

Alternatives to single-use plastics:

References

- Accorsi, R., Battarra, I., Guidani, B., Manzini, R., Ronzoni, M. and Volpe, L., 2022. Augmented spatial LCA for comparing reusable and recyclable food packaging containers networks. *Journal of Cleaner Production*, 375, p.134027.
- Advisory Committee on Packaging, 2008. *Packaging in Perspective*. Supported by INCPEN, the Packaging Federation and Valpak.
- Aeschelmann, F. and Carus, M., 2015. Biobased building blocks and polymers in the world: capacities, production, and applications—status quo and trends towards 2020. *Industrial biotechnology*, 11(3), pp.154-159.
- Ashfaq, A., Khursheed, N., Fatima, S., Anjum, Z., and Younis, K. (2022) 'Application of nanotechnology in food packaging: Pros and Cons', *Journal of Agriculture and Food Research*, 7.
- BBC News (2020) [Plastic bag tax raises more than £2m for Northern Ireland environment](#), this news article is available on the BBC News website.
- Behera, S. (2022) [Single-use plastic, the countries that have banned it](#). This news article is available from World excellence website
- [BEIS and Defra \(2021\) Consultation outcome: Standards for biodegradable, compostable and bio-based plastics: call for evidence](#). This research article is available from the UK Government website
- Bonwick, G., Bradley, E., Lock, I. and Romero, R., 2019. Bio-based materials for use in food contact applications. Report to the Food Standards Agency; Fera Science Ltd.: York, UK.
- British Plastics Foundation. [Why is plastic the sustainable choice?](#) This research article is available from the British Plastics Foundation website
- Burgess, M., Holmes, H., Sharmina, M. and Shaver, M.P., 2021. The future of UK plastics recycling: one bin to rule them all. *Resources, Conservation and Recycling*, 164, p.105191.
- Carina, D., Sharma, S., Jaiswal, A.K. and Jaiswal, S., 2021. Seaweeds polysaccharides in active food packaging: A review of recent progress. *Trends in Food Science & Technology*, 110, pp.559-572.
- Center for Science Education. [Some Greenhouse Gases Are Stronger than Others](#). This research article is available from the UCAR website
- Chaudhary, V., Bangar, S. P., Thaku, N. and Trif, M. (2022) 'Recent Advancements in Smart Biogenic Packaging: Reshaping the Future of the Food Packaging Industry', *Polymers*.
- [CMS \(2021\) Plastics and packaging laws in France](#). This legislation is available from the CMS website
- Coelho, P.M., Corona, B., Klooster, R., and Worrell, E. (2020) 'Sustainability of reusable packaging—Current situation and trends', *Resources, Conservation & Recycling*: X, 6(100037).
- Creighton, P (2022) [“Bowled over ... Wagamama to launch new recyclable takeaway containers as it aims to reduce its carbon footprint”](#). This news articles is available from the RDG Today website
- [Data Bridge. Global Seaweed Based Packaging Market – Industry Trends and Forecast to 2029](#). This research article is available from the Data Bridge website
- Defra Press Office. (2021). War on plastic pollution stepped up with expanded plastic bag charge.

- Defra, 2022. UK statistics on waste
- Diprose, G., Lee, L., Blumhardt, H., Walton, S. and Greenaway, A., 2022. Reducing single-use packaging and moving up the waste hierarchy. *Kaitiaki: New Zealand Journal of Social Sciences Online*, pp.1-22.
- Don't Waste Group. 2022. POST-CONSUMER RECYCLED PLASTIC VS VIRGIN PLASTIC
- Eggertsen, M. and Halling, C., 2021. Knowledge gaps and management recommendations for future paths of sustainable seaweed farming in the Western Indian Ocean. *Ambio*, 50(1), pp.60-73.
- [England \(2012\) Materials and Articles in Contact with Food \(England\) Regulations 2012](#). This legislation is available from the UK Government website.
- Environment, Food and Rural Affairs Committee (2022). MPs call for ban on all plastic waste exports. UK Parliament News Article.
- [European Bioplastics \(2020\) Market update 2020](#): Bioplastics continue to become mainstream as the global bioplastics market is set to grow by 36 percent over the next 5 years, This news article is available from the European Bioplastics website
- European Bioplastics. 2022. Bioplastics Market data.
- European Bioplastics (2022b) European Bioplastics Conference: Bioplastics Market Development Update 2022, Berlin, Germany.
- [European Bioplastics \(2023\) Frequently Asked Questions on Bioplastics](#). This news article is available from the European Bioplastics website
- [European Commission \(2018\) A sustainable alternative to plastic packaging](#). This legislation is available from the European Commission
- [European Commission \(2022\) Packaging Waste](#). This legislation is available from the European Commission
- European Food Safety Authority (EFSA), 2009. Guidelines on submission of a dossier for safety evaluation by the EFSA of active or intelligent substances present in active and intelligent materials and articles intended to come into contact with food. *EFSA Journal*, 7(8), p.1208.
- EUR-Lex (2019) 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, This legislation is available from [EUR -lex website](#)
- Fera 2019. [Bio-Based Materials for Use in Food Contact Applications \(PDF\)](#). This research article is available from the UK Government website
- Food Navigator. 2021. Sustainable packaging a 'growth opportunity' for food and consumer goods industry says IGD.
- Froehlich, H.E., Afflerbach, J.C., Frazier, M. and Halpern, B.S., 2019. Blue growth potential to mitigate climate change through seaweed offsetting. *Current Biology*, 29(18), pp.3087-3093.
- Future Bridge. (2022). Seaweed-based Packaging. This news article is available from [the Future Bridge website](#)
- Gerassimidou, S., Martin, O.V., Chapman, S.P., Hahladakis, J.N. and Iacovidou, E., 2021. Development of an integrated sustainability matrix to depict challenges and trade-offs of introducing bio-based plastics in the food packaging value chain. *Journal of Cleaner Production*, 286, p.125378.
- Globe Newswire (2022) Nanotechnology for Food Packaging Market: Segmented By Application ; By Technology and Region – Global Analysis of Market Size, Share & Trends for 2019–2020 and Forecasts to 2030, This research article is available from [the Globe Newswire website](#)
- Green Peace (2021) The world is ditching plastics with reuse and refill laws and practices, This Research article is available from [the Green Peace website](#)
- Government of Canada (2021) [Canadian Plastics Innovation Challenges – Environment and Climate Change Canada Phase 1 recipients](#), This legislation is available from the Government of Canada website

- Government of France (2021). [Les emballages plastiques des fruits et légumes frais n'auront plus cours](#). This legislation is available on the Government of France website
- Herrmann, C., Rhein, S. and Sträter, K.F., 2022. Consumers' sustainability-related perception of and willingness-to-pay for food packaging alternatives. *Resources, Conservation and Recycling*, 181, p.106219.
- Hoque, M., McDonagh, C., Tiwari, B.K., Kerry, J.P. and Pathania, S., 2022. Effect of high-pressure processing on the packaging properties of biopolymer-based films: A review. *Polymers*, 14(15), p.3009.
- Ishii, K. and Furuichi, T., 2013. Estimation of methane emission rate changes using age-defined waste in a landfill site. *Waste management*, 33(9), pp.1861-1869.
- Industrial Biotechnology Innovation Centre. 2018. [A Review of Standards for Biodegradable Plastics](#) (PDF). This research article is available from the UK Government website
- Innovate UK. 2023. Smart sustainable plastic packaging process evaluation report. This research article is available from [the UK Research and Innovation website](#)
- Jamróz, E. and Kopel, P., 2020. Polysaccharide and protein films with antimicrobial/antioxidant activity in the food industry: A review. *Polymers*, 12(6), p.1289.
- Kearney, 2023. No silver bullet: Why a mix of solutions will achieve circularity in Europe's informal eating out (IEO) sector. This news article is available from [the Kearney website](#)
- Keranen, O., Komulainen, H., Lehtimäki, T. and Ulkuniemi, P. (2021) 'Restructuring existing value networks to diffuse sustainable innovations in food packaging', *Industrial Marketing Management*.
- Kershaw, P., 2018. Exploring the potential for adopting alternative materials to reduce marine plastic litter.
- Keynes, J. 2021. Recyclable, Compostable, Biodegradable: What do these mean for our planet? Biffa
- Kourmentza, C., Plácido, J., Venetsaneas, N., Burniol-Figols, A., Varrone, C., Gavala, H.N. and Reis, M.A., 2017. Recent advances and challenges towards sustainable polyhydroxyalkanoate (PHA) production. *Bioengineering*, 4(2), p.55.
- Ludwicka, K., Kaczmarek, M. and Białkowska, A., 2020. Bacterial nanocellulose—A biobased polymer for active and intelligent food packaging applications: Recent advances and developments. *Polymers*, 12(10), p.2209.
- Markets and Markets. 2022. Polyhydroxyalkanoate (PHA) Market.
- McKeown, P. and Jones, M.D., 2020. The chemical recycling of PLA: A review. *Sustain. Chem*, 1(1), pp.1-22.
- Moradali, M.F. and Rehm, B.H., 2020. Bacterial biopolymers: from pathogenesis to advanced materials. *Nature Reviews Microbiology*, 18(4), pp.195-210.
- Morashti, J.A., An, Y. and Jang, H. (2022) 'A Systematic Literature Review of Sustainable Packaging in Supply Chain Management', *Sustainability*
- Mordor Intelligence A. PAPER PACKAGING MARKET - GROWTH, TRENDS, COVID-19 IMPACT, AND FORECASTS (2023 - 2028)
- Mordor Intelligence B. GLASS PACKAGING MARKET - GROWTH, TRENDS, COVID-19 IMPACT, AND FORECASTS (2023 - 2028)
- Mordor Intelligence C. METAL PACKAGING MARKET - GROWTH, TRENDS, COVID-19 IMPACT, AND FORECASTS (2023 - 2028)
- Mordor Intelligence D. ACTIVE AND INTELLIGENT PACKAGING MARKET - GROWTH, TRENDS, COVID-19 IMPACT, AND FORECASTS (2023 - 2028)
- Orion Market Research. UK Polylactic Acid (PLA) Market. This research article is accessible from [the Orion Market research website](#)
- Naser, A.Z., Deib, I. and Darras, B.M. (2021) 'Poly(lactic acid) (PLA) and polyhydroxyalkanoates (PHAs), green alternatives to petroleum-based plastics: a review', *RSC Advances*, 11, pp. 17151-17196
- NI Government (2022) Carrier bag levy, This legislation is available from [the Northern Ireland Government website](#)

- Nilsen, Nygaard, J., Fernández, E.N., Radusin, T., Rotabakk, B.T., Sarfraz, J., Sharmin, N., Sivertsvik, M., Sone, I. and Pettersen, M.K., 2021. Current status of biobased and biodegradable food packaging materials: Impact on food quality and effect of innovative processing technologies. *Comprehensive reviews in food science and food safety*, 20(2), pp.1333-1380.
- Northern Ireland 2012 - <https://www.legislation.gov.uk/nisr/2012/384/contents/made> Orion Market Research. 2020. UK Polylactic Acid (PLA) Market
- Petersen, K., Nielsen, P.V., Bertelsen, G., Lawther, M., Olsen, M.B., Nilsson, N.H. and Mortensen, G., 1999. Potential of biobased materials for food packaging. *Trends in food science & technology*, 10(2), pp.52-68.
- Petkoska, A.T., Daniloski, D., D'Cunha, N.M., Naumovski, N. and Broach, A.T., 2021. Edible packaging: Sustainable solutions and novel trends in food packaging. *Food Research International*, 140, p.109981.
- Pitawala, P., Danthurebandara, M. and Rajapaksha, L., 2022. Life cycle assessment of paper and plastic grocery bags used in Sri Lankan supermarkets. *International Journal of Environmental Science and Technology*, 19(11), pp.11183-11198.
- Plavec, R., Hlaváčková, S., Omaníková, L., Feranc, J., Vanovánová, Z., Tomanová, K., Božek, J., Kruželák, J., Medlenová, E., Gálišová, I. and Danišová, L., 2020. Recycling possibilities of bioplastics based on PLA/PHB blends. *Polymer Testing*, 92, p.106880.
- Price, C. 2020. Seaweed may be the solution to our plastic crisis. A London startup is making edible packaging out of it. *Insider*.
- Rana K. 2022. This is how to ensure sustainable alternatives to plastic. *World Economic Forum*. This research article is available at [the WeForum website](#)
- Rankin, J. 2022. [EU unveils plans to cut Europe's plastic and packaging waste. The Guardian](#). This news article is available from the Guardian
- Renewable Carbon News (2021) For the first time: Growth rate for bio-based polymers with 8 % CAGR far above overall polymer market growth, This news article is available from the [Renewable Carbon news website](#)
- Renton, M. (2020) Market and safety analysis of alternatives to plastic food packaging, UK: Food Standards Agency
- Ronzano, A., Stefanini, R., Borghesi, G. and Vignali, G. (2021) 'Agricultural waste as a source of innovative and compostable composite biopolymers for food packaging: a scientific review', 7th International Food Operations & Processing Simulation Workshop, FOODOPS.
- Salgado, P.R., Di Giorgio, L., Musso, Y.S. and Mauri, A.N., 2021. Recent developments in smart food packaging focused on biobased and biodegradable polymers. *Frontiers in Sustainable Food Systems*, 5, p.630393.
- Sand, 2020. Orchestrating More Sustainable Reusable Food Packaging. IFT
- Sharma, V., Sehgal, R. and Gupta, R., 2021. Polyhydroxyalkanoate (PHA): Properties and modifications. *Polymer*, 212, p.123161.
- Schmid A G, Azapagic A & Mendoza J M F. 2021. Reusable containers aren't always better for the environment than disposable ones - new research. *The Conversation*. This research article is available from [the Conversation website](#)
- Sheehan, B., Gordon, M. and Sommer, S., 2017. Greenhouse Gas Impacts of Disposable vs Reusable Foodservice Products: Literature Review and Inventory.
- Sifted. 2023. Packaging Unwrapped. This research article is available from [the Sifted website](#)
- Statista. (2023). Plastic waste in the UK - statistics & facts.
- Statista. (2023). Global paper packaging industry.
- Stefanini, R., Borghesi, G., Ronzano, A. and Vignali, G., 2021. Plastic or glass: a new environmental assessment with a marine litter indicator for the comparison of pasteurized milk bottles. *The International Journal of Life Cycle Assessment*, 26, pp.767-784.
- Tohme, H., and Nemes, S. (2023) *Packaging Sustainability 2030: Roland Berger*.

- Tesco (2021) [Big brands and everyday essentials in reusable packaging: Loop launches in Tesco stores](#). This news article is available from the Tesco website
- Tesco (2023) [Remove. Reduce. Reuse. Recycle](#). This news article is available from the Tesco website
- Thiyagarajan, S., Maaskant-Reilink, E., Ewing, T.A., Julsing, M.K. and Van Haveren, J., 2022. Back-to-monomer recycling of polycondensation polymers: opportunities for chemicals and enzymes. *RSC advances*, 12(2), pp.947-970.
- Trindade, M.A., Nunes, C., Coimbra, M.A., Gonçalves, F.J., Marques, J.C. and Gonçalves, A.M., 2022. Sustainable and Biodegradable Active Films Based on Seaweed Compounds to Improve Shelf Life of Food Products. In *Sustainable Global Resources of Seaweeds Volume 2: Food, Pharmaceutical and Health Applications* (pp. 235-252). Cham: Springer International Publishing.
- UK Government (2022) [Plastic Packaging Tax](#), This legislation is available from the UK Government website
- UK Government (2018) [Waste duty of care: code of practice](#), This legislation is available from the UK Government website
- UK Government (2023) [Far-reaching ban on single-use plastics in England](#), This legislation is available from the UK Government website
- UK Government (2023b) [Packaging waste: producer responsibilities](#), This legislation is available from the UK Government website
- UNEP. 2020 Single-use plastic bags and their alternatives: Recommendations from Life Cycle Assessments
- Vu, D.H., Åkesson, D., Taherzadeh, M.J. and Ferreira, J.A., 2020. Recycling strategies for polyhydroxyalkanoate-based waste materials: An overview. *Bioresource technology*, 298, p.122393.
- Wales 2012 – This legislation is available from the [Welsh Government website](#)
- Werner, B. G., Koontz, J. L. and Goddard, J. M. (2017) 'Hurdles to commercial translation of next generation active food packaging technologies', *Current Opinion in Food Science*.
- WRAP. 2022. Reducing household food waste and plastic packaging
- WRAP 2020 -Understanding plastic packaging. This research article is available from [the WRAP website](#) (PDF)
- Xiao, X., Agustí, S., Yu, Y., Huang, Y., Chen, W., Hu, J., Li, C., Li, K., Wei, F., Lu, Y. and Xu, C., 2021. Seaweed farms provide refugia from ocean acidification. *Science of the Total Environment*, 776, p.145192.
- Young, E et al. (2020). A Systematic Review of Consumer Perceptions of Smart Packaging Technologies for Food. *Frontiers in Sustainable Food Systems*
- Zhu, H., Cheng, J.H., Han, Z. and Han, Z., 2021. Cold plasma enhanced natural edible materials for future food packaging: structure and property of polysaccharides and proteins-based films. *Critical Reviews in Food Science and Nutrition*, pp.1-17.

Acknowledgements

We would like to thank our colleagues who made a significant contribution to the project and authored this report, particularly Laura Brownlee, Shraddha Kaur, Abby Reid and Hugh O'Reilly at RSM.

We also thank our advisor, Dr Samuel Short, for his valuable direction and guidance at each stage of the project. He provided quality assurance for the literature search strategy, overall methodology and peer-review of the draft and final report to ensure that any information about alternatives to single-use plastics was as accurate and robust as possible.

We would also like to thank Rachel Posaner from Knowledge Evidence Services at University of Birmingham for conducting the literature search for this project.

We would also like to thank the Food Standards Agency team for their support and guidance throughout the project, particularly Greg Wasinski, Marfot Miah and Anis Dadou.

Finally, we would like to express our gratitude to the panel of experts (listed in Appendix E) who supported the development of the research questions, provided feedback on our search strategy, shared key sources of information and engaged in productive and reflective discussions on the findings and what they mean for the FSA.