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Expanded Polystyrene (EPS) and Extruded Polystyrene (XPS) as Food Contact Materials and Life Cycle Analyses

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This report is a comprehensive study of the policies governing EPS and XPS as Food Contact Materials, the Life Cycle Analyses literature that is available specifically relating to EPS and XPS and the extent of recycling activities for end-of-life food service packaging EPS and XPS, with a particular focus on OSPAR member countries, but also across Europe and globally.

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Glossary of Terms / Acronyms

DRS	Deposit Return System
EFSA	European Food Safety Authority
EPR	Extended Producer Responsibility
EPS	Expanded Polystyrene
EUMEPS	European Expanded Polystyrene Manufacturers Association
FDA	Food and Drugs Administration (USA)
GHG	Greenhouse Gas
GPPS	General Purpose Polystyrene

ISO	International Standardization Organisation
OSPAR	OSPAR Commission
PET	Polyethylene terephthalate
PS	Polystyrene
PVC	Polyvinyl chloride
UNEP	United Nations Environment Programme
WHO	World Health Organisation
XPS	Extruded polystyrene

1. Introduction

Expanded polystyrene (EPS) and extruded polystyrene (XPS) have been in widespread use as materials for food service packaging and as disposable food service items for several decades. The insulating properties of both materials make them suitable for keeping cold or frozen foods cold and hot food and beverages hot. The range of container types that can be made from EPS and XPS in particular, and their relative low cost compared to other material types, have led to their use across the full spectrum of food service provision. The scope of this report covers a range of areas such as the applications for which EPS and XPS food packaging are used, the regulations relating to their use as Food Contact Materials, the existence of Extended Producer Responsibility (EPR) schemes for these products at end-of-life and an examination of the extent of recycling taking place.

1.1. EPS and XPS Food Service Applications

Food service EPS and XPS containers can be used by restaurants and canteens for both on-site and takeaway dining, takeaway food services such as fish and chips shops, outdoor market stall holders, delicatessens, indoor and outdoor festivals, supermarkets and food service provision in locations such as hospitals and prisons. The applications for EPS and XPS in terms of food contact are varied and many and include:

1.1.1 Mainly EPS

- Fish-boxes for the transport of fresh and smoked fish
- Lidded and open containers for the transport of fresh fruit and vegetables

1.1.2 Mainly XPS

- Egg-cartons
- Meat / poultry / fish trays
- Containers for ice-cream
- Clam-shell containers for takeaway food / fast food – both hot and cold
- Containers for sauces

1.1.3 EPS and XPS

- Cups for beverages, both hot and cold
- Containers for sauces

These applications, with the possible exception of egg cartons, will usually lead to food and/or liquid residues in the containers once used; these residues can present challenges when trying to divert these containers towards recycling at end-of-life.

1.2. Volumes in use

In a life cycle study[1] conducted in 2018, Alejandro Gallego Schmid of the University of Manchester and his colleagues highlighted the difficulties faced in trying to estimate the number of EPS/XPS containers

[1] *Environmental impacts of takeaway food containers,* by Gallego Schmid A., Mendoza J.M.F., & Azapagic A., published by the Journal of Cleaner Production 211:417-427, November 2018, available to download at: https://www.researchgate.net/publication/329166723_Environmental_impacts_of_takeaway_food_containers

used in the European Union (EU) in any given year. Using a range of data they estimated that at least 675 million disposable EPS/XPS containers are used annually in EU Member States alone. This figure seems quite conservative, compared to other estimates (see below).

In the same paper, "Environmental impacts of takeaway food containers", written in 2019 for the Journal of Cleaner Production[2] the authors stated that one estimate for the use of "extruded polystyrene (EPS)" containers is 7.5 billion in the USA alone, which equates to 58,500 tonnes of EPS usage annually. In another article in the Green Bay Press Gazette[3], undated, Mark Walter estimates that Americans "throw away 25 billion Styrofoam coffee cups" every year, although there is no data to back up this statement.

Ian Tiseo, writing for Statista, estimates[4] that the global production *capacity* for EPS was 10.3 million metric tons in 2019 and that with three new EPS plants in the pipeline, *capacity* will grow to 10.6 million by 2024. The only figure for XPS identified for this paper was an estimate[5] of US$5.5 billion in 2019 as the value for the global market size for XPS used in the construction industry; no global figures for XPS production or consumption were identified.

In a 2020 article[6] in the New York Times, Jim Lammers, the CEO of DART Container Corporation, possibly the largest XPS container manufacturer globally, was quoted as saying that the bans introduced across the USA are having an effect on sales. Of the USD$3 billion in sales generated by the company in 2019, about 20% of that was made up of foam (likely all XPS) containers, which equates to USD$600 million in revenues; this represented zero growth in sales year-on-year. DART also has manufacturing plants in the UK and South America.

All of these estimated figures, which vary quite considerably, nonetheless indicate how popular EPS and XPS food packaging is and the challenges facing EU Member States in phasing out the use of EPS containers when EU Directive 2019/904[7], on the reduction of the impact of certain plastic products on the environment, commonly referred to as the Single-Use Plastics (SUP) Directive, comes into force.

[2] *Environmental impacts of takeaway food containers,* by Schmid, A.G., Mendoza, J.M.F., & Azapagic, A., published by the Journal of Cleaner Production 211:417-427, November 2018, available at: https://www.researchgate.net/publication/329166723_Environmental_impacts_of_takeaway_food_containers

[3] 'Recycling: Styrofoam is convenient, but not environmentally friendly', by Mark Walter, published by Green Bay Press Gazette, undated, details available at: https://eu.greenbaypressgazette.com/story/news/2018/07/09/recycling-styrofoam-convenient-but-not-environmentally-friendly-mark-walter/760169002/

[4] 'Production capacity of expandable polystyrene worldwide from 2018-2024', published by Ian Tiseo, 27 January 2021, details available at: https://www.statista.com/statistics/1063653/expandable-polystyrene-production-capacity-globally/#:~:text=Global%20production%20capacity%20of%20expandable%20polystyrene%202018%2D2024&text=The%20global%20production%20capacity%20of,million%20metric%20tons%20in%202018. Accessed February 2021.

[5] 'Extruded Polystyrene Market by Application – Global Forecast to 2024', published by Markets and Markets, available at: https://www.marketsandmarkets.com/Market-Reports/extruded-polystyrene-market-152523829.html

[6] 'Your foam coffee cup is fighting for its life', by Michael Corkery, published by the New York Times, 10 February 2020, details available at: https://www.nytimes.com/2020/02/10/business/dart-foam-recycling.html Accessed February 2021.

[7] Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019, on the reduction of the impact of certain plastic products on the environment, published by the Official Journal of the European Union, 12 June 2019, available at: https://eur-lex.europa.eu/eli/dir/2019/904/oj

1.3. Food Contact Materials

Materials and substances which are used in the production of packaging that will ultimately come into contact with any foodstuff are known as Food Contact Materials (FCMs). Due to the inherent risk posed to human health by the use of poorly designed or unsuitable food contact products, there are rules and regulations regarding the manufacture and use of FCMs.

EPS and XPS are both used in food packaging and therefore they are both FCMs. While it has been referenced in the OceanWise WP5.6 report, the term Styrofoam™ is often used, erroneously, to refer to food service items which are actually made from XPS. Styrofoam™ is a brand name owned by the Dow Chemical Company which describes the XPS it produces for use as insulation. It is never used in the manufacture of food service products or FCMs. The use of the term is particularly prevalent in the US and in the Caribbean region.

1.3.1 Food Contact Materials - EU

EU Member States transpose EU Directives and Regulations into national legislation. In the EU the rules, regarding what may be used as a material for items which are designed to come into contact with food, are contained in the Commission Regulation (EC) No 1935/2004[8] as amended by Commission Regulation (EC) No 569/2009[9]. The principle underlying the Regulation is that the material must be sufficiently inert so none of its properties are transferred into the food such that it would pose a danger to human health or a deterioration in the quality of the food itself. Notable elements of the Regulation include:

- Substances used in the manufacture of FCMs must be assessed by the European Food Safety Authority (EFSA) to determine their suitability for inclusion on the authorised list of substances;
- The importance of traceability of materials used for FCM;
- The use of recycled materials is to be encouraged, once the requirements for food and consumer safety are met;
- Plastics are among the materials which may be covered by specific measures.

Annex II of the Regulation contains the symbol that should be used to identify a FCM – shown below:

Figure 1. EU symbol for FCM

[8] Regulation (EC) No 1935/2004 of the European Parliament and of the Commission of 27 October 2004 on materials and articles intended to come into contact with food and repealing Directives 80/590/EEC and 89/109/EEC, published by the Official Journal, 13 November 2004, available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32004R1935&from=EN

[9] Regulation (EC) No 1935/2004 of the European Parliament and of the Commission of 27 October 2004 on materials and articles intended to come into contact with food and repealing Directives 80/590/EEC and 89/109/EEC, amended by Regulation (EC) No 596/2009, published by the Official Journal, 18 July 2009, available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02004R1935-20090807

This symbol, or the text "For Food Contact", must be contained in any FCM products sold in the EU unless it is clear that the product is designed for food contact, such as a piece of cutlery or the product is sold with the food, such as a take-away container[10].

In recent years, food packaging has become more complex in nature, as companies use layers of materials and composites, often plastics, to improve the shelf life of their products and their visual attraction to consumers. In light of this development, the EU implemented further legislation specifically aimed at better regulating the use of plastics as FCMs. Regulation No 10/2011[11] repealed the Commission Directive of 2002[12] which had previously legislated for the use of plastic materials as FCMs. In this later regulation, "materials and articles and parts thereof consisting exclusively of plastics" are covered and therefore both EPS and XPS food and beverage containers fall under the remit of this law. Styrene is included in Table 1 as an authorised monomer with no Specific Migration Limit (SML). Styrene is one of the main components of EPS and XPS and its use in FCM is examined in more detail further on in the report.

Another EU regulation, No 282/2008[13], covers the use of recycled plastic materials and articles as FCMs. While most of the EPS and XPS being recycled currently is destined for use in new EPS/XPS products such as insulation, or polystyrene (PS) products such as garden furniture and clothes hangers, there are projects underway to recycle waste EPS into FCMs. In order to meet with the requirements of the EU regulation, anyone attempting to recycle waste EPS or XPS products will have to demonstrate that:

- The waste EPS/XPS been recycled through an authorised and quality assured recycling process;
- The waste EPS/XPS has originated from plastic materials and articles which were manufactured in accordance with EU FCM rules;
- That the waste EPS/XPS has originated from a closed product loop, which eliminates any possibility of contamination **or** that any contamination contained has been reduced, using scientific evidence, so it does not pose a human health risk;
- That the outputs comply with the criteria established by the 2004 Regulation.

These requirements effectively rule out the recycling of post-industrial and post-consumer non-food waste EPS and XPS into FCM; the closed-loop and lack of contamination requirements would be impossible to meet, given the amount of EPS packaging in particular that emanates from outside of the EU. For example, EPS packaging that protects electronic items imported from many Asian countries may contain flame retardant, which is banned under EU rules but not elsewhere. This

[10] Food Contact Materials Regulations in the European Union: An Overview, by Chuiyan Mo, published by Compliancegate, 27 February 2020, details available at: https://www.compliancegate.com/food-contact-material-regulations-european-union/ Accessed December 2020.

[11] Commission Regulation (EU) No 20/2011 of 14 January 2011 on plastic materials and articles intended to come into contact with food, published by the Official Journal of the European Union, 15 January 2011, available at: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:012:0001:0089:EN:PDF

[12] Commission Directive 2002/72/EC of 6 August 2002, no longer in force, details available at: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32002L0072

[13] Commission Regulation (EC) No 282/2008 of 27 March 2008 on recycled plastic materials and articles intended to come into contact with food and amending Regulation (EC) No 2023/2006, published by the Official Journal of the European Union, 28 March 2008, available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008R0282&from=EN

packaging however is suitable for recycling into products like insulation. The regulations also mean that converting waste EPS and XPS into FCM is likely to be a complex process, as demonstrated by the EPS-Life Sure project in Portugal (more details on the project can be found below).

Interestingly, the labelling of the recycled content of such plastics is deemed to be voluntary and can be done in accordance with the appropriate International Organisation for Standardization (ISO) or other standard.

As is stands, the EU may be considering a review of one specific article of EU Directive No. 1935/2004[14] which regulates FCMs. It was reported by the Food Packaging Forum[15] in February 2021 that the EU is considering whether or not a revision of Article 3 of the Directive could be beneficial. This follows a consultation which was undertaken by the EU where it asked stakeholders for their views on whether amendments to the existing regulation would be sufficient or if a complete overhaul was warranted. Article 3 covers the manufacturing requirements of FCMs, such that "they do not transfer their constituents to food in quantities which could endanger human health". Any changes to the existing regulation or entire revisions could affect the use of styrene and hence the manufacture of EPS and XPS food service products.

1.3.1.1 European Food Safety Authority

EFSA[16] is an agency of the EU charged with providing independent, scientific advice, based on data and evidence, on all aspects of food safety pertaining to EU Member States and EU food safety legislation. EFSA may examine substances at the request of the EU Commission, Parliament and Member States or it may undertake a review on its own initiative. In terms of FCM, it is the role of EFSA to evaluate the safety of substances used in FCMs and the safety of the recycling processes used for recycling materials that are then used in FCMs.

In terms of EPS and XPS there are two relevant EFSA publications:

1. A Scientific Opinion[17] published in May 2012 on the risk assessment of open-cell expanded polystyrene, manufactured with talc, CAS No 14807-96-6, FCM Substance No 615, and alkyl (C8-C22) sulphonic acid (salts) FCM Substance No 16. Following a review of migration and other tests and data, the Panel on Food Contact Materials, Enzymes and Processing Aids (CEP) concluded that the use of the material, as detailed, does not raise a safety concern when used as a liquid absorber in contact with fresh fish, meat and poultry.

[14] Regulation (EC) No 1935/2004 of the European Parliament and of the Council of 27 October 2004 on materials and articles intended to come into contact with food and repealing Directives 80/590/EEC and 89/109/EEC, published 13 November 2004, available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32004R1935&from=EN

[15] '*EC* considers full revision of existing FCM legislation', by Vanessa Srebny, published by the Food Packaging Forum, 26 February 2021, details available at: https://www.foodpackagingforum.org/news/ec-considers-full-revision-of-existing-fcm-legislation Accessed April 2021.

[16] European Food Safety Authority, website available at: https://www.efsa.europa.eu/

[17] *Scientific Opinion on the safety evaluation of open-cell expanded polystyrene, manufactured with talc, CAS No 14807-96-6, FCM Substance No 615, and alkyl (C8-C22) sulphonic acid (salts) FCM Substance No 16*, EFSA Panel on Food Contact Materials, Enzymes, Flavourings and Processing Aids, published 07 June 2012, available at: https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2012.2746

2. A Scientific Opinion[18] published in November 2017 on the safety assessment of isobutene, which is used as a foaming agent in the manufacture of EPS for FCM use. Following an evaluation of migration data, the CEP Panel concluded that the use of isobutene as a foaming agent does not raise a safety concern.

An EFSA paper[19] published in July 2011 referenced XPS but this was in the context of an examination of a risk assessment conducted on the flame retardant Hexabromocyclodocanes (HBCDD). This had been, prior to its phasing out, a flame retardant used in the manufacture of EPS and XPS insulation products.

1.3.2 Food Contact Materials – global standards

It appears that many countries outside of the EU and the US often rely on EU Directives and/or United States Food and Drug Administration (FDA) standards as the basis for their own food safety specifications. In addition there are other food safety standards (detailed below), including some on food packaging, which individual food packaging manufacturers and food service businesses can apply to their operations. Some nations operate on a Positive List system, whereby only those materials and substances which are included on the list may be used in the manufacture of FCMs which are produced in or imported into the country. The food safety agencies or authorities of most countries are also members of Codex Alimentarius (see below).

1.3.2.1 Codex Alimentarius

Run under the auspices of the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO), Codex Alimentarius[20] provides food safety standards, guidelines and codes of practice which can be used by any country. It facilitates the trading of foodstuffs globally by providing food safety standards on which countries can rely. Nearly every country in the world is a member, usually through their food safety authority or equivalent agency. It has published more than 190 commodity standards, 70+ guidelines and in excess of 4,000 Migration Limits covering 300 food additives.

In a joint publication with the World Trade Organisation (WTO), Trade and Food Standards[21], it notes that the Technical Barriers to Trade (TBT) Agreement covers packaging requirements, through technical regulations and standards.

[18] *Scientific Opinion on the safety assessment of the substance isobutene, for use in food contact materials*, EFSA Panel on Food Contact Materials, Enzymes, Flavourings and Processing Aids, published 07 June 2012, available at: https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2018.5116

[19] *Scientific Opinion on Hexabromocyclododecanes (HBCDDs) in Food,* EFSA Panel on Food Contact Materials, Enzymes, Flavourings and Processing Aids, published 2011, available at: https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2011.2296

[20] Codex Alimentarius, website available at: http://www.fao.org/fao-who-codexalimentarius/about-codex/en/#jfmulticontent_c453296-1

[21] *Trade and food Standards,* published by FAO and WTO, 2017, available at: http://www.fao.org/3/I7407EN/i7407en.pdf

In its code of Practice for Fish and Fishery Products[22], there is very detailed guidance on packaging and packaging procedures to be used but there is no reference to FCM, EPS or XPS.

1.3.2.2 International Organization for Standardization

ISO is a global network of national standards bodies and agencies. ISO has developed standards across a range of areas including Food Packaging Manufacturing (ISO 22002-4:2013). This standard was reviewed and confirmed in 2020. It is used globally as a benchmark for the production of FCMs.

1.3.2.3 Standards and Metrology Institute for Islamic Countries

The Standards and Metrology Institute for Islamic Countries[23] is a mechanism to provide harmonised standards across a range of areas for its 42 Member States.

While there are a number of standards in relation to food standards, with a focus on the preparation of Halal foods, there appear to be no standards relating to FCMs or food packaging.

1.3.2.4 The World Bank

The World Bank published its fourth edition of a document in 2020, the Food Safety Handbook[24]. It is designed as a practical guide to anyone operating a food business to assist them to do so with a strong emphasis on the management of food safety. There is one reference to FCM but that relates to another publication. There are several references to food packaging but none to EPS or XPS.

In World Bank another publication, the Safe Food Imperative[25], there are no references to FCMs or food packaging.

1.3.3 Food Contact Materials – outside the EU

The food safety authorities and agencies of all countries outside the EU were checked for specific regulations relating to the use of EPS and XPS as FCMs and their use as containers. There were surprisingly few specific references to either material globally, given their widespread use.

1.3.3.1 United Kingdom

In 2012 legislation, based on the EU Directives in place at the time, was passed. The Statutory Instrument, the Materials and Articles in Contact with Food (England) Regulations 2012[26], applies to

[22] *Code of Practice for Fish and Fishery Products*, published by FAO, WHO and Codex Alimentarius, last Amendment 2019, available at: http://www.fao.org/3/cb0658en/CB0658EN.pdf

[23] Standards and Metrology Institute for Islamic Countries, website available at: https://www.smiic.org/en

[24] *Food Safety Handbook: A Practical Guide for Building a Robust Food Safety Management System*, published by the International Finance Corporation/world Bank, Washington, 2020, available at: https://www.africanfoodsafetynetwork.org/wp-content/uploads/2020/09/Food-Safety-Handbook_IFC_2020.pdf

[25] *The Safe Food Imperative,* by S. Jaffee et al, published by the World Bank, 2019, available at: http://documents1.worldbank.org/curated/en/484371545400065950/pdf/133154-PUB-PUBLIC-9781464813450.pdf

[26] Statutory Instruments 2012 No. 2619, the Materials and Articles in Contact with Food (England) Regulations 2012, made 17 October 2012, available at: https://www.legislation.gov.uk/uksi/2012/2619/made/data.pdf

England only and applies the EU Directive standards to the use of plastic materials and articles. There are no specifics relating to the use of EPS or XPS as FCMs. Similar legislation enacted at the time governs the use of plastics in contact with food in Northern Ireland, Scotland and Wales. As the Food Standards Agency currently references the 2012 legislation in its section[27] on FCMs, there is no indication as yet that the UK intends to deviate from these standards following its departure from the EU.

At the end of December 2020, the Food Standards Agency published[28] its FCM authorisation guidance. Essentially, any FCM already approved and included on the positive lists authorised by the European Commission can continue in use while new FCMs must undergo the authorisation procedure, which is based on the approach of the EFSA. Recycled plastics may be placed on the market once they meet with the general criteria of existing FCM legislation.

1.3.3.2 Eurasia

The Eurasian Economic Commission, which comprises the Republics of Armenia, Belarus, Kazakhstan, the Kyrgyz Republic and the Russian Federation, publishes Technical Standards covering a wide range of commercial activities. There is a Technical Standard on Food Safety[29], which includes references to food packaging but there is no mention of EPS or XPS.

1.3.3.3 China

The food contact legislation was overhauled[30] in China in 2016 but data on whether there are specific references to styrene, EPS or XPS could not be found. The National Centre for Food Safety Risk Assessment (CFSA) is responsible[31] for assessing the risk of any new FCMs while the onus for the formulation of food safety standards for FCMs rests with the National Health Commission (NHC).

1.3.3.4 Hong Kong

In Hong Kong the Centre for Food Safety published an Abstract[32] in 2005 on a study conducted jointly by the Food and Environmental Hygiene Department and the Consumer Council. 30 disposable containers, made from a mixture of materials including EPS (XPS may also have been included), were tested for food safety parameters of heavy metals, residual styrene monomers and other substances. A further 30 containers were tested for migration properties into food. While all the containers

[27] Food contact materials regulations, Food Standards Agency, website available at: https://www.food.gov.uk/business-guidance/food-contact-materials-regulations

[28] 'Food contact materials regulations, published by Food Standards Authority, 31 December 2020, available at: https://www.food.gov.uk/business-guidance/food-contact-materials-regulations

[29] Technical Standards on Food Safety, Eurasian Commission, available at: http://www.eurasiancommission.org/ky/act/texnreg/deptexreg/tr/Pages/PischevayaProd.aspx

[30] *Legal Compliance of Packaging Materials - China,* published by Eurofins, undated, available at: https://www.eurofins.com/consumer-product-testing/packaging/services/global-legal-compliance/china/

[31] *China food Contact Materials Regulation*, by Yilia Ye, published by ChemLinked, 09 January 2020, details available at: https://food.chemlinked.com/foodpedia/china-food-contact-materials-regulation Accessed December 2020.

[32] *Disposable Plastic Containers for Take-away Meals,* Risk Assessment Section, Food and Environmental Hygiene Department, published by the Centre for Food Safety, December 2005, available at: https://www.cfs.gov.hk/english/programme/programme_rafs/programme_rafs_fc_01_03_dp.html

satisfied the food safety parameter tests, it was noted that the PS container (not stipulated if made from EPS or XPS) exceeded the migration limit when submitted to a simulation test for storage of fatty foods at 120 degrees. The container did not exceed the migration limit when the test was re-run at 100 degrees.

As a result the study concluded that while no physical deformity was evidenced when subjected to temperatures of 120 degrees, no EPS, Polyethylene Terephthalate (PET) or PS containers are deemed suitable for storing foods in temperatures in excess of 100 degrees. The characteristics of the food in terms of fat content and the likely duration of the storage time should also be factored in when choosing containers. The study recommends the use of Polypropylene (PP) or other materials for containers to store hot fatty foods in excess of 100 degrees. Alternatively the foods should be cooled down before being placed in an EPS, PS or PET container.

In 2006 the Centre for Food Safety published Guidelines on the Use of Disposable Plastic Containers[33]. The document states that due to the risk of migration of certain monomers, which can be harmful if ingested in excessive quantities, the appropriate container should be chosen for each food. The selection of which food containers to use should take into account the types of food to be served, the temperature at which the food will be served/stored and business should ensure that the containers only contain approved FCMs. The guidelines also recommend that EPS containers are avoided for the storage of food above 100 degrees and notes that they are not suitable for use in a microwave.

1.3.3.5 India

The Food Safety and Standard Authority of India is responsible for food packaging regulations. The food packaging regulations[34] were updated in December 2018 and the Schedule includes PS as safe for use in FCMs but there is no specific reference to EPS or XPS.

1.3.3.6 Japan

Japan operates on a Positive List system for FCMs, which was extensively updated in 2020[35]. PS is included in its Updated Positive List System for Food Utensils, Containers and Packaging[36] but there is no specific reference to EPS or XPS.

[33] *Guidelines on the use of Disposable Plastic Containers,* published by the Food and Environmental Hygiene Department and the Centre for Food Safety, 20069, available at: https://www.cfs.gov.hk/english/multimedia/multimedia_pub/files/disposable_plastic_containers.pdf

[34] The Food Safety and Standards (Packaging) Regulations, 2018, published by the Ministry of Health and Welfare, 24 December 2018, available at: https://www.fssai.gov.in/upload/uploadfiles/files/Gazette_Notification_Packaging_03_01_2019.pdf

[35] *Japan translates Positive List of Food Packaging and Container Substances*, report by Suguru Sato, published by United States Department of Agriculture, 18 June 2020, details available at: https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Japan%20Translates%20Positive%20List%20of%20Food%20Packaging%20and%20Container%20Substances_Tokyo_Japan_06-16-2020

[36] 'Japan releases revised positive list for FCMs', by Justin Boucher, published by the Food Packaging Forum, 05 May 2020, details available at:https://www.foodpackagingforum.org/news/japan-releases-revised-positive-list-for-fcms Accessed February 2021.

1.3.3.7 Singapore

The Singapore Food Agency (FSA)[37] is responsible for regulating all matters relating to food safety and hygiene. In the Agency's document, Good Handling Practices in Packing House for Vegetables[38], PS is referenced as suitable packaging but the accompanying photograph is of an EPS container used for the transport of fresh broccoli.

While there appears to be no specific material relating to the use of EPS or XPS on the Food Safety website, there are records of correspondence[39] between consumers and FSA officials, regarding the safe use of XPS (albeit it is referred to as Styrofoam). The most recent feedback, dated 2013, comes from a consumer query, titled "Health hazards from food consumption". The consumer in question makes a number of statements about the use of "Styrofoam" containers, such as hot food packed in such containers can cause health problems. He goes on to state that these receptacles contain styrene and benzene, which he refers to as carcinogens, and these toxins can leach into food that is acidic or oily. He also recommends that the containers are not placed in a microwave.

The response is from the Regulatory Administration Department and states that studies on the migration of styrene demonstrate that there are no ill health affects once the containers are used appropriately. It notes that very hot, oily or acidic foods should be cooled slightly before being placed in an XPS container. The Department response also notes that the Agri-Food & Veterinary Authority regularly tests XPS containers in a similar way to tests carried out by the US FDA and assures the consumer that the containers are safe to use.

[37] Singapore Food Agency, website available at: https://www.sfa.gov.sg/

[38] *Good Handling Practices in Packing House for Vegetables,* published by the Singapore Food Agency, undated, available at: https://www.sfa.gov.sg/docs/default-source/tools-and-resources/resources-for-businesses/ava_vegetablespackaging_9th

[39] Correspondence between consumer and the Regulatory Administration Department, Agri-Food & Veterinary Authority, published by the Singapore Food Agency, March 2013, available at: https://www.sfa.gov.sg/docs/default-source/forum-replies/2013/avareplystyrofoamcontainersaresafeforuse.pdf

Figure 2. XPS food service container

1.3.3.8 Vietnam

On its website, the Food Safety Bureau[40] has specific instructions relating to the use of XPS (referred to as Styrofoam) containers. While their use is permitted there are conditions attached:

- Only containers which comply with food safety regulations can be used;
- Containers can only to be used to store food at 70 degrees or below;
- Containers are not to be used to more than once or for prolonged periods of time;
- Containers are not to be used for hot or fatty foods, and certain food items containing sour ingredients such as lemon juice;
- Containers are not to be used in a microwave.

1.3.3.9 Australia & New Zealand

These countries have a bi-national food agency, Food Standards Australia New Zealand[41] (FSANZ), under which a Food Standards Code[42] has been developed. There are few references to food packaging and none to FCMs, EPS or XPS. FSANZ published the results of a project[43] it ran in 2017 to assess

[40] Guidance on ensuring food safety in using foam containers that contain and preserve food, Food Safety Bureau, Ministry of Health, 04 April 2013, available at: https://vfa.gov.vn/kien-thuc/huong-dan-bao-dam-an-toan-thuc-pham-trong-su-dung-hop-xop-chua-dung-bao-quan-thuc-pham.html

[41] Food Standards Australia New Zealand, website available at: https://www.foodstandards.gov.au/Pages/default.aspx

[42] Food Standards Code, published by Food Standards Australia New Zealand, available at: https://www.foodstandards.gov.au/code/Pages/default.aspx

[43] 'Chemicals in food Packaging', Food Standards Australia New Zealand, August 2018, available at: https://www.foodstandards.gov.au/consumer/chemicals/foodpackaging/Pages/default.aspx

unmanaged risks from the migration of chemicals used in packaging into foodstuffs but styrene does not appear to have been included in the review.

The Cancer Council of Australia has a Q&A section[44] on its website that references PS cups, and the accompanying photograph is of an XPS beverage cup. The question was posed by a consumer "does eating and drinking out of polystyrene food packaging cause cancer?" The Council's response is that tiny traces of styrene can migrate from containers into food or beverages. It goes on to note that the US National Research Council reviewed the evidence of styrene in 2014 and that while it concluded that styrene is reasonably anticipated to be human carcinogen, the evidence base was limited. It added that the Plastics Foodservice Packaging Group concluded that the migration of styrene in FCM was extremely low and well below the migration limit set by the US FDA. Finally it adds that the US FDA and EFSA have both concluded that PS is safe for use as an FCM following rigorous testing.

1.3.3.10 Canada

The food safety laws[45] were updated and consolidated in 2019 but make no reference to FCMs, EPS or XPS.

The Canadian Food Inspection Agency references[46] both expanded polystyrene and "Styrofoam" as Approved Media for the importation of plants (with roots) into the country. The Canadian Government includes PS on its list[47] of "acceptable polymers for use in food packaging applications".

The Government also published Guidelines[48] on the use of recycled plastics as FCMs. Under the Source Control section it notes that recyclers may limit the source of collection to food-contact plastics only, such as PS cups and plates from cafeterias.

1.3.3.11 Mexico

According to national regulations[49] regarding FCMs, foamed PS and styrene are both on the list of materials and substances permitted for use in the manufacture of articles designed to come into

[44] Question from Kate, Mosman, NSW, Australia, published by the Cancer Council, undated, details available at: https://www.cancer.org.au/iheard/does-eating-or-drinking-out-of-polystyrene-food-packaging-cause-cancer

[45] Safe Food for Canadians Regulations, SOR/2018-108, published by the Minister of Justice, available at: https://laws-lois.justice.gc.ca/PDF/SOR-2018-108.pdf

[46] D-96-20: Canadian Growing Media Program, Prior Approval Process and Import Requirements for Plants Rooted in Approved Media, published by the Government of Canada, available at: https://www.inspection.gc.ca/plant-health/plant-pests-invasive-species/directives/horticulture/d-96-20/eng/1323854223506/1386093487852

[47] 'List of acceptable polymers for use in in food packaging applications', published by the Government of Canada, available at: https://www.canada.ca/en/health-canada/services/food-nutrition/legislation-guidelines/guidance-documents/lists-acceptable-polymers-use-food-packaging-applications.html

[48] 'Guidelines for Determining the Acceptability and Use of Recycled Plastics in Food Packaging Applications', published by the Government of Canada, available at: https://www.canada.ca/en/health-canada/services/food-nutrition/legislation-guidelines/guidance-documents/guidelines-determining-acceptability-use-recycled-plastics-food-packaging-applications-1996.html

[49] Chapter II, Section 16 – Regulations on Materials and Articles of Polymer and Other Materials Intended to Come into Contact with Food Products and Mediums, 1071 Uniform Sanitary and Epidemiological and Hygienic Requirements for Goods subject to Sanitary Epidemiological Supervision (Control), 2011, available at: https://www.gob.mx/cms/uploads/attachment/file/389025/Capitulo_II_Secci_n16_Req_material_de_contacto_con_los_alimentos.pdf

contact with food. It specifically notes that the "use of PS for packaging of food products designated for the nutrition of children of preschool (older than 3 years) and school age is allowed" which could include EPS and XPS packaging.

1.3.3.12 United States of America

The FDA is the lead agency for food safety in the USA and it maintains a database[50] of food contact substances notified to it by manufacturers. There is no reference to EPS; XPS is included by one manufacturer.

The FDA has a Guidance document[51] on the use of recycled plastics in the manufacture of food packaging, which was issued in 2006. The only reference to PS is under the section on chemical contaminants. The FDA also has a database[52] of specific plastic manufacturers who have been licensed to use post-consumer recycled (PCR) plastics in the production of food contact plastics. There is no reference to EPS or XPS in the database; PS is referenced several times as a polymer with an indication that the recycled PS can be used in the manufacture of foodservice clamshells but it is not clear if the recycled PS is emanating from PCR EPS or XPS. Additionally there is a list[53] of indirect additives which may be used that includes polystyrene and styrene.

The Safe Quality Food Institute regularly updates a Food Safety Code it first published in 1995, Manufacturing Food Packaging. Now in its ninth edition[54], it sets out the technical and other specification for sites that manufacture food service products including "plastic and foam containers" and single-use containers.

The Plastic Food Service Packaging Facts website[55], which is a subsidiary of the American Chemistry Council, states that styrene is safe to be used as a FCM per the FDA. It refers to the updated migration data report[56] that the group provided to the FDA in 2013, which demonstrated that styrene migrates from PS foodservice packaging in extremely low quantities.

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[50] 'Inventory of Effective Food Contact Substance (FCS) Notifications, published by the U.S Food & Drug Administration, available at: https://www.cfsanappsexternal.fda.gov/scripts/fdcc/?set=FCN&sort=FCN_No&order=DESC&startrow=1&type=basic&search=%20polystyrene

[51] 'Guidance for Industry: Use of Recycled Plastics in Food Packaging (Chemistry Considerations), issued by the Center for Food Safety and Applied Nutrition, August 2006, available at: https://www.fda.gov/regulatory-information/search-fda-guidance-documents/guidance-industry-use-recycled-plastics-food-packaging-chemistry-considerations

[52] 'Submissions on Post-Consumer Recycled (PCR) Plastics for Food-Contact Articles', published by the U.S. Food & Drug Administration, available at: https://www.cfsanappsexternal.fda.gov/scripts/fdcc/index.cfm?set=RecycledPlastics&sort=Recycle_Number&order=DESC&startrow=151&type=basic&search=

[53] Part 177 – Indirect food Additives: Polymers, published by the Electronic Code of Federal Regulations, available at: https://www.ecfr.gov/cgi-bin/text-idx?SID=e956d645a8b4e6b3e34e4e5d1b690209&mc=true&node=pt21.3.177&rgn=div5

[54] *Food Safety Code: Manufacture of Food Packaging, Edition 9,* published by the Safe Quality food Institute, 2020, available at: https://www.sqfi.com/wp-content/uploads/2020/11/20227FMIN_FoodPackaging_v3-2-Final-w-Links.pdf

[55] 'FDA: Safety of Polystyrene Foodservice Packaging', published by Plastic Foodservice Packaging Facts, undated, available at: https://www.plasticfoodservicefacts.com/foodservice-safety/fda-safety-of-polystyrene-foodservice-products/

[56] *The Safety of Styrene-Based Polymers for Food-Contact Use 2013,* prepared by Plastics Foodservice Packaging Group, American Chemistry Council, submitted to the US FDA, available at: https://www.plasticfoodservicefacts.com/wp-content/uploads/2017/10/Polystyrene-Report.pdf

1.3.3.13 Caribbean & Latin/Central America

The Caribbean Agricultural Health & Food Safety Agency[57] has 12 Member States. Food safety is one of five core activities undertaken by the Agency but there is no reference to FCMs, food packaging, EPS or XPS.

1.3.3.14 Mercosur (South America)

The Mercosur[58] grouping of countries was established to promote free trade between the countries of the continent of South America. The member countries are Argentina, Brazil, Paraguay and Uruguay (the membership of Venezuela has been suspended since 2012). The Associate states are Bolivia, Chile, Colombia, Ecuador, Guyana, Peru and Surinam.

The regulation[59] of FCM is covered by resolutions, which were initially developed by the Packaging Working Group, before being adopted by the Common Market Group (GMC). There are a number of relevant GMC Resolutions; GMC 03/92, GMC 32/07 and GMC 02/12. GMC 02/12 contains a positive list of the polymers and substances that may be used in FCM. As it is modelled on EU Commission Regulation 10/2011, it is likely that styrene is permitted as a FCM, thereby allowing the use of EPS and XPS as FCM. These regulations are harmonised across the member countries.

1.3.3.15 Saudi Arabia

The Saudi Food & Drug Authority (SFDA) issued a statement[60] (undated) which followed up on correspondence it had received as a consequence of the circulation of two memos by the SFDA regarding the import of FCMs. The document specifies a requirement that the food grade sign (similar to that authorised by EFSA, above) is posted on all imported plastic or plastic-padded packing and packaging materials which come into direct contact with food. It goes on to state that certified authorised laboratory test results must also accompany any such imported materials. While there is no specific reference to EPS or XPS, the requirements outlined would extend to any EPS/XPS food packaging.

1.3.3.16 African Food Safety Network

The focus on food safety in Africa appears to be on improving the safety of the food itself, rather than packaging, as the WHO estimates[61] that 137,000 people die on the continent every year due to foodborne hazards.

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[57] Caribbean Agricultural Health & Food Safety Agency, website available at: https://www.cahfsa.org/

[58] Mercosur, website available at: https://www.mercosur.int/en/

[59] 'Regulation of Food Contact Materials in Latin America (Part 1), by Catherine R. Nielsen, published by PackagingLaw.com, 03 June 2019, details available at: https://www.packaginglaw.com/special-focus/regulation-food-contact-materials-latin-america-part-1 Accessed December 2020.

[60] Saudi Food & Drug Authority Announcement 255, undated, available at: https://www.sfda.gov.sa/sites/default/files/2019-09/announ_food_en_2.pdf

[61] 'A fatal public health problem in Africa that flies under the radar', by Tim McDonnell, published by NPR, 21 February 2019, details available at: https://www.npr.org/sections/goatsandsoda/2019/02/21/696385246/a-fatal-public-health-problem-in-africa-that-flies-under-the-radar?t=1614334121644 Accessed February 2020.

The African Food Safety Network[62] (AFoSaN) has members from 37 countries, in the main laboratories and testing facilities, with the objective of establishing and strengthening food safety control systems across the continent. However, there appears to be no regulations or standards in relation to food packaging or FCM. Their Resources section references the World Bank publication (see above).

1.3.3.17 East African Community

The East African Community[63] (Jumuiya YaAfrika Mashariki) has six member countries. In its Catalogue of Standards[64], most recently published in 2020, the areas of packaging and distribution of goods and packaging materials are covered. The document references food packaging but not specifically FCMs and there is no reference to EPS or XPS.

1.3.3.18 Food, Agriculture and Natural Resources Policy Analysis Network

FANRPAN[65] is a not-for-profit organisation which coordinates policy research and recommends strategies promoting food and agriculture across Africa. In their 2016-2023 Strategy document there is no reference to food packaging or FCMs; their focus is on improving the safety of the food available to the African people.

1.3.4 Food Contact Materials – Organisations & Companies

Some private-sector companies have made the decision to phase out the use of EPS and/or XPS packaging, often following pressure brought to bear on them by activist shareholders, investor and environmental non-governmental organization (NGO).

1.3.4.1 Food Packaging Forum

This not-for-profit organisation maintains a database[66] on initiatives undertaken by leading brands and retailers to address plastic packaging in their supply chain. To date, one company has already prohibited the use of EPS and PS for its own-brand products while four others have signalled their intention to phase out "Styrofoam" and EPS packaging. There are no references to XPS.

1.3.4.2 Amazon

In its most recently published (December 2020) FCM Restricted Substance List[67], Amazon prohibits the use of PS and EPS as packaging for its own-brand kitchen range. It describes materials on this list as non-recyclable.

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[62] African Food Safety Network, website available at: https://www.africanfoodsafetynetwork.org/?page_id=3849
[63] East African Community, website available at: https://www.eac.int/
[64] *Catalogue of East African Standards*, published by the EAC Secretariat, January 2020, available at: https://www.rsb.gov.rw/fileadmin/user_upload/files/pdf/new_stds/EAS_Catalogue_2020.pdf
[65] Food, Agriculture and Natural Resources Policy Analysis Network, available at: https://www.fanrpan.org/about/about-FANRPAN?block=who
[66] Brand & Retailer Initiatives Database, maintained by Food Packaging Forum, available at: https://www.foodpackagingforum.org/brand-retailer-initiatives
[67] *Amazon Chemicals Policy: Food Contact Materials Restricted Substance List (RSL),* last updated December 2020, published by Amazon, available at: https://sustainability.aboutamazon.com/amazon_chemicals_policy_food.pdf

1.3.4.3 Dunkin' Donuts

The company announced[68] in May 2020, that despite the pandemic restriction, polystyrene foam cups (which could be EPS or XPS) had been phased out completely from its global restaurant chain, and within the two-year time-frame the company had set itself. At the time the company estimated that it meant a reduction of a billion foam cups being sent to the waste stream on an annual basis.

1.3.4.5 McDonalds

The company ceased[69] the use of XPS cups in its chain of restaurants in the U.S. in 2012, and made 2019 the target year in which to phase out the use of all XPS packaging across its entire global brand network.

1.3.4.6 Merck Group

In its 2019 Corporate Responsibility Report[70], the company notes three ways in which it is tackling the use of EPS packaging across its supply chain:

1. It is replacing moulded EPS packaging where possible with cellulose and paper;
2. It offers a return service to its customers of clean but used EPS boxes, which are re-used where possible;
3. It has set a target to reduce the use of EPS by 20% by 2022, in part by replacing EPS packaging used in cold-chain supply with a cooler made from a plant-based alternative material.

1.3.4.7 Nestlé

In early 2020 the company provided a comprehensive overview[71] of the various initiatives it is undertaking to reduce the complexity of plastics in its packaging supply chain. Under the section on the simplification of packaging, it states that they have several rules which apply specifically to plastics and coated paper, one of which is to cease the use of PS and EPS.

1.3.4.8 Target

In 2017, Target announced[72] that, together with a number of other initiatives, it planned to phase out the use of EPS in all of its own brand packaging by 2022.

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[68] 'Farewell to Foam: Dunkin' complete global transition to paper cups', press release issued by Dunkin' Donuts, 11 May 2020, details available at: https://news.dunkindonuts.com/news/farewell-to-foam-dunkin-completes-global-transition-to-paper-cups#:~:text=Dunkin'%20today%20announced%20that%20100,by%20double%2Dwalled%20paper%20cups. Accessed January 2021.

[69] McDonald's promises to eliminate foam packaging by 2019', by Adam Redling, published by Recycling Today, 11 January 2018, details available at: https://www.recyclingtoday.com/article/mcdonalds-foam-packaging-2018/ Accessed February 2021.

[70] Packaging and Recycling, published by Merck Group, details available at: https://www.merckgroup.com/en/cr-report/2019/products/sustainable-products/packaging-and-recycling.html

[71] 'What is Nestlé doing to tackle plastic packaging waste?', published by Nestlé, available at: https://www.nestle.com/ask-nestle/environment/answers/tackling-packaging-waste-plastic-bottles

[72] 'Target's thinking outside the box with five new sustainable packaging goals', issued by Target, 18 April 2017, details available at: https://corporate.target.com/article/2017/04/sustainable-packaging-goals Accessed February 2021.

1.3.4.9 Walmart (Canada)

The company announced[73] in 2019 that it was setting itself several targets relating to the reduction of plastic waste, one of which was the elimination of "hard-to-recycle" EPS from its own-brand packaging by 2025.

1.3.4.10 Walmart (US)

As part of its aspiration for "zero plastic Waste", the company has a commitment[74] to eliminate all polystyrene packaging from its own-brands range by 2025, which would indicate that EPS and XPS are included in the target.

1.3.4.11 YUM Brands

This company, which owns the KFC, Pizza Hut and Taco Bell brands, announced[75] in March 2020 that polystyrene foam packaging (which would include XPS containers and cups) will be phased out globally across all three brands in 2022.

2. Styrene

Styrene is used in the production of both EPS and XPS products, including those used for food packaging, so styrene is also classified as a FCM. It is permitted for use globally but with some caveats. According to the US Environmental Protection Agency, styrene has been evaluated as a carcinogen[76] but notes that there is insufficient data to determine an Acceptable Daily Intake (ADI) amount. However, there is no reference to styrene and its use in the production of FCM and the citation appears to relate to its presence with other materials in hazardous waste streams. The Health and Environmental Effects Profile for Styrene (1984) and the Health Effects Assessment for Styrene (1989) can both be found on in the US National Technical Reports Library[77].

In 2014, the National Toxicology Program 12th Report on Carcinogens[78] in the US reported on its review of styrene that in some occupational settings, exposure to styrene was linked to an increase in the frequency of some cancers. It stated that there was evidence that styrene is genotoxic in exposed humans and so supported the listing of styrene as "reasonably anticipated to be a human carcinogen".

[73] 'Walmart Canada makes milestone commitment to plastic waste reduction', published by Cision News, 23 January 2019, details available at: https://www.newswire.ca/news-releases/walmart-canada-makes-milestone-commitment-to-plastic-waste-reduction-890393999.html Accessed December 2020.

[74] Aspirations and Goals, Walmart U.S. Commitment, available at: https://www.walmartsustainabilityhub.com/aspirations-and-goals

[75] 'KFC, Pizza Hut, Taco Bell stops Polystyrene Foam Packaging', by Axel Barrett, published by Bioplastics News, 09 March 2020, details available at: https://bioplasticsnews.com/2020/03/09/kfc-pizza-hut-taco-bell-stops-polystyrene-foam-packaging/ Accessed January 2021.

[76] US.EPA. Health and Environmental Effects Profile for Styrene, US Environmental Protection Agency, undated, available at: https://cfpub.epa.gov/ncea/risk/hhra/recordisplay.cfm?deid=39304#:~:text=Styrene%20has%20been%20evaluated%20as,provided%20sufficient%20data%20are%20available.

[77] Health Effects Assessment for Styrene, available to down load at: https://ntrl.ntis.gov/NTRL/dashboard/searchResults.xhtml?searchQuery=PB88182175&starDB=GRAHIST

[78] The National Toxicology Program 12th Report on Carcinogens, published National Center for Biotechnology Information, 2014, available at: https://www.ncbi.nlm.nih.gov/books/NBK241565/

In its 2019 "Report on the Status of Styrofoam and Plastic Bag Bans in the Wider Caribbean Region"[79], United Nations Environment Programme (UNEP) stated that "Styrofoam contains styrene and benzene – these chemicals are both known carcinogens that can leach into food or drinks". However, no research or data is cited to underpin this statement.

2.1. Styrene under review

This report comes at a time when the use of styrene is under review following the publication of a report by the International Agency for Research on Cancer[80] (IARC). IARC is an agency of the World Health Organisation (WHO) which promotes and encourages collaboration internationally on cancer research. Its well-respected evaluations of cancer risk factors, known as monographs, are referred to and relied on globally. The Agency notes that the term "carcinogenic risk" is taken to mean that an agent is capable of causing cancer but the inclusion of an agent in the Monographs does not imply that it is a carcinogen. Determination of the Group into which an agent that has been reviewed is placed is made by a Working Group of scientists following rigorous research of existing data, studies and experiments.

Agents which are reviewed are classified into Groups as follows:

- Group 1: The agent is carcinogenic to humans, based on sufficient evidence;
- Group 2A: The agent is probably carcinogenic to humans, based on limited evidence;
- Group 2B: The agent is possibly carcinogenic to humans, based on limited evidence;
- Group 3: The agent is not classifiable as to its carcinogenicity to humans;
- Group 4: The agent is probably not carcinogenic to humans.

Volume 121[81], the IARC Monograph published in 2019, focused on Quinoline (which had not been previously reviewed), Styrene (which had been reviewed in 1978, 1987, 1994 and 2002) and Styrene-7,8-oxide. The Working Group reviewed a broad and vast array of data to arrive at its conclusions, two of which are summarised below:

- Styrene concentrations in foods have not changed significantly since the 1980s;
- The fat content of food (where dairy foods, such as yogurts, were studied) plays an important role in the "solvation and mass transfer of styrene" from food packaging made from PS (which would include EPS and XPS) into food.

Based on its findings the Working Group concluded that styrene is probably carcinogenic and placed it in the 2A Group. It should be noted however that most of the studies researched concerned the exposure of workers in plants and factories producing styrene or where styrene was a component (e.g. fibre-glass and rubber plastics manufacturers) and where styrene exposure came about mainly due to inhalation (styrene is present in tobacco smoke for instance).

[79] *Report on the Status of Styrofoam and Plastic Bag Bans in the Wider Caribbean Region,* published by the UN Environment Programme, June 2019, available at: http://gefcrew.org/carrcu/18IGM/4LBSCOP/Info-Docs/WG.39_INF.8-en.pdf
[80] International Agency for Research on Cancer, WHO, website available at: https://www.iarc.who.int/
[81] Styrene, Styrene-7,8-Oxide, and Quinoline – IARC Monographs on the Evaluation of Carcinogenic Risks to Humans Volume 121, published by the International Agency for Cancer Research, available at: https://publications.iarc.fr/582

2.2. Styrene as a Food Contact Material under review

The use of styrene as a FCM, where it is generally one of a number of substances found in a material, like PS, is also under review.

2.2.1 As a result of the IARC findings (see above), the Panel on Food Contact Materials, Enzymes and Processing Aids (CEPS Panel) of EFSA was requested by the European Commission to re-evaluate the safety of styrene for use in plastic FCMs.

The report[82], which assesses of the impact of the IARC Monograph, was published in October 2020. It began by reviewing the history of evaluations of styrene as a FCM. Styrene was authorised in FCMs in 1982 and in 2005 the Scientific Committee on Food set its classification as 4B meaning "substances for which an acceptable daily intake (ADI) or tolerable daily intake (TDI) could not be established….". The first EU Directive which related to the use of plastic materials and substances intended to come into contact with food was published in 1990. Directive 90/128/EEC[83] listed a large number of agents, including styrene, which can be used in the manufacture of plastics articles. There is no SML for styrene. In Commission Regulation (EU) No 10/2011[84] styrene is again included as authorised in the manufacture of plastic materials for food contact with no SML or other restrictions.

The report lists the various applications for which styrene may be used including:

- Cups for hot beverages….made from general purpose polystyrene (GPPS) or EPS;
- Trays for packaging meat etc…..made of EPS or XPS;
- Cold boxes for fisheries, food or beer made of EPS.

The CEPS Panel then referenced a number of studies undertaken in both Europe and the US. It noted that styrene migration from packaging into food could take place but in very low amounts although these could be elevated when in contact with fatty foods. The Panel also noted that migration depends on the "free styrene content in the plastic", migration can increase with higher temperatures and when the material is in contact with fatty foods. Having reviewed the findings in the Monograph, the Panel found that as IARC based its conclusion, in the main, on high-dosage workplace inhalation exposure and animal studies, its evaluation could not be applied directly to the evaluation of risks to consumers associated with oral exposure from styrene FCM migration. However, the Panel concluded that a systematic review based on other data sets is required for assessing the safety of styrene for its use in FCM.

Further evaluation of the use of styrene in FCM by EFSA is ongoing.

[82] Assessment of the impact of the IARC Monograph Vol. 121 on the safety of the substance styrene (FCM No 193) for its use in plastic food contact materials, EFSA Panel on Food Contact Materials, Enzymes and Processing Aids (CEPS), adopted 09 September 2020, available at: https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2020.6247

[83] Commission Directive of 23 February 1990 relating to plastics materials and articles intended to come into contact with foodstuffs ((90/12/EEC), published by the Official Journal of the European Communities, March 1990, available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31990L0128&from=en

[84] Commission Regulations (EU) No 10/2011 of 14 January 2011 on plastic materials and articles intended to come into contact with food, published by the Official Journal of the European Communities, January 2011, available at: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:012:0001:0089:en:PDF

2.2.2 In Iceland in 2017, research[85] was carried out by Matís, the Icelandic Food and Biotech Research & Development agency, to determine if styrene migration took place, from the EPS fish-boxes used to transport fish from Iceland to the US, into the fish being transported. US clients had indicated that they wanted a plastic bag liner used to prevent the fish from coming into direct contact with the fish-box, due to concerns about styrene migration. A number of tests were carried out and the study concluded that the levels of styrene found in the fish were so low (0.01mg/kg while the US FDA permitted daily intake of styrene is 90 mg/kg per person) that the use of a plastic bag liner was not required.

2.2.3 The German Federal Institute for Risk Assessment[86] (BfR) publishes non-legally binding standards on FCMs, not subjected to any specific legislation, and they are accepted by EU Member States on the mutual recognition principle (see box below). In its database[87] on FCMs, BfR states that both Polystyrene and Styrene Copolymers are suitable for use as FCMs. In September 2020, EFSA, together with BfR and EU-FORA published a paper[88], Risk Assessment of Food Contact Materials. In it the authors refer to different sets of migration tests that had been conducted on styrene oligomers, all of which indicated a low or no evidence of health risk to consumers. The authors go on to state that the results of further tests based on modelling tools will be published at a future date.

The Mutual Recognition Principle ensures the market access for goods that are not, or are only partly, subject to EU harmonisation legislation. It guarantees any good lawfully sold in one EU country can be sold in another[89].

2.2.4 The International Chemical Secretariat in Sweden[90] compiled and keeps updated what is referred to as the SIN list, a list of chemicals which it says should be substituted where possible. Styrene was added to the list[91] in 2008 based on its categorisation as an endocrine disrupter in the EU Commission Database. However, styrene could not be found in a search of the database[92], which is administered by the Danish Environmental Protection Agency.

2.3. Styrene as marine litter

While all litter found in the marine environment is correctly viewed as harmful, there is a risk that PS litter (which would include any EPS or XPS product) could be particularly detrimental to human health. Research findings[93] by Prof. Chris Elliott of Queen's University Belfast were presented at the

[85] *Styrene migration from expanded polystyrene boxes into fresh cod and redfish at chilled and superchilled temperatures,* by Queguiner E., Margeirsson B., & Arason S., published by Skýrsla Matís, December 2017, available at: https://matisiceland.org/styrene-migration-from-expanded-polystyrene-boxes-into-fresh-cod-and-redfish-at-chilled-and-superchilled-temperatures/

[86] Bundesinstitut für Risikobewertung, website available at: https://www.bfr.bund.de/en/home.html

[87] Data BfR Recommendations on Food Contact Materials, available at: https://bfr.ble.de/kse/faces/DBEmpfehlung_en.jsp

[88] *Risk Assessment of Food Contact Materials,* by E. Beneventi, T. Tietz & S. Merkel, published by BfR, EU-FOR A and EFSA, 07 September 2020, available at: https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2020.e181109

[89] Mutual Recognition of Goods, details available at: https://ec.europa.eu/growth/single-market/goods/free-movement-sectors/mutual-recognition_en

[90] International Chemical Secretariat, website available at: https://sinlist.chemsec.org/

[91] Styrene, CAS Number 100-42-5, SIN List published by the International Chemical Secretariat, details available at: https://sinsearch.chemsec.org/chemical/100-42-5

[92] Endocrine Disruptor Lists, published by the Danish Environmental Agency, available at: https://edlists.org/

[93] 'Impacts of Micro and Nano Plastics on Human Health, findings by Ali Can & Chis Elliott, Institute for Global Food Security', presentation at Environment Ireland conference 2020 (slides available to conference delegates only)

Environment Ireland® (online) conference[94] in 2020. Prof. Elliott and his colleagues from the Institute for Global Food Security have conducted tests demonstrating that "polystyrene particles show toxicological effects on measures of oxidative stress, inflammation, mitochondrial dysfunction, lysosomal dysfunction and apoptosis". In layperson's terms this means damage to the nervous system of humans.

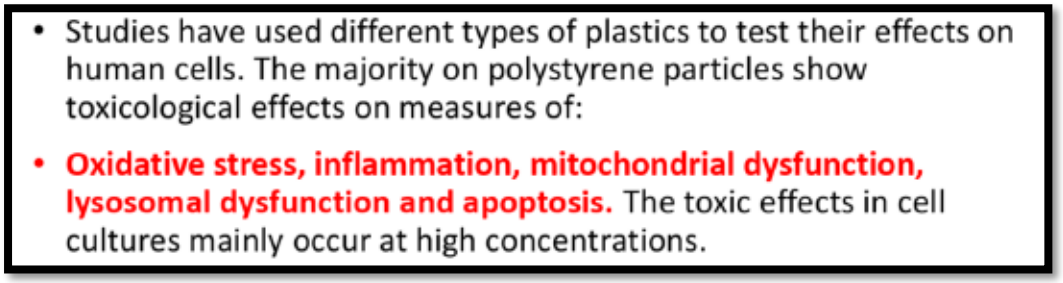

Figure 3. Extract from research findings presented by Prof. Chris Elliott, QUB

So while all plastic marine litter needs to be eradicated, it is particularly important that all waste EPS and XPS food service products are prevented from reaching our streams, rivers, seas and oceans. Food service items made from other materials, such as paper, may be littered in the same way, but their effects on the marine ecosystem, to the food chain, and ultimately to humans, may not be quite as severe.

3. Life Cycle Analyses

In order to determine the true costs of materials and products in terms of their economic, social and environmental affects, a life-cycle analysis (LCA) is necessary. Examining a product from its design stage, through its manufacture, distribution, use, and finally to its disposal, produces data which can be used to evaluate the performance of the product against a set of criteria, which can include:

- The amount of renewable / non-renewable resources used;
- The amount of energy consumed, during material extraction and manufacture of the product;
- The volume of water consumed during the extraction and manufacturing process;
- Greenhouse Gas (GHG) and other emissions discharged during the extraction, manufacturing and transport processes;
- Disposal impacts (reuse / recycling / incineration / landfill / littering).

All of this data can then be used to calculate the actual carbon footprint of an item, such as an EPS fish-box or an XPS clamshell container. In this way, comparisons with alternative materials, like paper[95] and bagasse[96] (made from sugarcane production outputs) can be made on an informed basis. For food service packaging, LCAs can also determine the number of times a non-disposable item needs to be used in order for its carbon footprint to compare favourably against that of a disposable product. Such information can then be used to determine what products should be and should not be used and when, depending on the type of food service provision, such as one-off outdoor festivals, in-house

[94] Environment Ireland® Conference 2020, details available at: https://www.environmentireland.ie/
[95] 'A sustainable paper-based alternative for EPS frozen food packaging', published by PaperFirst, 15 June 2020, details available at: https://www.paperfirst.info/a-sustainable-paper-based-alternative-for-eps-frozen-food-packaging/
[96] Bunzl Catering Supplies - Food Packaging Brochure (page 30), available at: https://www.bunzlcatering.co.uk/bunzl_content/uploads/2020/11/Bunzl_Catering_Food_Packaging.indd_.pdf

catering, restaurants, take-away food shops and delicatessens. The availability of separate waste collection systems and recycling infrastructure should also be factored in as these will also have a bearing on the overall LCA.

Many countries, at national, city or state level, have introduced bans and restrictions on the use of EPS and XPS food service containers, often citing the litter caused by these products when they become waste as the main reason for so doing. At the same time they often promote or encourage the use of substitute products, though in the main the stipulation is that these replacements must be made from materials which are biodegradable, compostable or recyclable. Yet there is rarely any reference to a LCA having been completed which confirms that these substitute products have a lower environmental footprint than those made from EPS and/or XPS.

There is an ISO Standard, ISO 14044:2006[97] which provides guidelines for those producing both LCA and Life Cycle Inventory (LCI); a peer review of the outputs is required under the standard. However there is concern[98] that some LCAs are conducted using parameters to produce a desired outcome i.e. the favourable comparison of one product against another. Added to this are the difficulties faced in trying to quantify environmental impacts; how is the harm measured, for instance, if an XPS clamshell container becomes marine litter. The number of fragments into which it breaks up, whether it floats back onto a beach or is ingested by a marine mammal - these are all possibilities but it is extremely challenging to try to measure the effects of any or all of these potential outcomes.

Ultimately the data from an independent LCA provides valuable information and can help public-sector organisations and private-sector companies alike make informed decisions about single-use plastic products in particular. But choosing one type of product over another based on an LCA on its own is not sufficient; a range of other factors such as waste management infrastructure, recycling capacity, the availability of water and renewable energy sources and even cultural traditions and norms also need to be considered.

This point is borne out in the recent UNEP publication, *Addressing Single-Use Plastics Pollution using a Life-Cycle Approach*[99]*.* It is designed specifically for policy-makers, such as legislators and city managers, when they are considering updating existing or introducing new policies concerning single-use plastics. A summary of its key points and general recommendations follows:

- The multiple uses of reusable products should be promoted;
- LCA and other validated information sources should be used;
- Specific conditions of the region must be factored in, such as energy types (renewable / non-renewable) and waste disposal options available;
- The reduction of environmental impacts throughout the production phase should be considered;

[97] ISO 14044:2006 Environmental Management – Life Cycle Assessment – Requirements and Guidelines, available at: https://www.iso.org/standard/38498.html#:~:text=ISO%2014044%3A2006%20specifies%20requirements,and%20critical%20review%20of%20the

[98] 'Are Life-Cycle Assessments worth the (recycled) paper they're printed on?', by Karine Vann, published by Ensia, 30 November 2020, details available at: https://ensia.com/features/life-cycle-assessment/ Accessed December 2020.

[99] *Addressing single-use plastic pollution using a life-cycle analyses approach,* lead author Alison Watson, published by UNEP, 2021, available at: https://www.lifecycleinitiative.org/wp-content/uploads/2021/02/Addressing-SUP-Products-using-LCA_UNEP-2021_FINAL-Report-sml.pdf

- Accepting the most feasible end-of-life scenario is crucial to determining the environmental impact (notwithstanding the difficulties posed when the likely end-of-life scenario is the product becoming marine litter);
- Reuse and circularity should be factored in at the design stage and the report notes that EPR can play a role here;
- The use of single-use products, regardless of material type, should be actively discouraged in favour of longer-lasting, more sustainable choices.

The report includes case studies of countries where single-use plastic products policies are already in place. The only references to EPS are contained within the case study details for Peru and there are no references to XPS.

Given the widespread use of EPS and XPS products, relatively few LCAs on these materials or products made from them have been conducted. A summary of the LCA and LCI documentation that is available specifically on EPS and/or XPS is detailed below, in date order.

3.1. 1991

3.1.1 In what was probably the first LCA of its kind, Martin B. Hocking published a paper[100] in Environmental Management in 1991, which compared "polystyrene foam" and paper cups. On the basis of raw material inputs including water, wood and hydrocarbons, the energy consumed in manufacturing each type of cup and the emissions produced, the "polystyrene foam" cup fared better, as more materials and energy were required to produce a paper cup. In terms of the likely end-of-life treatment, he found that while the foam cup would not degrade in landfill, the paper cup would decompose and produce methane. He found that there was no difference in emissions if both types of cup were subjected to incineration after use.

Having completed the LCA of the cups he concluded that "polystyrene foam, with an extension to plastics in general should be given more even-handed consideration relative to paper in packaging applications than is currently the case". This was not necessarily a recommendation that polystyrene foam cups were any better than paper cups in terms of carbon footprint; rather that the assumption, that paper cups had less of an environmental impact, should not be made. It should be noted however that the volume of disposable cups in use at the time, made from both paper and plastic, was significantly less than it is now.

3.2. 1994

3.2.1 In 1994, Martin B. Hocking published an article[101] which was a summary of his findings having conducted another LCA, this time on reusable and a range of disposable cups, one of which was XPS. He identified a number of factors affecting the energy requirements per use of each cup type,

[100] *Relative merits of polystyrene foam and paper in hot drink cups: Implications for packaging,* by Martin B. Hocking, published in Environmental Management 15, 731-747 (1991), abstract available at: https://link.springer.com/article/10.1007/BF02394812

[101] *Disposable cups have eco merit,* by Martin B. Hocking, published in Nature Vol. 369, 12 May 1994, available at: https://www.nature.com/articles/369107a0.pdf

including the energy cost of washing reusable cups, using a dish-washer. He found that, in certain circumstances, where the number of times a reusable cup was unlikely to be sufficient, i.e. less than 1,000 uses, an XPS disposable cup, could be deemed to be preferable. He also found that the XPS cup consumed the least amount of total energy per unit in comparison with other materials.

3.2.2 The Institute for Lifecycle Energy Analysis reviewed[102] Hocking's LCA and noted that he had used calculations based on a dishwasher, which was reasonably energy efficient, in order to determine the energy cost of washing reusable cups. The Institute concluded that if the data was calculated based on the use of a slightly less energy efficient dishwasher, it was impossible to determine the number of times that a reusable cup needed to be used, in order to have less of an environmental impact than an XPS cup. It found that, in situations where reusable cups were likely to get broken before being used a sufficient number of times, the use of a disposable cup was the preferred option.

It should be noted that none of the LCA research above included the effects on the environment if a disposable cup became general litter or marine litter.

3.3. 2006

3.3.1 An LCI on "polystyrene foam, bleached paperboard and corrugated paperboard foodservice products" was carried out on behalf of the American Chemistry Council in 2006, by Franklin Associates Ltd. It was an update of an LCI on the same products previously conducted in 1999. It states at the beginning that LCI is based on the energy use and emissions associated with the life cycle of specific products, but not the systems in which they are used. The products examined were hot and cold beverage cups, plates and sandwich clamshells; meat and poultry trays were excluded from the study due to a lack of alternatives in the marketplace at the time.

The study quantified the resource and energy use, solid waste, GHG and waterborne emissions for the life cycle of each product system, but did not include transport of the packaging nor use by the end consumer. For the purposes of the study EPS cups and General Purpose Polystyrene (GPPS) Foam (which appears to refer to XPS) clamshell containers were evaluated together with the other aforementioned materials. The authors, based on the low level of quantitative data available, estimated the recycling rate for the polystyrene foam foodservice products to be 2%.

Despite the detailed analyses undertaken, with a broad range of factors taken into consideration, the paper does not conclusively support or encourage the use of any one material over another.

3.4. 2011

3.4.1 In 2011, P*w*C and Ecobilan were tasked with completing an LCA of EPS fish-boxes for EUMEPS, the European Expanded Polystyrene Manufacturers Association. The whole-of-life study was conducted according to the requirements of ISO Standards 14040 and 14044. Their study[103] examined the performance of three types of fresh fish packaging, EPS fish-boxes, corrugated polypropylene (PP)

[102] *Reusable vs. Disposable Cups, University of Victoria 1994,* published by the Institute of Lifecycle Energy Analysis, available at: https://sustainability.tufts.edu/wp-content/uploads/Comparativelifecyclecosts.pdf

[103] *Life Cycle Assessment of the Industrial Use of Expanded Polystyrene Packaging in Europe. Case Study: Comparison of Three Fishbox Solutions,* by P*w*C and Ecobilan, published by EUMEPS, November 2011, available at: http://www.fishboxes.info/downloads/EUMEPS_report_PwC_112211.pdf

containers and corrugated cardboard with a polyethylene film, for three fish transport functions in France, Spain and Scandinavia.

When the performance of another packaging is within 20% of the EPS packaging value, the two are considered equivalent, due to uncertainties in LCA calculations.
When the performance of another packaging solution is lower by more than 20% than the one of the EPS packaging, the value is highlighted in green.
When the performance of another packaging solution is higher by more than 20% than the one of the EPS packaging, the value is highlighted in orange.

Indicator		EPS 4 kg France	PP 4 kg France	Cardboard 4 kg France	EPS 6 kg Spanish	PP 6 kg Spanish	Cardboard 6 kg Spanish	EPS 20 kg Scandinavian	PP 20 kg Scandinavian	Cardboard 20 kg Scandinavian
Non renewable primary energy	MJ	1	1.1	0.9	1	1.3	1.0	1	0.8	0.6
Depletion of Non Renewable Resources	kg eq. Sb	1	1.2	0.9	1	1.3	1.0	1	0.9	0.6
Emission of Greenhouse gases	kg CO2 eq., 100 years	1	0.9	1.0	1	1.0	1.4	1	0.8	0.7
Air acidification	g SO2 eq.	1	1.0	2.0	1	1.2	2.0	1	0.8	1.0
Photochemical Oxidants formation	g eq. ethylene	1	0.3	0.2	1	0.3	0.2	1	0.2	0.1
Water consumption	m3	1	0.8	3.3	1	0.7	3.5	1	1.0	4.1
Water Eutrophication	in g eq. PO43-	1	1.3	5.9	1	1.2	5.3	1	0.9	2.4
Total waste production	kg	1	3.4	7.6	1	2.1	4.1	1	1.5	2.4

Table 20: Comparative results of the three packaging solutions on the three markets

Figure 4. Comparison table from LCA study of EPS fish-boxes for EUMEPS[104]

The LCA incorporated several areas such as:

- non-renewable energy consumption
- non-renewable resource depletion;
- GHG emissions;
- water consumption;
- acidification;
- water eutrophication;
- photochemical oxidants formation;
- solid waste production.

Overall, the EPS fish-box performed better than the other containers but only in some areas. Four sensitivity analyses were also carried out, one of which was the use of the avoided impact approach to represent the recycling of plastics. When this was applied, the performance of the EPS fish-box was improved.

[104] Ibid.

Similarly to the reference scenario, the following table compares the relative performance of the three packaging scenarios when avoided impacts are considered for EPS and PP packaging. The results of the EPS packaging are taken as the reference.

Indicator		EPS	PP	Cardboard
		4 kg	4 kg	4 kg
		France	France	France
Non renewable primary energy	MJ	1	1.3	1.2
Depletion of Non Renewable Resources	kg eq. Sb	1	1.4	1.3
Emission of Greenhouse gases	kg CO2 eq., 100 years	1	1.1	1.3
Air acidification	g SO2 eq.	1	1.3	2.8
Photochemical Oxidants formation	g eq. ethylene	1	0.2	0.2
Water consumption	m3	1	0.9	3.6
Water Eutrophication	in g eq. PO43-	1	1.4	6.9
Total waste production	kg	1	3.7	8.5

Table 23: Comparative results of the three packaging solutions on the French market with avoided impacts considered for recycling

When credits are considered for recycling, the relative results of EPS packaging are improved. The EPS packaging performs better than PP and cardboard, except for the formation of photochemical oxidants.

Figure 5. Comparison table from LCA study of EPS fish-boxes for EUMEPS with sensitivity analysis[105]

The authors concluded that there is no packaging solution preferable for all environmental impacts analysed, but the EPS fish-boxes generally performed better than the other two materials in most but not all LCA areas examined. However they pointed out that the use of renewable energy to provide electrical power to EPS manufacturing sites would improve the overall performance of EPS fish-boxes.

3.5. 2012

3.5.1 A 2012 paper[106] prepared by Amanda Connolly, a student in Vancouver, compared reusable and disposable (paper and XPS) cups, specifically in the region of British Columbia, Canada. Connolly reviewed three types of cups; disposable made from paper lined with polyethylene resin, disposable made from EPS (which she refers to as Styrofoam although she notes that this term is incorrect) and reusable. She points to the extraction and use of raw materials used in the manufacture of all types of cup, and the energy consumption in the production of different materials and how it is difficult to directly compare the environmental impacts of these processes accurately.

In terms of recycling she noted that the availability and capacity of recycling and landfill infrastructure can vary quite significantly, leading to complicated disposal patterns, and therefore leading to difficulties in assessing which material type performs best. Connolly noted that the paper cups were difficult to recycle because of the resin lining and posed the (unanswered) question about how many of those that were collected were actually recycled. She also noted that EPS cups could be recycled

[105] Ibid.

[106] *A Qualitative Cradle to Grave Life Cycle Analysis of a BC Disposable-Coffee-Cup's Sustainability,* by Amanda Connolly, published by the University of British Columbia, November 2012, available at: https://open.library.ubc.ca/cIRcle/collections/undergraduateresearch/52966/items/1.0075651#downloadfiles

into PS resin for use in insulation and garden furniture but gave no indication as to the recycling rate of EPS cups, or indeed if there was a system in place to collect them once used.

Some of her conclusions and recommendations can be summarised as follows:

- EPS cups, when measured over a range of factors, were preferable to paper cups;
- Reusable cups were the best choice albeit they required a large number of uses in order to reduce their per-use environmental impact;
- An environmental tax/fee on disposable cups could help to pay for investment in improved recycling infrastructure.

3.6. 2014

3.6.1. A 2014 presentation was prepared by US-based Ashwin Basu and colleagues[107] (no affiliation accredited) on the LCA of a "Styrofoam" cup. They pointed to some potential health risks, such as headaches, from benzene and styrene absorption (both are used in the manufacture of XPS) albeit from environmental exposure rather than ingestion. The authors also noted that XPS does not decompose in landfill, and while it accounts for less than 1% of the mass weight, it takes up 20% of the space (no references provided to back up this statement). The paper references some alternatives to EPS/XPS packaging but there was no evidence presented as to whether this LCA found that XPS cups compared favourably or otherwise with those made from alternative materials.

3.7. 2015

3.7.1. An LCI study[108] conducted by a number of EU-based researchers, led by Carlo Ingrao of the University of Foggia, Italy, in 2015 reviewed "foamy polystyrene" trays used for packaging fresh meat. The description used in the paper indicates that the material reviewed was in fact XPS.

As the trays examined came from one manufacturer in Italy, the researchers noted that one objective of the paper was to provide data to the manufacturer that could be used to improve both the tray production system itself and the environmental policy of the company as a whole. Interestingly, the authors worked on the assumption that all waste XPS meat trays would be disposed of in the home and therefore would either be landfilled or incinerated for energy recovery; the possibility that the used XPS meat tray might be disposed of improperly, and therefore become litter or marine litter, was not a factor when completing the LCI. Collection of the meat trays after use, through kerbside collection or by consumers bringing them to a civic amenity site, was not considered.

Similar to other studies, the authors noted that XPS production contributed to non-renewable resource depletion, non-renewable energy use and GHG emissions. The authors concluded that no improvements could be made to the actual production processes of the PS granules from which the

[107] *Life Cycle Assessment of a Styrofoam Cup,* by Ashwin Basu, published by Prezi, June 2014, available at: https://prezi.com/ly3meba_h6q1/life-cycle-assessment-of-a-styrofoam-cup/

[108] *Foamy polystyrene trays for fresh-meat packaging: Life-cycle inventory data collection and environmental impact assessment,* by Ingrao C., et al, published by Food Research International Vol. 76 Part 3, October 2015, abstract available at: https://www.sciencedirect.com/science/article/abs/pii/S0963996915301204

trays were made, in order to improve its environmental performance; however a switch to renewable energy at the XPS-product manufacturing site would lead to a significant benefit in the overall environmental performance of the material.

Figure 6. XPS meat tray

As a number of countries which have banned or restricted the use of EPS and/or XPS packing products have often exempted these materials if used for fresh meat/poultry/fish, this study is of particular interest.

3.8. 2016

3.8.1 In 2016, the EPS Industry Alliance commissioned an LCA[109] of EPS resin production, which was conducted by Franklin Associates Ltd. The paper's goal was two-fold:

1. To provide interested parties with LCI data for EPS resin production, and;
2. To provide information about the "environmental burdens associated with the production of EPS resin".

It was intended that the data provided could then be for used for LCA analyses of specific EPS products in the future. The authors quantified the number of inputs and outputs associated with the production of EPS resin including total energy requirement, energy sources, water consumption, atmospheric pollutants, waterborne pollutants and solid waste. These measurements provide a valuable source of

[109] *Cradle-to-Gate Life Cycle Analysis of Expanded Polystyrene Resin,* by Franklin Associates, a Division of ERG, published by the EPS Industry Alliance, December 2016, available at: https://www.epsindustry.org/sites/default/files/LCA%20of%20EPS%20Resin%20LCA%202017.pdf

data for EPS product manufacturers, among others, to assist with determining the LCA of a specific EPS product.

3.9. 2017

3.9.1 At the 2017 Hamburg International Conference of Logistics, a conference paper[110] by Markus Trapp and colleagues of the Hamburg University of Technology, on the LCA of frozen food distribution schemes was presented. The paper focused specifically on the delivery of frozen foods directly to consumers in Germany to determine the amount of CO_2 emissions generated by this delivery system. Due to the requirement to keep the foods frozen, the maintenance of a cold environment throughout the delivery chain is essential. The paper noted that EPS packaging (they erroneously state "also known as Styrofoam") is often used as a material for delivering foods in this manner due to its ability to maintain foods at a stable temperature throughout the logistics process.

Three delivery methods were evaluated, one of which used EPS-packaging for delivery of the frozen food to the consumer. While the LCA for the delivery system using EPS packaging performed second out of all three in terms of GHG emissions, the authors noted the potential difficulties faced by consumers in relation to the disposal of the EPS box at end-of-life. The authors made the assumption that consumers would have to break the EPS box into fragments in order to dispose of it and that such packaging would always be placed into general waste. As all of the foods contained in the box would be sealed in separate packaging, the EPS boxes are likely to be clean and therefore would be suitable for recycling if the facility to drop them off at a civic amenity site was available to them; this does not appear to have been factored into the LCA as a possibility.

3.10. 2018

3.10.1 In 2018, a comprehensive EU-based LCA[111] was undertaken by Alejandro Gallego Schmid of the University of Manchester and colleagues, which specifically focused on single-use disposable containers and a reusable counterpart. The three disposable products evaluated were an aluminium container, a PP container and an XPS clamshell container. There were three goals of the study:

1. To compare the environmental impacts of the three containers (albeit they refer to EPS instead of XPS here);
2. To assess the environmental implications of reusing reusable containers;
3. To evaluate the environmental effects of end-of-life management options for the disposable containers.

Raw materials, production, use, end-of-life and transport were the stages considered when gathering the data. For the consideration of the impact of recycling, the authors made a number of assumptions

[110] *Life Cycle Assessment for frozen food distribution schemes,* by Trapp, M. et al, Hamburg University of Technology & Institute of Business Logistics and General Management, Conference paper, 2017, available at: https://www.econstor.eu/bitstream/10419/209337/1/hicl-2017-24-267.pdf

[111] *Environmental impacts of takeaway food containers,* by Alejandro Gallego Schmid, Joan Manuel F. Mendoza & Adisa Azapagic, published by the Journal of Cleaner Production 211:417-427, November 2018, available to download at: https://www.researchgate.net/publication/329166723_Environmental_impacts_of_takeaway_food_containers

which included one that no waste XPS containers were recycled (though no reason is given for this); they estimated that 50% went to landfill and the remaining 50% were incinerated for energy recovery.

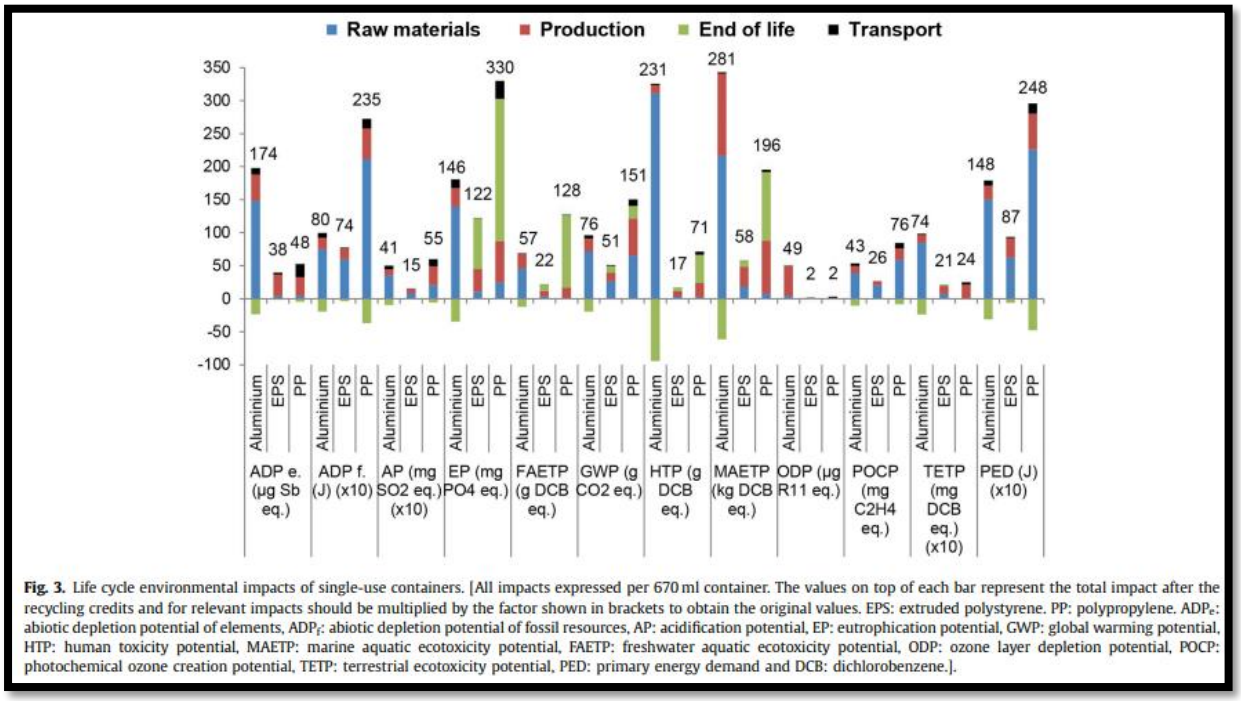

Fig. 3. Life cycle environmental impacts of single-use containers. [All impacts expressed per 670 ml container. The values on top of each bar represent the total impact after the recycling credits and for relevant impacts should be multiplied by the factor shown in brackets to obtain the original values. EPS: extruded polystyrene. PP: polypropylene. ADP_e: abiotic depletion potential of elements, ADP_f: abiotic depletion potential of fossil resources, AP: acidification potential, EP: eutrophication potential, GWP: global warming potential, HTP: human toxicity potential, MAETP: marine aquatic ecotoxicity potential, FAETP: freshwater aquatic ecotoxicity potential, ODP: ozone layer depletion potential, POCP: photochemical ozone creation potential, TETP: terrestrial ecotoxicity potential, PED: primary energy demand and DCB: dichlorobenzene.].

Figure 7. Extract from LCA by A. Gallego Schmid et al.[112]

The results of their analysis led the authors to conclude that of the three container materials evaluated, XPS performed the best across all environmental impact categories (see table above) compared to aluminium and PP. However, they also stated that in the absence of proper end-of-life management infrastructure to ensure the collection and recycling of the waste XPS containers, they could not be considered a sustainable packaging option.

Similar to other analyses, it was found that reusable containers needed a minimum number of uses in order to perform better on the environmental measurements, the volume of water required to wash the products after use being one of the main factors. They estimated the number of uses to be at least 24 to outperform EPS containers, a figure considerably lower than that cited by Hocking (see above).

3.10.2 An LCA[113] was commissioned by Stora Enso, a packaging manufacturer in Finland in 2018, which compared the LCA of an EPS fish-box against packaging made from corrugated board. Again a range of environmental and other categories were used to evaluate the performance of the two packaging systems.

LCA Consulting, the company which conducted the study, concluded that neither material could be described as a better performer when compared against the whole range of factors. The summarised results are shown below:

[112] Ibid.

[113] *LCA Study Report: Comparative Life Cycle Assessment (LCA) Study of Fish Packages Made of Expanded Polystyrene or Corrugated Board,* by LCA Consulting Oy, published by Stora Enso, 05 December 2018, available at: https://www.storaenso.com/-/media/Documents/Non-download-center/Study-report-Fish-packages.pdf?la=en

Table 2. Comparison of environmental performance of 10 kg and 20 kg EPS and corrugated board package based on LCIA results. Comparison is based on the burdens during the life cycle. Avoided burdens from material and energy recovery are not included in this table.

Impact category	10 kg package		20 kg package	
	EPS package	EcoFishBox™	EPS package	EcoFishBox™
Climate change	significantly worse	significantly better	worse	better
Acidification	worse	better	worse	better
Particulate matter	worse	better	ranking varies	ranking varies
Ionizing radiation	significantly better	significantly worse	significantly better	significantly worse
Photochemical ozone formation	worse	better	worse	better
Eutrophication, terrestrial	worse	better	ranking varies	ranking varies
Eutrophication, aquatic	worse	better	significantly better	significantly worse
Water use	worse	better	worse	better
Fossil resource depletion	significantly worse	significantly better	worse	better

Figure 8. Extract from Stora Enso LCA study[114]

The authors did find that the corrugated board packaging performed better in six out of nine environmental impact categories (see table above). The study also noted that other factors have significant effects on the LCA results:

- the location of production of the packaging, particularly in relation to the type of energy used during the manufacturing process;
- the weight of the packaging and fish combined for transport purposes;
- the country where the products reach end-of-life.

Table 3. Comparison of environmental performance of 10 kg and 20 kg EPS and corrugated board package based on LCIA results. Comparison is based on the net environmental impact results, including burdens during the life cycle and avoided burdens from material and energy recovery.

Impact category	10 kg package		20 kg package	
	EPS package	EcoFishBox™	EPS package	EcoFishBox™
Climate change	significantly worse	significantly better	worse	better
Acidification	worse	better	ranking varies	ranking varies
Particulate matter	worse	better	better	worse
Ionizing radiation	significantly better	significantly worse	significantly better	significantly worse
Photochemical ozone formation	worse	better	worse	better
Eutrophication, terrestrial	worse	better	ranking varies	ranking varies
Eutrophication, aquatic	ranking varies	ranking varies	significantly better	significantly worse
Water use	worse	better	ranking varies	ranking varies
Fossil resource depletion	significantly worse	significantly better	worse	better

Figure 9. Extract from Stora Enso LCA study

[114] Ibid.

3.10.3 A community research project[115] undertaken by third-level students in the University of British Colombia, Canada in 2018, was to complete a Life Cycle Analysis and "Eco-Efficiency Portfolio" of a number of single-use containers. As in many other publications and papers, the authors refer to EPS and note it is more commonly known as "Styrofoam". At the time, the City of Vancouver was considering the introduction of a ban on "Styrofoam" due to the large volumes of EPS being sent to landfill. The authors stated that while reusable containers would be an ideal way of reducing waste volumes, they recognised that these could present food safety and cost issues for food businesses. The objective of the report was to present "environmentally friendly disposable container" options (compostable or recyclable) to businesses, in order to decrease the solid waste volumes being sent to landfill.

They conducted LCA on a range of single-use containers, made from PP, PET, biodegradable plastic (corn-based polylactic acid (PLA)), paper and aluminium. The "Styrofoam" container was excluded from the sensitivity analysis for composting/recycling due to its "generally unrecyclable nature" but the EPS container (likely to be made from XPS) is included in the Environmental Impact table below.

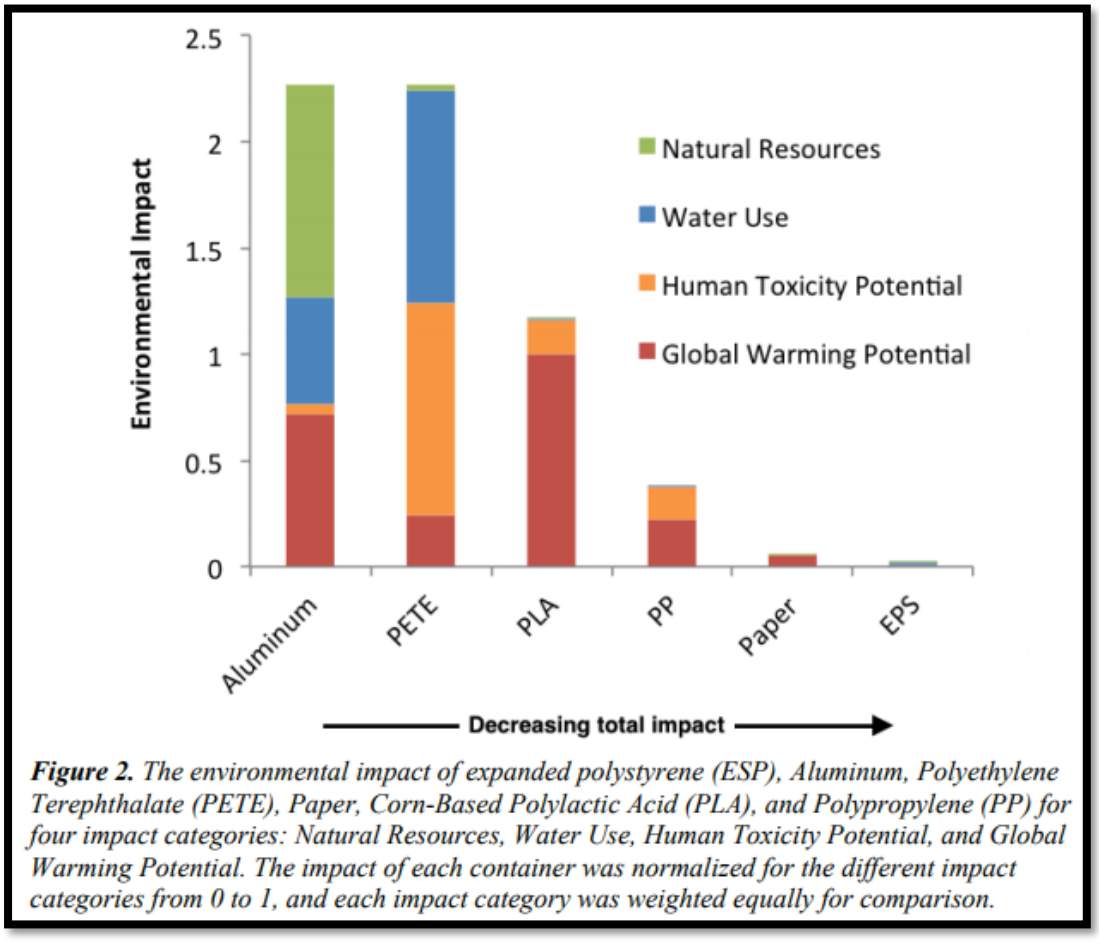

Figure 2. *The environmental impact of expanded polystyrene (ESP), Aluminum, Polyethylene Terephthalate (PETE), Paper, Corn-Based Polylactic Acid (PLA), and Polypropylene (PP) for four impact categories: Natural Resources, Water Use, Human Toxicity Potential, and Global Warming Potential. The impact of each container was normalized for the different impact categories from 0 to 1, and each impact category was weighted equally for comparison.*

[115] *Beyond Styrofoam: A Life cycle Analysis and Eco-Efficiency Portfolio of Single-Use Containers (Polystyrene, Plastic, Biodegradable Plastic, Paper and Aluminium),* by Misiurak A., Ramsay F., Tang X., & Yuan Y., published by University of British Columbia, 26 April 2018, available at: https://open.library.ubc.ca/cIRcle/collections/undergraduateresearch/52966/items/1.0366157

Figure 10. Extract from LCA study[116]

The "Styrofoam" container proved to be the most eco-efficient product, based on cost and CO_2 emissions but the point of the study was to provide cost-effective alternatives to "Styrofoam" for businesses. On this basis, the researchers concluded that the PP and PET containers were the best options available.

3.11. 2020

3.11.1 In a follow-up to the document it published in 2016, the US-based EPS Industry Alliance circulated a series of infographics[117] in July 2020 which were based on an LCA[118] conducted on its behalf by Intertek Sustainability. The study examined nine separate EPS packaging applications including food transport. The details of the study are not publicly available but the Alliance created a series of infographics which compare EPS life cycle impacts against other activities.

Figure 11. EPS Alliance infographic – EPS Life Cycle global warming

[116] Ibid.
[117] *EPS Life Cycle Infographic,* available at: http://www.epsindustry.org/sites/default/files/2020%20Life%20Cycle%20Infographics%20-%20All.pdf
[118] *The Life of Plastic Packaging,* press release from the EPS Industry Alliance, published by Cision PR Newswire, 01 July 2020, details available at: https://www.prnewswire.com/news-releases/the-life-of-plastic-packaging-301086948.html Accessed December 2020.

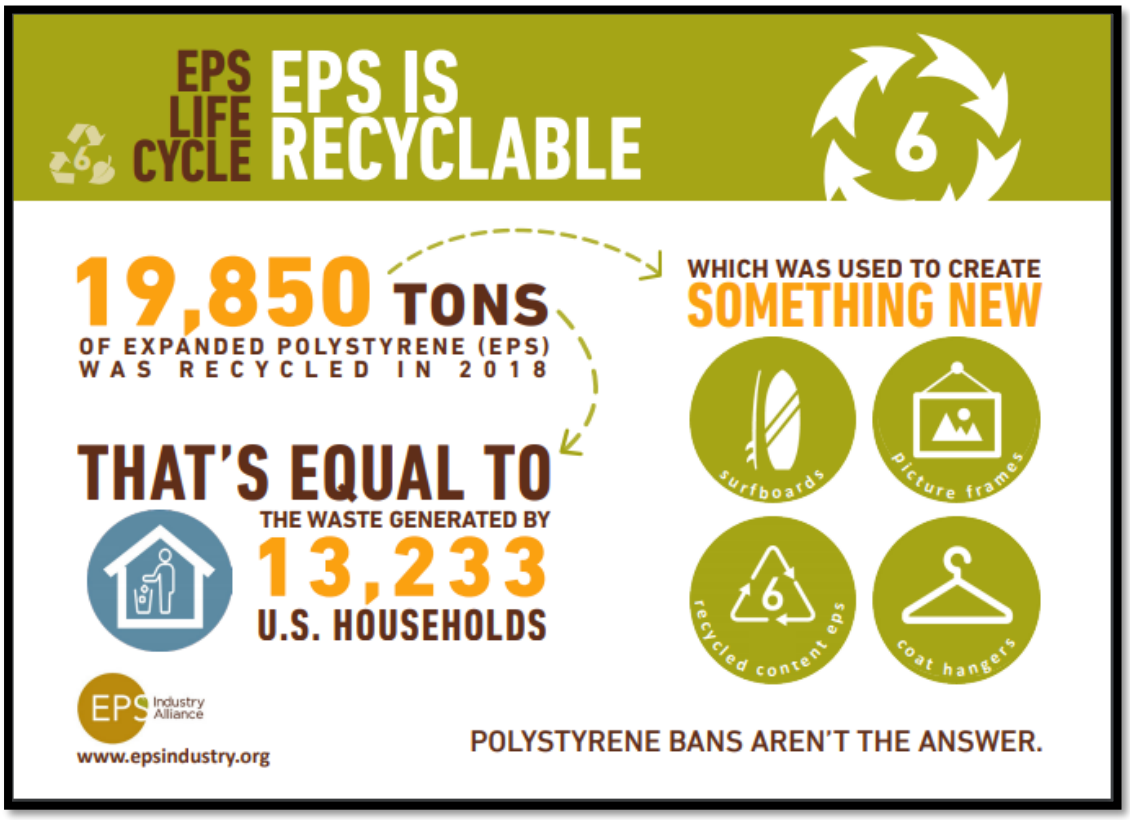

Figure 12. EPS Alliance infographic – EPS Life Cycle EPS is recyclable

3.12. Summary

The lack of an LCA for any of the materials referenced in the EU's SUP Directive was referenced in the statement[119] issued by the European Plastics Converters (EuPC) in October 2018. They noted that while Paragraph 18 of the Directive refers to the use of LCAs for designing plastic products for circularity, and Paragraph 14 references the importance of LCAs when Member States are introducing measures to reduce the use of single-use plastic products, no LCA was conducted.

MarILCA[120] is a European project that commenced in 2019 and runs to 2025; its primary function is to look at ways of integrating the potential environmental impacts of marine litter, particularly plastic-based litter, into LCA reviews. Its work is ongoing and preliminary results are awaited.

In another section of the OceanWise Report WP.6, a detailed and comprehensive methodology, to develop a circularity-sustainability assessment of the life cycle of EPS and XPS products and applications, is presented. This methodology, based on the review of existing LCA material relating to EPS and XPS, and circularity assessment methodologies and indicators state of the art, is essential in order to advance our understanding of EPS and XPS. This methodology guides us to assess circularity

[119] *Press release: single use plastics: a political or environmental decision?,* issued by European Plastics Converters (EuPC), 18 October 2018, available at: https://www.plasticsconverters.eu/post/2018/10/18/press-release-single-use-plastics-a-political-or-environmental-decision

[120] MarILCA, website available at: https://marilca.org/

as well as economic, environmental and social impacts of both current EPS and XPS applications and different alternatives that might be developed.

4. Recycling

The distinction between collecting and compacting EPS and recycling EPS has been made in another part of the OceanWise Report WP5.5. There are a number of companies which collect waste EPS from various sources and compact it, and then sell the compressed briquettes (as they are known) to other companies who in turn, recycle them into new products. Much of this type of compacted EPS emanates from EPS fish-boxes and in terms of food waste EPS, there is evidence to support the view that EPS fish-boxes are the most recycled products at end-of-life. They are used in their thousands and most come to end-of-life in fish processing operations and at fish markets. The volume of EPS fish-boxes available at these sites makes collecting and compressing them economically viable.

The research however also indicates that other food waste EPS applications like cups, and XPS products such as clamshell containers, are not collected and therefore not recycled at scale in OSPAR member countries. The main reasons for this appear to be two-fold:

1. Contamination of the products by residual food and/or liquids; and
2. The dispersed nature of the used containers, given the broad spectrum of applications and locations where they reach end-of-life (business / retail / consumer).

The first point is borne out in a short article[121] on the recycling of plastics in 2021 published by the Belgian Packaging Institute (IBE-BVI) which notes that recycling rates for plastic waste reach about 12%, at best. It notes that while mechanical recycling is likely to remain the most common form used, the recycled material can present issues in terms of its strength, flexibility and ability to withstand impacts, compared to virgin material. The report also states that "contaminations contribute to decreases in quality as well as to increases in variability of the recycled material". It is possible that contamination from leftover food and beverages in EPS/XPS food service products could cause these types of issues, if the products are recycled.

The recycling of EPS and XPS may also be facing other obstacles. The International Chemical Secretariat (ChemSec) published a report[122] in early 2021 titled "What Goes Around". ChemSec fully supports the development of a circular economy and acknowledges that far more recycling of items, like packaging, should be taking place. The report however, highlights the presence of chemicals in many materials as a major stumbling block to achieving increased recycling rates as it may not be possible to know exactly what chemicals are present in recycled material. Even if the chemicals are identified, it may be difficult to gauge the quantities in which they are present.

The report notes that more than 4,000 substances have been used to date in the production of plastic packaging and lists styrene as a hazardous monomer. As styrene is contained in all EPS and XPS

[121] 'Mechanical recycling of plastic packaging', published by IBE-BVI, 2021, available at: https://ibebvi.be/src/Frontend/Files/userfiles/files/03%2021%20Mechanical%20Recycling%20of%20Packaging%20Plastics.pdf

[122] 'What Goes Around – Enabling the circular economy by removing chemical roadblocks', published by ChemSec & the Laudes Foundation, 2021, available at: https://chemsec.org/app/uploads/2021/02/What-goes-around_210223.pdf

products, this may reduce any appetite manufacturers have for using material which contains recycled EPS and/or XPS products, particularly if it is designed to be used as a FCM. Food packaging manufacturers must have consistent quality and absolute clarity about what is contained in the materials they use in order to meet with legislative and regulatory requirements.

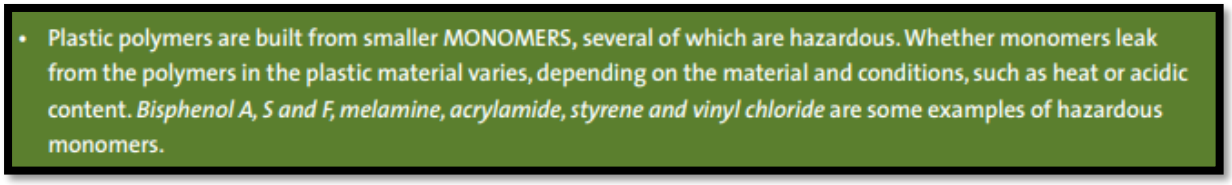

Figure 13. Extract from "What Goes Around" Report by ChemSec[123]

There is however, a positive development related to PS recycling. Styrenics Circular Solutions (SCS - a plastics industry initiative) issued a press release in March 2021 to advise that it has submitted its first application to EFSA for recycled PS (rPS) for use as FCM. Following a number of successful tests, using mechanically recycled post-consumer PS food packaging waste, SCS has produced a material which it believes will be suitable for food packaging applications. Jens Kathmann, the organisation's Secretary General is quoted as saying that they have a "recyclate that meets the strict and very high purity requirements for food contact materials". Further applications to EFSA are to follow and it is anticipated that EFSA will deliver a positive opinion. If their applications are successful it may drive further innovations in PS recycling generally, which may incorporate EPS and XPS recycling as well.

4.1 Recycling – OSPAR Parties

There are EPS recycling schemes and operations in place across most OSPAR member countries and they fall into four broad categories:

1. Recycling of post-industrial waste for their own products only, by EPS and XPS manufacturers, where the material recovered is remanufactured into EPS and XPS insulation and construction products;
2. Recycling of post-industrial waste and clean post-consumer packaging waste by EPS and XPS manufacturers, where the material recovered is remanufactured into EPS and XPS insulation and construction products;
3. Compacting or compacting and recycling of clean post-consumer and post-industrial packaging waste by companies, where the material recovered is recycled into new products;
4. Compacting or compacting and recycling of clean post-consumer and post-industrial packaging waste and/or EPS fish-boxes by companies, where the material recovered is recycled into new products.

Given the size of the market and the number of applications for EPS food service applications, there are relatively few food-waste EPS recycling schemes or programmes in place. Any recycling that is happening is generally at local level; there are no national EPS recycling programmes in any OSPAR member country. Private companies also appear to be at the forefront of most recycling efforts.

[123] Ibid.

The EPS industry associations in some countries promote the availability of EPS recycling services; for example EcoPSE® in France has an interactive map[124] which pinpoints EPS drop-off points around the country. It does not appear however that food-waste EPS is accepted at any of the points.

Some successful recycling operations were featured as case studies in the OceanWise WP5.5 Report. Details of the recycling programmes and schemes available across 14 countries are contained in the Country Fact Sheets contained in that report.

Information about the food waste EPS recycling schemes and initiatives taking place across OSPAR parties is provided below. Nearly all of the schemes referenced below involve compacting/recycling of waste EPS into new products but not into FCMs.

OSPAR Parties	No. of EPS recyclers	No. of EPS Recyclers for food-waste EPS
Belgium	11	0
Denmark	4	1
Finland	2	1
France	16	3
Germany	15	3
Iceland	0	0
Ireland	4	1
Luxembourg	0	0
Netherlands	11	1
Norway	3	2
Portugal	3	1
Spain	4	1
Sweden	2	1
Switzerland	3	0
UK	34	8

Figure 14. EPS Recyclers in OSPAR parties

4.1.1 Belgium

There are a number of EPS recyclers operating in Belgium but very few if any accept EPS fish-box waste and none appear to accept food-waste EPS or XPS.

4.1.2 Denmark

The EPS Gardentrays International[125] is the name of an initiative that arranges the collection and processing of waste EPS from the nursery sector in the Netherlands, Denmark and Germany. Subject

[124] Particulier, je souhaite deposer mon PSE, map available at: https://ecopse.org/carte-particuliers-pse/
[125] EPS Gardentrays International, website available at: http://www.eps-gardentrays.nl/com/

to certain conditions, the used seed and propagation trays from the horticultural industry across these three countries are collected at no charge and recycled into new products.

Much of the EPS collected in the country is sent to its many small-scale waste-to-energy plants which provide district heating. However, a company, EPS Recycle, started up in 2015 which specialised in collecting and compacting EPS fish-boxes at end-of-life. The business was taken over in 2020[126] by BEWiSynbra, one of the largest EPS manufacturers in the Nordic countries. It is likely that the collected waste is being recycled into new insulation material, as is happening at other BEWiSynbra recycling sites.

4.1.3 France

In 2018 it was announced that Syndifrais, the association of fresh dairy producers, was leading a project[127] together with a number of organisations, to trial the recycling of waste PS and EPS into new insulation products, but with a view to reaching the objective of achieving FCM standard with the recycled material. It is not clear if the project has yet reached that stage.

4.1.4 Germany

Germany participates in the EPS Gardentrays International initiative, more details about which can be found under Denmark.

Figure 15. EPS seed propagation tray

[126] 'EPS recycling movies into taken over factory', by Malin Folkesson, published by ReCyclinG, 07 August 2020, details available at: https://www.recyclingnet.se/article/view/729525/epsatervinning_flyttar_in_i_overtagen_fabrik Accessed February 2021.

[127] 'CITEO, TOTAL, Saint-Gobain and Syndifrais join forces to create a polystyrene recycling channel in France by 2020, issued by TOTAL, 27 June 2018, details available at: https://www.total.com/media/news/press-releases/citeo-total-saint-gobain-and-syndifrais-join-forces-create-polystyrene-recycling-channel-france-2020 Accessed December 2020.

4.1.5 Ireland

A private company, WasteMatters[128], operates a mobile EPS-compacting service around the entire country. Waste Matters operators drive their mobile units to the yards of their clients where the waste EPS has been stored; they compact the EPS into briquettes which are then transported back to the company's central depot. The briquettes are stacked on pallets and then shipped to continental Europe for recycling into new products. The company began by targeting EPS fish-boxes but now also collects waste packaging EPS from at least one major retailer.

Figure 16. Waste EPS fish-boxes awaiting compacting

4.16. Italy

A private company, Versalis, (part of Eni) announced[129] in April 2021 that it is launching a new food-packaging product which uses a high percentage of recycled PS from post-consumer waste sources. The new product, to be sold as Versalis Revive® PS Air F-Series Forever, will contain 75% rPS.

The company already supplies an EPS packaging product to the market, Versalis Revive® EPS 3000[130], which contains at least 35% recycled material but notes that it is not suitable as an FCM.

[128] WasteMatters, website available at: https://wastematters.ie/

[129] 'Versalis to launch new product for food packaging made with 75% post-consumer polystyrene', press release by Eni, 07 April 2021, available at: https://www.eni.com/en-IT/media/press-release/2021/04/cs-versalis-lancia-nuovo-prodotto.html

[130] Provisional Technical Data Sheet, Versalis Revive® Eps 3000, available at: https://versalis.eni.com/irj/go/km/docs/versalis/Contenuti%20Versalis/EN/Documenti/Prodotti/Stirenici/Schede%20Tecniche/EPS%20&%20EPS%20MC/Versalis%20Revive%C2%AE%20EPS%203000.pdf

It is not known if waste EPS and/or XPS from food service products is used in the production of either product.

4.1.7 The Netherlands

The Netherlands participates in the EPS Gardentrays International initiative, more details about which can be found under Denmark.

4.1.8 Portugal

An EU-funded project, to examine the feasibility of converting waste EPS into food-grade PS concluded in Portugal in 2020. The objective of the EPS Life-SURE project[131] was to test the feasibility of recycling post-industrial EPS waste (fish-boxes) into PS that was suitable for use as an FCM. In order to meet with the requirements of the EU regulations, the project managers had to demonstrate that the rPS met the:

- Challenge test, whereby rPS could be used to manufacture packaging for dairy products;
- Migration tests, where the prototypes met with all EFSA standards, using different percentages of rPS;
- Sensory organoleptic tests, to ensure that there was no lingering odour (due to the use of fish-box EPS).

The project managers highlighted the closed-loop nature of the waste EPS collection process which was established to ensure that no non-food contact EPS could enter the waste chain. They now hope that having proved the technical feasibility of recycling waste EPS into food-grade PS, new markets for recycled materials will be developed.

4.1.9 Spain

The second-largest fish market in the world is located in Madrid, MercaMadrid[132]. According to a major international EPS compacting machine supplier[133], the fish market is also home to an EPS fish-box compacting machine which processes all of the waste fish-boxes following the closure of the market each day. It is not clear what happens next to the compacted EPS in briquette form but like other operators, it is likely that it is sold, potentially through a recyclates trader, for recycling elsewhere in Europe.

4.1.10 United Kingdom

The Billingsgate Fish Market has, for several years, been compacting the estimated 900,000 EPS fish-boxes it amasses each year. The fish-boxes are disposed by the traders in the market at several points around the premises which are then brought to a central point where the compacting machine is

[131] EPS-SURE Life Project, website available at: http://www.life-eps-sure.com/en/the-project/
[132] MercaMadrid, website available at: https://www.mercamadrid.es/mercado-central-de-pescados/
[133] Greenmax™ Intco Recycling, details available at: https://www.greenmax-machine.com/Fish-Box-Recycling-in-Spain.html

based. Once compacted, the briquettes are palletised and sold abroad, through a recyclates trader, for recycling.

It remains to be seen if Brexit has any effect on the sale of compacted EPS from the UK to the EU.

Figure 17. Compressed EPS fish-boxes awaiting collection from Billingsgate

4.1.11 OSPAR Conclusions

There is evidence of recycling of post-industrial EPS fish-box waste taking place across a number of OSPAR member and European countries. Given how successful it can be, it is hoped that more companies will seize the opportunities posed by this particular waste-stream, particularly in light of the volume of EPS fish-boxes that are available in places such as fish markets and fish-processors. In terms of food waste EPS it is the most recycled material. It was not possible to obtain any statistics on the volumes of other food waste EPS or XPS recycled.

4.2 Recycling – North America

There are some recycling programmes and initiatives taking place on the continent that manufactures and uses billions of EPS and XPS containers; this usage is linked to the size of the takeaway industry in

the region. It was estimated[134] that consumer spending in the fast food sector in the U.S. alone was USD$279 billion in 2019.

4.2.1 Canada

At the G7 *Ministerial Meeting on Working Together on Climate Change, Oceans and Clean Energy* held in September 2018, it was announced[135] that three companies (ReVital Polymers, Pyrowave and INEOS Styrolution) would collaborate in a strategic partnership that would see the collection of post-consumer food waste polystyrene (it appears that both EPS and XPS would be collected). New recycling technology was to be deployed to recycle the waste into new products and packaging. However, it has not been possible to determine if the project proceeded and, if so, if its objectives were achieved.

Pyrowave subsequently announced[136] in 2018 that it was working with the municipal authorities of the City of Salaberry-de-Vallyfield, near Quebec, to recover post-consumer EPS and XPS (albeit referred to as "Styrofoam") packaging, plates and tumblers. The company noted that residents could deposit these items at an 'Ecocentre' in the city where the company would use its "microwave depolymerisation technology" to recycle the waste items into raw materials.

Another of the companies involved in the consortium referenced above, INEOS Styrolution, announced[137] in February 2021 that it is partnering with Polystyvert, to establish a "joint development agreement" to convert post-consumer PS waste into new PS resin. The technology used can process all types of feedstock, both post-consumer and post-industrial which may cover food waste EPS such as fish-boxes and single-use containers.

4.2.2 United States of America

The Food Service Packaging Institute, which is a trade association representing the manufacturers, distributors and users of single-use food service containers, launched the Foam Recycling Coalition[138] (FRC) in 2014. Its function is to support an increase in the volumes of EPS/XPS food service containers being recycled, with a focus on cups, bowls, plates, clamshells and cafeteria trays, although egg cartons and meat trays are also within its remit. Its foam recycling toolkit has five sections:

1. The basics of foam recycling;

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[134] 'U.S fast food restaurants statistics & facts', by S. Lock, published by Statista, 09 December 2020, details available at: https://www.statista.com/topics/863/fast-food/#:~:text=The%20total%20revenue%20of%20the,(COVID%2D19)%20pandemic. Accessed February 2021.

[135] 'ReVital Polymers, Pyrowave and INEOS Styrolution partner to launch closed-loop North American polystyrene recycling consortium', published by ReVital Polymers, September 2018, details available at: https://revitalpolymers.com/blogs/news/revital-polymers-pyrowave-and-ineos-styrolution-partner-to-launch-closed-loop-north-american-polystyrene-recycling-consortium Accessed December 2020.

[136] 'No. 6 Plastics and Styrofoam finally recovered thanks to Pyrowave!', published by Pyrowave , 09 November 2018, details available at: https://www.pyrowave.com/en/blog/press-room/no-6-plastics-and-styrofoam-finally-recovered-thanks-to-pyrowave Accessed February 2021.

[137] 'INEOS Styrolution and Polystyvert establish joint development agreement aimed at advancing a circular economy for polystyrene', published by INEOS Styrolution, 02 February 2021, details available at: https://www.ineos.com/businesses/ineos-styrolution/news/ineos-styrolution-and-polystyvert-establish-joint-development-agreement-aimed-at-advancing-a-circular-economy-for-polystyrene/ Accessed February 2021.

[138] Foam Recycling Coalition, website available at: https://www.recyclefoam.org/

2. Foam recycling end markets;
3. Foam recycling grants;
4. Foam recycling equipment;
5. Frequently asked questions.

In its interactive map[139] which pinpoints the locations where waste EPS/XPS food service containers and packaging can be dropped off, there are 428 places listed, some of which are in Canada. It also lists the companies which will buy the recycled (densified) product which are categorised per the Association of Plastic Recyclers.

The coalition provides statistics on the volumes of waste EPS/XPS recycled by the 15 programmes which it has grant funded since 2015:

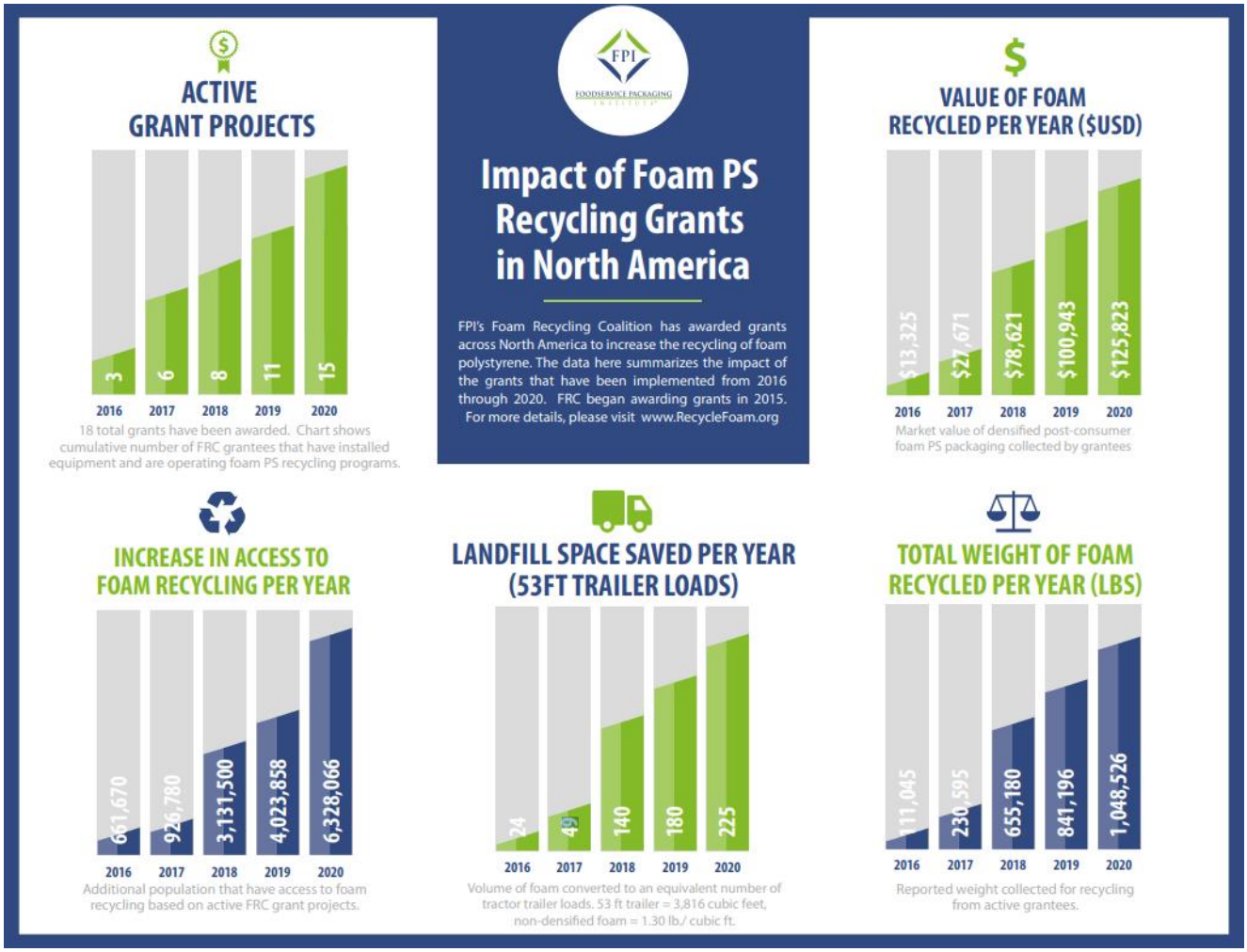


Figure 18. Infographic from the Foam Recycling Coalition

However, as their interactive map indicates that there are more than 400 drop-off locations for post-consumer EPS and XPS, the volume of these materials recycled is likely to be significantly higher than the 475 tonnes reported for 2020 (based on a survey of grantees only).

[139] 'Where to recycle foam', published by the Foam Recycling Coalition, available at: https://www.recyclefoam.org/about-foam-recycling

The EPS Industry Alliance[140] is the U.S. based association for EPS manufacturers. Its interactive map[141] details the different types of drop-off points available across the U.S. and Canada:

- Drop-off Transport only
- Drop-off Transport and Foodservice
- Foodservice only
- Loose Fill (peanuts)
- Large Volume
- Kerbside

Its 2019 Recycling Report[142] states that 21,700 tonnes of post-consumer EPS and 45,200 tonnes of post-industrial EPS were recycled. Unfortunately, there is no break-down of how much of the post-consumer waste relates to food-related waste, such as fish-boxes and food service containers. The report also refers to a new radio frequency fusion technology manufacturing process, which can produce EPS applications with 70% recycled content.

A 2021 report[143] by Eunomia, "The 50 States of Recycling", provides the most comprehensive data-set to date on recycling rates across all of the 50 States. It references the EPS bans in Maine and New Jersey (see OceanWise WP5.3 1a report) but does not provide separate information for EPS and/or XPS recycling – plastics with recycling numbers 3-7 are included in the Rigid Plastic group figures.

4.3 Recycling – elsewhere

There is little evidence that post-consumer food packaging waste made from EPS or XPS, such as clamshell containers and beverage cups, is being compacted/recycled at scale outside of the US and Canada. In many cases, recycling of such as waste is actively prohibited. For instance, the National Collection Network, established by Expanded Polystyrene Australia (EPSA) for the purposes of collecting clean post-consumer EPS packaging, specifically excludes[144] "meat trays, egg cartons, disposable food service items such as cups or clamshell containers and packaging peanuts".

Japan has a network of more than 130 EPS recycling points[145] but post-industrial EPS fish-boxes and EPS containers used for the transport of fresh fruit and vegetables appear to be the targeted items. End-of-life buoys are also compacted and recycled but there is no reference to post-consumer EPS or XPS food service containers.

[140] EPS Industry Alliance, website available at: https://www.epsindustry.org/
[141] EPS Recycling map, published by the EPS Industry Alliance, available at: http://www.epspackaging.org/index.php?option=com_content&view=article&id=37&Itemid=38
[142] 2019 U.S. EPS Recycling Report, published by the EPS Industry Alliance, 2020, available at: http://www.epsindustry.org/sites/default/files/2019%20RRR.pdf
[143] *The 50 States of Recycling: A State-by-State Assessment of Containers and Recycling Rates,* published by Eunomia, March 2021, available at: https://www.ball.com/getattachment/na/Vision/Sustainability/Real-Circularity/50-States-of-Recycling-Eunomia-Report-Final-Published-March-30-2021-UPDATED-v2.pdf.aspx?lang=en-US&ext=.pdf
[144] 'Polystyrene foam recycling options', published by BusinessRecycling, available at: https://businessrecycling.com.au/recycle/polystyrene
[145] JEPSA Country Report 2018, published by Japanese Expanded Polystyrene Association, November 2019, available at: https://epsrecycling.org/content/6-eps-recycling/jepsa-country-report-2018_nov-2019.pdf

Post-consumer food packaging waste made from EPS or XPS is usually disposed of by consumers in their black bin (residual) waste, or in litter bins provided by municipal authorities in public areas, or worse, thrown away carelessly such that it becomes marine litter. This dispersal of the waste and the lack of separation, combined with its extremely light weight and the presence of contamination by food, make it very challenging to collect and recycle it, in an economically sustainable manner. The general response by policy makers to the issues caused by EPS and XPS waste, i.e. volumes going to landfill, incineration, the visual harm caused by litter and marine litter, seems to be to ban these items rather than to devise ways of collecting and recycling them.

The Sustainable Packaging Coalition® (SPC[146]) is a collaborative initiative involving most of the world's leading packaging manufacturers, Fast Moving Consumer Goods (FMCG) producers and retailers. Its Design for Recycled Content Guide[147] is one of the most comprehensive in terms of the guidance relating to recycling. It contains a full section on PS which has some useful data and statistics:

- There is limited use of recycled PS in packaging and for durability and performance purposes, the percentage additional to virgin material is generally 25% or less;
- EPS packaging is only accepted in a minority of consumer-facing recycling programmes;
- There are markets for post-industrial recycled EPS in the construction industry, but little demand in the packaging industry;
- There is relatively little volume of food-grade recycled PS. The tests required to demonstrate that contaminants are removed during a recycling process, which would make the recycled material suitable for FCM, involve the use of chemicals which would dissolve PS. For this reason the Guide states that "there is no pathway for the use of PS packaging collected in commingled residential programs to be used in new food-grade packaging";
- While recycled PS can be cheaper than virgin material, the costs of including recycled PS in a manufacturing process, which makes it a more complex procedure, can negate any savings made;
- Chemical, rather than mechanical, recycling is likely to offer more potential for recycling EPS back into FCM.

This section of the document concludes that protective packaging which is not used for food contact is the application most likely to offer opportunities for recycled EPS.

5. Extended Producer Responsibility

The Organisation for Economic Co-operation and Development (OECD) defines[148]EPR as "an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life-cycle". Simply put EPR is a policy tool or mechanism that is

[146] Sustainable Packaging Coalition®, website available at: https://sustainablepackaging.org/
[147] *Design for Recycled Content Guide,* published by the Sustainable Packaging Coalition, available at: https://recycledcontent.org/
[148] Extended Producer Responsibility, published by the OECD, available at: http://www.oecd.org/environment/waste/extended-producer-responsibility.htm#:~:text=OECD%20defines%20Extended%20Producer%20Responsibility,of%20a%20product's%20life%20cycle.

used to transfer the burden of the cost of dealing with end-of-life products away from municipal authorities and back to the companies that manufactured them in the first place. In so doing, the rationale is that the companies will ensure that their products are designed in such a way to prolong the life of the product and ensure that the end-of-life management can be achieved as economically and efficiently as possible. The idea is that manufacturers of poorly-designed products, in terms of their recyclability or potential for reuse, will invest in improving them at the design phase, in order to reduce the economic cost of their participation in mandatory EPR schemes.

During an online seminar[149] in January 2021, which involved speakers from the European Environment Agency, the Ellen MacArthur Foundation, the European Commission and a Member of the European Parliament, the point was raised that EPR is essential if the development of the market for recycled plastics is to succeed; otherwise recycled plastics will be unable to compete with virgin materials.

5.1 EPR – EU level

The EU has passed legislation and Member States have initiated laws which have resulted in the establishment of a number of EPR schemes covering a wide range of products including:

- Waste Electrical & Electronic Equipment (WEEE), Batteries & Bulbs;
- Packaging & Farm Plastics;
- End-of-life Tyres (ELTs);
- End-of-life Vehicles (ELVs).

The two most common ways that EPR schemes can operate are:

1. Take-back scheme: the producer accepts, directly or indirectly, their products at end-of-life and disposes of them in a responsible manner. In the case of WEEE for instance, the major electrical producers (can be the manufacturer or retailer) enrol in the EPR scheme in the countries where their products are sold. Based on the volume of products they place on the market, the producers pay membership fees which are used to finance deposit points for consumers to drop-off their waste WEEE products, the collection of the items and the responsible waste-processing of their components, be it reuse, recycling or another treatment.
2. Deposit-Return scheme: this method is attractive for lower-value items such as PET bottles. The consumer pays for the product and an amount is included in the cost, which the consumer can reclaim, once they deposit the item in a specific location. The producer of the bottle (in this example) pays a fee for every bottle placed on the market, usually through an administrator, which funds the deposit-return infrastructure.

In many cases the schemes are administered by Producer Responsibility Organisations (PROs) which are established to administer all aspects of the scheme collectively on behalf of the producers, including the payment of membership fees, organising the collection of the specific waste stream,

[149] 'Stakeholders discuss global plastic treaty', by Vanessa Srebny, published by the Food Packaging Forum, 01 February 2021, details available at: https://www.foodpackagingforum.org/news/stakeholders-discuss-global-plastic-treaty Accessed February 2021.

managing the data to ensure compliance with the scheme requirements and arranging communication campaigns targeted at consumers and other stakeholders.

EPR schemes can be set up as part of a series of policy actions; there may be a drive to improve recycling rates, reduce marine litter amounts or introduce landfill bans. EPR schemes are often viewed as complementary to other activities; for instance the EU's SUP Directive has mandated the establishment of an EPR scheme along with a number of other legislative requirements, such as labelling and restrictions on placing certain items on the market.

A report[150] carried out in 2014 for the EU by Deloitte examined a sample of the various EPR schemes that were in place in a number of EU Member States at the time. The EPR schemes researched covered batteries, graphic paper, ELVs, oils, packaging and WEEE. The authors made some notable findings, though it caveated these by noting that there was a lack of comprehensive data on the technical performance and on the financial aspects of the schemes in general:

- The collection rates varied greatly between the end-of-life products and between Member States;
- The recycling rates varied greatly between the end-of-life products and between Member States;
- The fees paid by producers diverged considerably, and this could be linked to the cost-effectiveness of the scheme and/or the value of the recycled material obtained;
- The fees paid by producers sometimes did not fully cover the treatment costs of the waste stream.

The authors concluded that no single EPR model could be identified as the best performing and the most cost-effective. They went on to devise a number of Guiding Principles based on their analysis and extensive stakeholder engagement:

- Clarification of the definition and objectives of EPR
- Shared responsibility
- Full net cost coverage
- True end-of-life costs
- Fair competition
- Transparency
- Reporting harmonisation
- Monitoring and surveillance

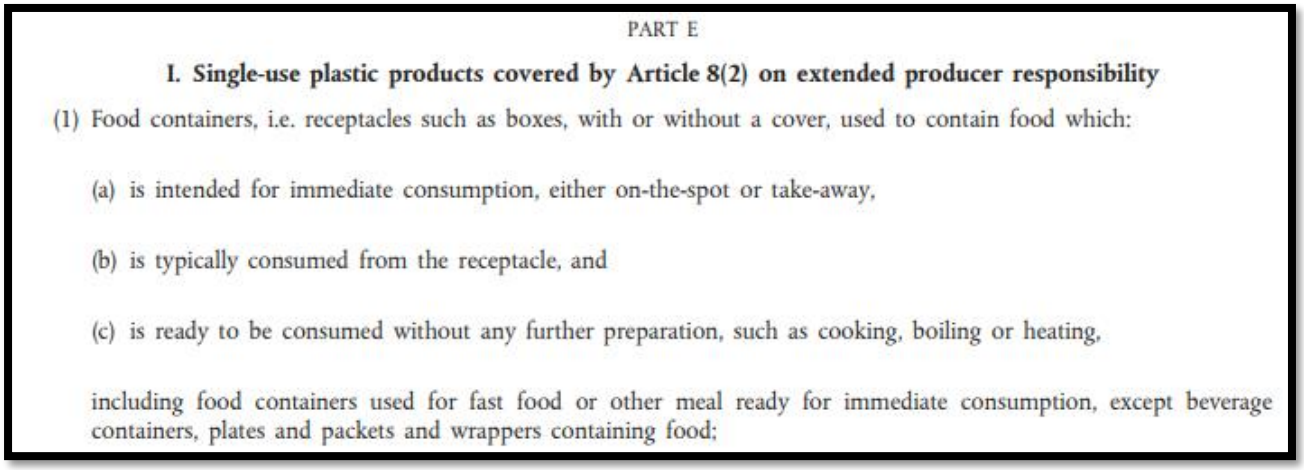
These principles could be applied to the EPR scheme as envisaged under the SUP Directive and may be considered by EU Member States as they draft the legislation to implement the EPR programme.

[150] *Development of Guidance on Extended Producer Responsibility: Final Report – European Commission, DG Environment,* by bio by Deloitte, in collaboration with Arcadis, ecologic, IEEP & umweltbundesamt, published by Deloitte, 2014, available at: https://www2.deloitte.com/content/dam/Deloitte/fr/Documents/sustainability-services/deloitte_sustainability-les-filieres-a-responsabilite-elargie-du-producteur-en-europe_dec-15.pdf

5.2 EPR – waste EPS and XPS

There appear to be no EPR schemes or programmes in place specifically designed to manage end-of-life EPS and XPS food service containers. The lack of EPR schemes for such products, in one sense, is surprising. These products are constantly referred to as "hard-to-recycle" or "non-recyclable" and yet it appears that no effort has been made to give the manufacturers of these items the responsibility for managing them at end-of-life. While these containers, made from both EPS and XPS are both technically recyclable, there is no doubt that the contamination caused by food and beverage waste makes recycling very challenging, as evidenced by RECOUP which ran a pilot scheme[151] in the UK (see OceanWise WP5.5 report). It would appear that the EPR scheme, as required by the EU's SUP Directive, for certain single-use products, will be the first of its kind in the world.

It should be noted here that as EPS food containers will be prohibited (under Part B of the SUP Directive) it will be XPS food containers, and single-use food containers made from other materials, that will fall under the remit of the EPR Scheme as per Part E of the Directive.



PART E

I. Single-use plastic products covered by Article 8(2) on extended producer responsibility

(1) Food containers, 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, and

(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 meal ready for immediate consumption, except beverage containers, plates and packets and wrappers containing food;

Figure 19. Extract from Part E, EU SUP Directive

The supply chains covered by the Directive have the potential to be quite long and imposing an EPR scheme could prove to be challenging. Take for example, a fish and chip shop on the west coast of Ireland. The shop buys its XPS containers from a wholesaler, which in turn buys them from a distributor. The distributor in Ireland buys the containers from a distributor in France, who sources them from an Italian distributor, who purchases them from the factory that produces the containers. Putting in place a scheme whereby the Italian producer of the XPS food service containers funds the recycling process for the same containers in Ireland will be a complex process.

[151] 'RECOUP promotes recycling at Welsh airshow', by Waqas Quershi, published by Packaging News, 11 July 2018, details available at: https://www.packagingnews.co.uk/news/environment/recoup-promotes-recycling-welsh-airshow-11-07-2018 Accessed January 2021.

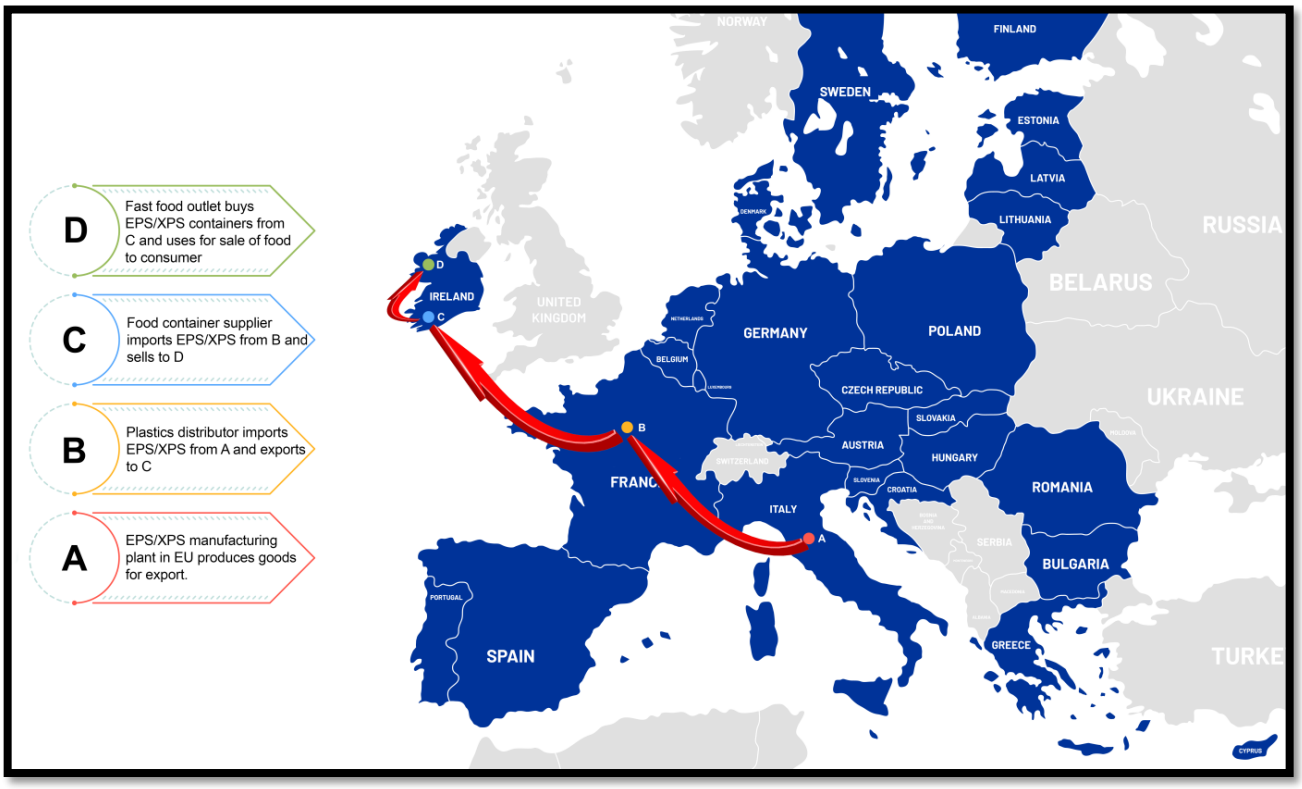


Figure 20. Visual representation of the XPS container journey in the EU

As all Members States have to establish EPR Schemes, there's an opportunity for collaboration between EU Members to design an EPR system that meets the Directive requirements but one which can be flexible enough to adjust to the constraints and factors that can vary between individual countries. A standard approach would help product manufacturers to plan for and navigate the EPR schemes that will need to be in place by 2024.

5.3 EPR – outside of the EU

At a policy level there seems to be little appetite for EPR schemes outside of the EU. The countries, states and cities which have decided to tackle the waste and marine litter caused by food waste EPS and XPS have proceeded to do so by banning the distribution and use of these items, rather than implementing an EPR scheme or programme. In the publication the B.A.N List 2.0[152] for instance, the authors argue that solving the "polystyrene problem" is achieved by banning EPS and XPS from use entirely and replacing them with products made from alternative materials.

The recycling of EPS and XPS that is taking place in the U.S. and Canada appears to be solely due to industry-funded initiatives and programmes; there are very few packaging EPR schemes in place in North America and none to cover specifically food waste EPS/XPS containers. A review of EPR schemes

[152] *Better Alternatives Now: B.A.N. List 2.0,* collaboratively published by a number of NGOs and marine litter initiatives, undated, available at: https://static1.squarespace.com/static/5522e85be4b0b65a7c78ac96/t/5aa0618a8165f553aa68b8b8/1520631281665/5+Gyres+BAN+List2.pdf

legislation[153] which may be forthcoming in some state legislatures in 2021 indicated that many of the proposals would include plastics and/or plastic packaging but none appear to focus specifically on food waste packaging. The situation is fluid however and two recent blog posts, both published in March 2021, indicate that a drive for more EPR for packaging may be forthcoming.

Matt Prindiville, writing for UPSTREAM [154], a policy institute, states that while previous attempts to establish EPR schemes for packaging were unsuccessful, the time is right for individual states to introduce EPR legislation, given how the US lags behind other regions in this regard. He makes several recommendations to policy makers, one of which is the importance of setting targets for a number of areas such as packaging reduction and reuse/refill, recycling, litter prevention and outreach initiatives.

In a post[155] for the Reusable Packaging Association, Tim Debus writes that the US should look to the EU where waste recovery and recycling rates are significantly higher than in the US. While he notes that EPR has played a part in these achievements, the importance of the Circular Economy Action Plan as a strategy to reinforce EPR, rather than the other way round, is emphasised. He has some recommendations for aligning EPR with Circular Economy Principles, including the exemption of reusable packaging, treating reuse differently to recycling and investment in reuse operations.

EPR on its own cannot solve the problem of general or marine litter, but making manufacturers responsible for the single-use plastic items they produce at end-of-life is a policy lever that has not yet been used to its full potential.

6. Findings

The uses of EPS and XPS in FCM applications are varied and billions of food service products and containers are used globally every year. There are very few references specifically to either material in terms of their suitability as FCMs. The use of styrene has been subject to rigorous investigation in recent years and continues to be examined. Its exposure to heat or fatty foods, when used in the manufacture of food service packaging, can be problematic.

Given the widespread use of both EPS and XPS containers, surprisingly few full life cycle analyses on them have been completed. The majority of the LCA that have been carried out have been conducted in Europe and North America, where some recycling is taking place. If the same studies were conducted in parts of Asia, where many waste EPS and XPS food service containers are landfilled in poor conditions, incinerated or burnt with few if any environmental controls, the results could differ significantly.

[153] '2021 could be the year for packaging EPR, nearly a dozen state bills in play', by Megan Quinn, published by Waste Dive, 12 February 2021, details available at: https://www.wastedive.com/news/2021-state-extended-producer-responsibility-recycling/594873/ Accessed February 2021.
[154] 'EPR for packaging: then and now', by Matt Prindiville, published by UPSTREAM, March 2021, available at: https://upstreamsolutions.org/blog/epr-for-packaging-then-and-now Accessed April 2021.
[155] 'Extended Producer Responsibility for Packaging is Missing the Circular Opportunity', by Tim Debus CEO, published by the Reusable Packaging Association, 01 March 2021, details available at: https://www.reusables.org/extended-producer-responsibility-for-packaging-is-missing-the-circular-opportunity/ Accessed April 2021.

Few LCA conducted find that EPS and/or XPS are the preferred materials in comparison to alternatives; those that do were generally conducted more than two decades ago, when the issue of marine litter had not become as problematic as it is today.

While it is imperative that LCA and LCI studies continue to be conducted, it should be recognised that the measuring the environmental effect of an EPS/XPS container when it becomes marine litter is very difficult. Containers made from these materials can fragment over time increasing the likelihood of some of the material being ingested by a marine species. Measuring the impact this has on the marine environment or on human health when organisms that have ingested PS are consumed, presents a real challenge.

However it should be noted that while there are demands for EPS and XPS containers to be banned, substitutes need to be assessed in terms of their potential for environmental harm. For instance, as recently as February 2021, Belgium, Luxembourg and the Netherlands issued a joint statement[156] calling for the withdrawal of "bamboo melamine plastics" from the EU market, due to their non-compliance with Article 5 of EU Regulation No. 10/2011. Many of these products on the market exceed the SMLs for formaldehyde and melamine.

While some food service waste EPS and XPS recycling is taking place, most of these containers used appear to be destined for landfill, incineration or to become litter.

There is a disconnect between the approaches taken to EPS and XPS and other packaging products. For instance, there has been much innovation and investment to make plastic bottles for soft drinks (which are generally made from PET) lighter and easier to recycle, and to increase the amount of recycled material used in the manufacture of the bottles themselves. DRS Schemes specifically for plastic bottles are in the process of being rolled out in a number of countries. Yet food-contaminated EPS and XPS packaging is effectively written off as too difficult and/or not economically feasible to recycle; there have been relatively few attempts to better manage it at end-of-life.

With pressures on landfill availability, councils and municipal authorities are bringing in bans on EPS and XPS products due to the space they take up when disposed of as waste; however, this is often in the absence of any collection or recycling infrastructure to manage these products until they can be phased out, or indeed enhanced collection systems and composting facilities where biodegradable/compostable is a requirement of the substitute material.

While EPR schemes are a regular feature of the waste management landscape in the EU and further afield, there appears to be no EPR scheme anywhere that is specifically designed for EPS and/or XPS food service products.

The longer-term effects of the pandemic have yet to be felt but in the short-term, it has led to a spike in the use of single-use items, particularly plastic.

[156] 'Benelux demand market withdrawal of bamboo plastics', by Vanessa Srebny, published by the Food Packaging Forum, 17 February 2021, details available at: https://www.foodpackagingforum.org/news/benelux-demand-market-withdrawal-of-bamboo-plastics Accessed February 2021.

7. Conclusions

The ongoing review of styrene for its suitability in the manufacture of FCMs could have implications for the use of EPS and/or XPS products. As styrene is contained in every EPS and XPS item, any restrictions in its use as a FCM would severely curtail the use of these materials in food service packaging.

LCAs need to encompass more factors such as the benefits of avoided costs, particularly when comparing single-use food service packaging with reusable items; these might include less food resources lost due to the presence of marine litter; fishermen catching more fish and less litter; lower volumes of materials lost to landfill leading to less emissions, particularly of methane; a reduction in illnesses in people due to lower amounts of plastic and chemicals in the food chain. These factors could make significant differences to the comparison of EPS and XPS with other materials.

Specific applications should be given more consideration in terms of end-of-life management; for instance, an LCA of EPS fish-boxes should factor in the feasibility for fish-boxes to be collected, compacted and recycled. On the other hand, the LCA of an XPS container should consider that the likelihood of it being recycled is low, and it is usually going to be landfilled, incinerated or littered.

What is clear that is EPS works extremely well in certain applications, such as fish-boxes, and alternative materials are not necessarily leaving a lighter carbon footprint when all possible factors are considered. Given how successful EPS fish-box recycling can be, more private sector engagement in particular, is needed to develop the requisite infrastructure and markets for the recycled product.

Where the use of EPS and XPS in applications is such that collection and recycling is not viable, then consideration should be given to the phasing out of such products. However, plans should be made to manage the products at end-of-life, as phasing out periods can last for months or even years. In addition, simultaneous development of recycling infrastructure and/or composting facilities is needed if compostable materials are to replace EPS/XPS.

EPS and XPS food service packaging recycling is taking place at reasonable scale across the US. EU Member States could look to specific state legislators and industry organisations for insights about what aspects of the collection and recycling systems work well, so they can apply those learnings in the development of the EPR scheme required under the EU's SUP Directive.

EPR schemes can be complex and cumbersome to establish and maintain; the dispersed nature of EPS and XPS food service packaging at end-of-life is going to make the development of the EPR scheme in each Member State under the SUP Directive extremely challenging. Existing PROs may be best placed to apply to manage this new Scheme.

Even if the use of EPS and XPS food waste packaging was halted overnight, there are still thousands of tonnes of these materials in use globally and unfortunately, much of it is in our oceans. While banning the use of EPS and XPS in a number of countries may bring about a gradual reduction in the use of these products, solutions to capture these containers at end-of-life and find viable ways to recycle them, into other products, need to be found. There should be enough available material to warrant investment in collection systems and recycling technologies so these used containers can get a second lease of life in another application, be it packaging, FCM or insulation.

The EU's SUP Directive is likely to have an effect on the use of EPS food service products but it will take some considerable time to measure its effectiveness in terms of reducing marine litter. Similarly, Member States have until the end of 2024 to establish the EPR Scheme for XPS and other single-use plastic food service items; the outcomes and associated benefits from the schemes' establishment across the EU will not be seen for some years.

Compostable containers are often seen as the natural replacement for EPS and/or XPS products and they can be considered a sustainable alternative. It is essential though that the requisite investment is made, in terms of developing appropriate and adequate waste separation and collection facilities, together with the industrial composting capacity required, to ensure their correct end-of-life treatment.

More engagement is needed with the waste industry when EPS and XPS usage policies are being developed. Ultimately the companies that collect the waste from domestic households and businesses and organisations are the same companies that then sort the waste collected into the various waste streams; they have first-hand knowledge on the types of waste going into individual bins, the volumes involved and the levels of contamination. They also have extensive experience of finding markets for the various recycling streams, be it plastic, paper, aluminium or glass and disposing of waste streams to landfill or incinerator operators. It is an industry which can provide valuable insights.

As with all other aspects of trying to reduce the volumes of litter entering the marine environment, human behavioural change is key. Countries which still view dumping waste directly into the ocean as a waste management treatment option must stop this practice. Improved collection and recycling infrastructure is essential. But each individual also has a responsibility to ensure that they safely and correctly dispose of their waste, ideally having reduced the amount of waste they produce in the first place.

The OceanWise reports should help policy-makers, legislators, NGOs and private sector organisations to make more informed, and therefore better decisions about EPS and XPS use.