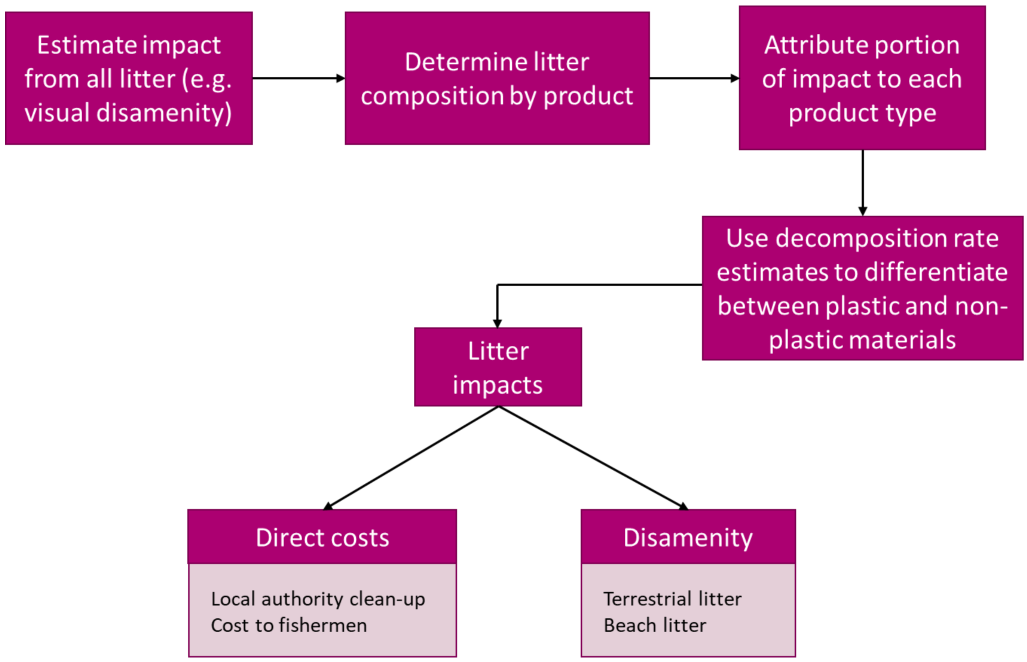

Figure 6: Description of the calculated litter impacts

A detailed description of the model and the data used within it are described in Appendix A.1 and Appendix A.2.

3.3.1 Terrestrial and beach litter modelling

The model assumptions around the composition of terrestrial and beach litter are given in Table 3 and their derivation is referenced in Table 4 and explained below.

Table 3: Assumed composition of EPS food and beverage containers in terrestrial and beach litter

	Terrestrial litter	Beach litter
Beverage cups	0.14%	0.24%
Take-out containers and to-go boxes	0.43%	0.74%
Food trays and chip cones	0.43%	0.74%
Pots	0.05%	0.08%

The composition assumptions used in the modelling are based on informed estimates. No suitable composition data was available for terrestrial or beach litter that clearly identified the EPS food and drink containers as separate items. However, several sources were identified to inform the model estimates.

Terrestrial litter composition was informed by a recent Resource Futures study of litter in Wales[39]. The Welsh national composition analysis of litter waste analysed litter picked up manually from the ground, and litter from litter bins was excluded from our analysis for this EPS study. A total of 885kg of material was sorted from 37 samples of litter pick waste from four Welsh local authorities. The composition by item count was calculated using the count of items of each material divided by the total of all items.

The analysis found that expanded polystyrene cups made up 0.14% of dropped litter waste by item count. Expanded polystyrene 'trays' made up 0.91% of dropped litter waste by item count. This category consisted of EPS food boxes, trays and pots. From photos of the litter items very few pots were found - we assume 5%. Food boxes and trays appear roughly equal in number, which correlates with the production numbers in the model, so the remainder is split 50:50.

Table 4: Rational for terrestrial litter composition estimates, by item count

Product	Composition	Rationale	Calculation
Beverage cups	0.14%	Expanded polystyrene cups made up 0.14% of dropped litter waste by item count.	0.14%
Take-out containers and to-go boxes	0.43%	After pots are removed from the 'EPS trays' category it is split 50:50 with the remaining product types.	(0.91% - 0.05%) / 2 = 0.43%
Food trays and chip cones	0.43%	As above.	(0.91% - 0.05%) / 2 = 0.43%
Pots	0.05%	Few pots were seen in photos of the 'EPS trays' category. We assume 5%	0.91% * 5% = 0.05%

Beach litter composition was informed by analysis of ten years of survey data from the Marine Conservation Society[40] and the impact assessment for the proposed EU Single-use Plastics Directive[41]. 'Polystyrene (small)' and 'Polystyrene foam' categories account for 9% of litter found on beaches. We assume a small minority (20%) of this is from EPS food and drink containers. This is because the majority of EPS used is from EPS in consumer goods packaging, construction products, fish boxes and other EPS products from the fishing and aquaculture industries, including accidental spillage of these in shipping at sea and in ports. We split that 20% into individual products shown above on the same ratio as applied to terrestrial litter.

The model assumes there is no change in public littering behaviour and so the same number of items will be littered. However, the non-plastic products decompose at a much faster rate than plastic and so the observable beach litter impacts are reduced. This difference between the materials used is an important factor in estimating the beach litter impacts.

[39] Resource Futures (2019) Welsh Litter Study

[40] Nelms et al. (2017) Marine anthropogenic litter on British beaches: A 10-year nationwide assessment using citizen science data, https://www.sciencedirect.com/science/article/pii/S0048969716325918

[41] European Commission (2018) Impact Assessment, Reducing Marine Litter: action on single-use plastics and fishing gear, http://ec.europa.eu/environment/circular-economy/pdf/single-use_plastics_impact_assessment2.pdf

Table 5 shows decomposition rate estimates for common types of marine debris. This data is widely used in the literature and popular articles on marine litter. However, the values have not been verified. We were unable to find the original source of the data, and so we cannot be certain it is from a study by the US EPA, nor can we check the methods used to estimate the decomposition rates. As noted in the footnote to the table, decomposition rates for plastics are estimates only. Complete decomposition cannot have been measured yet as the polymers used in these products have been used in manufacturing for less time than the hundreds of years shown.

Table 5: Decomposition rates for common types of marine debris [42]

Item	Decomposition rate
Paper towel	2-4 weeks
Newspaper	6 weeks
Wax carton	3 months
Plywood	1-3 years
Plastic grocery bag	10-20 years*
Styrofoam cup	50 years*
Plastic beverage bottle	450 years*
Fishing line	600 years*
Apple core	2 months

* NOAA comments: Many scientists believe plastics never entirely go away. These decomposition rates are estimates for the time it takes for these items to become microscopic and no longer be visible. Sources: EPA, Woods Hole Sea Grant

Given the uncertainty in decomposition rates, particularly plastics, we conservatively assume that plastic decomposes 100 times slower than paper. This method recognises the distinction between degradability of different materials. The assumptions are used to estimate the relative decomposition of materials, e.g. that to whatever degree the plastic products have degraded in that period, the non-EPS products, at least the bulk of the product excluding any lining, will have degraded much more. Whilst fracturing and dispersal of plastic products is undesirable, for non-plastic products such as paperboard products this is likely to hasten decomposition and reduce disamenity impacts when products are no longer recognisable. Future work could look to incorporate more sophisticated decomposition rates when estimating impacts, e.g. recognising that the distinction between non-plastic and plastic is likely to be small at first but more significant in longer timeframes. Another area of interest concerns decomposition rates for other alternatives such as bagasse[43]. The main NOAA data sources did not cover this type of packaging. An

[42] Talking trash & taking action, Ocean Conservancy & NOAA Marine Debris, https://marinedebris.noaa.gov/sites/default/files/publications-files/talking-trash-educational.pdf. 'Wax carton' is thought to refer to a Tetra Pak-style container of card with laminates of plastic film and aluminium.

[43] Bagasse is the dry pulpy fibrous residue that remains after sugarcane or sorghum stalks are crushed to extract their juice. It is used as a biofuel for the production of heat, energy, and electricity, and in the manufacture of pulp and building materials.

unverified data source indicates the decomposition rate for bagasse could be of the order 30-60 days[44], similar in length to the paper-based materials described above.

4 Findings

4.1 The market for each single-use product

This section presents information regarding each of the researched products and how they are used, supplied, and disposed of. Four types of products are specifically considered in this research. These are EPS beverage cups, EPS take-away containers and to-go boxes, EPS food trays and chip cones, and small EPS cups used for foodstuffs.

4.1.1 EPS beverage cups

Figure 1: Example EPS cup

4.1.1.1 Uses

There are several situations where EPS cups might be used, where food and drink establishments provide them to customers:

- Use on the premises mainly to save costs of washing reusable cups, e.g. at community fairs/events/conferences. In particular these may be used for hot drinks given EPS's insulation properties;
- Taken out with drinks which cannot otherwise be imbibed 'on-the-go', at barbeques/ picnics/parties/takeaways/with 'food to go' meals or

[44] Information obtained from https://www.naturehousegreen.com/faq

- To avoid a security risk associated with glass or other materials e.g. in prisons, hospitals, care homes

EPS cups are normally supplied to the customer for 'free' (i.e. no separate additional charge) at the point of sale alongside a purchase of takeaway/café beverages. Hence, most cups are bought business-to-business and supplied to caterers, takeaway businesses, restaurants, pubs, hotels and retailers. Only a few items are sold direct to consumers at supermarkets (e.g. for picnics, barbeques etc). In the foodservice sector some establishments are now beginning to make a small charge to customers when supplying disposable beverage cups.

It should be noted that although beverage cup lids are included in the Directive definition for restriction on plastic and paper cups, they are not specifically considered in this research for a ban. These are presently made from non-expanded polystyrene since this provides the necessary functional performance required for hot beverage on-the-go disposable cups.

4.1.1.2 Alternative materials

Single-use cups can be made from a variety of materials, EPS being one of them. There are several other types of materials used, including[45];

- Non-expanded plastic - PS, PET and PP
- Polylactic acid (PLA)- a bioplastic made from a variety of plant matter sources, from various roots to sugarcane
- Plant starch - a bioplastic made from fermented plant starch (often corn starch)
- Paper – ridged paper, typically reinforced with either an air pocket insulation and with a plastic (polyethylene) lining
- Reusable cups are also available made from various materials, such as aluminium, thicker plastic, bamboo and ceramic.

From the literature search conducted as part of the research and stakeholder engagement the most common alternative material to EPS used for beverage cups has been identified as paper/board.

4.1.1.3 Sales volume

A 2011 report estimated that as many as 2.5 billion disposable coffee cups are used each year in the UK in total, i.e. 38 disposable cups per capita/yr[46]. However, the majority of these will now be fibre-based since, based on the findings of stakeholder discussions, the large high street retailers and events businesses have already switched to these alternatives to EPS. It was not possible to 'top down' estimate the proportion of this market which were small businesses using EPS cups from the total. Therefore 'bottom up' estimates were necessary based on data provided by UK manufacturers.

Sales volume data for EPS beverage cups in this report are informed by information provided to us by stakeholders (large UK manufacturers), based on their understanding of the UK market and their understanding of market share data, downscaled to England based on the relative population of the UK to England. This information is thought to be representative, but is commercially sensitive so it is not possible to replicate exactly how the estimate was made. It is noteworthy the estimate cover only the proportion of

[45] https://www.webstaurantstore.com/guide/610/types-of-disposable-cups.html
[46] https://publications.parliament.uk/pa/cm201719/cmselect/cmenvaud/657/65705.htm

the single-use cups market, which is served by EPS cups, not the total (>2.5 billion) beverage cups market. Based on data and information provided by stakeholders we have estimated **472 million EPS cups** were sold in England in 2018. The all UK estimate we made was allocated to England based on ONS figures of relative population of England to the UK (84%[47]). This equates to approximately **8.4 EPS cups per capita/yr**.

4.1.1.4 Product price

Disposable cups sold business to business are typically sold in bulk, ranging from 150 to 1000 units per pack, and are purchased either directly from the producer or from distributors. Online research and stakeholder engagement revealed a range of prices for both plastic product and paperboard-based alternatives. For the central estimate in the modelling, a single unit price of £0.03 was applied for the EPS item and £0.04 for the paper alternative, identified through online research and stakeholder engagement. A record of data and assumptions for each of the products is provided in Appendix A.2.

4.1.1.5 Disposal

In terms of waste and recycling behaviours, our assumption for the research is that because cups are lightweight and predominantly used in restaurants, fast food outlets, workplaces, or at events or parties, they are typically discarded to general waste rather than being collected for recycling due to the effort required to segregate and clean them and to sort and send to recovery (recycling or composting). EPS containers are not widely recycled. EPS is often contaminated and normally arises from dispersed locations in small volumes when discarded. Moreover, it is lightweight, bulky and costly to transport to reprocessing facilities. To date, we understand the EPS that is recycled in the UK comes from sources such as retail distribution centres and construction sites, where significant quantities of clean transit packaging and construction packaging arise at the same point and can be process and bulked suitable for recovery into unexpanded polystyrene applications.

Paper-based cups are also not presently widely recycled in the UK. These have a polymeric lining (PET or PLA, Polyethylene or a 'dispersion coating)[48]. While the polymeric lining can technically be separated from the fibre exterior in some pulping recycling facilities, most in the UK do not have such capabilities, resulting in the majority of cups presently being disposed of with general residual waste. This may change since these facilities can accept some contaminated feedstock if bailed and new recycling collections and reprocessing capacity is coming on stream[49].

It has been estimated that around 4% of disposable coffee cups are littered[50]. According to a UK Parliament report[51], in a survey of litter on 900 sites across the City of London in 2016/17, 170 sites (or 18% of the sample) had some form of branded coffee item littered on them, though clearly such a highly urbanised sample area would not be typical of the England and Wales overall.

[47] https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates#timeseries
[48] Stakeholder interview, Richard Ali, Huhtamaki
[49] https://resource.co/article/climate-impact-coffee-cup
[50] https://publications.parliament.uk/pa/cm201719/cmselect/cmenvaud/657/65705.htm#footnote-082
[51] Ibid

4.1.2 EPS Take-Out Containers and To-Go Boxes

Figure 7: Example EPS to-go box

These types of EPS containers are typically made using an extrusion process. They include clamshells and burger boxes, both square and rectangular in shape. The product has low levels of grease and water absorbency and is cheap so is a cost effective way of meeting food preparation hygiene standards. Many of the large high street hospitality businesses and events businesses have already replaced EPS with paper containers, since these can be printed upon to brand the packaging whilst also meeting food hygiene standards.

4.1.2.1 Uses

EPS takeaway containers are predominantly used at takeaway premises (high street vendors and events, such as at music festivals, street food vendors). Some are used by the hospitality sector in hotels and pubs and in high street takeaway delivery businesses and at festivals and other events.

Most are bought business-to-business and supplied to caterers, takeaway businesses, events, restaurants, pubs and hotels. The items are sold to consumers via the foodservice sector and to businesses via foodservice wholesalers.

4.1.2.2 Alternative materials

Other than EPS, disposable takeaway containers can be made from a variety of materials[52], including:

- Other 'food grade' plastic – PET and polystyrene (not expanded)
- Paper/board – with and without polymeric lining

[52] https://www.webstaurantstore.com/47255/disposable-take-out-containers.html

- Bagasse (produced as a bi-product from growing sugarcane, it is grease and water resistant and also can accommodate high temperature content)
- Reusables, using a variety of materials such as ceramic, aluminium, PET and bamboo. These may use lids, rather than being hinged to contain the food.

Online research and stakeholder discussions revealed the main alternative to EPS for take-out containers and to-go boxes is paper/board and these are already used by the majority of large businesses. 'Paper' containers may be made from compressed or layered card and may be bleached or natural in colour. Paper containers are biodegradable and microwaveable. However, uncoated paper can absorb grease and boxes can collapse under the weight of heavier food. Plastic laminated paper, i.e. a PE or PLA lining , may be used to avoid the packaging absorbing grease.

Another popular alternative, particularly among high-street businesses, are bagasse takeaway containers. Bagasse is made from sugarcane, and thus many producers claim it is compostable, which is popular among consumers. It looks and feels like its paper/board alternative, however it provides better insulation and strength, which makes it particularly suitable for heavy and greasy foods. However, as there are few facilities in the UK that have composting capabilities, many times these containers are disposed of with residual waste.

4.1.2.3 Sales volume

Sales volume data in this report are informed by information provided to us by stakeholders on their understanding of the UK market and market share data. For EPS containers, market share information from a major UK packaging manufacturer was used. The estimated figure was based on a manufacturer claim for domestic market share and their estimate that a further 5% of the market is imports. The total consumption of EPS clamshells (distributed primarily in the SME foodservice sector only) was estimated to be **176 million, or about 3.1 EPS take-away containers per capita/yr**.

4.1.2.4 Product price

Regarding the sales price of each product, online research and stakeholder engagement revealed a range of unit prices for both the EPS product and the paper alternative modelled. The prices were investigated at wholesale value. For the modelling central estimate, a current and single unit price of £0.04 has been used to represent a typical EPS take-out food container, and £0.14 per unit for the paper alternative product. A record of data and assumptions for each of the products is provided in Appendix A.2. The impact of economies of scale in production and supply was not factored into the modelling for the central estimate due to uncertainty. It is likely the difference in prices between EPS and its alternatives would be reduced over time as production was scaled up. Sensitivity analysis around product unit prices is undertaken in the research in Section 4.7.

4.1.2.5 Disposal

No specific evidence base was identified in the research on behaviours regarding how disposable takeaway containers are used and disposed of. Undoubtedly the vast majority of EPS products that are used are disposed of correctly into the general residual waste stream. For the small proportion that is littered, EPS products can be broken and fragment when littered, so it is not possible to say with certainty if EPS pieces found in litter picks and beach clean ups were originally part of polystyrene takeaway beverage and food containers. However, large visible items of polystyrene beverage and food containers are regularly seen as litter (for example, a Resource Futures study for the Welsh Government[53] analysed a total of 885kg of material from 37 samples of litter from four Welsh local authorities, and found that 1.05% of the sample were made up of EPS takeaway containers and cups by count). Since other forms of EPS such as construction and packaging EPS were not frequently found in the vicinity of litter bins, we have assumed that all of terrestrial EPS litter found in this survey will refer to the product categories (i.e. take-out containers).

This assumption is less likely to be reliable in the context of marine litter, perhaps because of commercial use of polystyrene in the fishing industry. On a global scale, Ocean Conservancy's International Coastal Clean-up have found 'foam take-away containers' as the 10th most frequently collected item from their 2016 beach clean-ups[54]. The impact assessment for the proposed SUP directive ban supports this. While it states that polystyrene found on beaches (by item count) represents the highest proportion of material found (making up 13.8%), these are pieces measuring between 2.5 and 50 cm, and thereby the original product is unknown. By contrast, intact food containers made up only 0.66%, and intact beverage containers made up 0.56%[55]. Evidently in their entirety these are infrequently found marine litter items, albeit it is not known what proportion of these items could be degraded into the smaller unspecified plastic fragment categories in beach litter counts. For this reason, we have assumed that a small minority, 20%, of the EPS litter found on beaches will refer to the product categories modelled (including take-out containers).

4.1.3 EPS Food Trays and Chip Cones

Figure 8. Example EPS food tray (left) and chip cone (right)

EPS trays and chip cones are investigated together in this section, given their similar market share and unit weights and price.

[53] Welsh Government (Unpublished) Composition analysis of litter waste in Wales. Report by Resource Futures. Draft June 2019
[54] https://oceanconservancy.org/wp-content/uploads/2017/06/International-Coastal-Cleanup_2017-Report.pdf
[55] https://eur-lex.europa.eu/resource.html?uri=cellar:4d0542a2-6256-11e8-ab9c-01aa75ed71a1.0001.02/DOC_2&format=PDF

4.1.3.1 Uses

EPS food trays are used in similar situations to the to-go containers and boxes, except that some do not have attached lids as the boxes/containers do. For this reason, some food trays may be used in other situations such as in supermarket meat and fish, and fresh produce. In line with the Directive definition, meat, fish other products contained and displayed in trays would be exempted from the ban and so would not be included in our analysis. However, EPS food trays and chip cones may be used in:

- Fish & Chip shops to serve food to be consumed on the premises or on-the-go
- Chip cones may be used to serve chips and other snacks (e.g. churros, crepes, etc), also to be consumed on the premises or on-the-go
- Single serve or on-the-go fruit and food displayed in EPS trays could be eligible for the potential ban, if indeed there are single unit items such as oranges, displayed and sold in a tray.

Multipack fresh produce/fruit presented in trays in supermarkets would also be exempted since they are packaging and not included in our analysis. While some of these multipacks may be bought and consumed for picnics etc, rather than consumed in the home, the risk is likely to be lower.

4.1.3.2 Alternative materials

Other than EPS, materials used for food trays and chip cones include:

- Paper/board – with and without polymeric lining (for food trays and cones)
- Bagasse (for food trays and cones)
- Aluminium foil, with a paper/board lid (for food trays)
- Refillable systems with rigid plastics and ceramics

4.1.3.3 Sales Volume

Sales volume data in this report are informed by information provided to us by stakeholders on their understanding of the UK market and market share data. For EPS trays and chip cones, market share information from a major packaging manufacturer was used. Based on the proportion of EPS trays and chip cones that made up their total sales figure for EPS products in 2018, and including the remaining market share not belonging to this producer, we estimated **185 million EPS trays and chip cones** were sold in England in 2018, or about **3.3 EPS trays and cones per capita/yr**.

4.1.3.4 Product Price

Regarding the sales price of each product, online research revealed a range of prices for both the EPS products and the alternatives modelled. The prices were investigated at wholesale value, and not sold as individual units in supermarkets. For the modelling central estimate, a single unit price of £0.03 has been used to represent EPS trays, and £0.07 per unit for the paper alternative product. These figures were identified through online research and stakeholder engagement. A record of data and assumptions for each of the products is provided in Appendix A.2.

4.1.3.5 Disposal

EPS trays and chip cones are disposed of in a similar way as described for EPS food containers (Section 4.1.2.5). As with EPS food containers, we cannot know for certain whether the visual disamenity associated with terrestrial and marine EPS litter is due to these products.

4.1.4 EPS pots used for foodstuffs

Figure 9. Example EPS cup use for foodstuff

Whilst it is not clear whether these products are included in the Directive, small EPS cups are used for hot and cold foodstuffs. These are included in this research since they contribute to similar terrestrial litter and marine litter and are also consumed on-the-go. Note that pot lids, such as the one pictured in Figure 4, are not included in this research.

4.1.4.1 Uses

These small EPS cups are usually single serve portion pots served on-the-go. They are often used in a deli and takeaway context for foodstuffs. Some example of use include for mushy peas in fish and chip shops, Chinese and curry takeaway sauces, soup, salad dressings and other cold foodstuffs (curry sauce, soup, deli foods, single-serve ice cream). EPS pots are low cost, hygienic and are used in smaller businesses in takeaway applications, as wells as in hospitals and care homes to serve single-portion food to patients.

4.1.4.2 Alternative materials

Besides EPS, materials used for portion pots may include:

- Plastic – PET, PS, PP with or without an attached/hinged lid.
- Paper – often without a lid
- Cardboard – with or without a polymeric lining. Cardboard portion pots often come with a polystyrene lid (see Figure 10).

- Refillable systems with rigid plastics and ceramics

Based on our stakeholder engagement, the most common alternative to single-use EPS portion pots are made from paper/board, as in Figure 10.

Figure 10.Paper/board alternative to EPS portion pot (Source: National Federation of Fish Friers)

4.1.4.3 Sales volume

For EPS portion pots, commercially confidential market information from a major packaging manufacturer was used. Based on the proportion of EPS portion pots that made up their total sales figure for EPS products in the UK in 2018, and including the remaining market share not belonging to this producer, we have estimated **313 million EPS portion pots** were sold in England in 2018, or about **5.6 EPS pots per capita/yr**. This estimate was allocated to England based on ONS figures of relative population of England to the UK (84%).

4.1.4.4 Product price

Regarding the sales price of each product, online research revealed a range of prices for both the EPS products and the alternatives modelled. The prices were investigated at wholesale value, and not sold as individual units in supermarkets. For the modelling central estimate, a single unit price of £0.02 has been used to represent EPS portion pots, and £0.06 per unit for the cardboard alternative product. A record of data and assumptions for each of the products is provided in Appendix A.2

4.1.4.5 Disposal

As many EPS portion pots are sold with accompanying food (presumably in a similarly disposable container such as EPS to-go box), we assume that EPS sauce pots are disposed of with the food container it is sold with. This means many of the assumptions made for food trays are made for EPS portion pots as well. Those EPS pots not served with accompanying food, such as those used for deli foods, ice cream, etc, will likely be heavily soiled, and thereby disposed of in litter bins or residual waste bins.

4.2 Stakeholder consultation findings

A summary of the main findings/sentiment gained from the interviews and from other correspondence with stakeholders engaged in the research is provided in this subsection of the report. Comments are categorised by overall context, key findings, economic, environmental and social impacts.

4.2.1 Overall context

The products examined in this research are mainly used by the foodservice sector in fast food and takeaway outlets. Some are also used at private events (e.g formal and community events) and by industrial caterers, pubs and resturants, however these make up a smaller market (by unit sales). A few single-portion food trays may be sold in supermarkets (smaller / express size stores) for picnics etc (e.g. protection of picnic soft fruit). The majority of the market for these products consists of small, medium and micro businesses in the fast-food sector (kebab houses, fish and chip shops, burger shops etc.).

Each of the four products examined in the research can be used either outdoors or indoors. Indoors these are likely to effectively disposed of in the household bin. Because of the frequency of their use in specific localities outdoors (and their size, colour and shape) EPS food containers and cups often appear as litter (around takeaway premises, roadside verges, beaches, events etc).

4.2.2 Key findings

Discussions with the sample of key stakeholders engaged in the research revealed:

- Strong support for a ban was identified from stakeholders representing the large businesses in the catering and hospitality sectors. These sectors regularly interact with high-street retailers that are responsive to the customer. The green events sector and some of the large events sector readily procures plastic free items for events and requires food takeaway concession businesses/membership to do the same. They are largely receptive to implementing actions that are seen as being ‘environmentally friendly’. They have already changed to alternatives or begun to phase out EPS.
- There was strong support for a ban from stakeholders involved in the production and manufacture of alternative products to EPS. These supported a ban on the grounds that EPS causes negative impacts associated with litter and that less polluting alternatives that provide adequate functionality for the user exist in the marketplace. Several stakeholders noted that fibre-based double walled cups had been successful alternatives for coffee cups.
- The predominant use of EPS in these products was in small and medium sized enterprises (SMEs). It was widely reported that the part of the market still using EPS was SMEs (businesses and other organisations), especially in chicken takeaways, kebab shops, curry houses and fish and chip shops.

Many stakeholders interviewed supported a ban as a way of engaging these businesses, ensuring a reduction in the use of EPS.

- Opposition amongst stakeholders and trade associations representing EPS plastics production and manufacture. They raised the concern that banning specific materials will not influence consumer littering behaviour, or improve waste management infrastructure
- Organisations providing comments against the ban also stressed that details surrounding the use of alternative materials for foodservice products and potential unintended consequences need to be examined. They raised concerns that EPS alternatives are heavier and more costly to manufacture and that fibre and bagasse alternatives for food trays have inferior functionality regards insulation for hot food and strength and recyclability, and are more environmentally impactful to produce. However, they recognised EPS has a high propensity to be littered, and that it is not cost-effective to recycle at present. The main manufacturers each indicated that in the event of a ban they would actively consider a way of supplying EPS alternatives to the UK market.
- Mixed or no opinion amongst stakeholders representing retailers, consumers, and civil society. Several within this stakeholder group supported a ban. Others said they could not form an opinion without knowing all the details, such as related costs of using alternative materials and indicated they would appreciate guidance from the government on alternatives if a ban were to be legislated.
- In terms of most common alternative materials used for products, there was a slight inclination toward fibre-based products over products made from bagasse, as bagasse products are marginally more expensive and are imported. Several respondents pointed out the good functionality of bagasse and its compostability.
- Some stakeholders felt the draft SUP directive was poorly drafted with unclear definitions and justification as to why some products had been chosen for action at the last minute in the drafting process. In particular, some stakeholders emphasised that the directive text referred to ‘expanded’ polystyrene (EPS) whereas several products in this category were ‘extruded’ polystyrene (XPS). In contrast to EPS (which is injection moulded) XPS is manufactured using a different process - polystyrene is purchased, gas expanded at points of extrusion, then thermoformed into packaging. Another concern was why polystyrene had been singled out as a particular plastic, whereas all other measures required in the SUP directive relate to plastics (i.e. all polymers).
- Some stakeholders suggested alternatives to a ban including funding anti-littering measures, consumption reduction targets for products made from these materials and a product levy (with all proceeds going to reducing litter and increasing on-the-go recycling collections of EPS).

4.2.3 Economic impacts

Regarding economic impacts the discussions with the sample of stakeholders revealed:

- The EPS foodservice market and non-EPS alternatives are highly commoditised sectors producing high volume and low unit cost products. Due to its bulkiness and costliness to transport, the manufacturing base for EPS is predominantly in the UK. The UK manufacturing market is dominated by two main players. Imports were thought to be small - between 5% and 10%, mainly from Turkey and India.
- Widespread agreement that alternatives to EPS food and beverage containers are available but are more expensive, ranging from a 30% to 300% depending on the alternative material. There was

some recognition that supply of alternatives would be scaled up and economies of scale would be possible if a ban were enacted. However, it was felt that these products would always be more expensive than their EPS counterparts. No additional information about the nature of the additional costs was given by manufacturers (e.g. whether these related to the investment, the costs of material, or labour, transport etc).

- For those already using alternatives to EPS/XPS products (large and high end food retailers) the increase in costs for alternatives had already been passed on to the consumer.
- For those SMEs that are not already using alternatives to EPS/XPS products, there was mixed opinion regarding consumers' willingness to pay for the increase in costs, with some saying the increase is negligible and that consumers will happily pay for a 'greener' product. Some others stated that the increase in cost would be noticeable, especially in the independent takeaway, fish and chip shops and mobile caterers whose customers are the least able to afford a price increase. Some felt that these businesses are under a lot of pressure, and that the increase in price may push some of these small shops out of business, with the consequence of related job losses. There was however no evidence provided to support these concerns.
- Transitional costs associated with the ban were reported as small. Capital costs associated with moving away from EPS manufacture to produce products from new materials were given of the order of £30 million per manufacturing factory (to our knowledge there are four factories in the UK). If a ban were implemented stakeholders said they would make a business decision to invest in producing in the UK or to import product.

4.2.4 Environmental impacts

Regarding environmental impacts, the stakeholder discussions revealed:

- A general view that EPS food and beverage containers purchased at take-away outlets are littered.
- Mixed views regarding which packaging material has the least environmental impact, with pros and cons given for each material. For example, EPS manufacturers view is that EPS is lightweight (93% air) so has the lowest environmental (carbon) impacts associated with production and distribution compared to other materials. Conversely, paper and bagasse container stakeholders stated their products had advantages in terms of sustainable production and has a low production impact because bagasse is made from a by-product of sugar cane processing.
- Several stakeholders said they were selling or using more compostable materials, such as bagasse and products made from PLA as they believe they are acting in the interests of the environment. There was an appreciation that these materials are not normally composted. There was a widespread view that government guidance is needed in terms of the merits of plastic products and their alternatives, including compostables and reusables.
- A concern was raised that paper and card products could be damaging if heavy and not sourced from sustainable forestry initiatives, or from food grade recycled content (which can only come from controlled sources).
- Concerns were raised that alternatives are not plastic free. Fibre-based packaging has polymeric linings made from PE as there are no watertight non polymeric barriers. Cups and food containers are recycled in pulping facilities in mainland Europe, but that are not presently collected from the general recycling stream and recycled in pulping plant in the UK. This is because coatings have to be

removed during their pulping, increasing production costs for the manufacturers. PLA is a compostable polymeric material alternative made from starch, but this is seldom composted in the UK since it cannot be processed in most anaerobic digestion and (low temperature) windrow composting facilities as it requires In-vessel Composting (IVC) facilities that operate at high temperature.

- Concerns were expressed from several stakeholders that it is not practicable to recycle EPS/XPS food tray and beverage cups (they are not recyclable if contaminated, are costly to clean and to collect from dispersed sources. Few recycling collection trials have been undertaken for foodservice EPS so far).
- One stakeholder highlighted the possibility/consequence of a ban specifically on EPS bringing about innovation (within 1-2 years) in terms of expansion of other polymers (PP or PE) which have the advantage that they can be made from recycled content. However, presumably these products would still be littered and would be brittle and fragment.
- One manufacturer pointed out that banning EPS could mean a reliance on alternative products that cannot be produced in the UK (bagasse products are imported and coated board is mainly produced outside the UK). A reliance on imports could have significant environmental impacts related to international shipping of the material.
- Beverage cup lids are included in the Directive definition for restriction. These are presently made from non-expanded polystyrene since this provides the necessary functional performance required for hot beverage on-the-go disposable cups. However, these lids are likely to be littered with the cup, and while they are less brittle than EPS, they can still be broken into plastic fragments.

4.2.5 Social impacts

Regarding social impacts the discussions with the sample of stakeholders revealed:

- Universal awareness of the public concern over use of single-use plastics, littering and marine litter impacts.
- Concerns that the price increase associated with switching from EPS to alternative materials could unfairly/inequitably impact low-budget community functions (e.g. village fairs, community and school sporting events) as well as small takeaway businesses (and their customers) in less affluent areas.
- One manufacturer was concerned about possible health risks related to bagasse products. In order to have grease and moisture resistance in these products, a perfluorocarbon coating is required, which is a chemical that has been associated with negative health impacts. There was concern that new chemicals used on these products have not been properly tested.
- A few stakeholders believed certain applications of the product should be exempted from a ban. Notably, NHS and prisons, as it was felt the functionality (hygienic-sterile nature, safety) and the low price of EPS is especially well suited for these two sectors. Manufacturers felt that they would not be able to justify their EPS operations if the market was limited to these sectors alone.
- One manufacturer stressed that measures were needed to target the core issue of littering, which they claimed was higher in the UK than any other European country, and stated that if this problem is not tackled, any alternative material product will still be littered. This manufacturer stressed the

importance of tackling litter given that the out-of-home consumption market is growing at ~7% a year, and also emphasised that that improved collection and recycling systems were necessary to complement any legislation seeking to reduce the amount of single-use plastics placed on the market.

- There are potential health and safety risks associated with scalding if non-EPS alternatives are not sufficiently insulating and are less safe. However, suitable non-EPS alternatives were identified in this research.
- Reduction in use, rather than switching material was emphasised by some (make less available/default service, refillables, deposit returns etc) as preferable to address the root cause of the problem.

4.2.6 Lead time/implementation risks

Regarding the lead-in time required for a ban, the discussions with stakeholders revealed:

- Alternatives to EPS already exist in the market which can provide similar/adequate product functionality. No significant barriers were identified to introducing alternatives to EPS into all submarkets.
- In terms of supply, widespread agreement that the time to use up existing stocks is relatively short ("a couple of months"), as the products are generally fast-moving.
- In terms of UK production capacity, it could take manufacturers 2-3 years to reinvest to produce a product from an alternative material (such as fibre) in the UK (close existing process, make the business case, re-equip, develop and commission the new processes and scale up production). It was felt there is a risk that production could be moved to Europe or Asia. If some financial support was provided there was a belief that the set-up of an alternative process in the UK could be achieved in 1-2 years. Other alternatives to EPS, made from expanded PP and PE might be advanced in these timescales.
- A need for clarity and consistency regarding implementation of the directive. In particular, it was highlighted that aligning the ban with the 2021 deadline in the SUP directive for non-market restriction measures contained within it would make most sense as this will give enough time for even small businesses to phase out their EPS products.
- Regardless of the lead-in time, there was general agreement that it needs to be communicated clearly, as there was a general feeling that the types of businesses still using the product (mainly takeaway shops) are unaware of any potential interventions (legislative or otherwise) to reduce EPS consumption.

Specifically, the following implementation risks for a ban of the products were identified in the research:

- A risk that a ban on EPS will lead to an increased dependence on imports into the UK as the alternative materials (paper, sugarcane) are currently mostly imported. Existing board production capacity could be adapted (there are at least 5 plants in the UK), there are packaging manufacturing sites and there is at least one UK plant providing a polymeric lining process for packaging all of which (stakeholders have reported to us) could be upscaled and replicated. It is not clear how EU Exit will affect supply, however with or without Brexit there is a risk of exports overwhelming the market if a ban is implemented too quickly, risking the loss of UK-based manufacturing jobs and expertise in the supply chain (~400-600 jobs impacted).

- A risk of inequity since the legislative ban would principally affect SMEs and their customers, potentially from less affluent backgrounds.
- A risk that disposal and recovery options for alternative materials will not be improved. Notably, materials recovery facilities tend not to sort paper beverage cups because the large UK pulping plant are not seeking coated board. They could do since the paper recycling standard permits 1.5% non-target material in paper load, but this could increase process residence time and add production and disposal cost to paper recycling processes. Stakeholders interviewed from the paper sector and from the paper-based packaging sector felt that players in the UK paper industry would be likely to adapt their process to enable layered packaging in future to meet existing demand in countries such as Germany and domestically to meet the growing foodservice packaging sector.
- There is a risk of legal challenge from producers of 'extruded' polystyrene if it is included in the scope of a ban, since this term is not specifically used in the SUP directive. [The report authors note that both expanded and extruded products are gas expanded, littered and brittle and prone to fragmenting, so this may be a semantic issue]. There is also risk of challenge since the expanded polystyrene sector may feel singled out, since all other measures in the SUP directive relate to all types of plastics, rather than a specific polymer type.
- There is also a risk that the directive will not be partially be transposed into UK law in the event of a no-deal Brexit, or not transposed at all.
- There are risks of unintended consequences if the text of the legislation is poorly or ambiguously phrased, including namely that:
    - If the ban is implemented too quickly, alternatives such as bagasse and fibre-based containers may need to be imported. Some supply may be from less regulated countries and sources with respect to food contact packaging, with unknown additives introducing negative health risks. Since bagasse is derived from sugar cane, strengthening this market could promote sugar production and land used to produce it which is potentially incongruous with government Sugar Tax policy.
    - industry could innovate and decide to shift from EPS to expanded PP and PE, which might have some environmental advantages in terms of recycled content, but may be more costly and as impactful with respect to litter.
    - If beverage cup lids are not included in the text of the ban (or innovation in the market is not encouraged to find replacement materials) then although the litter impact associated with the body of EPS beverage cups will be addressed, the impact associated with non-expanded polystyrene lids or cups made of non-polystyrene materials will not be addressed. Balanced against this there may be potential health and safety risks associated with scalding if no suitable non-plastic alternatives to non-expanded PS lids are developed.
    - the SUP directive and a ban might also encourage more durable, reusable plastic packaging, or coated and multi material refillable packaging in the long run. Since these are presently new or niche systems, impacts and user behaviours are not known. There are risks (e.g. overengineering of packaging, reduced recyclability, impactful and costly product cleaning and transport etc) and uncertain economic, environmental and social impacts associated with these systems which are not quantified in this research.

4.3 Descriptions of the scenarios modelled

Following stakeholder discussions, further qualitative and quantitative analysis was undertaken to understand the potential magnitude of the impacts of a ban. A specific proportion of the market was modelled for the small and medium sized business and organisations, as the predominant uses of EPS products. Implementation profiles were represented in the impact model for both 'Ban' and 'No Ban' scenarios. These were informed by the discussions with stakeholders. The scenarios modelled for a central estimate are described in this subsection.

4.3.1 Ban scenario: legislative ban

This scenario represents the anticipated change under a **Ban** scenario for the affected products.

- A shift from a 'baseline' EPS product use to a final base share of 1% is represented in the central estimate, with the share reducing by 20 percentage points in Year 1 and in subsequent years under a ban from the current (baseline) EPS market share of 80%. This was applied for all four different types of food and beverage containers.
- In the Ban scenario, product total sales (both EPS and non-EPS products) are assumed to increase by a uniform 3% per annum each year over the 10 year period modelled. This represents a product of both market growth in the food service sector which is reportedly as high as 7% p.a. in terms of market sales and a reduction in the overall use of packaging – an unknown in terms of prevention and use of refillables in the market.
- In the Ban scenario 95% of EPS is produced domestically and 95% of fibre-based packaging is also assumed to be produced domestically in the central estimate. This represents rapid growth in domestic production, mirroring growth that has been recently achieved in the paper coffee cups market within large foodservice organisations.

4.3.2 No Ban scenario: voluntary change/do nothing

This scenario represents the anticipated change in markets in the absence of a policy intervention. In this scenario leading businesses and organisations continue to reduce avoidable product use and find non-EPS alternatives. The government would also continue to provide support measures – engagement with trade associations and bodies to promote the desired product and behavioural changes and innovation support could be provided to English product suppliers and manufacturers to help them to innovate and invest where alternatives were not present in the market.

The following assumptions were made in modelling the **No Ban** scenario:

- A shift from the same 'baseline' plastic product use of 80% EPS, with the share reducing by 1 percentage point each year. This reduces at a lower rate than the Ban scenario.
- In the No Ban scenario, product total sales (both EPS and non-EPS products) are assumed to increase by a uniform 3% per annum each year over the 10 year period modelled. This is the same as the Ban scenario.
- In the Ban scenario 95% of EPS is produced domestically and 95% of fibre-based packaging is also assumed to be produced domestically in the central estimate. This represents rapid growth in domestic production, mirroring growth that has been recently achieved in the paper coffee cups market within large foodservice organisations.

The product sales used in the model for the central estimate are shown in Table 6 to Table 9. These tables show the effect of an annual reduction in total sales and a shift from EPS products to alternatives over the 10 year period modelled.

Table 6: Beverage cups – model estimate of sales (million units)

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Ban (total)	**589**	**606**	**623**	**641**	**659**	**678**	**697**	**717**	**737**	**758**	**780**
of which plastic	472	364	249	128	7	7	7	7	7	8	8
of which paper	118	242	374	513	653	671	690	710	730	751	772
No ban (total)	**589**	**606**	**623**	**641**	**659**	**678**	**697**	**717**	**737**	**758**	**780**
of which plastic	472	479	486	494	501	508	516	523	531	538	546
of which paper	118	127	137	147	158	169	181	194	206	220	234

Table 7: Take-out containers and to-go boxes – model estimate of sales (million units)

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Ban (total)	**220**	**227**	**233**	**240**	**247**	**254**	**261**	**268**	**276**	**284**	**292**
of which plastic	176	136	93	48	2	3	3	3	3	3	3
of which paper	44	91	140	192	244	251	258	265	273	281	289
No ban (total)	**220**	**227**	**233**	**240**	**247**	**254**	**261**	**268**	**276**	**284**	**292**
of which plastic	176	179	182	185	187	190	193	196	199	201	204
of which paper	44	48	51	55	59	63	68	72	77	82	87

Table 8: Food trays and chip cones – model estimate of sales (million units)

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Ban (total)	**214**	**220**	**226**	**233**	**239**	**246**	**253**	**260**	**267**	**275**	**283**
of which plastic	171	132	90	47	2	2	3	3	3	3	3
of which paper	43	88	136	186	237	243	250	257	265	272	280
No ban (total)	**214**	**220**	**226**	**233**	**239**	**246**	**253**	**260**	**267**	**275**	**283**
of which plastic	171	174	176	179	182	184	187	190	193	195	198
of which paper	43	46	50	53	57	61	66	70	75	80	85

Table 9: Pots - model estimate of sales (million units)

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Ban (total)	**391**	**402**	**413**	**425**	**437**	**450**	**462**	**475**	**489**	**503**	**517**
of which plastic	313	241	165	85	4	4	5	5	5	5	5
of which paper	78	161	248	340	433	445	458	471	484	498	512
No ban (total)	**391**	**402**	**413**	**425**	**437**	**450**	**462**	**475**	**489**	**503**	**517**
of which plastic	313	318	322	327	332	337	342	347	352	357	362
of which paper	78	84	91	98	105	112	120	128	137	146	155

Figure 11: Assumptions for EPS product share of total market in the two modelled scenarios: Ban and No Ban. Note that in the modelling a proportional increase in EPS-free alternatives is modelled, mirroring the reduction in plastic sales.

Figure 11 illustrates the reduction in EPS market share. In the modelling a proportional increase in EPS-free alternatives is modelled, mirroring the reduction in EPS sales. In this preliminary research, a linear reduction in EPS market share is represented. In reality, the decline is likely to be non-linear. For example, significant and exponential decline in EPS use may occur in the first few years whilst the subject is topical followed by slow and extended declining trajectories thereafter, but this is not known. The linear relation is acknowledged as a simple representation. It concentrates on the speed and depth of market change and anticipated differences between each of the scenarios and markets, given the insights that have been gained in the research. The overriding rationale is that over time, different types of ‘consumers’ (householder and business buyers) will be affected and will change, and under the Ban scenario the intervention will bring about change much more quickly and deeply.

4.4 Economic impacts

The central estimates for the impacts are presented in Table 10 to Table 14. The values represent the impacts associated with the EPS product and the alternative product combined. The values are shown in net present value (NPV) terms over a ten-year period from 2020 to 2029. Column A indicates the impacts associated with the product in the Ban scenario, and Column B shows impacts under the No Ban scenario. The third column calculates an estimated impact of the Ban over the No Ban scenario by subtracting column B from column A.

4.4.1 Summary table

Table 10 provides a summary of the combined impact for all products i.e. the sum of the estimates for all four individual products researched. The estimates are rounded to **three significant figures**. Due to rounding values differences between the scenarios may not sum exactly. All figures **exclude VAT**.

Table 10: All products, financial impact estimates, NPV 2020 to 2029 (£m)

	Ban (Column A)	No Ban (Column B)	Difference - Ban over No Ban (C = A – B)	Difference - % change from No Ban
Financial costs to the economy				
Regulatory implementation cost	1.4	none	1.4	n/a
Business implementation cost	4.2	0.3	3.9	+1363%
One-off capital investment	116.0	none	116.0	n/a
Waste treatment cost	11.1	6.6	4.5	+68%
Local Authority clean-up cost	59.1	60.9	-1.8	-3%
Cost to fishing industry	0.2	1.0	-0.8	-81%
Economic growth impacts				
Sales value	702.0	440.0	262.0	+59%
Revenues to UK manufacturing	370.0	232.0	138.0	+59%
Environmental and social impacts				
UK - Value of traded CO2e	5.8	9.3	-3.5	-38%
UK - Value of non-traded CO2e	1.3	0.7	0.7	+99%
EU - Value of traded CO2e	0.1	0.2	-0.1	-43%
EU - Value of non-traded CO2e	negligible	negligible	negligible	negligible
RoW - Value of CO2e	0.1	0.3	-0.2	-57%
Terrestrial litter visual disamenity	272.0	272.0	none	negligible
Beach litter visual disamenity	9.6	51.5	-42.0	-81%

It can be seen that estimated differences in costs between the Ban over the No Ban (column C) are generally modest in scale overall. This is not surprising because the quantitative modelling is just for the proportion of the market which has not switched already from EPS (the SME market) and not the whole market. The difference in the results for Ban and No Ban are a product of the speed and depth of change that is modelled in the market for each scenario. Under a Ban a 20% reduction in EPS is modelled, whereas only a 1% shift away from EPS each year is represented in the No Ban scenario, reflecting change in the market irrespective of a ban.

The main financial and economic costs that are described in the table would help address the market failure for these plastic products reducing the range of environmental and social impacts, and waste treatment/clean-up costs and costs to the fishing industry modelled in the table. Notably, based on current prices, sales value and hence associated revenues to UK manufacturing are increased in the Ban - by £262 million and £138 million according to the modelling (relating to the benefits for UK manufacturing, after retails costs and profits). This is because the non-EPS alternatives are more costly than the EPS products. In the different in unit prices would decrease due to increasing economies of scale.

An investment would need to be made in domestic manufacturing capacity for the alternative material. For the central estimate, the modelling considers that the effect of the ban on domestic paperboard-based manufacturing of both beverage cups and food containers which would be scaled up to the size of the previous EPS market. Hence a one-off capital investment is represented in this research.

4.4.2 Findings by product

Table 11 to Table 14 indicate the main differences between the scenarios by product. Over time, a ban would decrease the demand for EPS products and increase the demand for alternative products that comply with the legislation. Whilst a large proportion of these alternative products are currently imported, we assume that manufacturers will respond to the change in demand and will invest in new manufacturing within the UK.

The most significant difference between the scenarios (column c) is for sales value (i.e. consumer expenditure) which would increase for all products under the ban. These differences are caused by the price differential between the EPS and the alternative products, and the starting point and change in market under Ban and No Ban scenarios. In particular, the unit price of alternate take-out containers is 3.5 times more expensive than EPS products and paper pots are 3 times more expensive, which over the 10 year market shift period translates to an increase in sales NPV of 94% and 82% respectively.

For this central estimate it is assumed that 95% of the paper alternative market will be served by UK manufacturing. The increase in sales represents an additional cost to the consumer and revenue to UK manufacturing industries. The market research suggested that an approximate £120million investment would be required to invest in four factories to produce paper products. This is represented in the table as a 'One-off capital investment' and the total value is allocated to each product based on sales volume. It is assumed investment will occur shortly after announcement of the ban and so the £120m is discounted for occurring in future years. The modelling does not specifically consider production costs, or profit, for these industries, which affects the difference in unit price. The investment would be likely to continue to make a return after the 10 year modelling period.

Table 11: Beverage cups, financial impact estimates, NPV 2020 to 2029 (£m)

	Ban (Column A)	No Ban (Column B)	Difference - Ban over No Ban (C = A – B)	Difference - % change from No Ban
Financial costs to the economy				
Regulatory implementation cost	0.6	none	0.6	n/a
Business implementation cost	1.7	0.1	1.6	+1363%
One-off capital investment	47.7	none	47.7	n/a
Waste treatment cost	2.7	1.8	0.9	+50%
Local Authority clean-up cost	7.9	8.1	-0.2	-3%
Cost to fishing industry	negligible	0.1	-0.1	-81%
Economic growth impacts				
Sales value	184.0	154.0	29.2	+19%
Revenues to UK manufacturing	96.9	81.4	15.4	+19%
Environmental and social impacts				
UK - Value of traded CO2e	1.4	2.7	-1.3	-47%
UK - Value of non-traded CO2e	0.3	0.2	0.2	+96%
EU - Value of traded CO2e	negligible	0.1	negligible	negligible
EU - Value of non-traded CO2e	negligible	negligible	negligible	negligible
RoW - Value of CO2e	negligible	0.1	-0.1	-63%
Terrestrial litter visual disamenity	36.2	36.2	none	negligible
Beach litter visual disamenity	1.3	6.9	-5.6	-81%

Table 12: Take-out containers and to-go boxes, financial impact estimates, NPV 2020 to 2029 (£m)

	Ban (Column A)	*No Ban (Column B)*	*Difference - Ban over No Ban (C = A – B)*	*Difference - % change from No Ban*
Financial costs to the economy				
Regulatory implementation cost	0.2	none	0.2	n/a
Business implementation cost	0.6	negligible	0.6	+1363%
One-off capital investment	17.8	none	17.8	n/a
Waste treatment cost	4.2	2.1	2.1	+98%
Local Authority clean-up cost	24.3	25.1	-0.8	-3%
Cost to fishing industry	0.1	0.4	-0.3	-81%
Economic growth impacts				
Sales value	225.0	116.0	109.0	+94%
Revenues to UK manufacturing	119.0	61.3	57.6	+94%
Environmental and social impacts				
UK - Value of traded CO2e	2.1	2.6	-0.5	-19%
UK - Value of non-traded CO2e	0.5	0.2	0.3	+104%
EU - Value of traded CO2e	negligible	0.1	negligible	negligible
EU - Value of non-traded CO2e	negligible	negligible	negligible	negligible
RoW - Value of CO2e	negligible	0.1	negligible	negligible
Terrestrial litter visual disamenity	112.0	112.0	none	negligible
Beach litter visual disamenity	3.9	21.2	-17.3	-81%

Table 13: Food trays and chip cones, financial impact estimates, NPV 2020 to 2029 (£m)

	Ban (Column A)	No Ban (Column B)	Difference - Ban over No Ban (C = A – B)	Difference - % change from No Ban
Financial costs to the economy				
Regulatory implementation cost	0.2	none	0.2	n/a
Business implementation cost	0.7	negligible	0.6	+1363%
One-off capital investment	18.7	none	18.7	n/a
Waste treatment cost	2.6	1.9	0.7	+36%
Local Authority clean-up cost	24.3	25.1	-0.8	-3%
Cost to fishing industry	0.1	0.4	-0.3	-81%
Economic growth impacts				
Sales value	121.0	74.9	45.9	+61%
Revenues to UK manufacturing	63.7	39.5	24.2	+61%
Environmental and social impacts				
UK - Value of traded CO2e	1.4	3.1	-1.7	-54%
UK - Value of non-traded CO2e	0.3	0.2	0.1	+93%
EU - Value of traded CO2e	negligible	0.1	negligible	negligible
EU - Value of non-traded CO2e	negligible	negligible	negligible	negligible
RoW - Value of CO2e	negligible	0.1	-0.1	-68%
Terrestrial litter visual disamenity	112.0	112.0	none	negligible
Beach litter visual disamenity	3.9	21.2	-17.3	-81%

Table 14: Pots, financial impact estimates, NPV 2020 to 2029 (£m)

	Ban (Column A)	No Ban (Column B)	Difference - Ban over No Ban (C = A – B)	Difference - % change from No Ban
Financial costs to the economy				
Regulatory implementation cost	0.4	none	0.4	n/a
Business implementation cost	1.1	0.1	1.1	+1363%
One-off capital investment	31.6	none	31.6	n/a
Waste treatment cost	1.6	0.7	0.8	+113%
Local Authority clean-up cost	2.6	2.6	-0.1	-3%
Cost to fishing industry	negligible	negligible	negligible	negligible
Economic growth impacts				
Sales value	172.0	94.9	77.4	+82%
Revenues to UK manufacturing	91.0	50.1	40.9	+82%
Environmental and social impacts				
UK - Value of traded CO2e	0.8	0.9	-0.1	-7%
UK - Value of non-traded CO2e	0.2	0.1	0.1	+105%
EU - Value of traded CO2e	negligible	negligible	negligible	negligible
EU - Value of non-traded CO2e	negligible	negligible	negligible	negligible
RoW - Value of CO2e	negligible	negligible	negligible	negligible
Terrestrial litter visual disamenity	11.8	11.8	none	negligible
Beach litter visual disamenity	0.4	2.2	-1.8	-81%

The main monetised benefits calculated by the model for each of the four products are improvements in beach litter reducing the associated visual disamenity. The monetary values are estimated to be £42m across all four products. However, there is a large degree of uncertainty in this figure, not least because beach survey data that is available does not distinguish EPS coming from food and drink containers from other EPS products. The central estimate assumed that a small minority (20%) of all EPS found on beaches comes from food and drink containers, other sources including those from the fishing sector, from global littering of packaging and construction EPS and from marine haulage. A sensitivity range is explored in Section 4.7 due to the uncertainty around this estimate.

Regulatory costs would be borne by Local Authorities' trading standards bodies, and there is expected to be a small additional business burden estimated for each product associated with transition costs on suppliers and retailers, which is represented in the business costs. The exact costs and the period they were incurred over would need to be confirmed in formal stakeholder consultation regarding a ban on EPS.

Waste treatment costs are relatively small but do increase under the Ban scenario. Paper products are heavier and so cost more in these forms of waste treatment, which are typically charged by weight. Almost half of the £4.5m difference is from take-out containers – £2.1m difference. Few of these single-use products are presently thought to be recycled because they are typically consumed outdoors or on-the-go where opportunities for recycling are less available and they are also likely to be soiled from food and drink. Improved collections and recycling rates, especially for cups may happen since a number of initiatives are presently being set up. However, recycling is complicated by contamination issues and is expensive to haul. The modelling therefore assumes no financial value is gained from recycling the products.

Local authority clean-up costs and the cost to the fishing industry caused by littered items are not expected to vary much, in absolute terms, as a result of a ban. The products in question only account for a small proportion of the total terrestrial and beach litter. Costs to the fishing industries decrease as paper products disintegrate in shorter time periods than EPS. A small change in the litter volume may not translate linearly into proportional cost savings for local authorities and their contractors as their staff will still be required to clean the same areas with similar frequency of service.

Carbon emissions vary due to the environmental intensities of different materials, mostly associated with production, the unit weight of different products, and waste treatment. Carbon impacts are similar for cups, take-out containers, and food trays under the No Ban scenario. UK traded CO_2e emissions are reduced under a Ban. This is largely driven by the production burden as paper production emissions are 25% of those associated with polystyrene. However, paper products are also heavier so the net effect is less pronounced.

In contrast, UK non-traded carbon equivalent (CO_2e) emissions increase under a Ban. This change is driven by landfill impacts. Paper has a significantly higher carbon factor per tonne when disposed of to landfill, 1042 kg CO_2e per tonne for paper compared to 9 kg CO_2e per tonne for polystyrene. In addition, paper products are 2 to 5 times heavier than EPS products, so more material is landfilled under a Ban.

Traded and non-traded CO_2e emissions are small in the EU and the rest of the world (RoW) as we assume 95% of EPS and paper products are served by the UK manufacturing market. Carbon emissions decrease under a Ban predominantly due to a lower production burden.

Whilst terrestrial litter impacts are significant for these category of products, there is little benefit indicated in the modelling from switching to paper products. This is because the model assumes no change in the total quantity of products littered and that most terrestrial litter (EPS or paper) will be cleaned up before it biodegrades or disintegrates. However, some litter is not cleaned up quickly such as litter alongside roads and in remote or difficult to reach areas. Products that disintegrate quicker in these areas are arguably better. Estimations of the social cost of litter and its allocation to marine litter is an area of research that is developing. Analysis regarding uncertainty about the method used to allocate litter impacts was explored in previous Defra research studies on proposed bans[56] [57].

4.5 Environmental impacts

4.5.1 Litter impacts

Resource Futures has reviewed the evidence base on the economic and environmental impacts of terrestrial and marine litter for Defra's preliminary research on the economic impacts of a proposed ban on plastic straws, drink stirrers and plastic-stemmed cotton buds[58]. This review found that comparatively few data sources were available and appropriate to England and some data sources were found not to be robust. Further details concerning the modelling of environmental and litter impacts in this research are provided in Appendix A.2.

There are many impacts associated with littering, and the 'willingness to pay' method that is used to indicate impacts reflects, to some extent, how concerned the public is about the issue.

Considering litter composition studies and previous research on direct and indirect economic costs the following data sources were used to represent quantifiable impacts:

- Keep Britain Tidy (2014) [59] data was used to represent terrestrial litter disamenity impact (£4.2 billion value for all types of marine litter as the upper estimate, which is £4.4 billion in today's prices).
- A historical study, Eftec (2002) [60], was used to quantify beach litter visual disamenity impacts (£220 million to £404m). This value is based on the public's willingness to pay for litter-free beaches.

Scientific understanding of the exact impacts of plastic waste is still in its infancy and the relative risks associated with different types and sizes of plastic debris is only just beginning to be considered[61]. Hence

[56] Defra (2018) A preliminary assessment of the economic, environmental and social impacts of a potential ban on plastic straws, plastic stem cotton buds and plastics drinks stirrers. Research by Resource Futures, May 2018. http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=20086&FromSearch=Y&Publisher=1&SearchText=eq0115&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description

[57] http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=20144&FromSearch=Y&Status=3&Publisher=1&SearchText=balloon&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description

[58] Defra (2018) A preliminary assessment of the economic, environmental and social impacts of a potential ban on plastic straws, plastic stem cotton buds and plastics drinks stirrers. Research by Resource Futures, May 2018. http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=20086&FromSearch=Y&Publisher=1&SearchText=eq0115&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description

[59] Keep Britain Tidy (2014), Exploring the Indirect Costs of Litter in England. Values adjusted following methodological improvements in work by Zero Waste Scotland, see Appendices for details.

[60] Eftec (2002), Valuation of Benefits to England and Wales of a Revised Bathing Water Quality Directive and Other Beach Characteristics Using the Choice Experiment Methodology

[61] http://ec.europa.eu/environment/integration/research/newsalert/pdf/clarity_needed_plastic_waste_environmental_impact_for_evidence_based_policy_506na3_en.pdf

the monetisation of these impacts is associated with uncertainty - willingness to pay cost derived from a sample of the public has to be allocated to specific types of litter based on their prevalence in litter survey data. There are also likely to be terrestrial and marine impacts that are not encompassed in the litter visual disamenity estimate and the present state of research makes it difficult to estimate these quantitatively. In particular, the costs of beach litter visual disamenity impacts would benefit from being updated given recent public awareness of the marine damage caused by single-use plastics and these could be much larger than this historical estimate.

The disamenity cost is estimated in the modelling based on changes in sales volumes and assumptions regarding items which become litter, disamenity impact and litter degradation rates. The findings indicated in Table 11 to Table 14 show a reduction in impact for the Ban scenario for beach litter. The reduction is mainly driven by the faster decomposition rate of paper. No change is expected in terrestrial litter as the model predicts no overall reduction in consumption, no change in littering behaviour as the result of a ban, and that terrestrial litter will typically be picked up before paper decomposes.

Decomposition rates for common types of marine debris are shown in Table 15. The alternative products that would replace plastic are made from paper, reducing the decomposition period from tens or even hundreds of years to a matter of weeks or months.

Table 15: Decomposition rates for common types of marine debris [62]

Item	Decomposition rate
Paper towel	2-4 weeks
Newspaper	6 weeks
Wax carton	3 months
Plywood	1-3 years
Plastic grocery bag	10-20 years*
Styrofoam cup	50 years*
Plastic beverage bottle	450 years*
Fishing line	600 years*
Apple core	2 months

* NOAA comments: Many scientists believe plastics never entirely go away. These decomposition rates are estimates for the time it takes for these items to become microscopic and no longer be visible. Sources: EPA, Woods Hole Sea Grant

In the marine environment, non-plastic littered items will decompose much faster than the plastic products and this will lead to fewer being found on beaches and other marine environments. No empirical data was found on which to base an estimate. A conservative approach was taken and we assume the decomposition

[62] Talking trash & taking action, Ocean Conservancy & NOAA Marine Debris, https://marinedebris.noaa.gov/sites/default/files/publications-files/talking-trash-educational.pdf. Note that these values have not been verified. We were unable to find the original source of this data table online, and so we cannot be certain it is from a study by the US EPA, nor can we check the methods used to estimate the decomposition rates. As noted in the footnote to the table, decomposition rates for plastics are estimates only. Actual decomposition rates cannot have been measured yet as the polymers used in these products have been used in manufacturing for less time than the decomposition rates shown. ‘Wax carton’ is thought to refer to a Tetra Pak-style container of card with laminates of plastic film and aluminium.

rate of paper, at least for the bulk of the product excluding any lining, is 1% of the decomposition rate of plastic, although the table above suggests this could be as low as 0.1%. More field studies are needed to inform these estimates.

4.5.2 Life cycle impacts and risks

The Government's Waste and Resources Strategy takes a life cycle approach to managing resources in a circular economy, emphasising that at every stage of the life cycle there is scope for people to do all they can to maximise resource value and minimise waste.

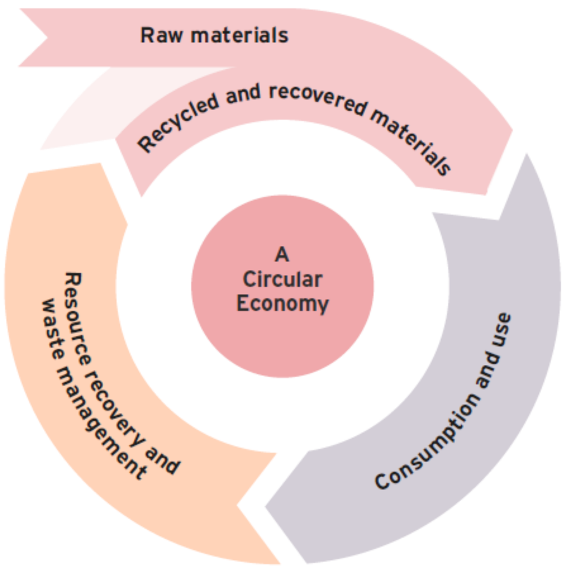

Figure 12: Excerpt describing proposed life cycle thinking approach in Resources and Waste Strategy[63]

A potential risk of a ban is that avoiding plastics such as EPS could encourage the use of alternatives and behaviours which themselves cause an impact of greater magnitude elsewhere at a different life cycle stage. Bans are often considered blunt instruments and as such they are potentially associated with risks of unintended consequences if the potential impacts are not carefully considered and the text of a ban is not carefully drafted.

Life Cycle Thinking[64] can be used to extend risk assessment and inform decisions to ensure there is an overall reduction in environmental impact. It can help understand potential risks right across the life cycle and prevent potential 'burden-shifting'. Impacts are considered at each stage of the supply chain, in use and at point of recovery/disposal chain to ensure impacts of similar or equal magnitude are not transferred elsewhere in the system.

[63] Our Waste, Our Resources: A Strategy For England https://www.gov.uk/government/publications/resources-and-waste-strategy-for-england/resources-and-waste-strategy-at-a-glance

[64] http://ec.europa.eu/environment/waste/publications/pdf/Making_Sust_Consumption.pdf

Life Cycle Thinking may be applied qualitatively to identify and better appreciate the risks, or quantitatively in some detail using detailed Life Cycle Assessment studies (LCAs) which estimate the scale and severity of the impacts of different product alternatives at each life cycle stage cradle to cradle and show their effects on different types of environmental pollution impact. The following diagram summarises the main life cycle stages involved in supplying a product such as packaging. It shows the relationship between life cycle thinking and LCA and circular flow of resources in a circular economy.

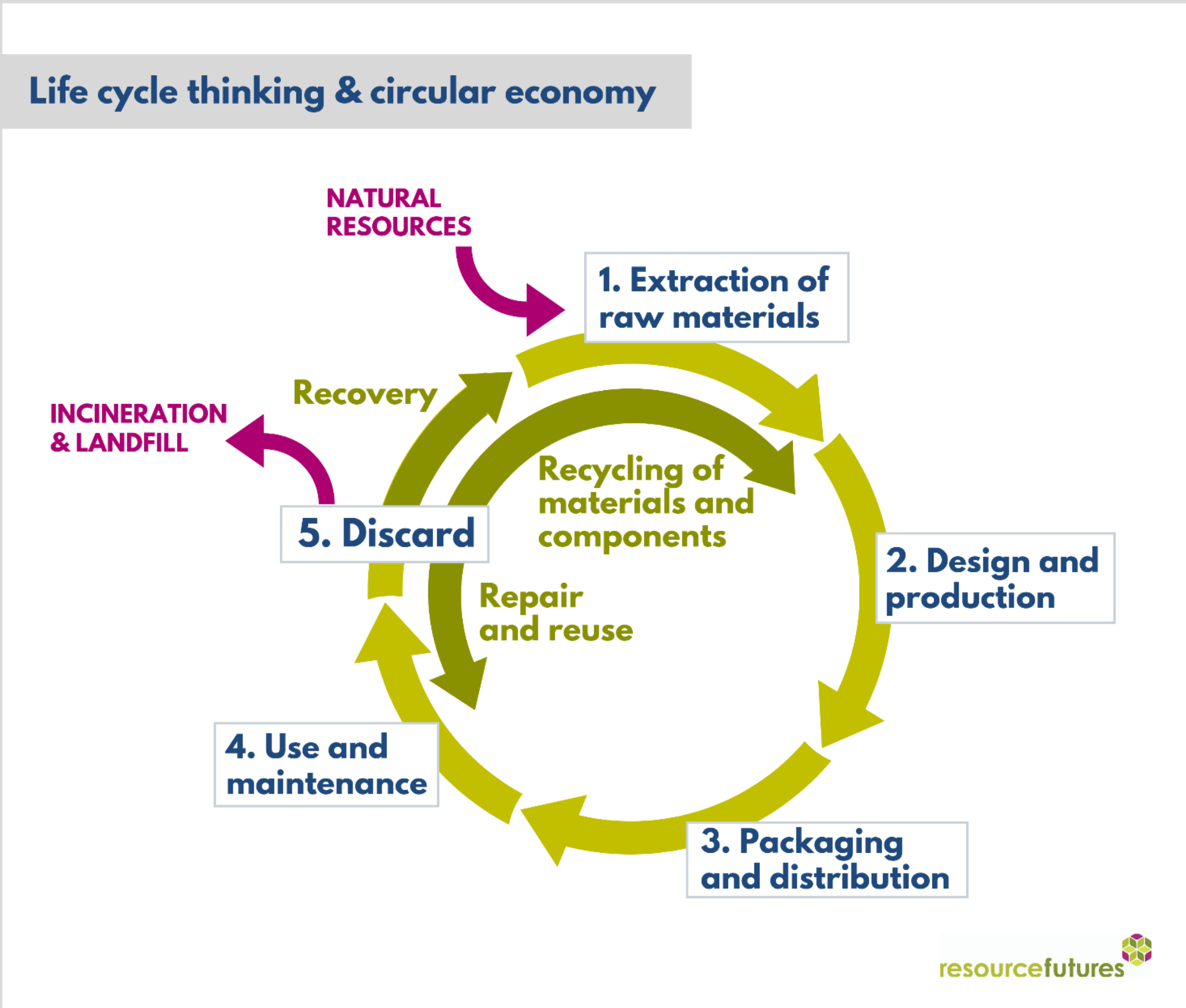

Figure 13: Relationship between life cycle thinking and circular economy[65]

4.5.3 Life cycle thinking

A first question when considering the life cycle impacts of a product concerns the functional suitability of a product or an alternative to it. In particular, whether the product alternative performs equally or less well

[65] Adapted from http://genselective.blogspot.com/2011/10/design-to-minimise-waste.html

than a comparator product i.e. does it match rivals in terms of strength/durability/application during its intended use? Is it functionality equivalent? Or is it adequate/fit for purpose?

Stakeholders recognised the functionality of EPS. EPS is 93% air, so is a lightweight material with very good insulating properties. It is also impermeable and retains its shape and strength. For hot food and hot beverage applications, alternative fibre-based cups and trays must be double walled or thick if they are used in hot food and beverage applications in order to provide similar functionality.

The risk is that when a product is different in order to solve one problem, it may perform less well and an impact may be created elsewhere in the life cycle of a similar or greater scale. For example, the functionality may change the way the product is used (e.g. more spillages of food).

Since non-EPS alternatives are already used within the UK marketplace and it is postulated that these provide adequate but not identical functionality, with little or insignificant differences in product performance.

A follow on question concerns the number of products or the weight of material that is required to fulfil the same function. If the alternatives are heavier then overall life cycle costs can be increased, depending on the material, due associated life cycle impacts over the supply chain[66]. In this research the suggestion is that paperboard food and beverage containers would be heavier than their plastic counterparts (approximately 2-5 times the weight of EPS products). Whilst the fibre-based products might be more environmentally benign from a marine litter perspective, they are heavier and manufacturing and distribution impacts in the supply chain will be different.

A very basic life cycle comparison of the impact associated with the different product weights was undertaken in the modelling for this research based on product weight and disposal impact using UK Government Greenhouse Gas (GHG) Conversion Factors for Company Reporting[67]. In carbon terms, the findings in Section 4.1 suggests that when the carbon-intensity of each material and the resulting emissions on disposal are taken into account, the overall differences are small. In general, because EPS and its alternatives are both comparatively lightweight so the risk of contributing significant and adverse global warming impact is low - and very low compared with other societal choices. The analysis did not account for weight differences and their effect on transport impacts in the supply chain. A detailed American LCA study which did compare EPS and other materials over the full life cycle was inconclusive as to which material (EPS, Paperboard and PLA) was preferential, when compared for several different environmental impacts[68]. Another alternative material, bagasse is made from a bi-product of sugar cane production so has a low manufacturing carbon footprint. A stakeholder interviewed for the research indicated that recent modelling they have conducted indicated this is approximately half that of EPS[69]. More detailed LCA research would be required which properly considers the impact of clearly land to grow more sugar cane to satisfy the market should be considered and the efficiency of UK logistics for the specific products to understand the magnitude of differences and to understand them across the entire supply chain.

[66] https://plastics.americanchemistry.com/Plastics-and-Sustainability.pdf
[67] https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting
[68] https://www.plasticfoodservicefacts.com/wp-content/uploads/2017/12/Peer_Reviewed_Foodservice_LCA_Study-2011.pdf
[69] Personal correspondence, Sam Walker, Biopack 10/9/19

4.5.4 Human health impacts in use

EPS is inert and is deemed safe for food contact[70], with occupational health risks associated with exposure to styrene during production. However, concerns have been expressed in the trade press that alternatives to EPS can contain substances which are potentially harmful to human health. For example, aromatic amines which are carcinogens have been found in paperboard-based food packaging and consumer groups have raised concerns over food safety.[71]

Polyfluoroalkyl substances (PFAS) have been found in bagasse packaging, in contrast to paper-based products where such substances were not found to be present[72]. These are used to provide barrier properties and are thought to be environmentally persistent substances that are potentially toxic to humans[73] [74] [75]. We understand that leading bagasse suppliers to the UK market are making sure such banned substances are not present in the packaging they import and are working with manufacturers to use less hazardous short chain PFAS alternatives[76]. Other packaging alternatives such as bamboo packaging have also been associated with health risks associated with the use of formaldehyde resin as a filler material used to bond fibres[77].

4.5.1 Life cycle impacts at start and end of life

Fossil fuel-based products are generally considered less environmentally sustainable than bio-based alternatives because they rely on finite fossil fuel-based resources and release greenhouse gas emissions if they are incinerated when disposed of[78]. Moreover, in this research it is likely the fibreboard alternatives will contain recycled content and primary fibre would come from managed forests in the UK and Europe.

However, it is not always the case that bio-based materials are superior from an environmental impact perspective and there are risks. Bio-based materials may not be grown in a sustainable way, and if their growing results in significant land use change (e.g. to monoculture), or their production is very inefficient (depends on fossil-based energy and fertilisers), then there is a risk of increasing the overall burden.

At 'end of life', disposal and recycling behaviours for discarded packaging determine the environmental impacts associated with resource recovery and waste management. If consumers tend to recycle items, then products should be designed to be compatible with the recycling systems. If overwhelmingly composted, then products should be designed to biodegrade and if disposed of, then they should be appropriate for that as the prevailing treatment system.

This research indicates that, depending on the context of their use, each of the researched products and their alternatives can be either recycled, composted, or disposed of in general waste. Disposal is most likely to be the predominant behaviour because these products are lightweight or contaminated (so are not perceived as valuable from a material resources perspective) or are consumed in foodservice contexts

[70] https://www.plasticfoodservicefacts.com/foodservice-safety/fda-safety-of-polystyrene-foodservice-products/
[71] https://www.beuc.eu/publications/eu-needs-rules-chemicals-coffee-cups-straws-and-other-paper-food-packaging-consumer/html
[72] https://www.ceh.org/wp-content/uploads/CEH-Disposable-Foodware-Report-final-1.31.pdf
[73] https://www.theguardian.com/commentisfree/2019/aug/16/is-your-takeout-lunch-bowl-covered-in-toxic-forever-chemicals
[74] https://newfoodeconomy.org/pfas-forever-chemicals-sweetgreen-chipotle-compostable-biodegradable-bowls/
[75] https://www.packagingdigest.com/food-packaging/what-chemicals-of-concern-are-in-your-food-packaging-2018-06-08
[76] Personal correspondence, Sam Walker, Biopack 10/9/19
[77] https://fr.wessling-group.com/en/news/bamboo-dishes-that-contain-plastic/
[78] the carbon they are composed of is not derived from the short-term carbon cycle, whereas plant-based material such as paper is carbon drawn down from the atmosphere in the last 100 years. If the packaging is incinerated at end of life biogenic CO_2 is produced which is not counted towards climate change under the convention used for policy appraisal.

where they are specifically used to reduce labour time. Whilst clean EPS foodservice packaging can be recycled[79] it is not widely recycled in the UK[80]. Since it is lightweight and dispersed EPS used in food service packaging is inherently costly to collect and contamination within it means it is not wanted by reprocessors[81].

Recycling of foodservice paperboard packaging is also difficult due to the lack of on-the-go recycling collections infrastructure and potential food contamination. According to a recent House of Commons' Environmental Audit Committee report on disposable coffee cups only 1 in 400 disposable cups (0.25%) were recycled because the lining is difficult to separate at most recycling facilities[82], but the recycling market for paper cups appears to be developing. Some stakeholders expressed concerns whether UK paper recyclers would accept fibre-based foodservice packaging with layered polymeric coatings and wet strength additives. We understand such coatings can be removed at the pulping stage, but this increases the residence time of the material within the process[83]. CPI's Recyclability Guidelines[84] indicates the current paper reprocessor view of food and plastic contamination in paper recycling. Paper and board containing nonfibrous material can be recycled if it is presented to mills that can handle it in baled form. It can also be processed at 'standard' facilities, but it is removed as contamination for energy from waste or landfill. Papermakers want plastic to be designed out, particular polymers with polymers with low shear strength since these can pass through wastewater screens and be discharged from the process.

For paper cups it is notable that a national collection service has been established for office beverage cups[85]. It is predicted that over 120 million cups will be recycled in DS smith paper mill in Kent[86]. The research also identified a recycler of paper cups in the North West of England.[87]

4.5.2 Prevention and reuse

In addition to switching to fibre-based products or other alternative materials to EPS, a possible outcome of a ban will be some reduction in the overall volume of single-use products used – through reducing unnecessary avoidable use altogether. There is also a likelihood of a corresponding increase in the use of reusable foodservice items such as rigid plastic and metal containers and refillable beverage cups.

The impact of both eliminating packaging use altogether and reuse systems is a reduction in the quantity of materials required. There will evidently be a consequent reduction in the life cycle impacts associated with the production, supply and disposal of the materials.

The scope of the impact research included modelling the impact of the total reduction in use in single-use disposable products but did not model any parallel increase in the use of reusable products and the impacts associated with reuse behaviours (returning and cleaning). The main concern for reusable products is whether they can be hygienically cleaned at reasonable financial and environmental cost.

[79] https://www.ineos.com/businesses/ineos-styrolution/news/ineos-styrolution-collaborates-with-indaver-aiming-at-a-chemical-recycling-for-polystyrene/
[80] https://www.recyclenow.com/what-to-do-with/polystyrene-1
[81] Personal correspondence, Polystyrene Recycling 11/9/19
[82] https://publications.parliament.uk/pa/cm201719/cmselect/cmenvaud/657/657.pdf
[83] Personal correspondence, Ulrich Leberle, Confederation of European Paper Industries
[84] https://paper.org.uk/PDF/Public/Publications/Guidance%20Documents/CPI%20Recyclability%20Guidelines%20Final.pdf
[85] https://www.letsrecycle.com/news/latest-news/ds-smith-launches-business-coffee-cup-recycling-scheme/
[86] https://resource.co/article/climate-impact-coffee-cup
[87] https://www.circularonline.co.uk/

It is not yet clear whether refillable systems offer environmental advantages over disposable systems since these system are new, there are many variables (such as product material and weight, transport) and individual consumer reuse behaviours differ.

The European Commission's modelling undertaken for the SUP directive, which compared disposable products and their alternatives, has indicated a potential reduction in environmental impacts. For instance, reductions are calculated for the reusable systems modelled, especially where the best case conditions were modelled[88].

Detailed LCA research has attempted to indicate the so called 'breakeven point' when reusable packaging products outperform their disposable counterparts, modelling a range or variables and conditions. For example, researchers who recently compared EPS and reusable PP containers in the UK[89] concluded EPS containers have lower material and electricity requirements in their production. The research concluded it was necessary to reuse the refillable PP cup between 3-208 times depending on the type of product and the way it was cleaned and reused. Further research in favour of reusable cups has recently been highlighted by Zero Waste Scotland[90].

Research commissioned by the fibre-based foodservice packaging manufacturer Huhtamaki[91] has indicated that paper-based cups can have an advantage over reusable cups, especially where recycled. According to the study, a ceramic cup in a cafe would need to be reused around 350 times before a reduction in the carbon footprint over a single-use paper cup. The number of necessary reuses was found to be affected by how efficiently the cup is washed.

A study cited in 2018 research[92] serve to indicate the significance of material selection for reusables and the potential risks of increased impacts associated with consumer behaviours. OVAM (2017)[93] reviewed the findings of several published LCA studies which compared different types of disposable and reusable drinking cups and utensils used at festival events in Europe in terms of their contribution to global warming potential. The findings are summarised in Table 16 below. These generally indicate an alignment with the waste hierarchy – if items are reused more, the impacts associated with production are overcome. However, the review did indicate exceptions for new glass, metal and ceramic cups. For these, climate change burden would be greater than for both plastic reusable and disposable items (an offsite cleaning service behaviour using carbon-intense energy to heat water was assumed in some of the studies).

[88] https://ec.europa.eu/environment/enveco/economics_policy/pdf/studies/DG%20ENV%20Single%20Use%20Plastics%20LCA%2018121 3.pdf

[89] Environmental impacts of takeaway food containers https://www.researchgate.net/publication/329166723_Environmental_impacts_of_takeaway_food_containers

[90] https://www.zerowastescotland.org.uk/research-evaluation/cups-sold-separately-report

[91] https://www.huhtamaki.com/globalassets/global/highlights/responsibility/taking-a-closer-look-at-paper-cups-for-coffee.pdf

[92] Resource Futures and Nextek (2018) Eliminating avoidable plastic waste by 2042: a use-based approach to decision and policy making https://ciwm-journal.co.uk/wordpress/wp-content/uploads/2018/06/Eliminating-avoidable-plastic-waste-by-2042-a-use-based-approach-to-decision-and-policy-making.pdf

[93] OVAM (2017), Manual For Event Organizers: Study drinking and eating utensils at events, Ecolife & Ecofest for OVAM Waste and Materials Management Department http://www.ovam.be/wegwijzer-cateringmateriaal

Table 16: OVAM (2017) Comparison of cups and utensils used at events for meta-analysis of 16 LCA studies

Material type	Reuse - high (>150)	Reuse - low (<150)	Recycling	Residual waste or compost
Second-hand crockery (glass, ceramic, metal)	A	A		C
RPET (recycled PET)	A	A	B	C
PLA (poly lactic acid) & C-PLA	A	A	B	C
Bio-PE (polyethylene) BIOGENIC	A	A	A	B
PP (polypropylene)	A	B	C	D
PET (polyethylene terephthalate)	A	B	C	D
PS (polystyrene)	A	B	C	D
PC (polycarbonate)	B	C	D	E
Copolyester	B	C	D	E
Modified starch				D
Cardboard (recycled)			B	C
Form of cardboard (moulded fibre)				B
Sugar Cane fibre (bagasse)				B
Wood				C
Cellulose pulp				D
Glass (recycled)	B	C	E	G
Metal	B	D	G	G
Ceramics	C	E		G

Letters A – G represent the lowest to highest carbon impact

These studies highlight that choice of material and the way the packaging is used, reused and disposed of determines the environmental impact. We suggest consumer behaviour market research and further environmental LCA studies should be undertaken. These should compare disposable and reusable alternatives to food and beverage containers in a UK-specific context should be undertaken to understand the impacts of such market changes. This could help inform which materials are preferential, what use-phase behaviours (cleaning practices and the number of repeat uses) should be encouraged and which peculiar behaviours and practices should be discouraged. The study should be future-looking considering the impact of changes in the future carbon intensity of energy and transport on the environmental impact of refillable systems.

4.6 Social/consumer impacts

4.6.1 Sales price and consumer utility

A quantitative impact assessment on sales expenditure was estimated in the research and was shown in Table 10. For the researched products, our analysis indicates that the non-EPS substitute products would be, depending on the product type, between 30% and 300% (from 30% to three times) more costly than the existing EPS product (at least initially), adding between 1-10 pence per individual unit. The least increase would be for beverage cups where the market is already providing large volumes of non-EPS alternative products. The largest cost difference was for alternative container boxes providing the same or similar functionality as EPS containers.

Standard economic theory assumes that consumers of goods and services act rationally whilst making decisions about the amounts of goods or services they agree to supply or purchase. Thus, in deciding to purchase or supply an item for a given sum of money (say £1), a consumer is assumed to act rationally. It follows that when buying such an item a consumer must derive an amount of 'utility' (broadly, use or pleasure) from that item which is at least equal to the £1 they spent acquiring it. If the item was worth less to the consumer than £1, then being rational, they would not have bought it. Similarly, if the item is worth more to them than £1, but costs less than £1, then they buy it and experience a 'bonus' for which they have not paid. This 'bonus' is termed 'consumer surplus' and reflects the idea that the consumer derives more pleasure from the item than it actually costs them. The idea that the price of an item can be treated as a proxy for its value is simplistic (and does not take account of any consumer surplus that may be derived) but it is convenient and is often applied, for example in counting the sales of goods.

All stakeholders, whether they are wholesale or retail, would be expected to act rationally in the face of changes in the price and nature of food and beverage containers. If the market price of a product is set right (theory indicates it has to be for the market to 'clear'), then the market should initially be at an equilibrium, where demand equals supply. Some consumers may find that after a change in the product, they may draw less (or more) utility from the purchase. EPS was recognised in the research as providing high insulation and strength, and it is a lightweight material. If an alternative product has an inferior level of performance, or is more expensive, then the consumer's product experience diminishes, and (assuming the purchase is discretionary rather than unavoidable) demand for the product will fall accordingly. Likewise, improvements and price reductions will have a positive effect on demand. Such market changes could be expected following a ban, after which a new equilibrium must be found as consumers (who were previously content to buy and use EPS items) switch to alternatives likely to have different prices and characteristics.

The market for food and beverage containers, as it currently operates, is driven by business to business purchasing decisions, with retailers, caterers and food suppliers making decisions about the kind of food containers they prefer to buy on behalf of their customers. In reality, we know little about what shapes these decisions, or about the elasticity of demand and supply with respect to price (or quality) – i.e. how much a change in price (or in quality) would affect overall purchasing and supply decisions. Added to this, the market for food and beverage containers is complicated by the fact that retail customers do not directly pay for the containers, the cost of which is absorbed within their overall food bill, and the decisions taken within this part of the market are even more opaque.

Our model by necessity has therefore simplified the relationship between price, quality, demand and supply (losing some 'real world' accuracy in the process) by treating price as a proxy for consumer satisfaction, and assuming that consumers are happy to simply exchange the substitute good for the existing one – even if the new product costs more. Therefore (with the exception of some broad assumptions about overall future market growth) there are no changes to the overall demand and supply of the products even in the face of changes in materials and prices.

There is some rationale for doing this. Consumer reactions to market changes are very difficult to predict. Though the price of alternative food and beverage containers may be more expensive, any price increase to the business owner is likely to be relatively small, and would usually be passed on to the consumer. As we have seen these items are provided as part of a hospitality package experience (e.g. in takeaways, restaurants etc) to end users, with the prices of containers usually hidden within the overall price of the service. Marginal changes in a relatively small element of overall costs, because they are wrapped up in a larger bill, would probably be unnoticeable to the end user. We note that large retailers have already switched from EPS for beverage cups and food containers so in these cases the consumer has already accepted the price increase. In addition, discussions with stakeholders suggested that following a ban economies of scale would be likely as production and supply is scaled up, meaning that the unit price differences between EPS and non-EPS products would be reduces over time.

Recognising the difficulty of accurately forecasting future demand and supply in response to the imposition of a material ban, we have undertaken a sensitivity test on the volume growth rate to help indicate the potential impact of deviations. This is shown in Table 18.

4.6.2 Marine welfare benefits

Terrestrial and beach litter disamenity impacts have been quantified in this study. However, the social impacts of marine litter (e.g. welfare benefits - knowing and seeing that the sea itself is cleaner, reassurance that marine life is not being impacted) are acknowledged but are not quantified in this research. Further, contemporary ‘willingness to pay’ research is recommended regarding this subject.

4.7 Sensitivity analysis

Several uncertainties were identified during the research. For example, estimates for the total number of units sold of each type of product and their unit sales value. Assumptions also had to be made regarding the speed and extent of change in market share in the Ban scenario.

It was decided to undertake sensitivity analysis around the main uncertainties in two parts:

1. Market growth uncertainty
2. Other uncertainties around the central estimate.

4.7.1 Market growth uncertainty

Given a lack of available data on future growth in the foodservice packaging sector there is uncertainty in the analysis about how and whether the market will grow over the next ten years, regardless of the Ban/No Ban scenario proposed. Our central estimate assumes the market will continue to grow incrementally each year over the plan period.

One stakeholder interviewed for the research reported that the total takeaway market in the UK (covering large and SME operators) was presently growing at 7% per year. Given it is unlikely this consumer trend will be reversed in the immediacy our central estimate reflects the growth, though at a reduced rate. We assume growth of 3% for each of the scenarios and all the products each year over the plan period. This is more modest than the reported recent value growth in the market. It reflects the market growth but also considers a modest user reduction in unnecessary packaging that can be avoided altogether.

It is plausible, however, that a high profile government-led intervention such as a ban and the difference in price between EPS packaging and paperboard production will have a greater effect on the market, bringing about an overall reduction in packaging use, which might not happen at all (or would happen later) under the No Ban scenario. It is possible that some types of packaging may be unnecessary and can be eliminated altogether. For example, fish and chips trays are used as a convenient portion size measure. The retailer may use a portion size scoop instead and could offer the service without the tray altogether, such that trays are provided on a customer 'on request' basis only. Moreover, it is a stated objective of the SUP directive to bring about refillable packaging systems in the future. Uncertainty in our market growth assumption and the impact it has on the finding of the study is therefore explored discretely in this section of the report.

Table 17 show the impact estimates for an overall reduction in consumption of these products, representing an increasing public awareness of the undesirability of single-use products/packaging under both scenarios, and additionally under the ban, also the potential 'signalling' effect of a ban and the effect of higher prices, i.e. in both the Ban and No Ban scenarios the markets are assumed to shrink, at a rate of 1.5% and 0.5% respectively each year. Table 17 shows detailed results for 'all products' as a group, with absolute impacts calculated in the Ban and No Ban scenario for both the central and lower sensitivity (a representing a reduction in overall sales volume). This shows the impact of the ban (difference between Ban and No Ban scenario) in the central and lower sensitivity tests. Appendix A.4 provides these differences individually for each of the four products. The sensitivity results can be compared with the central estimates, presented in Table 10 to Table 14, the differences can be seen in relative terms in column F of the first table and column C of the subsequent tables.

Comparing the two tables, both the costs and the benefits of the Ban are reduced over the central estimate. This is not surprising since fewer products sales are made in both the Ban scenario than in the No Ban. The most striking effect associated with a Ban that causes an additional reduction in sales over the No Ban, is the effect on the total sales value (i.e. cost to the consumer) and the consequent revenues to UK manufacturing. According to the modelling these would be reduced by 30% over the discounted plan period. It is, however, noteworthy that there is still an overall increase in sales value over the No Ban due to the modelled price difference between EPS and paperboard packaging. It should also be noted that this analysis does not include the impacts of a corresponding increase in refillable systems, if indeed, that is an outcome. This would increase impacts on both the sales value and manufacturing revenue and would also establish a service sector and new revenues associated with providing the services and cleaning the refillable containers.

The corresponding environmental impacts of refillable systems are also not modelled since evidence was not identified on typical UK behaviours for the products examined in the research and these services are developing.

If more reusables are used, as seems likely, they would require cleaning, leading to environmental impacts on water, energy and chemical use as well as any social disutility associated with inconvenience. Since the proportion of the market is likely to be small it is expected the impact of litter and waste management would also be small. We suggest further research is considered such as market research/evidence review on the proportion of consumers which would be prepared to shift to reusable products. Their likely behaviours and any evidence could then potentially be incorporated within subsequent economic and environmental impact assessments of legislation on single-use products.

Table 17: All products – market size reduction in Ban and No Ban, even stronger in Ban scenario due to signalling effect and price differential, (i.e. total market size declines by 1.5% pa in Ban and 0.5% in No Ban scenarios) financial impact estimates, NPV 2020 to 2029 (£m): calculated values and percentage change from the central estimate.

	Central - Ban (£m) (Column A)	Central - No Ban (£m) (Column B)	Central - Difference - Ban over No Ban (C = A – B)	Lower - Ban (£m) (Column D)	Lower - No Ban (£m) (Column E)	Lower - Difference - Ban over No Ban (F = D – E)	Lower Difference - % change from Central Difference (C and F)
Financial costs to the economy							
Regulatory implementation cost	1.4	none	1.4	1.4	none	1.4	none
Business implementation cost	4.2	0.3	3.9	4.2	0.3	3.9	none
One-off capital investment	116.0	none	116.0	116.0	none	116.0	none
Waste treatment cost	11.1	6.6	4.5	8.7	5.5	3.2	-29%
Local Authority clean-up cost	59.1	60.9	-1.8	47.1	51.1	-4.0	-118%
Cost to fishing industry	0.2	1.0	-0.8	0.2	0.8	-0.7	+17%
Economic growth impacts							
Sales value	702.0	440.0	262.0	552.0	368.0	184.0	-30%
Revenues to UK manufacturing	370.0	232.0	138.0	292.0	194.0	97.1	-30%
Environmental and social impacts							
UK - Value of traded CO2e	5.8	9.3	-3.5	4.4	7.5	-3.1	+12%
UK - Value of non-traded CO2e	1.3	0.7	0.7	1.0	0.6	0.4	-34%
EU - Value of traded CO2e	0.1	0.2	-0.1	0.1	0.2	-0.1	+14%
EU - Value of non-traded CO2e	negligible	negligible	negligible	negligible	negligible	negligible	-28%
RoW - Value of CO2e	0.1	0.3	-0.2	0.1	0.2	-0.1	+17%
Terrestrial litter visual disamenity	272.0	272.0	none	216.0	228.0	-11.5	none
Beach litter visual disamenity	9.6	51.5	-42.0	8.7	43.4	-34.7	+17%

4.7.2 Other uncertainties around the central estimate

The research team also selected possible upper and lower values, based on insights gained in the stakeholder engagement and plausible, rationale assumptions for other, potentially, data uncertainties and assumptions modelled. Values were changed in the model to represent the potential range in the results based on the findings of the preliminary research and stakeholder discussions. The parameters that were changed are listed in Table 18. Most notably, sales units, price and weight are varied by 25% either side of the central estimate. The speed of market change under each of the scenarios is also varied to indicate the effect on the model results.

The results for this sensitivity analysis are presented cumulatively, rather than individually for each sensitivity. Further analysis was conducted to identify the key determinants of the impact modelling and is provided in commentary accompanying the tables.

Table 18: Variables tested for plausible upper and lower range analysis around the central estimate

Model variable	Product types	Central est.	Central Value	Lower (Best)	Lower value	Upper (Worst)	Upper value
Sales units p.a.	All	Item estimates	1	75%		125%	
Unit weight (g)	All	Item estimates	1	75%		125%	
Unit price (£)	All	Item estimates	1	75%		125%	
Speed of shift - Ban	All EPS products	20 point drop in EPS % market share each year, e.g. linear reduction of 80% to 60% to 40%	20%	100%	20%	200%	40%
Speed of shift - No ban	All EPS products	1 point drop in EPS % market share each year, e.g. 50% to 49% to 48%	1%	100%	1%	1000%	10%
% imports into UK	All	95% domestic production, 5% import	5%		5%		50%
Items littered	All	% of items littered	1	50%	0.5	200%	2.0
Visual disamenity value - terrestrial and beach litter	All	Eunomia (2014, adjusted as described); Marine: Eftec (2002)	Mid-point		Lower Range		Upper Range

The lower and upper columns show how model assumptions are varied from the central estimate. For example, the first line of the table shows that sales units for all three products were varied +/-25% from the central values for sales units (billions/millions per annum). The fourth line of the table shows that it was felt the speed of market shift for the ban would be unlikely to be less than the central estimate value of 20% but could be double that of the central value of 20%. Line 7 halves littering rates in a lower range and doubles littering in the upper range.

Sensitivities around the market growth rate, as explored in section 4.7.1, were not included in addition to those listed in Table 18. By presenting these sensitivity results separately it is easier to distinguish the significant of the growth uncertainty relative to other uncertainties in the modelling.

Table 19 compares the central value and lower variation where all sensitivities in Table 18 were applied, providing ranges as recommended in HM Treasury's Green Book. The final column in the table compares the impact of the ban (i.e. the difference between Ban and No Ban) in the central and lower variation to indicate the effect of the lower sensitivity values. Similarly, Table 20 compares the central value and upper variation of sensitivities in Table 18. Overall, the estimated results were increased or decreased in the expected direction. The table shows a range for the uncertainties examined.

Table 19: Cumulative range impact estimates for all products combined; absolute values in ban and no ban for central and lower estimates, NPV 2020 to 2029 (£m), and comparison of difference between ban and no ban - calculated values and percentage change from the central estimate

	Central - Ban (£m) (Column A)	Central - No Ban (£m) (Column B)	Central - Difference - Ban over No Ban (C = A – B)	Lower - Ban (£m) (Column D)	Lower - No Ban (£m) (Column E)	Lower - Difference - Ban over No Ban (F = D – E)	Lower Difference - % change from Central Difference (C and F)
Financial costs to the economy							
Regulatory implementation cost	1.4	none	1.4	1.4	none	1.4	none
Business implementation cost	4.2	0.3	3.9	4.2	0.3	3.9	none
One-off capital investment	116.0	none	116.0	116.0	none	116.0	none
Waste treatment cost	11.1	6.6	4.5	6.2	3.7	2.5	-44%
Local Authority clean-up cost	59.1	60.9	-1.8	14.4	14.8	-0.4	+76%
Cost to fishing industry	0.2	1.0	-0.8	negligible	0.2	-0.2	+76%
Economic growth impacts							
Sales value	702.0	440.0	262.0	395.0	248.0	147.0	-44%
Revenues to UK manufacturing	370.0	232.0	138.0	208.0	131.0	77.7	-44%
Environmental and social impacts							
UK - Value of traded CO_2e	5.8	9.3	-3.5	3.2	5.2	-2.0	+44%
UK - Value of non-traded CO_2e	1.3	0.7	0.7	0.7	0.4	0.4	-44%
EU - Value of traded CO_2e	0.1	0.2	-0.1	0.1	0.1	-0.1	+44%
EU - Value of non-traded CO_2e	negligible	negligible	negligible	negligible	negligible	negligible	-44%
RoW - Value of CO_2e	0.1	0.3	-0.2	0.1	0.2	-0.1	+44%
Terrestrial litter visual disamenity	272.0	272.0	none	18.5	18.5	none	none
Beach litter visual disamenity	9.6	51.5	-42.0	1.6	8.8	-7.2	+83%

Table 20: Cumulative range impact estimates for all products combined; absolute values in ban and no ban for central and upper estimates, NPV 2020 to 2029 (£m), and comparison of difference between ban and no ban - calculated values and percentage change from the central estimate

	Central - Ban (£m) (Column A)	Central - No Ban (£m) (Column B)	Central - Difference - Ban over No Ban (C = A – B)	Upper - Ban (£m) (Column D)	Upper - No Ban (£m) (Column E)	Upper - Difference - Ban over No Ban (F = D – E)	Upper Difference - % change from Central Difference (C and F)
Financial costs to the economy							
Regulatory implementation cost	1.4	none	1.4	1.4	none	1.4	negligible
Business implementation cost	4.2	0.3	3.9	4.2	2.8	1.3	-66%
One-off capital investment	116.0	none	116.0	61.0	none	61.0	-47%
Waste treatment cost	11.1	6.6	4.5	18.2	15.2	3.0	-33%
Local Authority clean-up cost	59.1	60.9	-1.8	235.0	239.0	-3.2	-71%
Cost to fishing industry	0.2	1.0	-0.8	0.3	1.7	-1.4	-71%
Economic growth impacts							
Sales value	702.0	440.0	262.0	1150.0	975.0	175.0	-33%
Revenues to UK manufacturing	370.0	232.0	138.0	326.0	311.0	14.5	-90%
Environmental and social impacts							
UK - Value of traded CO2e	5.8	9.3	-3.5	4.3	6.8	-2.5	+28%
UK - Value of non-traded CO2e	1.3	0.7	0.7	2.2	2.7	-0.5	-176%
EU - Value of traded CO2e	0.1	0.2	-0.1	2.4	2.0	0.4	+546%
EU - Value of non-traded CO2e	negligible	negligible	negligible	negligible	negligible	negligible	-35%
RoW - Value of CO2e	0.1	0.3	-0.2	2.4	2.0	0.4	+339%
Terrestrial litter visual disamenity	272.0	272.0	none	1870.0	1870.0	none	none
Beach litter visual disamenity	9.6	51.5	-42.0	21.3	114.0	-93.1	-122%

Table 21 compares the impact of the ban (i.e. the difference between Ban and No Ban) as calculated in the sensitivity analysis. It is notable that sales cost/expenditure (the first row of economic growth impacts) and the closely linked (a proportion of allocated sales) manufacturing revenues (second row of economic growth impacts) are significantly affected. Uncertainty in the research regarding the quantity of product placed on market and the (long term) price differential between paper and EPS products were identified as the key determinants of the differences.

Table 21: Cumulative range estimates, Difference – Ban over No Ban, impact estimates for all products combined; absolute values in central, lower and upper estimates, NPV 2020 to 2029 (£m), and % change on central values in lower and upper estimates

	Central (£m)	Lower (£m)	Upper (£m)	Lower - % change from central estimate	Upper - % change from central estimate
Financial costs to the economy					
Regulatory implementation cost	1.4	1.4	1.4	none	negligible
Business implementation cost	3.9	3.9	1.3	none	-66%
One-off capital investment	116.0	116.0	61.0	none	-47%
Waste treatment cost	4.5	2.5	3.0	-44%	-33%
Local Authority clean-up cost	-1.8	-0.4	-3.2	+76%	-71%
Cost to fishing industry	-0.8	-0.2	-1.4	+76%	-71%
Economic growth impacts					
Sales value	262.0	147.0	175.0	-44%	-33%
Revenues to UK manufacturing	138.0	77.7	14.5	-44%	-90%
Environmental and social impacts					
UK - Value of traded CO2e	-3.5	-2.0	-2.5	+44%	+28%
UK - Value of non-traded CO2e	0.7	0.4	-0.5	-44%	-176%
EU - Value of traded CO2e	-0.1	-0.1	0.4	+44%	+546%
EU - Value of non-traded CO2e	negligible	negligible	negligible	-44%	-35%
RoW - Value of CO2e	-0.2	-0.1	0.4	+44%	+339%
Terrestrial litter visual disamenity	none	none	none	none	none
Beach litter visual disamenity	-42.0	-7.2	-93.1	+83%	-122%

Because many of the sensitivities are cumulative (the uncertainties are multiplied together e.g. sales units, price), this represents a very broad lower and upper range. In reality, it is likely each of the 8 sensitivities examined will not all act at the same time or the same direction – they may be cancelled out by each other tending towards the central estimate.

The impacts of individual sensitivities are:

- Sales units, price and weight – these have widespread effects across many impacts

- Speed of market shift – these particularly affects sales revenue, revenues to UK manufacturing and environmental impacts
- Visual disamenity value - terrestrial and beach litter – affect terrestrial litter impacts in particular
- % imports – have a pronounced effect on the UK manufacturing sales revenue and the balance of traded sector carbon emissions between the UK, EU and rest of the world
- Items littered – demonstrate the level of uncertainty around marine litter impacts.

The cumulative sensitivity analysis appears to produce a pronounced effect in terms of percentage change on the carbon impacts (though these are relatively low in absolute terms), predominantly due to uncertainty around whether UK manufacturing will respond by producing paper alternative products to meet new demand or whether these will continue to be imported. The different is striking because the convention is different for reporting traded and non-traded carbon.

The lower and upper estimates by product are presented in Appendix A.4, with the same trend observed for each of the products. No single product stands out as being more impactful across the main areas investigated.

5 Discussion

5.1 Overall findings

A preliminary assessment of the impacts and the possible consequences of a legislative ban for EPS food and beverage containers is provided in this research. The research has identified a gap in the publicly available market information for the products being researched. Through evidence review and the engagement of a sample of stakeholders, relevant information about the products and their markets was gathered for the research. The quantitative modelling undertaken for the research filled some of the remaining gaps with logical and plausible assumptions.

Overall, the findings of the research are supportive of a legislative ban for EPS food and beverage containers.

5.1.1 Quantitative impacts

The quantitative modelling, carried out under the assumptions we have made, indicates that a ban would be likely to have benefits in terms of a desired reduction in the use of single-use plastics. Alternatives to EPS would still be littered under a ban, but environmental impact would be reduced and this would be likely to be done at relatively low negative economic impacts.

The alternatives to EPS would be costlier and would affect sales revenues, at least in the short term, representing a cost to internalise the market failure, which itself is distributed to consumers. In time, the difference in unit costs can be expected to reduce due to economies of scale as the production and supply of alternative products in scale.

The research identifies that a reduction in the use of EPS would be likely to reduce beach litter disamenity impacts and emphasises that these benefits could be greater still due to limitations in the methodology for monetising these types of impacts and allocating them to different types of products. The research also suggests there are other terrestrial and marine litter reduction impacts which may be significant, which cannot readily be quantified such as effects on wildlife, fisheries and social wellbeing associated with knowing the environment is cleaner.

The sensitivity analysis around the central estimate confirms that costs and benefits and the differences between scenarios are still likely to be modest in scale when data and model uncertainties are accounted for. If the impact of a ban was felt earlier and deeper, then the benefits of a ban would be even greater. If the ban affected and reduced overall product sales then the ban would reduce both benefits and costs, but would still change the market at modest cost.

5.1.2 Qualitative impacts

Since the quantitative costs and benefits of a ban are predicted to be relatively modest, the qualitative findings of the research are perhaps an important determinant for a ban and must be considered carefully.

A ban would contribute to a reduction in the volume of plastics littered terrestrially in England and associated litter on the beaches and coasts. If EPS products are replaced with alternatives to EPS then quantities of products littered would not be reduced (because behaviours are not changed). But it is likely that the presence terrestrial, beach and marine litter will be reduced as these alternatives decompose faster. Research is needed on how much quicker this litter would degrade and be reduced from accumulating on land and beaches given terrestrial and beach litter cleaning activity.

The ban would be likely to bring about market change earlier and more deeply amongst the researched products than voluntary measures alone. It would contribute to UK and EU policy objectives and would be likely to satisfy some of the public's current appetite for action on plastics waste. A ban would be an opportunity for the English government to show leadership in this field and would be likely to encourage innovation, strengthen markets for alternatives and help the business case for investment in the UK in production and refillable packaging systems. Essentially, the ban would help address the significant plastic litter market failure, improving the environment, reducing damage to wildlife and mitigating a range of externality costs associated with litter.

The research has indicated that leading foodservice businesses have already reduced their use of EPS. Hence a ban would be likely to be supported by these businesses. Since the large takeaway retailers and events have already switched away from EPS it is expected that the shift to non-EPS alternatives in the SME market could also be achieved at relatively low business and regulatory cost. Non-EPS alternatives are already present and readily available in large businesses and are being promoted and used. A ban could help convert virtuous intentions into behaviours and level the playing field for business, ensuring implementation amongst smaller players in the market and consistent implementation across, for example, large franchised organisations.

However, a number of potentially significant risks are raised in this research. In particular, the ban may be considered by small businesses as inequitable since it would principally affect SMEs and their customers, potentially from less affluent backgrounds. The government might prepare such companies through taking additional care in the form of communicating the ban and the reasons for it, and supporting the development of guidance regarding limiting overall consumption and choosing alternatives to EPS.

Another significant uncertainty is whether and how the UK-based supply chain will respond to the ban in terms of producing and supplying the necessary alternatives to EPS. Will manufacturers and recyclers be able to make the business case for new investment in the UK, especially in the context of uncertainty around Brexit? In addition to the loss of UK-based EPS foodservice packaging manufacturing expertise, a risk exists that the necessary investment for alternatives to EPS could be made elsewhere. The UK would lose out from the value added of having the supply chain within the country. A precedent exists for paper coffee cups, where UK investment has been seen, as well recent investment in recycling collections and reprocessing. An early signal from the government on supporting a ban would help to provide surety needed for investment.

Another risk concerning imports is over the nature of the additional regulatory controls which would be necessary to regulate a ban to ensure that imports and online sales of alternatives were actually EPS-free and suitable for food contact. Some risks and views were highlighted by stakeholders during the research for all the main types of packaging materials.

Regards product functionality the view from stakeholders was that EPS provides high quality product performance at low cost, but that alternatives were available and suitable for the majority of applications. Any concerns about the acceptance and acceptability of alternatives to EPS in specific use contexts would presumably be identified in any forthcoming formal government consultation.

5.2 Legislation for implementation of new ban

The nature of the legislation required for bans on single-use plastic items has been discussed at length in previous research for Defra on bans for plastic-stemmed cotton buds, plastic straws and plastic stirrers[94].

Evidently careful phrasing of technical legal requirements in a legislative ban is advised to ensure the desired outcomes. Specifically, in this research it was identified that whilst the SUP directive covers *expanded* polystyrene, it may not, technically, cover *extruded* polystyrene. The Directive does not explicitly include extruded polystyrene. However, the view we have adopted during this research is that, extruded polystyrene has a similar use and function to expanded polystyrene and has similar environmental impacts as well. The same type of environmental risk (litter, disintegration into macro and microplastics and their persistence in the environment) exists for each type of polystyrene. Not including XPS might also mean that there potentially could be a shift from EPS to XPS, therefore for the purposes of this research XPS has been included. In the authors' view each type should be included within the scope of a ban. The European Commission may wish to consider this issue in further guidance on the directive which is due to be published in July 2020.

Moreover, since the ban would only apply to EPS, Defra may wish to consider preventing other types of alternatives with environmental risks being developed in its place. For example, expanded polymers such as Expanded Polypropylene, which may pose similar environment impacts. Furthermore, since a ban on EPS would not preclude other plastics, the government may wish to use phrasing in any legislation to prevent single use plastic alternatives for these products being used which themselves cause greater environmental damage. For example, single use unexpanded plastic alternatives would also not be permitted in a ban, permitting only durable plastic alternatives that for use in reusable/refillable contexts.

[94] Defra (2018) A preliminary assessment of the economic, environmental and social impacts of a potential ban on plastic straws, plastic stem cotton buds and plastics drinks stirrers. Research by Resource Futures, May 2018. http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=20086&FromSearch=Y&Publisher=1&SearchText=eq0115&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description

Defra might also review the phraseology used within bans mentioned in the introductory section of this research or those as they are proposed in European member states and UK devolved administrations, and their timing to avoid any free market trade issues.

5.3 Complementary/alternative measures

Consumer behaviour is a recurrent theme in the research and it is consumers and organisations' behaviours which ultimately determine how much single-use product is consumed and whether it is littered. Prevention is generally considered better than cure and reducing the unnecessary use of disposable products and promoting good disposal practices which prevent littering behaviours are desired policy outcomes. For instance, the Government's Environment, Food and Rural Affairs committee on packaging recently concluded that "*reduction is the most important way to reduce waste, and greater efforts need to be put into this. A fundamental shift away from all single use food and drink packaging, plastic or otherwise, is vital for the future protection of the environment*"[95]

Whilst a legislative ban would significantly reduce foodservice packaging made from EPS it will not necessarily cause businesses to reduce the overall quantity of packaging they require, how this is provided and from where it is sourced. Modelling was undertaken in this research to account for uncertainty on sales growth since it is not known what effect a ban might have with regards to reducing the overall use of packaging. Our central analysis assumes a like-for-like replacement of EPS with replacement materials, with sensitivity analysis showing a Ban could have a signalling effect in terms of reduction over a No Ban. Guidance from trade associations could help their members reflect on the necessity of single-use packaging in their businesses and help with choosing cost-effective and sustainable alternatives.

Discussion from some stakeholders also concerned changing consumer behaviours on littering measures. A ban will not reduce the quantity of items littered. Nudging towards positive behaviours and anti-littering measures (e.g. enforcement of on-the-spot fines) are relevant here. Several stakeholders felt improved recycling infrastructure for on-the-go products in public places or around local littering hotspots could help enable better behaviours and reduce litter. Here, product recycling labelling, proposed deposit return collections and refillable deposit systems for packaging could help promote good behaviours.

5.4 Next steps

5.4.1 Further discussion / direction

This research is strategic and is at the preliminary stage. It is intended to help inform the Government's next stage decision on whether to pursue a legislative ban for the researched products.

The research findings are clear:

A significant quantity of single-use food and beverage containers made from EPS are used each year and our research discussions with a sample of stakeholders indicate that a ban to restrict their use is feasible. The ban would help address a market failure and would promote action on the problematic use of this type plastic in the foodservice use context. A ban would be likely to bring forward market change and harmonise the market at reasonably low cost. Since most large foodservice businesses and events have already voluntarily switched away from EPS, it figures remaining small and medium-sized business would also be

[95] https://publications.parliament.uk/pa/cm201719/cmselect/cmenvfru/2080/208008.htm

able to readily shift away from EPS if encouraged to do so. The research indicates the market shift would come earlier and be more complete if the sector was compelled to make the shift rather than left to adopt the position voluntarily.

Regardless of whether implementing a ban is preferred, complementary/alternative measures can be progressed and trialled. Making single-use packaging less available to the consumer may be possible for some operators. For example, asking customers if they have brought their own cups and changing the culture of handing out receptacles could encourage customers to use less single-use packaging, as could instituting innovative reusable and refillable packaging systems within their businesses. Care should be taken to mitigate any potential additional impacts (environmental and inconvenience) associated with any corresponding reduction in product use and increase in reusables.

Further consultation is recommended for all the products because our research is preliminary, and our discussions were only with a sample of stakeholders representing the market. Any legislative ban for these products should be coordinated with other potential bans or measures for different types of single-use plastic products. In the interim ahead of any intervention, complementary and alternative measures can be encouraged.

5.4.2 Information gaps and further research

Appendix A.3 provides a list of the information gaps and further research which could ideally be addressed ahead of a ban proposal. Notably, further consumer market research and modelling is suggested regarding the size of the impacts associated with an overall reduction in product use and an increase in the use of reusables. Further research is also suggested on behavioural change around littering behaviours.
As is being done in Scotland[96], it is suggested Defra could work with an industry steering group to seek to overcome such needs and provide an implementation path, gathering further required evidence/primary data.

[96] https://beta.gov.scot/publications/stemming-the-plastic-tide-ministers-statement/

Appendices

A.1 Modelling and calculations

This appendix outlines the impact model developed for the research and provides an overview of its calculations.

A description of the modelling process is illustrated again here in Figure 14. The number of product sales was estimated in future years under Ban and No Ban scenarios. This was used to estimate the tonnes of products sold, which in turn was used to estimate other impacts. The economic and environmental impacts associated with production, waste management and littering of each item were estimated per tonne of product sold.

The scope of the model was focussed on single-use products and does not include the impacts associated with reusable products, or indeed the reuse of single-use products e.g. washing of items. The impacts calculated are based on current processes which have not, for example, been modified in future years to account for changes in production processes or decarbonisation of the electricity grid and transport.

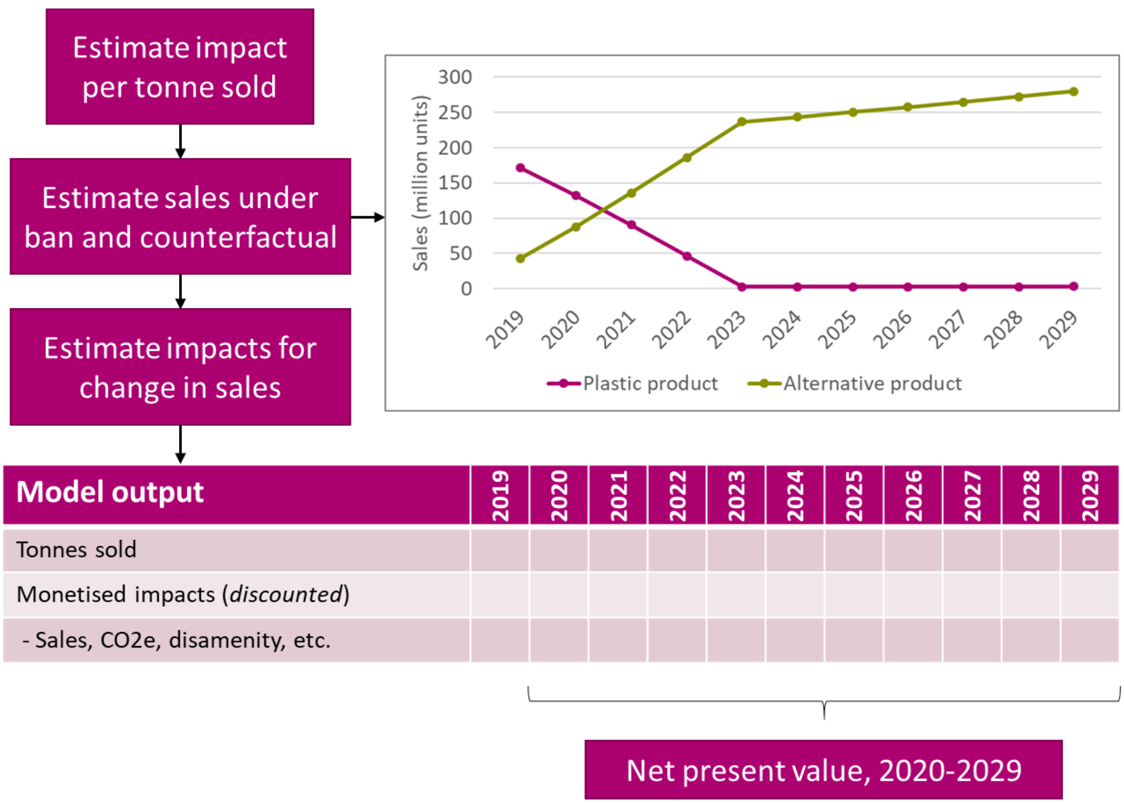

Figure 14: Description of the main structure and calculations in the model

In terms of model's scope, the economic impact assessment was guided by HM Treasury's Green Book Appraisal Guidance[97]. It focussed on the direct economic impacts to the UK, i.e. the effects on English-

[97] https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent

based manufacturers, wholesalers and retailers, and did not include impacts on 'rest of the world' businesses. Figure 15 shows how economic impacts were estimated for retail/wholesale and manufacturing. The value to retail/wholesale is estimated by deducting VAT where appropriate and assumes that two thirds of revenues are passed on to manufacturing.

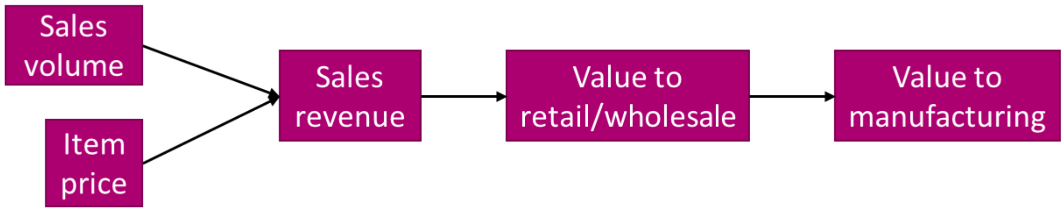

Figure 15: Description of the calculated economic impacts to retail/wholesale and manufacturing

The estimates covered the costs of readily quantifiable direct and indirect costs associated with waste management and littering. Indicative environmental impacts were calculated for 'carbon' associated with production of materials and the disposal of products. These were classified into traded and non-traded carbon and according to their geographical origin by world region. Fossil GHGs associated with combustion of fossil carbon in plastic are included in the assessment. The carbon impacts associated with transport are not estimated in the model. These are assumed to be the same for plastic and non-plastic products.

Quantifiable social costs were also examined. These included the change in household expenditure (i.e. sales value/cost) and the visual disamenity costs associated with terrestrial and beach litter, the latter estimated from secondary Willingness to Pay studies.

It is noted that the model assumes a reduction in sales volume due to a growing trend away from single-use products and 'avoidable plastics', and a further reduction under a Ban due to the 'signalling effect' raising public awareness of the issue for the specific products in question. These market changes are likely to reduce overall consumption and also likely to increase demand for reusable products, the sales and impacts of which have not been included in this model. This is discussed further in Section 4.7.1, and recommendations are made for further research in this area.

A simple modelling approach was taken for indirect impacts. For example, potential rebound effects associated with changes in consumption were not considered. Externality costs, for example placed on the tourism sector, were embodied within the visual disamenity cost.

Figure 16 shows how the tonnes of product sold were used to estimate the greenhouse gas (GHG) emissions associated with production of the goods and waste management, as well as the costs of waste management.

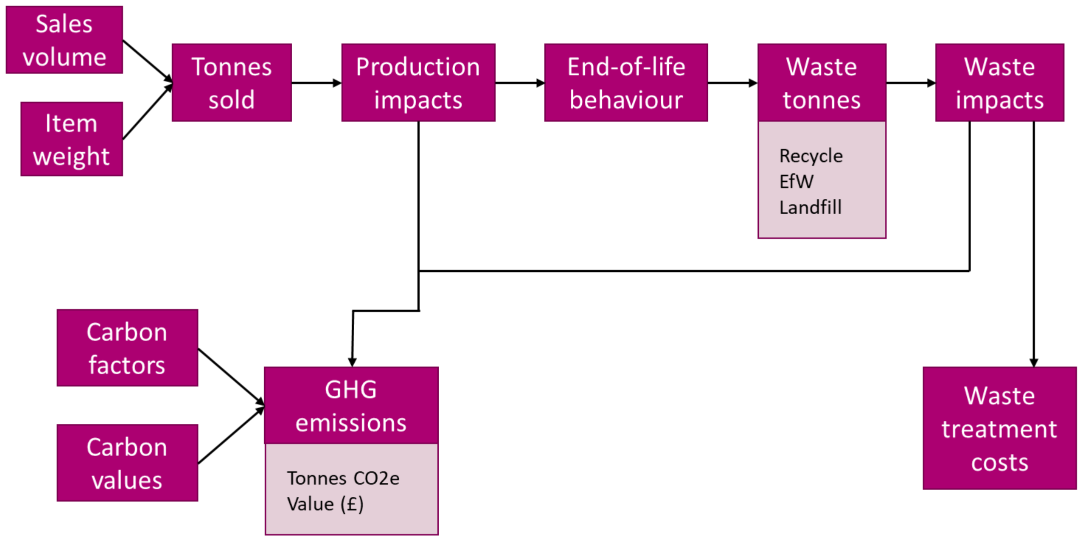

Figure 16: Description of the calculated production and waste management impacts

Figure 17 illustrates how the impacts of terrestrial and beach litter were estimated. Since beach litter visual disamenity effects are presence, costs were allocated to each type of product based on their prevalence in beach litter counts and composition data.

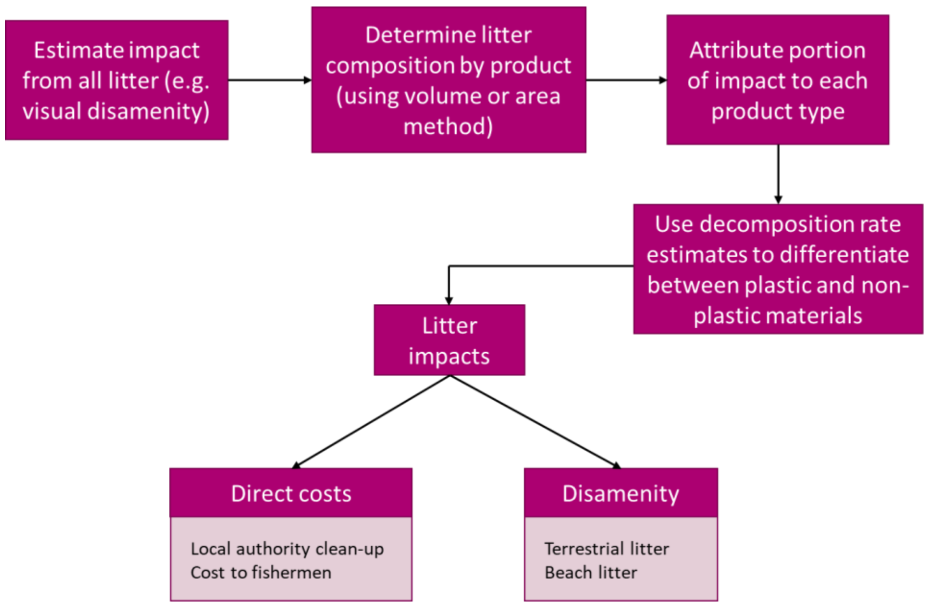

Figure 17: Description of the calculated litter impacts

Key data and uncertainties

The main data and assumptions used in the model and the uncertainties associated with each of them are presented in Table 22 below.

Table 22: Overview of data sources used in the model

Data / assumption	Sources	Level of uncertainty
Baseline sales volume for products	Based on consumption data reported by large companies/estimates for market share, or associated items, e.g. coffee cups/ 'bottom-up' estimates based on likely behaviours.	Medium uncertainty
Speed of market change	Based on research insight gained on degree of voluntary change and speed of previous bans/proxy policies and through stakeholder interviews	Medium-high uncertainty
Effect of measure on total product sales over plan period	Based on insights from stakeholders. Ban and relative price difference may have signalling effect and reduce consumption	Medium-high uncertainty
Littering and waste management	Mix of data on effectiveness of capture of litter and assumed consumer behaviours at each stage of pathway.	Medium-high uncertainty
Item price and weight	Spot values from main manufacturers and from wholesale and retail websites. Direct alternative products were not found for small beverage carton straws or medical-enabling straws.	Medium uncertainty
Terrestrial and Beach Litter Impacts	From historical, published research studies. KBT (2014) Exploring the Indirect Costs of Litter in England. Eftec (2002) Valuation of Benefits to England and Wales of a Revised Bathing Water Quality Directive and Other Beach Characteristics Using the Choice Experiment Methodology. Methodology underpinning each were examined.	Medium uncertainty
Business and regulatory costs	Default/proxy costs informed by costs from impact assessments for bans for Microbeads and an assessment for introducing open scope categorisation for waste electrical and electronic equipment (WEEE), and they include annual cost and one-off costs over the period.	Low uncertainty/low significance

Data / assumption	Sources	Level of uncertainty
Carbon emission factors	UK Government GHG Conversion Factors for Company Reporting, Defra/DECC GHG Protocol, Carbon Valuation in UK Policy Appraisal traded and non-traded prices. For the purposes of informing the policy, GHG emissions associated with the burning of fossil carbon are included and biogenic emissions resulting from biomass materials are not included.	Low uncertainty/low significance. The method is limited since it does not quantify impacts associated with transport and the impacts associated with an increase in reusables.

A.2 Record of data and assumptions

The appendix provides screenshots from the model illustrating the main data sources used to generate the central estimate.

Total market sales data was not available for each of the different types of products examined. So, estimates had to be derived from available information to provide preliminary data used to populate the model. This appendix includes discussion around some of the key sales data used for the quantitative research. Uncertainty surrounding the estimates is examined through sensitivity analysis.

Table 23: Model assumptions for baseline product sales, central estimate for England

Product	Volume (million units per annum (to 3SF)	Approximate number of units per capita per annum
Single-use EPS cups	472	8.4
Single-use EPS take-out containers and to-go boxes	176	3.1
Single-use EPS food trays and chip cones	185	3.3
Single-use EPS cups for foodstuffs	313	5.6

A ‘bottom up’ estimate was made for consumption in takeaway businesses, outdoor events, office events, restaurants and pub use, supermarket sales with on-the-go food and party /picnic use. A range of data gathered in the public domain was used to make estimates such as numbers of takeaway meals per annum, consumption at events etc and plausible use behaviours for the English population.

More research (and specifically primary data collection) is required if more precision is required with these numbers. The sensitivity analysis elsewhere in this research considers uncertainty in this number.

Table 24: Model assumptions for EPS/XPS polystyrene products (central value in brackets) [98] [99]

Product	Sales price per unit (£ incl. VAT)	Per unit weight (g)	Material
Cups	0.02-0.03 (0.03)	2.35-3.00 (2.68)	EPS
Take-Out Containers and To-Go Boxes	0.04-0.05 (0.04)	6.00-6.64 (6.32)	EPS
Food trays and chip cones	0.03-0.04 (0.03)	(7.98)	EPS
Pots used for foodstuffs	0.01-0.04 (0.02)	1.00-1.16 (1.13)	EPS

Table 25: Model assumptions for alternative products (central value in brackets)

Product	Sales price per unit (£ incl. VAT)	Per unit weight (g)	Material
Cups	0.02-0.05 (0.04)	5.10-7.90 (6.50)	Paper/board
Take-out containers and To-go boxes	0.14-0.15 (0.14)	19.00-36.50 (27.75)	Paper/board
Food trays and chip cones	(0.07)	(16.00)	Paper/board
Pots used for foodstuffs	0.05-0.06 (0.06)	(6.00)	Paper/board

Widely used estimates of decomposition rates for common types of marine debris are shown in Table 26. The alternative products that would replace plastic are made from paper, reducing the decomposition period from tens or even hundreds of years to a matter of weeks or months.

Table 26: Decomposition rates for common types of marine debris [100]

[98] Informed by costs obtained from https://www.catering24.co.uk ; https://www.cater4you.co.uk ; and stakeholder interviews
[99] Informed by weights obtained from https://www.aqua-calc.com/calculate/volume-to-weight
[100] Talking trash & taking action, Ocean Conservancy & NOAA Marine Debris, https://marinedebris.noaa.gov/sites/default/files/publications-files/talking-trash-educational.pdf. Note that these values have not been verified. We were unable to find the original source of this data table online, and so we cannot be certain it is from a study by the US EPA, nor can we check the methods used to estimate the decomposition rates. As noted in the footnote to the table, decomposition rates for plastics are estimates only. Actual decomposition rates cannot have been measured yet as the polymers used in these products have been used in manufacturing for less time than the decomposition rates shown. ‘Wax carton’ is thought to refer to a Tetra Pak-style container of card with laminates of plastic film and aluminium.

Item	Decomposition rate
Paper towel	2-4 weeks
Newspaper	6 weeks
Wax carton	3 months
Plywood	1-3 years
Plastic grocery bag	10-20 years*
Styrofoam cup	50 years*
Plastic beverage bottle	450 years*
Fishing line	600 years*
Apple core	2 months

* NOAA comments: Many scientists believe plastics never entirely go away. These decomposition rates are estimates for the time it takes for these items to become microscopic and no longer be visible. Sources: EPA, Woods Hole Sea Grant

The model assumptions for how the products are disposed of and treated in waste management and litter terms is outlined in Table 22. We identified no composition or behaviour data for the specific products. Our rationale for the recycling rate used is that because the products are low weight/low value/high contamination there will be a low percentage recycled. The EfW and landfill estimates are based on the national statistics for local authority waste[101] after taking account of recycling and litter estimates.

Table 27: All products – waste management and litter end point model assumptions

	Plastic	Paper
Recycle	0%	10%
EfW	77%	61%
Landfill	23%	18%
Commercial composting	0%	10%
Terrestrial litter	0.5%	0.5%
Beach litter	0.000500%	0.000005%
Total	100%	100%

The litter values shown in the tables above are primarily used for mass-balance purposes for estimating waste management impacts. However, the difference between the plastic and non-plastic values encapsulates the decomposition assumptions, which is transferred to the litter impact estimates. Table 28: Rationale for plastic vs. non-plastic litter assumptions incorporating decomposition rates details how the decomposition rates are incorporated into the model assumptions for the percentage of the product placed on the market (P.O.M.) that is found in litter.

[101] Defra (2018) Statistics on waste managed by local authorities in England in 2017/18. Table 2 Management of all Local Authority collected waste financial year figures in England 2012/13 to 2017/18, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/763191/LACW_mgt_annual_Stats_Notice_Dec_2018.pdf

Table 28: Rationale for plastic vs. non-plastic litter assumptions incorporating decomposition rates

Product	% plastic product P.O.M. found in litter	% non-plastic product P.O.M. found in litter	Rationale	Calculation
All products, terrestrial litter	0.5%	0.5%	We assume that terrestrial litter is typically cleaned up before these products can decompose significantly. The model values are therefore the same for plastic and non-plastic products.	N/A
All products, marine litter	0.000500%	0.000005%	**Table 5** suggests plastic decomposition rates in the order of tens or even hundreds of years compared to timescales of weeks or months for paper. We conservatively assume plastic products decompose 100 times slower than paper.	0.000500% * 1% = 0.000005%

Understanding of litter pathways reveals that some terrestrial litter is transferred to beaches and the marine environment, e.g. via storm drains, and so should be counted in both terrestrial and beach litter estimates. This pathway has not been quantified in the research and is likely to be well within the margin of error of the estimates used in the model, and so it is not separately included below. As such the waste management and litter end point assumptions sum to 100% for simplicity in mass-balance calculations.

A review of the research into the costs of terrestrial and beach litter is presented in Defra's preliminary research on the economic impacts of a proposed ban on plastic straws, drink stirrers and plastic-stemmed cotton buds[102]. This research is used to inform the visual disamenity impact estimates.

[102] Defra (2018) A preliminary assessment of the economic, environmental and social impacts of a potential ban on plastic straws, plastic stem cotton buds and plastics drinks stirrers. Research by Resource Futures, May 2018. http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=20086&FromSearch=Y&Publisher=1&SearchText=eq0115&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description

Economic data used for estimates

Product data used in the assessment (for England)

	Total market - Baseline			Plastic product				
	Million units p.a.	Baseline plastic share	Proportion domestic B2C	Million units p.a.	Per unit weight (g)	of which is plastic component that will be switched with alternative	Material	Sales price per unit, incl. VAT (£)
Food boxes	220	80%	1%	176	6.32	100%	EPS	0.0400
Trays	232	80%	1%	185	7.98	100%	EPS	0.0300
Cups	589	80%	1%	472	2.68	100%	EPS	0.0300
Pots	391	80%	1%	313	1.13	100%	EPS	0.0200
				Alternative product				
				Million units p.a.	per unit weight (g)	of which is alternative	Material	Sales price per unit, incl. VAT (£)
English population (million)	55.98		Food boxes	44	27.75	100%	Paper	0.1400
Ratio English to UK populatic	84%		Trays	46	16.00	100%	Paper	0.0700
			Cups	118	6.5	100%	Paper	0.0400
			Pots	78	6.00	100%	Paper	0.0600

Changes in the market under each of the scenarios

B. Scenario data			2019	2020	2021	2022	2023
		Linear drop in % share each year	**Baseline**	**Year 0**	**Year 1**	**Year 2**	**Year 3**
Food boxes	Plastic share - ban	20.0%	80%	60.0%	40.0%	20.0%	1.0%
Trays	Plastic share - ban	20.0%	80%	60.0%	40.0%	20.0%	1.0%
Cups	Plastic share - ban	20.0%	80%	60.0%	40.0%	20.0%	1.0%
Pots	Plastic share - ban	20.0%	80%	60.0%	40.0%	20.0%	1.0%
Blank - Not used	Plastic share - ban	0.0%	0%	1.0%	1.0%	1.0%	1.0%
Blank - Not used	Plastic share - ban	0.0%	0%	1.0%	1.0%	1.0%	1.0%
Food boxes	Plastic share - no ban	1.0%	80%	79.0%	78.0%	77.0%	76.0%
Trays	Plastic share - no ban	1.0%	80%	79.0%	78.0%	77.0%	76.0%
Cups	Plastic share - no ban	1.0%	80%	79.0%	78.0%	77.0%	76.0%
Pots	Plastic share - no ban	1.0%	80%	79.0%	78.0%	77.0%	76.0%
Blank - Not used	Plastic share - no ban	0.0%	0%	10.0%	10.0%	10.0%	10.0%
Blank - Not used	Plastic share - no ban	0.0%	0%	10.0%	10.0%	10.0%	10.0%
Ban - Product growth/reduction	3%	* see comment below		Proportion of single-use product market that is imports	Proportion of imports of single-use products produced in the EU		
No ban - Product growth/reduction	3%	** see comment below	EPS	5%	20%		
			Paper	5%	50%		
			Wood				

** <u>comment on 3% 'Ban' scenario growth figure</u>: "Assume no signalling effect for EPS containers modelled, so same growth rate as No Ban scenario"*

***<u>comment on 3% 'No Ban' scenario growth figure</u>: "Assume growth continues at same rate given in Just Eat report[103]: spending on takeaways increased from 7.4 £bn in 2009 to £9.9bn in 2016, roughly 3% p.a. after adjusting for inflation"*

103 https://jeweb-11431-s3.s3.eu-west-2.amazonaws.com/application/files/2215/0045/3682/TAKEAWAY_ECONOMY_REPORT_2017.pdf

End of life management assumptions

Consumed/disposed	EPS food/bev packaging	Paper food/bev packagin
Recycle	0.00%	10.00%
EfW	76.74%	61.32%
Landfill	22.76%	18.18%
Commercial composting	0.00%	10.00%
Terrestrial litter	0.50%	0.50%
Beach litter	0.0005%	0.000005%
Total	100%	100%

Example assumptions held in model - litter

Composition of litter (estimates)

	Central value	
	Terrestrial litter	Beach litter
Food boxes	0.43%	0.74%
Trays	0.43%	0.74%
Cups	0.14%	0.24%
Pots	0.05%	0.08%

A.3 List of information gaps and further research

This appendix provides a list of the data gaps and suggested further research actions.

Table 29: Data gaps/further research needs

Data gap/uncertainty	Further research needs
Improved estimates for the starting volume of products to improve precision of the impact modelling	Primary market research/questionnaire regarding procurement of the products in each of the submarkets and particularly for importers.
Confirmation of impact assessment variables – implementation costs, necessary exemptions and lead-in times, pace of market transition, depth of market change, understanding supplementary/alternative measures	Formal consultation and steering/consultation group to review the research findings and assumptions.
Improved knowledge of predominant waste management, littering behaviours and pathways to marine litter for single-use plastics and their alternatives	Consumer insights research around littering behaviours and reduction for different types of single-use plastics and packaging. Mass flow (Sankey) estimates by product type for disposal and littering routes.
Improved understanding of decomposition rates of products and materials	More robust data on decomposition rates is needed as this is a key determinant of the marine litter impacts. This study draws upon a widely used table of decomposition rates, but the values were not verified as the original source of the data could not be found.
Signalling effect of a ban on overall consumption and the shift to reusables	Determine if the effect of such a ban has been evidenced quantitatively in a related context and how this impacted on reducing consumption. For example, analysis of data on consumer demand for reusable systems such as market interest in refillable packaging systems.

Data gap/uncertainty	Further research needs
Price elasticity of supply and demand / effects of voluntary reduction scenarios	Manufacturer and other stakeholder consultations/questionnaires to establish whether increased unit costs for non-plastic products would be short-lived or long term. Consumer surveys (of both businesses and domestic consumers) to assess buyer/consumer attitudes to potential new materials and reusables, and how these would affect demand. What reduction in products is possible through reduced use behaviours in this sector? Further modelling/sensitivity analysis research could indicate the potential impacts in the scenarios.
Comparative environmental life cycle assessments regards single-use products and alternatives for EPS products, compared with reusables such metals, ceramics and rigid plastic.	Detailed review of current life cycle research. Call for evidence encouraging main producers to provide multi-impact comparative product LCAs (carbon and other eco-toxicological consequences) which ensure biodegradation and low overall environmental outcomes. For reusable items, identify critical determinants of whether reusable product conveys environmental advantage over single-use products (e.g. how many times reused, user behaviours such as the resource intensity of cleaning, return transport and how durable does a product need to be for it to be classed in a standard as 'reusable').
Valuing the costs and impacts of marine litter – direct costs, externalities and disamenity	Detailed literature review and compilation of data estimates to a structured approach to cover market and non-market costs such as disamenity and avoid any double counting. New primary 'Willingness to pay' research may be relevant for England (We note Defra has commissioned such research and Scotland has commissioned social research on attitudes in Scotland on the marine environment and marine issues).

Data gap/uncertainty	Further research needs
Evidence on which sizes and types of marine debris are most environmentally and socially significant – volume, size or count-based allocation	Which types of marine litter are most visible/socially undesirable? How robust is the evidence-base on marine litter disamenity? Which size plastic objects are most deleterious to the marine supply chain and to higher forms of marine life` e.g. in terms on ingestion and chemical migrations? We note Defra has commissioned new primary willingness to pay research at the product level. Research into decomposition rates of laminated materials in the terrestrial and marine environment.
Evidence of causality / the impact of bans in UK waters	To strengthen the evidence-base for bans counts of single-use items such as carrier bags and comparison of the presence of Microbeads pre and post ban.
Further consumer research on public support for bans and complementary and alternative measures on single-use items	To confirm public attitude towards bans for the specific products in this research relative to other types of interventions/behaviours.
Examine the drafting of relevant legislation and the success of its implementation	Review international legislation, regulatory impact assessment and practices/the consequences of restrictions.

A.4 Sensitivity analysis by product

These tables show sensitivity analyses for each product. Table 30 to Table 34 show the central and lower estimates for an overall reduction in consumption for each of the products.

Table 30: Beverage cups – market size reduction with signalling effect and price differential in Ban scenario, financial impact estimates, NPV 2020 to 2029 (£m)

	Central (£m)	Lower (£m)	Lower - % change from central estimate
Financial costs to the economy			
Regulatory implementation cost	0.6	0.6	0%
Business implementation cost	1.6	1.6	0%
One-off capital investment	47.7	47.7	0%
Waste treatment cost	0.9	0.6	+31%
Local Authority clean-up cost	-0.2	-0.5	-118%
Cost to fishing industry	-0.1	-0.1	+17%
Economic growth impacts			
Sales value	29.2	16.1	+45%
Revenues to UK manufacturing	15.4	8.5	+45%
Environmental and social impacts			
UK - Value of traded CO2e	-1.3	-1.1	+15%
UK - Value of non-traded CO2e	0.2	0.1	+34%
EU - Value of traded CO2e	0.0	0.0	+16%
EU - Value of non-traded CO2e	0.0	0.0	+29%
RoW - Value of CO2e	-0.1	0.0	+18%
Terrestrial litter visual disamenity	0.0	-1.5	0%
Beach litter visual disamenity	-5.6	-4.6	+17%

Table 31: Take-out containers and to-go boxes – market size reduction with signalling effect and price differential in Ban scenario, financial impact estimates, NPV 2020 to 2029 (£m)

	Central (£m)	Lower (£m)	Lower - % change from central estimate
Financial costs to the economy			
Regulatory implementation cost	0.2	0.2	0%
Business implementation cost	0.6	0.6	0%
One-off capital investment	17.8	17.8	0%
Waste treatment cost	2.1	1.5	+27%
Local Authority clean-up cost	-0.8	-1.6	-118%
Cost to fishing industry	-0.3	-0.3	+17%
Economic growth impacts			
Sales value	109.2	79.6	+27%
Revenues to UK manufacturing	57.6	42.0	+27%
Environmental and social impacts			
UK - Value of traded CO2e	-0.5	-0.5	-1%
UK - Value of non-traded CO2e	0.3	0.2	+33%
EU - Value of traded CO2e	0.0	0.0	+6%
EU - Value of non-traded CO2e	0.0	0.0	+27%
RoW - Value of CO2e	0.0	0.0	+14%
Terrestrial litter visual disamenity	0.0	-4.7	0%
Beach litter visual disamenity	-17.3	-14.3	+17%

Table 32: Food trays and chip cones – market size reduction with signalling effect and price differential in Ban scenario, financial impact estimates, NPV 2020 to 2029 (£m)

	Central (£m)	Lower (£m)	Lower - % change from central estimate
Financial costs to the economy			
Regulatory implementation cost	0.2	0.2	0%
Business implementation cost	0.6	0.6	0%
One-off capital investment	18.7	18.7	0%
Waste treatment cost	0.7	0.5	+34%
Local Authority clean-up cost	-0.8	-1.6	-118%
Cost to fishing industry	-0.3	-0.3	+17%
Economic growth impacts			
Sales value	45.9	32.3	+29%
Revenues to UK manufacturing	24.2	17.1	+29%
Environmental and social impacts			
UK - Value of traded CO2e	-1.7	-1.4	+16%
UK - Value of non-traded CO2e	0.1	0.1	+34%
EU - Value of traded CO2e	0.0	0.0	+17%
EU - Value of non-traded CO2e	0.0	0.0	+31%
RoW - Value of CO2e	-0.1	-0.1	+18%
Terrestrial litter visual disamenity	0.0	-4.7	n/a
Beach litter visual disamenity	-17.3	-14.3	+17%

Table 33: Pots – market size reduction with signalling effect and price differential in Ban scenario, financial impact estimates, NPV 2020 to 2029 (£m)

	Central (£m)	Lower (£m)	Lower - % change from central estimate
Financial costs to the economy			
Regulatory implementation cost	0.4	0.4	0%
Business implementation cost	1.1	1.1	0%
One-off capital investment	31.6	31.6	0%
Waste treatment cost	0.8	0.6	+26%
Local Authority clean-up cost	-0.1	-0.2	-118%
Cost to fishing industry	0.0	0.0	+17%
Economic growth impacts			
Sales value	77.4	55.9	+28%
Revenues to UK manufacturing	40.9	29.5	+28%
Environmental and social impacts			
UK - Value of traded CO2e	-0.1	-0.1	-43%
UK - Value of non-traded CO2e	0.1	0.1	+33%
EU - Value of traded CO2e	0.0	0.0	-9%
EU - Value of non-traded CO2e	0.0	0.0	+26%
RoW - Value of CO2e	0.0	0.0	+11%
Terrestrial litter visual disamenity	0.0	-0.5	n/a
Beach litter visual disamenity	-1.8	-1.5	+17%

Table 34 to Table 37 show the central, lower and upper estimates for sensitivities, as described in section 4.7.2, for each of the products.

Table 34: Beverage cups - Cumulative sensitivity analysis, Difference – Ban over No Ban, impact estimates; absolute values in central, lower and upper estimates, NPV 2020 to 2029 (£m), and % change on central values in lower and upper estimates

	Central (£m)	Lower (£m)	Upper (£m)	Lower - % change from central estimate	Upper - % change from central estimate
Financial costs to the economy					
Regulatory implementation cost	0.6	0.6	0.6	0%	0%
Business implementation cost	1.6	1.6	0.5	0%	+66%
One-off capital investment	47.7	47.7	25.1	0%	+47%
Waste treatment cost	0.9	0.5	0.6	+44%	+33%
Local Authority clean-up cost	-0.2	0.0	-0.4	+81%	-71%
Cost to fishing industry	-0.1	0.0	-0.2	+81%	-71%
Economic growth impacts					
Sales value	29.2	16.4	19.5	+44%	+33%
Revenues to UK manufacturing	15.4	8.7	-9.2	+44%	+160%
Environmental and social impacts					
UK - Value of traded CO2e	-1.3	-0.7	-0.8	+44%	+37%
UK - Value of non-traded CO2e	0.2	0.1	-0.1	+44%	+178%
EU - Value of traded CO2e	-0.0320	-0.0180	0.0929	+44%	+390%
EU - Value of non-traded CO2e	0.0	0.0	0.0	+44%	+35%
RoW - Value of CO2e	-0.0518	-0.0291	0.0838	+44%	+262%
Terrestrial litter visual disamenity	0.0	0.0	0.0	0%	0%
Beach litter visual disamenity	-5.6	-0.7	-12.4	+87%	-122%

Table 35: Take-out containers and to-go boxes - Cumulative range estimates, Difference – Ban over No Ban, impact estimates; absolute values in central, lower and upper estimates, NPV 2020 to 2029 (£m), and % change on central values in lower and upper estimates

	Central (£m)	Lower (£m)	Upper (£m)	Lower - % change from central estimate	Upper - % change from central estimate
Financial costs to the economy					
Regulatory implementation cost	0.2	0.2	0.2	0%	0%
Business implementation cost	0.6	0.6	0.2	0%	+66%
One-off capital investment	17.8	17.8	9.4	0%	+47%
Waste treatment cost	2.1	1.2	1.4	+44%	+33%
Local Authority clean-up cost	-0.8	-0.2	-1.3	+75%	-71%
Cost to fishing industry	-0.3	-0.1	-0.6	+75%	-71%
Economic growth impacts					
Sales value	109.2	61.4	73.1	+44%	+33%
Revenues to UK manufacturing	57.6	32.4	13.0	+44%	+77%
Environmental and social impacts					
UK - Value of traded CO2e	-0.5	-0.3	-0.6	+44%	-16%
UK - Value of non-traded CO2e	0.3	0.1	-0.2	+44%	+173%
EU - Value of traded CO2e	0.0	0.0	0.2	+44%	+1183%
EU - Value of non-traded CO2e	0.0	0.0	0.0	+44%	+35%
RoW - Value of CO2e	0.0	0.0	0.2	+44%	+570%
Terrestrial litter visual disamenity	0.0	0.0	0.0	0%	0%
Beach litter visual disamenity	-17.3	-3.0	-38.3	+82%	-122%

Table 36: Food trays and chip cones - Cumulative sensitivity analysis, Difference – Ban over No Ban, impact estimates; absolute values in central, lower and upper estimates, NPV 2020 to 2029 (£m), and % change on central values in lower and upper estimates

	Central (£m)	Lower (£m)	Upper (£m)	Lower - % change from central estimate	Upper - % change from central estimate
Financial costs to the economy					
Regulatory implementation cost	0.2	0.2	0.2	0%	0%
Business implementation cost	0.6	0.6	0.2	0%	+66%
One-off capital investment	18.7	18.7	9.9	0%	+47%
Waste treatment cost	0.7	0.4	0.5	+44%	+33%
Local Authority clean-up cost	-0.8	-0.2	-1.3	+75%	-71%
Cost to fishing industry	-0.3	-0.1	-0.6	+75%	-71%
Economic growth impacts					
Sales value	45.9	25.8	30.7	+44%	+33%
Revenues to UK manufacturing	24.2	13.6	2.8	+44%	+89%
Environmental and social impacts					
UK - Value of traded CO2e	-1.7	-0.9	-1.0	+44%	+41%
UK - Value of non-traded CO2e	0.1	0.1	-0.1	+44%	+181%
EU - Value of traded CO2e	0.0	0.0	0.1	+44%	+307%
EU - Value of non-traded CO2e	0.0	0.0	0.0	+44%	+35%
RoW - Value of CO2e	-0.1	0.0	0.1	+44%	+216%
Terrestrial litter visual disamenity	0.0	0.0	0.0	n/a	n/a
Beach litter visual disamenity	-17.3	-3.0	-38.3	+82%	-122%

Table 37: Pots - Cumulative sensitivity analysis, Difference – Ban over No Ban, impact estimates; absolute values in central, lower and upper estimates, NPV 2020 to 2029 (£m), and % change on central values in lower and upper estimates

	Central (£m)	Lower (£m)	Upper (£m)	Lower - % change from central estimate	Upper - % change from central estimate
Financial costs to the economy					
Regulatory implementation cost	0.4	0.4	0.4	0%	+0%
Business implementation cost	1.1	1.1	0.4	0%	+66%
One-off capital investment	31.6	31.6	16.7	0%	+47%
Waste treatment cost	0.8	0.5	0.6	+44%	+33%
Local Authority clean-up cost	-0.1	0.0	-0.1	+75%	-71%
Cost to fishing industry	0.0	0.0	-0.1	+75%	-71%
Economic growth impacts					
Sales value	77.4	43.6	51.8	+44%	+33%
Revenues to UK manufacturing	40.9	23.0	7.9	+44%	+81%
Environmental and social impacts					
UK - Value of traded CO2e	-0.1	0.0	-0.2	+44%	-151%
UK - Value of non-traded CO2e	0.1	0.1	-0.1	+44%	+172%
EU - Value of traded CO2e	0.0	0.0	0.1	+44%	+2327%
EU - Value of non-traded CO2e	0.0	0.0	0.0	+44%	+35%
RoW - Value of CO2e	0.0	0.0	0.1	+44%	+808%
Terrestrial litter visual disamenity	0.0	0.0	0.0	n/a	n/a
Beach litter visual disamenity	-1.8	-0.3	-4.0	+82%	-122%

Glossary

Term	Definition
Allocation/Attribution	The process of sharing out/estimation based on a relative approach e.g. allocating total UK sales of a product to England based on the relative population of each country
Bagasse	Dry pulpy fibrous residue that remains after sugarcane or sorghum stalks are crushed to extract their juice. It can be formed into packaging and other materials
Beach litter visual disamenity	The economic disadvantage/lowered amenity caused visually specifically at beaches
Bio-based/Biogenic	Products whose main constituent substance is originally derived from a recent living organism such as plant matter
Biodegradable	A substance or object of any material capable of being decomposed by bacteria or other living organisms
Bioplastic	Plastics derived from renewable biomass sources, such as vegetable fats and oils, corn starch, or microbiota or agricultural by-products
CO2e	A universal unit of measurement that allows the global warming potential of different Greenhouse Gases (GHGs) to be compared
Compostable	Is capable of decomposing back into natural elements under composting conditions. This may be under ambient environmental conditions, or under controlled composting conditions. A standard exists for the compostability of packaging (EN 13432:200) which defines requirements for disintegration and biodegradation of packaging, and limits its toxicity.
Deterministic sensitivity analysis	Analysis of how the uncertainty in the output of a mathematical model or system can be apportioned to different sources of uncertainty in its inputs. Deterministic sensitivity analysis changes one or more input parameters to determine the extent the change has an impact on the output values
Disamenity	The economic disadvantage or reduced level of amenity, for example in a place, area or job
Disutility	In economics disutility represents the dissatisfaction experienced by the consumer from a good

Term	Definition
EPS	Polystyrene is a synthetic aromatic hydrocarbon polymer made from the monomer styrene. Expanded polystyrene can be used in packaging and a range of other applications. EPS is a rigid closed-cell foam with a normal density range of 11 to 32 kg/m3 and is made of pre-expanded polystyrene beads. For the purposes of this research study, EPS also includes the variant extruded (XPS).
Fossil material/resources	Material/resources used to produce items such as products whose main constituent substance is originally derived from fossil fuels such as oil, coal and gas
Functionality	The purpose that something is designed or expected to fulfil
Lead-in time	A lead-in time is the time interval between initiation and full implementation
Life cycle assessment (LCA)	A technique to assess environmental impacts associated with all the stages of a product's life from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, disposal, re-use or recycling
Life cycle thinking	An approach which considers how an entire product or activity system impacts the environment
Net Present Value (NPV)	A measurement of worth calculated by subtracting the present values of cash outflows (including initial cost) from the present values of cash inflows over a period
Sales value	The monetary value of items sold each year excluding sales tax
Single-use plastics	Disposable plastics which are used only once before they are thrown away or recycled. These items are things like plastic bags, straws, drinks stirrers, water bottles and most food packaging.
Terrestrial litter visual disamenity	The economic disadvantage/lowered amenity caused by visual litter on land (not in the marine environment/at beaches)
Type 1 multiplier	An economic multiplier used to estimate the indirect economic benefits to the wider economy of an increase in consumption of a specific product or service. The indirect effects relate to activity in the manufacturing supply chain
Value of traded CO2e	Monetary value of greenhouse gas equivalent emissions that can be traded under the European Union Emissions Trading System
XPS	Extruded polystyrene material that can be used in packaging and other applications. XPS is expanded at point of extrusion, then thermoformed. For the purposes of this research study it is included in the Single-use plastics directive definition of expanded polystyrene.