

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., Hlaváková, S., Omaníková, L., Feranc, J., Vanovánová, Z., Tomanová, K., Božek, J., Kruželák, J., Medlenová, E., Gáliková, 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.

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