Enterprise Development and Microfinance, 33:4, 1–17
<https://doi.org/10.3362/1755-1986.22-00073>

Preserving food without creating plastic pollution: A primer on progress in developed and low- to middle-income countries

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Abstract: *The role of single-use plastics in the preservation and packaging of food has expanded dramatically and it is estimated that up to 88 per cent of plastic pollution on the world's coastlines is derived directly from food packaging. The issues of plastic pollution and food preservation have become heavily entwined. Having recognized the problem, both developed and developing countries have responded by implementing control measures of varying severity and effectiveness. The article presents a primer on the progress being made and the innovations underway to address the problems. We highlight a number of organizations addressing plastic pollution and food waste within low- to middle-income countries (LMICs) and developed countries and classify them into five areas: mapping, collection, prevention, recycling, and alliances-led business models.*

The article demonstrates that any intervention on preventing food loss, minimizing plastic packaging (that is non-biodegradable, non-compostable, and non-recyclable), and reducing plastic pollution must be systemic, engaging multi-disciplinary sectors, and must include large-scale awareness and advocacy. Government incentives are required for a) research and development for finding new solutions to disrupt the nexus between plastic packaging and food waste, and b) supporting existing innovations/solutions developed by businesses, some of which are highlighted in the paper. This support is important to inspire, promote, and scale up business solutions and innovations that have the best chance to succeed.

Introduction

It is estimated that up to 88 per cent of plastic pollution on the world's coastlines is derived directly from food packaging (Morales et al., 2021). In recent decades, the issues of plastic pollution and food preservation have become heavily entwined. This article presents field perspectives on how plastic pollution from the plastic packaging in the food and drink industry is being addressed by governments, businesses, and other key organizations in both developed economies and in

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low- and middle-income countries (LMICs). This paper considers the World Bank definition of LMICs as having a per capita gross national income from $1,085 to $13,205 in 2021. Over the past two decades, plastic pollution has become an increasingly visual problem in the oceans and on land across all continents, with significant environmental impacts (Borrelle et al., 2020). Developed and developing economies have responded to the problem of plastic pollution by implementing control measures of varying severity and effectiveness. At the same time, the role of single-use plastics in the preservation and packaging of food has increased dramatically across the developing and developed world, as the material becomes more sophisticated and is adopted for an increasing number of commodities. In this article, we examine four research questions (RQs) that aim to clarify the problem (RQ1), determine the responses of governmental organizations and businesses in LMICs (RQ2) and in developed economies (RQ3), and explore how to scale up successful business-led solutions (RQ4).

Research questions

1. What is the nature and magnitude of the interrelated problems of food loss, and plastic packaging and pollution?
2. What has been the response from governments and businesses in LMICs?; and
3. What has been the response from governments and businesses in developed economies? How have governments understood the problem? What supportive policy/legislative framework exists and what is being done and how? What programmes and interventions are being undertaken to address the nexus? And are they effective? What are the challenges encountered in the implementation of a specific/enabling policy framework, if any? For businesses, what are the technologies/intervention models being deployed for tackling food packaging plastic waste? What is the current scale of these deployments? What are their technology readiness levels?
4. What is needed to scale up solutions deployed by businesses with a focus on small and medium enterprises (SMEs)? What support do these solutions need from government and local/municipal authorities and from the grant-giving funders or from the alternative/innovative finance such as green finance?

Methods

The paper uses a number of contextually relevant approaches to first understand the nature and magnitude of the interrelated problems of food loss, plastic packaging, and pollution, and goes on to develop a deeper understanding of governmental responses in both developed economies and LMICs. The paper also analyzes the responses from SMEs, for which a select number of innovators were interviewed, to explore contextually relevant solutions being devised and implemented across different countries that provide a lesson towards managing food loss without necessarily creating plastic pollution in developed and developing economies.

Selection of organizations for study

The paper captures both academic and practitioner perspectives on the issues of plastic packaging, food waste, and plastic pollution. Academic discourse is synthesized through an extensive review of literature on the research subject. Practitioners'/field perspectives are captured through interviews with the innovators (including SMEs) in this space. A web search on innovators was carried out and a shortlist of innovators was prepared based on the criteria of relevance of their solutions to disrupting the nexus of plastic packaging-led plastic pollution. Shortlisted innovators were invited to an interview with the authors and those who responded were interviewed. The material used in describing the innovations in this paper has been provided by the interviewed innovators. A list of innovators reviewed is provided in Appendix A.

Data extraction and analysis

The research questions are answered through primarily three methods:

1. Extensive review of literature: the selection of literature for the article was carried out based on the research questions being investigated. These literature sources include peer-reviewed articles by subject matter experts, publications from organizations working in this space (such as the United Nations Environment Programme), and blogs and writings from fora and networks who are promoting innovations and accelerating change to address the nexus (such as the World Economic Forum).
2. Review of organizations and interviews with key informants from SMEs and NGOs, especially the innovators who are at the forefront of developing and deploying solutions to disrupt the nexus between plastic packaging-led pollution.
3. Narrative synthesis based on all the perspective gathered and evidence collected.

Results

RQ1 Nature and magnitude of the interrelated problems of food loss, plastic packaging, and pollution

Plastic production, consumption, and waste

The global plastic industry has increased annual production exponentially since 1950, up to more than 400 million tonnes (Mt) in 2015 (Geyer et al., 2017). On the basis of the life cycle of different product types, Geyer et al. estimated an annual waste of 350 Mt in 2015. The vast amounts of plastic waste reaching landfills, rivers, and eventually oceans have been causing significant economic and environmental damage. Mismanaged plastic waste in Africa in 2010 was estimated at 4.4 Mt (Jambeck et al., 2018) and it is estimated that approximately 164.7 Mt of plastics will reach their end of life in Africa in the next decade (Babayemi et al., 2019). Although the average per capita consumption of plastic (11 kg/annum) in India is much lower than the world average (38 kg/person) or that of the US (139 kg/annum), the EU (65 kg/annum), or

China (38 kg/annum) (FICCI, 2017), the impact of plastic waste will be high in India and other LMICs given the large population and inadequate facilities for plastic waste management. The plastic waste problem in Nigeria has arguably been one of the worst in Africa. Between 1990 and 2017, 117.6 Mt of plastics entered Africa, and of this, Nigeria contributed 16.9 per cent (Babayemi, 2018). Besides being a heavy producer, Nigeria is a heavy consumer of plastics. These plastics are not separated for municipal solid waste and typically become the fuel for landfill fires (Morales et al., 2018). Asia arguably suffers the most from plastic pollution, with certain coastlines described as reaching catastrophic levels, and it is estimated that 80 per cent of total leakage into the oceans comes from Asia. In Indian, Vietnam, Nigeria, and other LMICs, a large proportion (50 to 80 per cent) of ocean plastic waste comes from ineffective management of solid waste at source; the rest is due to leakage from inefficient treatment facilities, including unhygienic, open burial landfills.

Plastic packaging for food preservation

Food and beverages account for 69 per cent of the global consumer packaging industry, valued at US$380 billion as of 2009 (FAO, 2014). This overwhelming importance of food within the packaging market applies across developed countries and LMICs. It has been estimated that more than 60 per cent of packaging is plastic (FAO, 2014), although this may vary considerably by country (EU figures indicate a value nearer 20 per cent). Flexible packaging accounts for almost 50 per cent of plastic consumption (Holder et al., 2019). Food production has become more focused in LMICs (FAO, 2011), and export from LMICs to developed countries has increased. Within export supply chains, there has been a move over the past decade to pack produce at source prior to export. This has led to an increase in packaging technology available within LMICs. This probably also increases the packaging technology available for domestic markets. Packaging in LMICs is also influenced by an increase in production of snack foods, increased urbanization, and economic growth, leading to the need for longer shelf life and for more prepared and convenience foods.

Single-use packaging is adopted by different parts of the food and drink sector for a number of reasons. In the UK, for example, graded peppers can be grouped together in packaging and this allows the sale of peppers that might otherwise be rejected by retail consumers. The leafy vegetable sector, traditionally a sector with very low profit margins, has been able to develop new 'added value' products in the form of mixed bagged salads. These products increase the economic value of perishable foodstuffs, and arguably reduce food waste. The rise of the 'food to go' culture has been particularly rapid in the UK and in LMICs with a rising middle class, such as South Africa.

Magnitude of food loss and waste

The estimated levels of loss during post-harvest handling and distribution for different food types in LMICs are summarized in Figure 1 (FAO, 2011). In terms of food crops, as expected, fruit and vegetables show higher losses than cereals, oil seeds, and pulses. Losses for dairy, fish, and seafood are perceived to be significantly higher than for meat. Between 2009 and 2019, packaging waste across the EU increased from 66 Mt in 2009 to 79.6 Mt in 2019.

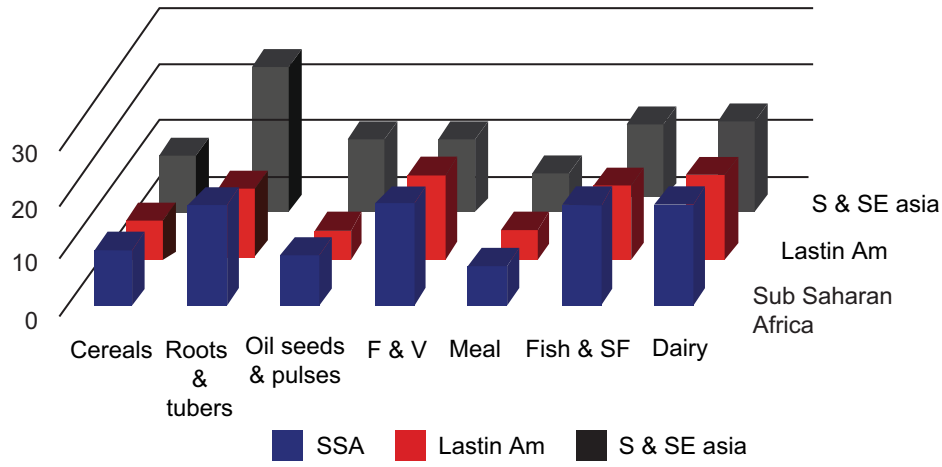

Figure 1 Percentage of produce lost during handling, storage, and distribution by food type. Collated from FAO, 2011.

Notes: F & V: Fruit & Vegetables SF: Seafood

RQ2 Government and business responses to food packaging-based plastic pollution in LMICs

There has been a widespread response to the problem of plastic packaging-led plastic pollution, but quite different approaches have been adopted by different countries. Several less developed economies responded by rapidly banning applications of single-use plastics, in particular plastic bags, while developed economies have reacted more slowly, possibly due to the difficulties involved in moving from an already established infrastructure into a new circular economy.

Government responses in Africa

In Africa, 34 countries have brought in some level of restriction on single-use plastics, with varying degrees of success. Zanzibar was the first to attempt to ban plastic bags in 2005, before going nationwide in Tanzania a year later. Tanzania's single-use plastics bags ban only came fully into effect in June 2019, following strict enforcement policies taken from Rwanda. Arguably, the most successful rise in sustainable living and plastic reduction has been witnessed in Rwanda, where reduction in plastic consumption through a total ban on plastic bags and single-use plastics has been achieved alongside an increase in national GDP and GDP per capita (Babayemi et al., 2019). Enforcement is stringent and the Rwandan authorities even search vehicles at border posts for any plastic bags or packaging. The ban has incurred problems without viable alternatives for users, especially in instances of food packaging (Butkute, 2019). Despite these issues, Rwanda is repeatedly viewed as the model for the reduction of plastic pollution.

Government responses in Asia

India progressively introduced a ban on single-use plastic bag consumption in 2002. Most Indian states/union territories (UTs) now have some form of ban (partial or

complete) on single-use plastic, but the implementation is often a challenge and plastic bags continue to be used.

Most LMICs have waste collection systems dominated by the informal sector – low-income pickers who collect waste of all kinds (including plastic) and take it to small shops, which separate and sell usable waste to larger shops, who in turn sell them to small and large recyclers. The formal system of waste collection is defined by the municipal authorities' responsibilities for collection, segregation, and disposal of plastic waste. However, this system has not evolved properly to effectively manage all the food and plastic waste generated and, despite its contribution, an informal sector still operates on the fringes.

Innovative responses from SMEs in LMICs

WasteBazaar (Nigeria)
Based in Nigeria, this innovator company provides a clean tech waste-to-recovery solution, leveraging informal sector waste collection. The WasteBazaar app offers consumer incentives through green credits for effective waste disposal through a convenient and affordable service. Green credits earned by consumers can be converted into local currency for day-to-day transactions (e.g. to buy groceries or pay utility bills). The solution has been demonstrated to create value from waste and to solve the urban waste management crisis and is currently operating at technology readiness level (TRL) five (Armstrong, 2015).

TONTOTON (Vietnam)
Based in Vietnam, this innovator company provides a unique plastic credit programme for a community-based solution for the collection and management of orphan plastic (single-use and multi-layered plastic mostly used in food packaging). The idea behind this initiative is that every company that uses plastic has an environmental footprint. TONTOTON helps these companies to take responsibility for not only recyclable plastic waste but also orphan plastic. The collected orphan plastic is used to produce alternative fuels and raw materials. The Control Union (an international agricultural certification system) certifies the processing activities for plastic neutralization. In effect, the certification provides a set of mechanisms for the companies' plastic footprint, while generating a business model that supports community livelihoods (informal sector waste pickers and aggregators), leading to an efficient and effective waste management solution. This is currently operating at TRL level six.

Kabadiwalla Connect (India)
Based in India, this innovator company provides decentralized waste management and collection solutions for LMICs. The technology (based on the internet of things (IoT)) propagated by Kabadiwalla helps to leverage a city's existing informal waste infrastructure for the collection and processing of solid waste. Kabadiwalla's solution is relevant for cities across the developing world where the informal sector is dominant in waste collection and recovery. The solution leads to the mapping of waste collection infrastructure, digitalization of material tracking, sourcing of raw material for processors/recyclers, and reverse logistics solutions for collection by municipalities/urban local bodies. The solution is currently operating at TRL level five.

Karo Sambhav (India)
India's first Producer Responsibility Organization (PRO), Karo Sambhav, was formed by 30 leading brands and aims to redirect all recyclable material away from landfills by 2025. The solution is currently operating at TRL level three.

Saahas Zero Waste (India)
Based in India, this company develops and implements multiple solutions to address plastic and other waste. It runs a zero-waste certification programme for building complexes, ensuring a 96 per cent landfill diversion rate, while strengthening recycling opportunities. As per their impact report (Saahas Zero Waste, 2021), 21,000 Mt of plastic waste is diverted from landfill. The collected plastic consists of 94 per cent food packaging waste that is non-recyclable. This waste plastic is co-processed for energy recovery. It supports 20 brands as part of its extended producer responsibility (EPR) for plastic collection and is currently collecting in 40 cities and towns. Based on the scale of implementation, it is assessed to be operating at TRL level seven.

Banyan Nation (India)
Based in India, this company's vision is to transform the way India consumes, recovers, and recycles. Banyan's technology provides virgin-grade recycled plastic granules, producing what is called 'Better Plastic'. Banyan uses mobile, cloud, and the IoT to integrate thousands of informal sector waste collectors into its supply chain. Based on the publicly available information, the solution is assessed to be operating at TRL level six.

RQ3 Government and commercial responses to food packaging-based plastic pollution in developed countries

UK
In the UK the issue of plastic pollution is high profile, resulting in significant investment in research and innovation, with funding mechanisms to support this (UK Research and Innovation), and the promotion of sustainable policy both by the government and in large company strategies (Phelan et al., 2022). In 2019 the Smart Sustainable Plastic Packaging (SSPP) challenge was launched and included £60 million funding to be industry-matched. Alongside this was a well-coordinated approach by the Waste and Resources Action Programme (WRAP) and the Ellen MacArthur Foundation (EMF) to introduce the UK Plastics Pact in April 2018, creating a national initiative to implement a new circular economy for plastic. The pact has 79 business members, representing retail, manufacturing, hospitality, the plastic supply sector, plastic recycling, and resource management. Its members are responsible for 85 per cent of plastic packaging sold through UK supermarkets (WRAP, 2019a). Specific targets were set for implementation by 2025 (WRAP, 2019b), which included eliminating problematic or unnecessary single-use packaging through redesign, innovation, or alternative (reuse) delivery models and ensuring that 100 per cent of plastic packaging is reusable, recyclable, or compostable. In order to achieve these targets, the UK Plastic Pact members have created a roadmap identifying what needs to be done by interim target dates (2019 and 2022) (WRAP, 2019b).

WRAP has produced a number of studies to support the sector. Recently it has compared the shelf life of a range of fresh produce in loose and packaged form under UK domestic conditions (WRAP, 2022). Of the produce studied (apples, bananas, broccoli heads, cucumber, and potatoes), little effect of packaging was reported on shelf life except that plastic packaging extended shelf life of broccoli heads in the fridge by seven days (35 per cent) and bananas at ambient temperature by 1.8 days (23 per cent). In the latter case, it is notable that most UK households remove bananas from packaging once at home. There are many commodities that could not be sold loose, such as baby leaf salad and shredded lettuce. The authors are currently extending the WRAP study and undertaking another on the shelf life of a wider range of UK produce in different types of plastic packaging over a range of domestic environments.

Recycling of films and flexibles, both important for food packaging, is a particular challenge. In the UK, films and flexibles represent a quarter of all consumer plastic packaging, but only four per cent is currently recycled, and this is by the retailers, as the infrastructure for consumer recycling is essentially non-existent.

European Union

Public awareness across EU member states has led to initiatives to reduce single-use plastic waste. The European Plastic Pact has since followed in the wake of the UK's. Countries are applying different approaches, with some looking to address the situation at source, with changes to the law and enforcing regulations, and others adopting a greater emphasis on academic research for potential closed-loop/end-of-life solutions. In mainland Europe, companies across the value chain of flexible packaging have come together to form CEFLEX (www.ceflex.eu). This is a collaboration of over 160 European companies, associations, and organizations representing the entire value chain of flexible packaging with a mission to make all flexible packaging in Europe circular by 2025. CEFLEX stakeholders have endorsed a five-step roadmap to build a circular economy for flexible packaging.

Since 2022, policies to ban fresh produce plastic packaging have been put into place in France, with certain exemptions, and Spain plans a similar approach in 2023.

The Netherlands follows the EU's policies on food loss and waste prevention, providing data as stipulated (EU Food Loss Waste Prevention Hub). The Netherlands has one of the lowest levels of food loss and waste recorded in the EU. They have invested in a number of studies by Wageningen University's Food and Biobased Research, focusing on the technical challenges of recycling plastic packaging.

United States

The US is one of the largest producers and consumers of plastics and this is reflected in its high degree of waste. In 2017, the Trash Reduction Act and the Save Our Seas Act were introduced to address the plastic pollution problem. Since then, further action has been taken to capture plastics, but these focus on landfill and incineration, and less on circular economy activity. However, some circular economy schemes have started to pick up traction, including the Gimme 5 programme, whereby plastics can be sent by mail to be melted down and remanufactured into alternative products,

and the US Composting Council aiming to connect compostable packaging product sellers with regional composting centres. Consumer demand for sustainable packaging is growing and companies such as Good Natured, which use plant-based materials, continue to emerge and grow.

Australia

In Australia, there are a number of organizations that promote recycling and sustainability. The Australian Packaging Covenant Organisation (APCO) works with government and businesses to reduce the environmental impact of packaging. APCO embodies an industry-driven product stewardship approach. APCO has over 2,000 Australian business members from across the packaging supply chain, ranging from large multinational corporations to small local businesses. These are responsible for the Australasian Recycling Label (ARL).

In 2018, Australia established the ambitious 2025 National Packaging Targets. The targets create a new sustainable pathway for the way packaging is managed. The four targets are similar to those of the UK Plastics Pact, but with a 50 per cent rather than 30 per cent target for incorporating recycled content. The National Packaging Targets apply to all packaging that is made, used, and sold in Australia. APCO is charged with delivering the industry-led targets (20 per cent).

Innovative responses from SMEs in the UK

Nextek (UK)

Nextek Ltd has recently helped set up a consortium, NEXTLOOPP, to undertake a programme of work packages to push forward the recycling of polypropylene for food-grade packaging. NEXTLOOPP focuses on developing strategies and technologies for sorting and mechanical recycling (i.e. without chemical processing) and decontamination (www.nextloopp.com). Fluorescent marker technology allows rapid and accurate separation of food and non-food packaging. The programme will set up a commercial-scale demonstration for sorting, decontamination, and recycling of plastic packaging for food use. Although NEXTLOOPP is located primarily in the UK, some activities are being carried out in Germany. This programme is currently assessed to be operating at TRL level five but aims to reach six by the end of the programme.

Sweed (UK)

This newly emerged company has developed a material from seaweed to act as an alternative to plastics. It is compostable and ocean-friendly. As the product is made from seaweed, it can also sequester carbon dioxide during the life cycle and does not require the use of fertilizers or land, as required by some other bioplastics, and equally does not compete with land for food crops.

Xampla (UK)

This spin-out company from Cambridge University has created a plant protein material for commercial use. This claims to perform like synthetic polymers whilst decomposing naturally and completely in the environment without causing harm. The company mission is to replace difficult-to-manage plastics, such as sachets and flexible films, with a biodegradable and sustainably produced material.

Planglow (UK)
This multi-award-winning company has developed five collections of plant-based packaging and labelling for the 'food to go' sector.

Vegware (UK)
Initially developers of a polylactic acid bioplastic for cups, cultlery, and food packaging, designed to decompose after use, Vegware has worked with the waste sector since 2012 to identify new routes to commercial composting. In 2015, they were awarded SME of the Year for their product development and activism. They have since created their own 'Close the Loop' service and offer advice to support users with their own on-site composting systems, as well as developing a UK-wide post-back service.

Loop – TerraCycle (UK and 21 other countries)
Loop Global Holdings is managed by TerraCycle, a social enterprise set up to 'eliminate the idea of waste'. It now operates across 22 countries and collects and recycles hard-to-recycle materials. Loop has now become a global platform for reuse, collaborating with brands and manufacturers across the food and drink sector and beyond to allow for refillable versions of single-use products.

Global responses to food packaging-based plastic pollution
An international movement led by the UN has recognized this type of pollution, with the UN member states endorsing a historic resolution at the UN Environment Assembly in Nairobi (March 2022) to End Plastic Pollution and forge an international legally binding agreement by 2024 (UNEP, 2022).

Many large global food and beverage companies have outlined company strategies to address the problems surrounding contamination of the environment from packaging. PepsiCo, Nestlé, and Kraft Heinz have all committed to using 100 per cent recyclable, reusable, or compostable materials by 2025. The UK Food and Drink Federation (FDF) and the Industry Council for Research in Packaging and the Environment (INCPEN) have created a Sustainability Checklist for members of the food and drink sector. The US has also built such networks and organizations; for example, the Sustainable Packaging Coalition provides resources, activities, and awards. It offers free information surrounding best practice for redesigning to prevent food waste, responsible sourcing of fibres for compostable packaging, and other such documents that aim to break the nexus between plastic pollution and food packaging. These organizations can have a significant impact on government policy. Indeed, government policy in LMICs is largely reliant on technological innovation emerging from either the private sector alone or from investments in funding to unite research institutions with commercial partners. This has also helped drive new businesses and unlock new revenue streams, whether through adopting recycled plastics or exploiting advances in compostable packaging. A report from Platform for Accelerating the Circular Economy (PACE and World Economic Forum, 2019) says that 'the economic value of implementing best practice in packaging design and heralding recycling as an end-use alternative to incineration, landfill and energy recovery is estimated at $2–$3 billion annually across OECD countries', and this can be seen in the emergence and expansion of SMEs in the sector.

Discussion

Classification of responses/solutions in developed and developing economies

To address the problems of plastic pollution and food waste, organizations within both developing and developed countries are implementing context-specific solutions, which can be classified into five broad areas:

- **Mapping:** this is about generating data and evidence on the main underlying drivers of food waste and plastic pollution across the plastic life cycle. Authentic research and data are being collected for understanding the severity of the problem (including underlying drivers) and for designing solutions.
- **Collection:** formal and informal waste segregation and collection streams are being streamlined and integrated for effective actions on tackling plastic and other waste generated (including food waste).
- **Prevention:** this is about behaviour change related to segregation, as it can reduce food packaging-led plastic pollution. Behaviour change campaigns are being undertaken to create a stimulus for consumer, business, and political actions. There are a few initiatives in developing economies that are incentivizing these behaviour changes, but this is a more common approach in developed economies.
- **Recycling:** life cycle analysis and techno-economic assessment of technological solutions, and piloting and scaling-up of technological options (such as conversion of plastic waste to chemical feedback, plastic waste to energy recovery, conversion of biodegradable 'plastics' to compost substrate) are underway.
- **Alliances-led business models:** these are systemic solutions to a systemic problem through alliances and voluntary commitments. They play an important role, given that a systemic problem can only be addressed collaboratively by all actors working in a system. These are scalable business models that can work with initial seed funding from the investing businesses (addressing their plastic footprints) or through Sustainable Development Goals (SDGs) or green finance.

As the analysis above indicates, reduction in food- and drink-related plastic packaging waste can be achieved by different routes:

1. Prevention at source, i.e. reduction in the use of plastic packaging
2. Establishment of a circular infrastructure
3. End-of-life capture

In order to achieve reliable food-safe recycled plastics, technologies for automated sorting are required both in terms of chemical composition and previous use. These are a necessity in developed economies (for example, NEXTLOOPP).

In terms of alternative materials, there are few as lightweight as plastic, so it is important to consider the additional fuel needed to transport heavier materials, such as glass or metal. Bioplastics are becoming increasingly popular but are not necessarily less polluting. In some cases, plastics are mistakenly classified as biodegradable, when they only partially break down, leading to an increase of microplastics within the environment. There is, however, potential to develop cellulose

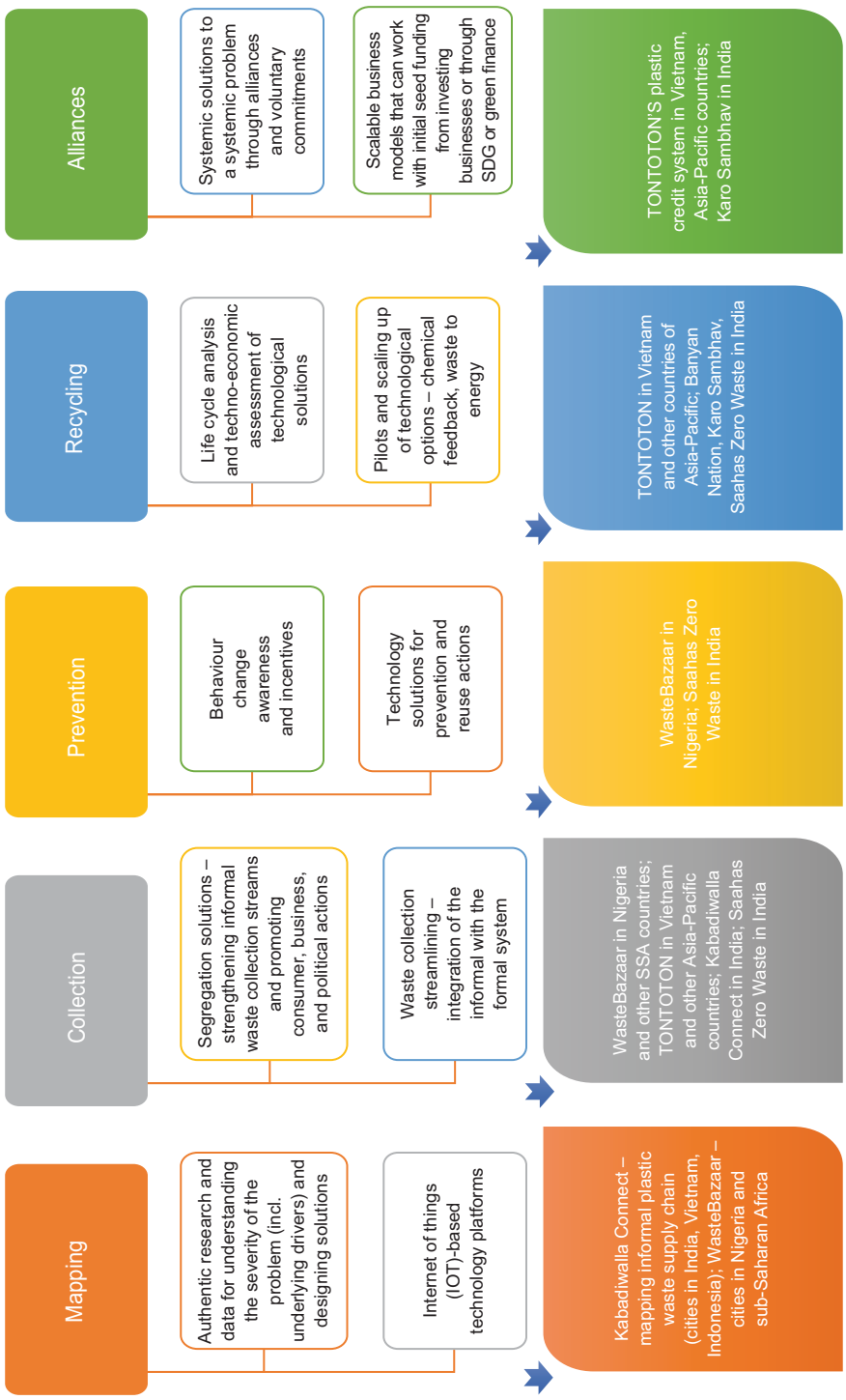

Figure 2 Plastic economy solutions underway in developing economies

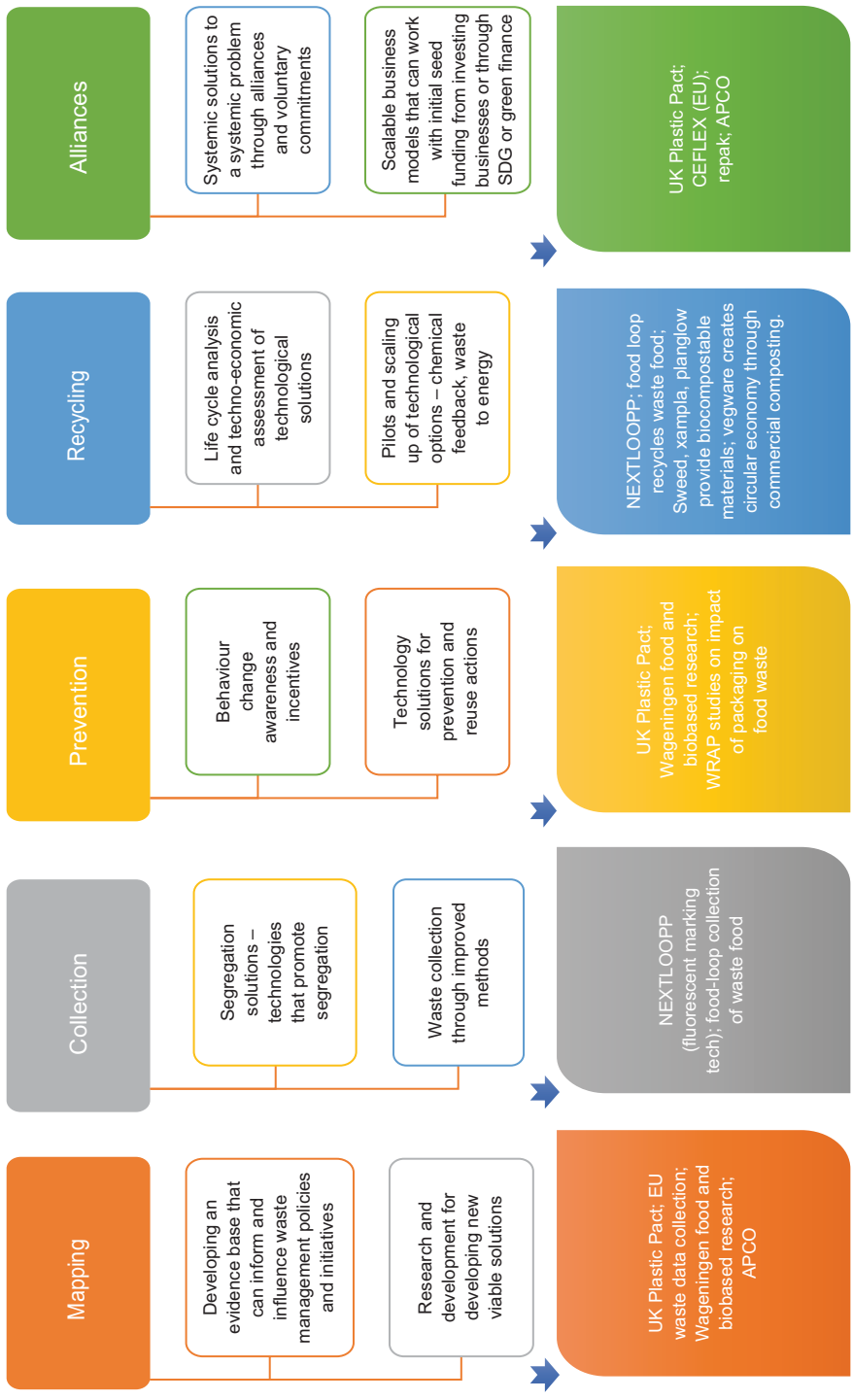

Figure 3 Classification of plastic economy solutions underway in developed economies

and other plant-based packaging, ideally from existing waste streams, which can biodegrade easily. However, there are issues with how an infrastructure could be implemented, in particular one that would not contaminate the infrastructure for recycled plastics.

Conclusions

Our research demonstrates that any interventions on preventing food loss, minimizing plastic packaging (that is non-biodegradable, non-compostable, and non-recyclable), and reducing plastic pollution must be systemic, engaging multidisciplinary sectors (social science, food science, engineering, business, and management), and must include large-scale awareness and advocacy. The 'Breaking the Plastic Wave' report (Pew Charitable Trusts and Systemiq, 2020) concurs that there is no single solution. This report found that there are a number of initiatives being carried out across both developing and developed countries, but to date there appears to be no evidence that any country has implemented an effective recycling or composting infrastructure that allows the complete adoption of a circular economy. Neither has any country developed a clear roadmap as to how single-use plastics used for food packaging can safely contain recycled plastic.

For those countries that are investing in research and innovation, it is our opinion that barriers for establishing a circulare infrastructure can be overcome with clearly defined studies and proof-of-concept trials (e.g. NEXTLOOPP). Meanwhile, for countries that cannot afford this kind of investment, prevention at source or end-of-life capture are more feasible, both of which require incentivizing and enforcing. This may be done with the implementation of deposit return schemes, which aim to place a value on the plastics involved. This approach will likely work for robust food packaging made from polyethylene terephthalate (PET), whereas for plastic films the use of compostable materials may prove more beneficial. These activities require both global and local company support. Multinationals, such as Coca-Cola, are installing deposit return schemes and there are examples of SMEs adopting compostable film packaging for fruit and vegetables. One challenge for multinationals arises from a lack of uniformity across developing and developed countries in their approach, which makes it very difficult to implement an effective, concise corporate strategy.

Our recommendations include:

- Inspire, promote, and scale up business solutions and innovations that have the best chance of success. This requires government incentives to support research and business.
- Encourage the food and drink sector to adopt producer responsibility and provide capture mechanisms and funding in heavily food plastic-polluted areas. This can be achieved by building in rewarded targets to government strategies.
- Work towards a global commitment to the manufacture of two or three easily recyclable plastic materials.
- Work towards a global commitment for the generation of biocompostable plastic standards.

Appendix A List of innovators/SMEs interviewed

Name and designation	*SME affiliation and country*	*Date of interview*
Siddarth Hande, Founder and Director	Kabadiwalla Connect, India	17 February 2022
Amusa Victor, Founder and Director	WasteBazaar, Nigeria	18 February 2022
Mae Catibog, Head of Sustainability Compliance and CSR marketing	TONTOTON, Vietnam	28 February 2022
Ha Trinh Thai, Vietnam Plastic Action Network Coordinator	WWF, Vietnam	10 March 2022
Visrut Shivkumar, Sustainability Leader	Noble Plastic, India	17 March 2022

UK-based SMEs	*URL, date accessed, name of interviewee, and date of interview*
Nextek (UK)	https://www.nextloopp.com (accessed 28 Feb 23), Kelvin Davies, 12 July 2022
Sweed	https://www.sweed.uk/ (accessed 28 Feb 23) -
Xampla	https://xampla.com/ (accessed 28 Feb 23) -
Panglow	https://planglow.com/ (accessed 28 Feb 23) -
Vegware	https://www.vegware.com/uk-en/ (accessed 28 Feb 23) -
TerraCycle	https://www.terracycle.com/en-US/ (accessed 28 Feb 23) -

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