2050 Packaging Material Demand

DEVELOPING FORESIGHT INTO 2050 PACKAGING MATERIAL

Research by Oakdene Hollins and Valpak
for UKRI Innovate UK

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Preface

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Executive summary

The Foundation Industries, which include the glass, metals, paper, and plastics sectors, provide the feedstock to the vital packaging sector. But the long investment cycles mean that many companies in these sectors are today planning facilities that could be in operation for 30 years. The need to reduce carbon emissions and improve resource efficiency are impacting not just the foundation industries, but also their customers. What types of materials and products will the packaging sector be purchasing this far into the future?

To help understand what these changes may mean for the materials that will be demanded from the foundation industries, the Transforming Foundation Industries (TFI) Challenge commissioned this research project to look at how different futures scenarios might influence (retail) packaging material requirements. It is hoped that this will help the foundation industries to understand more about possible market opportunities and threats, consider the impact of disruptive products or business models, and help to refine their R&D needs.

Through a series of structured interviews and expert workshops, including representatives from across the packaging supply chain and Foundation Industries, five different scenarios were explored.

1. **Consumption of 2020 = 2050 Aftermath** showed a future in which we continue consuming, business-as-usual, in a linear economy, leading to material scarcity and resource shortages. Society and the environment are facing the extreme consequences of our industrial activity.
2. **Consumerism of 2020 in Part-sustainable 2050** showed a future in which steps have been taken for us to consume more sustainably, leading to material substitutions and technology development to mitigate the impact of our consumption-on-demand behaviours. Improved and more sustainable industrial activity takes place in some sectors, but with unintended negative effects in others.
3. **Re(use)volution** showed a future in which systems are designed to facilitate reuse. The materials we use are more durable and contain composite materials.
4. **Doorstep to Fork** showed a future in which systems are designed to produce and circulate resources and energy locally. There is less transport packaging required as consumers can purchase what they need locally; the packaging that does exist is made from biomaterials.
5. **Augmented Circularism** showed a future in which technology has optimised systems to incorporate circularity (and reuse) into our daily lives. All packaging is tagged with RFID (radio-frequency identification), and Internet of Things (IoT) connects different parts of the supply chain so that we always know where packaging is. However, we require more critical raw materials to produce RFIDs, and packaging consists of durable composite plastics (for which recycling technologies have been created).

There is necessarily no single “winning” scenario, although a business-as-usual scenario is universally seen as undesirable. However, looking across current barriers and trends, the collective thinking is that the future will most likely consist of elements from a ‘Consumerism of 2020 in Part sustainable 2050’ and a ‘Re(use)evolution’. This will drive significant changes in the packaging supply chain, such as infrastructure to support high rates of chemical recycling, and to enable circular reuse and refill business models.

This is reflected in many big fast-moving consumer goods (FMCG) players already investing in zero waste / refillable start-ups and committing to zero waste to landfill goals. But the pace of change in the sector means that the other scenarios should not be completely dismissed, and all scenarios are expecting to exist in parallel, even if some only to a limited extent.

From high value durable packaging, perhaps with RFID, to low impact mono-material packaging, there are a wide range of innovation opportunities for suppliers to the packaging sector, with the choice of packaging type driven closely by the behaviours of their different end customers.

This research demonstrates that the types of material used and how we source raw materials for packaging will likely change substantially from today. This will have consequences for the types and volumes of materials the packaging sector requires from the Foundation Industries in the future. Conventional packaging materials, such as metals and plastic, may be displaced by biodegradable, bio-based, and composite materials. While existing supply chains will likely contract, new supply chains will need to be established – ongoing collaboration between the packaging sector and the Foundation Industries will be crucial in the transition to Net Zero.

Glossary

Abbreviations

AR	augmented reality
EPR	extended producer responsibility
FMCG	fast moving consumer goods
IOT	'Internet of Things'
IP	intellectual property
i4.0	Industry 4.0
PaaS	product as a service
PESTLE	political, economic, societal, technological, legal and environmental factors
RFID	radio frequency identification

Definitions

Deep sea mining	The process of retrieving mineral deposits from the seabed[1]
Dematerialise	Having little or no need to own products and physical things
Industry 4.0	A new phase in the industrial revolution that focuses on interconnectedness, automation, machine learning, and real time data[2]
'Internet of Things'	A system of interconnected computers, machines (both mechanical and digital) or living creatures that are each given unique identifiers that transfer data over a network without the need for manual intervention[3]
Regenerative	This type of packaging mimics regeneration often seen in nature, where material can be brought back into existence[4]
SMART material	Material that interacts with packaging to increase shelf life, or material that contains RFID tags so that information about the package can be collected[5]
Urban mining	The process of reclaiming raw materials from waste found in landfills[6]

[1] IUCN (2022) Deep sea mining. Available here. 20 April 2022
[2] EPICOR (2022) What is Industry 4.0 – the Industrial Internet of Things (IIoT)? Available here 20 April 2022
[3] TechTarget (2022) What is the internet of things (IoT)? Available here 20 April 2022
[4] Packaging Europe (2021) Sustainability Perspectives: A regenerative approach with Evertis. Available here 20 April 2022
[5] LEAD (2019) 5 things you should know about SMART packaging. Available here 20 April 2022
[6] Rts (2021) What is urban mining? Available here 20 April 2022

1. Background

1.1. Packaging industry

Packaging Sector

The UK packaging sector was worth £4 billion[7] and employed 85,000 people in 2022[8]. Over its history, the sector has seen significant changes, including in the ways in which packaging materials have been manufactured, used, and disposed of. Historically, high raw material costs led the sector to develop circular packaging solutions that kept packaging materials and products in use for as long as possible. For example, the iconic glass milk bottle was used and reused multiple times. However, after World War II, the rapid growth of single-use packaging marked a shift towards the more linear take-make-dispose model with the development of low-cost, high-volume packaging solutions, and the demand for greater convenience[9]. In recent years, there has been a shift towards a recycling economy model whereby packaging materials are collected for reprocessing and re-used, before being disposed of[10]. The current societal and legislative environment is driving the packaging industry to take further steps to become more circular once more, and to contribute to meeting the UK's Net Zero targets through reducing greenhouse gas emissions both internally and along their supply chains[11,12,13].

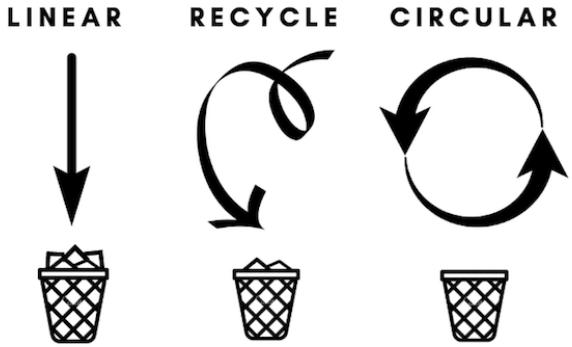


Figure 1: Image describing the three types of material economies[10]

This shift in the packaging industry can be seen in:

- The increased use of secondary (recycled) materials and the reduction in the use of primary (virgin) materials.
- The adoption of more resource-efficient manufacturing processes, i.e., reducing manufacturing losses.
- The promotion of durable design for prolonged or repeated use of packaging.
- The increased diversion of materials from landfill and incineration towards recycling (e.g., expanding recycling infrastructure).
- The adoption of novel recovery and recycling technologies.
- The development of business models that support changes to consumer behaviour (e.g., takeback schemes).

A key policy driver for the transition to a recycling economy was the *Producer Responsibility Obligations (Packaging Waste) Regulations*[14], introduced in 1997, which set national recycling targets and aimed to reduce the amount of packaging waste that ended up in landfill or incineration. Raw material manufacturers, converters, packer-fillers, and sellers were obligated to take responsibility for the environmental impact of the packaging they placed on the market[15]. This has led to significant improvements in the recycling rate of packaging waste from a rate of 40% in 2000[16] to 69% in 2018[17].

More recently, the *Plastic Packaging Tax* was introduced in April 2022, which levies a tax of £200 per tonne of plastic packaging placed on the market that does not contain a minimum of 30% recycled content[18].The tax aims to encourage the use of recycled plastic in packaging, stimulating greater demand, collection and recycling of plastic waste, and reducing the volumes of material going to landfill, incineration or being lost in the environment, e.g. marine litter.

[7] IBS World (2022) Packaging Services in the UK. Available here 15 April 2022
[8] The Packaging Federation (2022) The UK Packaging Manufacturing Industry. Available here 15 April 2022
[9] Conscious Container (2020) The History of Refillable Bottle Systems in the U.S. Available here 19 April 2022
[10] Muntagnard (2020) Our Perspective on Circularity in Textiles. Available here 25 April 2022
[11] UKRI (2021). Transforming Foundation Industries Challenge. Available here 9 April 2022
12 KTN (2021) Foundation Industries. Available here 22 April 2022
[13] DS Smith (2022) Net Zero emissions by 2050 - DS Smith - DS Smith Packaging. Available here. 9 April 2022
[14] UK Environmental Agency (2014) Packaging waste: Producer Responsibilities. Available here. 15 April 2022
[15] Valpak (2022) Packaging Waste Regulations. Available here 9 April 2022
[16] Eurostat (2022) Recycling rate of packaging waste by type of packaging. Available here 19 April 2022
[17] Statista (2022) Volumes of packaging waste arisings and total recovered/ recycled in the United Kingdom in 2020 Available here.19 April 2022
[18] HM Revenue & Customs (2022) Plastic Packaging Tax: steps to take. Available here. 19 April 2022

Going forwards, the *Extended Producer Responsibility (EPR) for packaging* legislation[19] is set for implementation in 2024 and represents a significant revision to the existing packaging obligations. It aims to motivate the industry to become more circular by improving the quality and quantity of recyclable material collected for further use in the manufacturing of high value products[20]. This will include initiatives such as improving household recycling collections through the inclusion of plastic films and flexible packaging, mandatory takeback schemes for disposable coffee cups.

Alongside changes in legislation, there has been continual development in the materials that are being produced for packaging applications. These include materials that are increasingly high-performance, durable, bio-based, biodegradable, and contains critical raw materials (e.g., used in the 'Internet of Things' (IOT) tracking technologies) - material demand for packaging continues to evolve in new directions.

The Foundation Industries

The UK Foundation Industries include the cement, glass, ceramics, paper, metals, and bulk chemicals sectors and encompass over 7,000 UK businesses[11], employ approximately 500,000 people, mostly outside of the South East, and is worth £45 billion/year to the UK[21]. The Foundation Industries supply raw materials to a multitude of sectors, including the packaging sector, and play a key role in the UK economy, and beyond. The Foundation Industries are the largest industrial greenhouse gas emitter, generating 10% of the UK's CO_2 emissions every year[21].

The UKRI Transforming Foundation Industries Challenge is supporting the development of innovative technologies to reduce energy and resource use within the Foundation Industries[11]. These future technologies / facilities can have a life expectancy of 30 years or more and can involve considerable investment; therefore, it is important to understand today how factors, such as changes in the packaging sector, will affect material demand in the future. Industry decisions in the short term need to consider what material usage will look like in 2050. For the UK Foundation Industries to plan for future material demand there needs to be a robust understanding around market threats and opportunities, and what advancements in technologies and business models might emerge that will help move towards a more sustainable future.

1.2. Aim

This research aims to identify the UK's potential future packaging consumption, and how it might affect the material requirements of the UK packaging sector in 2050. In addition, this research aims to outline challenges and opportunities the Foundations Industries might face in the future, including how their operations might be affected by changing demand for materials in the packaging sector.

[19] Department of Environment, Food and Rural Affairs (2022) Packaging and packaging waste: Introducing Extended Producer Responsibility. Available here. 15 April 2022
[20] Valpak (2022) EPR for packaging waste. Available here. 9 April 2022
[21] Innovate UK, correspondence (2022)

2. Research methodology

This study used a 'Futures' approach to develop an outlook of what the 2050 socio-techno-environmental landscape might look like and explore how this might affect the design of and types of materials used in packaging in the UK. The UK Government Office for Science has published *The Futures Toolkit*[22], which provides a comprehensive overview of the Futures approach used in this research. Further information on the approach taken in this study is presented in Appendix A. Futures research involves in-depth literature review and stakeholder engagement to gather intelligence about the long-term issues, challenges, and trends that are shaping our future. With this information, different scenarios were developed to explore possible, probable, and preferable futures for the UK packaging sector. The scenarios developed are narratives that describe alternative ways that the packaging industry may develop in the future. Each scenario explores how different conditions might enable or prevent the growth of different types of packaging materials.

2.1. Data collection

The data used in this research was collected between January and March 2022. Key drivers and levers for change were characterised as political, economic, societal, technological, legislative, or environmental factors (PESTLE). (A more detailed description of the data collection steps can be found in Appendix A):

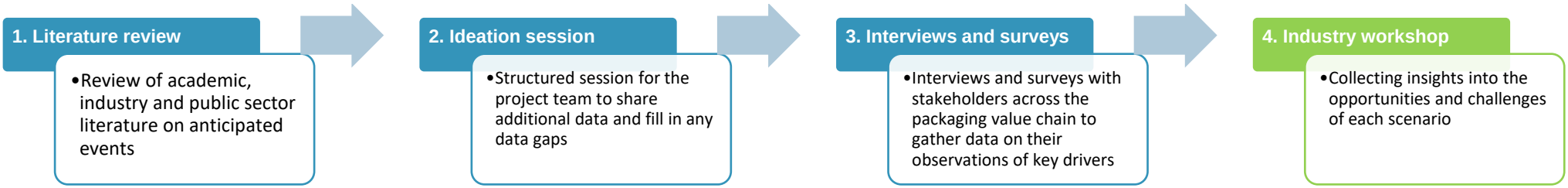


Figure 2: Process flow diagram of data collection steps

2.2. Analysis

The factors gathered in the first three steps in Figure 2 were identified as either:

- A trend: a general tendency or diction of a development or change over time,
- a driver: the cause of one of more effects that can lead to change or shape the future, or
- a signal: a measurable event that is certain to happen or pieces of information that indicate that events might happen.

These were then mapped out thematically (according to PESTLE) to identify interrelated events that could take place in the next 30 years. An example of this mapping exercise is shown on page 29. From the analysis, five scenarios were developed through mapping out connections between trends, drivers, and signals. The development of the scenarios involved identifying and grouping societal, technological, and environmental drivers for change (i.e., anticipated events that may occur between the current "state of play" and far into the future), and policy-, economy- and legislation-based levers for change (i.e., anticipated policies, legislations or changes in the economy that may occur between the current "state of play" and far into the future).

The project team analysed the scenarios to identify what packaging materials might be used in 2050, based on the constraints of the socio-techno-environmental landscapes described in each scenario. In particular, a list of the likely types of packaging materials, packaging innovation and material sourcing was identified. Finally, the identified scenarios were evaluated qualitatively in terms of their likelihood and their impact on material demand. Following the internal analysis, an industry workshop was held to gain additional insights into the opportunities and challenges for material demand in each of the scenarios, as well as how likely each scenario was perceived to be.

[22] UK Office of Science (2017) The Futures Toolkit. Tools for Futures Thinking and Foresight Across UK Government. Available here 6 April 2022

Details on how each step in this process connects to the scenario sections in Chapter 4 can be found in Appendix B.

3. Lessons from the past

This section outlines the events that have taken place in recent history (in the past 30 years) that the packaging industry perceives as key lessons to learn from when making decisions about future activity. The views presented in this section are collated from stakeholder interviews and the idea generation session.

Society

Historically, society has operated in a circular model, driven by the high material cost of raw materials, such as, glass. However, over the past 30 years, packaging consumption trends have evolved into a linear economy, to accommodate and satisfy high consumer demand through single-use and convenience. One example of this significant shift is in the alcohol and beverage industry and the increase in home consumption of beer. This has led to a move from the large refillable kegs used in public houses, to large numbers of one-way glass or aluminium containers used at home. (For example, one 50 litre keg is equivalent to approximately 150 glass bottles (330ml) or 114 aluminium cans (440ml).) The soft drinks industry moved in a similar single-use direction when manufacturing bases changed from regional to centralised production. This increased the distances between the producer and the retailers and increased the complexity of takeback schemes. This resulted in a drop of the refillable glass market share of 60% in 1977 to 3% in 1987 and to almost zero in 2020. One of the remaining doorstep delivery systems still in use today in the UK is the regional milk delivery system, but this has also seen a decline with consumers choosing to purchase their milk in supermarkets instead, where refillable packaging is not the norm. In 1975, the refillable milk market share was 94%, with the remainder in beverage cartons. By 1994, reusable bottles had dropped to 32%, cartons had grown to 32% and milk plastic bottles dominated with a 45% market share.[23] Currently, the refillable milk market share is less than 4% in the UK[24]

Additionally, the growth in internet / home shopping has resulted in more waste packaging, such as corrugated cardboard, being generated by households rather than within the supply chains (at retailers or distribution centres). This has resulted in higher levels of contamination of recovered materials and lower levels of recovery.

These societal trends have led to a wide range of packaging designs and materials being manufactured at scale and disposed of after use. An example is complex packaging, such as multi-layered flexible films (e.g., crisp packets, detergent pouches, toothpaste tubes), which have been effective in aesthetics (i.e., making packaging more attractive from a 'branding' perspective), preserving perishable goods, and meeting large-scale high-intensity production standards with often limited regard to recovery at end-of-life.

In recent years there has been a significant increase in public awareness of the environmental impacts associated with packaging waste. Consumers have increasingly been shown (via social media, news, and documentaries) evidence of the impacts of waste, pollution, and overconsumption, including the issues of climate change and plastic contamination in the environment (e.g., oceans pollution[25]) and the human body[26]. An increasing awareness of these issues has also come from consumers' exposure to and engagement in climate activism (Greta Thunberg[27], Extinction Rebellion (XR)[28]) and global environmental conferences (COP26[29]). Brand owners and the packaging industry in general, have responded to this by going beyond regulatory policy in the environmental credentials of their products, e.g., 100% recycled content.

With increasing consumer awareness and alternative consumption models emerging (e.g., packaging reuse and refill models, recycling schemes, plastic bag charges) some consumers are changing their behaviour and prioritising the environmental impacts when purchasing, consuming, and disposing of products. This shift towards pro-environmental values of consumers is reflected by fast moving consumer goods (FMCG) brands who are increasingly advertising the sustainability credentials of their packaging[30].

Technology

Packaging design trends to date have included the use of complex materials (e.g., multi-layered films) and (largely) plastics, to produce high quality packaging that can be produced at large volumes, and at low-cost (e.g., using composites packaging to achieve the same strength at lighter weights). Packaging design innovation has also largely focused on protecting consumables and extending product shelf-life, for example, to reduce food waste. Historically, sustainability has not been a major priority for the packaging industry, and there has been a lack of focus on the flow of packaging through all stages of its lifecycle, from raw material production to end-of-life. Although some design and cost reduction strategies reduced the use of raw materials, such as

[23] European commission (2020) Available here. 19 April 2022
[24] Foulger's Dairy (2018) Is it time to go back to fresh milk in glass bottles? Available here. 9 May 2022
[25] National Oceanic and Atmospheric Administration (2020) Ocean pollution and marine debris. Available here. 18 April 2022
[26] Carrington, D (2022) Microplastics found in human blood for the first time. Available here 18 April 2022
[27] Kraemer, D (2021) Greta Thunberg: Who is the climate campaigner and what are her aims? Available here 18 April 2022
[28] Extinction Rebellion (2022) About us. Available here 18 April 2022
[29] UK COP26 (2021) What is a cop? Available here 18 April 2022
[30] Unilever (2022) We're making the switch to recycled food packaging. Here's how. Available here 18 April 2022

through light-weighting, the industry continues to extract virgin resources and use materials that are not widely recycled (e.g., multi-material composites). For those materials that are recycled, the issue of poor material segregation can mean that their value cannot be retained, resulting in losses or use in the production of lower value products (e.g., high value PET bottles being recycled and used in garden furniture or timber alternative products[31], instead of being retained in the packaging loop).

There has been packaging material innovation emerging in biodegradable biomaterials, such as bioplastics. However, there has been consumer confusion around disposal of biodegradable packaging, as well as a lack of infrastructure for collection at kerbside (such packaging requires specific processing environments for biodegradation). The resulting uncertainty over the effectiveness of biodegradable packaging is pertinent with calls from both the public and policy makers for greater transparency in environmental claims.

There has been further innovation in packaging design, such as in regenerative (e.g., mushroom-based packaging[32]) and even edible packaging materials. These design approaches tie into supporting the circular- and bioeconomy in the UK, which encourages a more sustainable use of resources from natural environments.

The UK packaging sector recognises the need for the whole supply chain to communicate and work together to fully harness the sustainability, innovation, and technology ambitions of the packaging supply chain.

Environment

The key issues affecting the environment in the context of packaging in the recent past include:

- Global mass-production and high demand contributing to high greenhouse gas emissions and climate change.
- Unsustainable and extensive exploitation of virgin oil-based packaging for use in packaging manufacturing that cannot be replenished as fast as they are used up.
- Unintended environmental impacts of packaging marketed and perceived as 'environmentally-friendly' (e.g., incorrect disposal leading to losses such as bioplastics contaminating the plastics recycling stream, exploitation of indigenous land for material farming of monocrops such as the destruction of the Amazon for timber production[33]).
- Increased consumption of single-use products in open-flow systems where materials 'leak out' and pollute natural environments.
- Green washing that has been used in marketing to sway consumers' purchasing decisions towards buying products perceived (incorrectly) as sustainable.

This changing environmental landscape has demonstrated to manufacturers that there should be a greater emphasis on how packaging materials are sourced and produced, and what impacts packaging has on the environment across its lifecycle. Industry decisions must be based on robust scientific evidence, and the evaluation of its impacts - such as those associated with energy use, material exploitation or carbon footprint - should be at the forefront of industry decision-making.

Policy

The Packaging Waste Regulations[34] are seen by industry to have been the most effective policy instruments driving activity in the packaging sector. The Packaging Waste Regulations were the component of the UK's Extended Producer Responsibility policy that first placed responsibility on the producer for their products' lifecycles. These regulations were introduced with the aim of:

- reducing the amount of packaging waste going to landfill,
- controlling the volumes of heavy metals used in packaging, and
- ensuring packaging fulfils its essential requirements (in relation to preservation or protecting the product).

When the Regulations were first introduced, they had a significant impact on the industry and led to a significant increase in recycling collection rates. They now need to be extended to further improve the industry's recycling ambitions beyond simply meeting recycling targets, investments, and activity: local authorities are often unaware of where funding goes and are unable to see an improvement in recycling rates. Greater transparency of funding (e.g., when and where investments are made) and demonstration of the resulting increases in recycling rates through investment in better collection and recycling infrastructure is needed. As a revised Extended Producer Responsibility policy nears its introduction for the packaging industry, there is a concern from industry

[31] Sciencing (2022) The Disadvantages of Recycled Plastics. Available here
[32] Packaging Digest (2018) Regenerative packaging puts the cherry on top of sustainability. Available here
[33] The Guardian (2021) Indigenous peoples by far the best guardians of forests-UN report. Available here
[34] UK Environmental Agency (2014) Packaging waste: Producer Responsibilities. Available here. 15 April 2022

around how well the Packaging Waste Regulations have prepared the industry for the transition to the new policy, given the significant scale of change required such as infrastructure needed to separate flexible packaging from other recyclable waste or the development of takeback schemes for certain types of packaging[35].

While these policies are an important driver for change, the packaging sector requires strong industry leadership (whether at an organisational level or an individual level) to encourage change by advocating lower environmental impacts of packaging use and motivating collaboration and active engagement in sustainable circular practices

Legislation

This research showed that legislations are important drivers for change, and that some businesses require enforcement and penalties to ensure they adopt sustainable and safe practices. Furthermore, the interviews highlighted that the current recycling infrastructure is not capable of keeping up with the changes in materials used in packaging (e.g., the use of composite and multi-layered packaging), highlighting a need for legislation developments that ban certain packaging or investments in infrastructure that can facilitate the processing of a wider range of materials.). This research also highlighted the importance of preventing 'green washing' practices, and that legislation should be developed to ensure the industry's communication to consumers is on the environmental impacts of packaging is unambiguous, accurate and clear. Recent legislative developments have included the Green Claims legislation[36], which protects consumers from such misleading claims with the aim of protecting businesses from unfair competition.[37]

The Net Zero to 2050 legislation, published in 2019 is also an important driver for change. This requires the UK to bring all greenhouse gas emissions to net zero by 2050, in comparison to emission levels in 1990[38]. This requires collaboration from all sectors and businesses and will benefit businesses through a reduction in running costs, attracting new customers and investors, maintaining competitive advantages, and building a more sustainable supply chain.

Economy

In the past, decisions on economic growth did not consider the availability of natural resources (both material and energy) and the environmental impact of packaging. Key economic trends include:

- Economies of scale – namely global, on-going mass production and automation – which have driven down the cost of packaging manufacture.
- Many packaging formats facilitate long shelf lives, thereby increasing the 'use by' date of consumables and reducing waste. However, an unintended consequence of this is that products can be shipped from further afield with additional environmental impacts associated with transportation.
- Economic growth relies on the availability of materials and energy.
- FMCG brands have expanded their business activities in response to increasing demand under the business-as-usual approach to the lifecycle of packaging.
- Intellectual property (IP) concerns and competition have hindered 'systems thinking' approaches to packaging consumption and to collaboration across the supply chain, e.g., there is often limited visibility of different suppliers because of proprietary data restrictions.

Section conclusion

Going forwards it is vital that the industry prioritises sustainability of resources and considers the environmental limitations to their supply when planning future business activity. It is also important that packaging industry stakeholders throughout the supply chain, as well as government and academia, work together to achieve an economy that thrives within planetary boundaries. It is encouraging that collaboration between industry stakeholders has increased in recent years, and there have been more communication activities across the supply-chain, such as at round-table discussions, industry conferences (such as the annually held Sustainability in Packaging Europe event) and in practice (e.g., multi-business collaboration to facilitate packaging reuse through Loop's platform[39]).

[35] Department of Environment, Food and Rural Affairs (2022) Packaging and packaging waste: Introducing Extended Producer Responsibility. Available here. 15 April 2022
[36] UK Competition and Marketing Authority (2021) Green Claims Code: making environmental claims. Available here 18 April 2022
[37] HM Government (2021) Green Claims Code. Available here.
[38] Department of Business, Energy & Industrial Strategy (2019) UK becomes first major economy to pass net zero emissions law. Available here
[39] Loop (2022) A Global Reuse Ecosystem. Available here 18 April 2022

4. Future scenarios

Overview

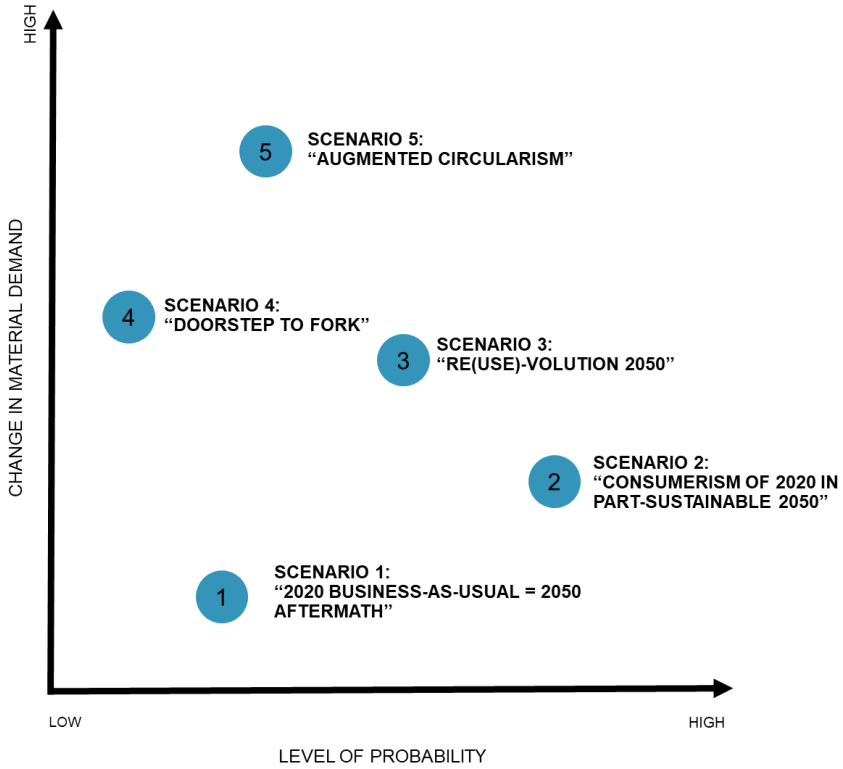


Figure 3:

The Foundation Industries covers six different materials, of which four (glass, metal, paper, and chemicals) are critical to the packaging industry. Each scenario developed has a different impact on these four materials. While each section provides a description of the expected future and the path taken to get there in terms of the packaging industry, the materials section will briefly outline the material impact to the Foundation Industries in 2050.

Summary of scenarios

2020 business-as-usual = 2050 aftermath	We consume at our convenience and on demand. Economic growth is coupled with GDP and goods are produced at high volumes, in the global linear economy. Environments are polluted and volatile.
Consumerism of 2020 in part-sustainable 2050	We consume at our convenience and on demand; sustainable packaging designs and recovery systems mitigate the impacts of our high demand. Environments are part-regenerated due to unintended consequences.
Re(use)volution 2050	We are a collaborative and community-oriented society. Our economy thrives; systems are designed to facilitate reuse as we close the packaging 'loop. The environment is cleaner and begins to regenerate.
Doorstep to fork	We are a collaborative sustained society of minimalists; systems are designed to produce and circulate resources and energy locally. We live in condensed communal areas and in symbiosis with the natural world.
Augmented circularism	We value convenience and experience, and trust in technology. Our systems are controlled and optimised, and data is used to maintain the thriving Circular Economy in the hyper-biodiverse world we live in.

The impact on material demand for the different Foundations Industries is summarised below:

Scenario	Glass		Metal		Paper		Chemicals	
	Material demand	**What can be expected?**	**Material demand**	**What can be expected?**	**Material demand**	**What can be expected?**	**Material demand**	**What can be expected?**
2020 business-as-usual = 2050 aftermath	↑	Consumption remains the same and there is an increased demand for glass in a resource-scarce world.	↑	Consumption remains the same and there is an increased demand for metal in a resource-scarce world. We begin to explore alternative forms of accessing materials.	↑	Consumption remains the same and there is an increased demand for paper in a resource-scarce world.	↑	Consumption remains the same and there is increased demand for chemicals in a resource-scarce world. Plastic recycling is difficult and there is a heavy reliance on virgin plastic material.
Consumerism of 2020 in part-sustainable 2050	=	Demand remains constant, and high recycling rates ensure that new packaging has 100% recycled content.	↓	To reach light-weighting targets, manufacturers will switch to other materials or reduce the amount of metal used in packaging.	↑	Cardboard packaging demand will increase but material for this will primarily be sourced from recycling facilities.	↓	Demand for chemicals for plastic packaging will be replaced by demand for biomaterials.
Re(use) volution 2050	↓	A focus on durability and reusability will steer manufacturers away from using glass.	↓	Refill and recovery infrastructure will keep material in the loop for longer periods of time. End-of-life material is likely to be recycled back into new packaging.	↓	A focus on durability and reusability will steer manufacturers away from using cardboard.	↓	Refill and recovery infrastructure will keep material in the loop for longer periods of time. End-of-life material is likely to be recycled back into new packaging. There is a focus on using more durable plastics.
Doorstep to fork	↓	A focus on reusability and durability will reduce the demand for glass.	↓	A focus on reusability and durability will reduce the demand for metals. Materials are likely to have a high recycled content.	↓	Less transit packaging is required, due to short supply chains. This reduces the demand for paper-based packaging. Bio-based packaging will replace some of the paper demand.	↓	A focus on reusability and durability will reduce the demand of chemicals. Materials are likely to have a high recycled content.
Augmented circularism	↓	There is a strong emphasis on high-performance materials such as composites, reducing glass demand.	↑	A highly technologically enabled environment requires more specialised metals	↓	3D printing will reduce the need to transport some goods long distances, reducing paper demands.	↑	High performance composites will be used in this future. Material is likely to come from recycling facilities.

This research develops five scenarios of the future in which various landscapes, while uncertain, might be adopted at scale in 2050 and influence change in demand and supply of core packaging materials. This section presents each of the future scenarios, describing the socio-techno-environmental landscape, their impact on packaging materials demand, the events anticipated to take place on the path towards them, as well as the opportunities and challenges associated with those futures for the UK Foundation Industries and packaging sector. The scenarios presented are often inconceivable to many stakeholders and offer descriptions of extreme futures. These scenarios are not predictions but can provide a deeper understanding when approaching the future. It is likely that the future will consist of aspects from more than one scenario, as shown in Appendix D where participants in the industry workshop noted that the most likely scenario will be a combination of scenarios 2 and 3.

Scenario 1

4.1. 2020 Business-as-usual = 2050 Aftermath

This is a future in which we consume at our own convenience, as we did in 2020; where economic growth is coupled with GDP. Finite resources and goods are produced at high volumes and reach us from the global economy to be used quickly and disposed of. Our environments are polluted and volatile due to climate change. The materials used in packaging will have remained unchanged for 30 years.

4.1.1. Socio-Techno-Environmental Landscape

Society: Convenience and Demand

We consume at our convenience and in high volumes – our behaviours have not changed since 2020.

We overconsume

We are an egotistic society driven by convenience and have therefore not been inclined to make any significant behavioural changes. We do not value how we affect the environment and others as much as we value meeting our needs and desires. The large middle-class community has enough disposable income to make regular purchases (based on desires and not just needs[40]) in line with affluent lifestyles. Ultimately, society continues to over-consume by purchasing goods it does not need. Our behaviour has led to material scarcity and a polluted environment. Climate change – drought, extreme weather, and rising sea levels – has led to increased migration of climate refugees escaping to urban areas.

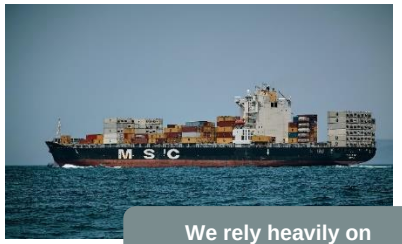
We continue to pollute

Technology: Linear System

There are insufficient advances in recycling technology and resource-efficient manufacturing.


We produce as in 2020

Technological advances focus on producing and selling faster and greater volumes of products to consumers. There is a lack of focus on the environmental consequences of this trend. Mass-production and long supply chains still prevail, with industries operating in a global economy. Advances in packaging design include light-weighting and material substitution – these are adopted because of cost reduction strategies and material scarcity. The recycling infrastructure is in place but is insufficient to provide a closed-loop supply of materials, meaning we continue to exploit natural resources. We began exploiting new and unknown natural environments, with novel deep-sea mining infrastructure and processes in operation. Processes for hazardous urban mining of landfill sites have also been developed.



We rely heavily on imports

[40] McWhinniy. J. (2021) 6 Signs that you have made the middle class. Available here

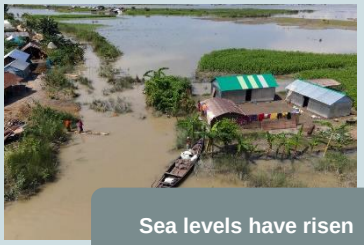
Environment: Pollution and Climate Change

Volatile and damaged natural world.

We have reached our limits to growth, constrained by resource availability. There are water- and food-security issues. Production of resources, such as silica, plastic, and wood, cannot meet current demands. We continue to landfill and incinerate waste. We manufacture intensively, which can result in air, water, and soil pollution. Human health and animal welfare are affected by the changing natural landscape.


We have overexploited our resources

The shortage of virgin raw materials has led to explorations in urban and seabed mining. This can lead to the release of toxic gases from older closed-off landfills and further damage to coral reefs.


Sea levels have risen

[41] QUASA (2021) 5 Helpful Tips on Effective Product Packaging for Your Small Business, Available here, 4 April 2020
[42] Reddit (2019) Egg carton for one, Available here. 4 April 2020

4.1.2. What materials might we use?

Material

Our demand for material has increased as more of the population strives to live decadent lives. Resource scarcity has led to using alternative materials in packaging. Multi-layered material and composites are still in use and continue to be difficult to recycle.

The types of materials used are a mix of recyclable and non-recyclable mono- and multi-materials.

Plastic | Glass | Paper | Metals

Innovation

The focus of innovation has been on convenient consumption, aesthetics and sales, mass-production, and global supply. Examples of emerging packaging innovation include individually packed goods, lighter packaging (particularly for FMCGs), and high-quality branded outer packaging (e.g., in fashion and electronic goods).

Sourcing

Virgin materials are sourced unsustainably, as we are increasingly exploiting natural environments. We consume more than our environment can replenish. We explore alternative forms of accessing material, including mining for virgin resources from the deep seabed and urban mining of hazardous landfill.

[43] Green Matters (2019), What do I do with Non-recyclable plastic? (And how do I identify it?) Available here, 4 April 2022
[44] Zero Waste Scotland (2021), What to do with crisp packets? Available here, 4 April 2020

4.1.3 Path to the future

Drivers

Convenience and the throwaway culture have been the norm since 2020. The packaging materials used in products are hard to recycle[45]. Our recycling infrastructure has been incapable of handling large amounts of post-consumer packaging made of several material types - the industry has been innovating in material composites to alter packaging properties (e.g., beverage cartons that are lined with polyethylene[46]). Evidence has been emerging on how industry activity has created climate change and pollution[47].

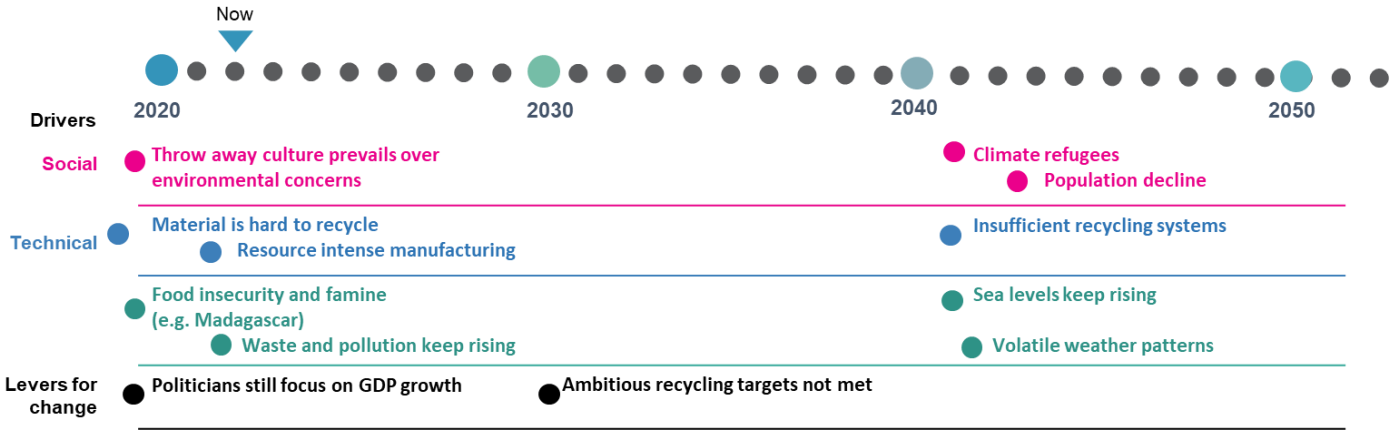
There have been unpredictable weather patterns and rising sea levels[48]. Climate change induced famine occurs around the globe where areas once known for their rich flora turn into infertile deserts. The population of Madagascar becomes the first victims of climate change[49].

Levers for change

Government and industry continue to prioritise economic growth, measured by profits and GDP[50]. Moving to sustainable practices has been avoided and seen as too disruptive and costly[51]. Government incentives or legislation have been insufficient for the industry to innovate in sustainable packaging design material and novel business models[50].

We have been exporting our waste[52]. Society has been ignoring the impacts of our consumption behaviours. Although the Net Zero targets have been set out by government[53], since their talks in the early 2020s policymakers have modified the targets to ease the impacts of the transition on economic growth[54] .We have been failing to meet the targets and emissions continued to rise.

A volatile, exploited, and damaged environment has also disrupted the financial market resulting in an increase in the cost of living. As a result, and to cut costs, the packaging industry has been driven to choose cheaper, unsustainable packaging materials (i.e., virgin resources, non-recyclable materials).



[45] WRAP (2020) Difficult to recycle products and material. Available here 15 August 2022
[46] Lonsdale. T and Dunne T (2020) Circular Economy: Rethinking composite plastic packaging. Available here 18 April 2022
[47] Eco to go (2020) How Food Packaging Affects the Environment. Available here
[48] Carbon Brief (2021) Mapped: How climate change affects extreme weather around the world. Available here 18 April 2022
[49] Katanich, D. (2022), How climate change is turning once green Madagascar into a desert, Available here 4 April 2022

[50] Stakeholder interviews and brainstorming sessions
[51] Krosofsky. A. (2021) The Cost of Environmentalism: Why Sustainable Products are Expensive. Available here 18 April 2022
[52] Laville, S. (2021) UK under pressure to ball all exports of plastic waste. Available here 18 April 2022
[53] UK Department of Business, Energy and Industrial Strategy (2021) Net Zero Strategy: Build Back Greener Available here 18 April 2022
[54] UK Department of Business, Energy and Industrial Strategy (2021) UK enshrines new target in law to slack emissions by 78% by 2035. Available here 18 April 2022

4.1.4 Opportunities and challenges

Opportunities

Resource scarcity may push industry to innovate in materials design and methods of sourcing. From this, some businesses may see the competitive advantage that lies in having sustainable packaging design and a circular business model as an alternative to this linear system. In addition, an increasing amount of waste could promote growth in the energy-from-waste industry driven by energy strategies rather than waste or environmental strategies.

The carbon footprint of using multi-material packaging is likely to be lower than that from spoilage from non-packaged consumables that end up in landfills. Globally food waste contributes to 8% of all greenhouse emissions while only 5% of carbon emissions in food systems are attributed to food packaging[55]. In a food scarce environment, packaging provides an opportunity to further prolong the shelf life of food.

Challenges

This scenario could lead to a more volatile and uncertain future of material supply and living conditions. Mass-production and global consumption rates, together with our reliance on fossil fuels, will drain the supply of non-renewable energy and material resources.

There have been consultations to explore deep sea mining as an alternative route to sourcing materials, with biologists and environmentalists concerned about the impact this may have on the natural environment[56]. Similarly, urban mining could bring a range of unintended consequences and pose threats to environmental and human health due to the risks of exposure to toxic gases and hazardous chemicals.

Scenario uncertainty

It is possible that if we continue business as usual, this scenario will become a reality. While the industry's activity has been unsustainable, steps are made to improve industrial activity through emerging policies and frameworks (e.g., Net Zero legislation[57], Circular Economy Action Plan[58], Greener Industrial Revolution[59]) and innovation in packaging design (e.g., edible packaging, compostable alternative for plastics[60]) and business models (e.g., reuse[61]). As we are running out of resources[62], we begin to look for alternative ways of sourcing from the natural environment. While efforts are made to develop recycling technologies, there is a lack of whole-system redesign and collaboration that would enable us to capture and utilise materials we already have flowing in the economy.

[55] Huhtamaki (2021) We believe food packaging can help protect our climate and nature's habitats. Available here
[56] IUCN (2022) Deep Sea Mining. Available here. 18 April 2022
[57]UK Department of Business, Energy and Industrial Strategy (2021) Net Zero Strategy: Build Back Greener Available here 18 April 2022
[58] European Commission (2022) Circular Economy action plan Available here 18 April 2022
[59] Department of Business, Energy & Industrial Strategy and Prime Minister's Office (2020) The ten point plan for a green industrial revolution. Available here 18 April 2022
[60] Netscribes (2021) Sustainable packaging innovations to watch out for in 2021. Available here 18 April 2022
[6161] Loop (2022) A Global Reuse Ecosystem. Available here 18 April 2022
[62] Spasic, V (2021) Earth Overshoot Day is July 29: resource consumption rebounds after pandemic. Available here 18 April 2022

Scenario 2

4.2 Consumerism of 2020 in Part-Sustainable 2050

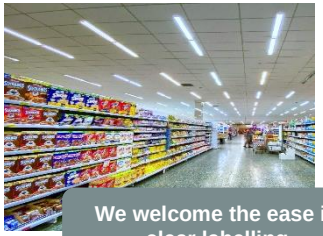
We consume at our own convenience and on demand; sustainable packaging designs and recovery systems mitigate impacts of our high demand. Environments are part-regenerated, part-exploited.

4.2.1. Socio-Techno-Environmental Landscape

Society: Demand-as-usual, Adaption

As "old habits die hard", we still have single-use packaging, but we buy and discard more responsibly.

Our purchasing habits remain the same

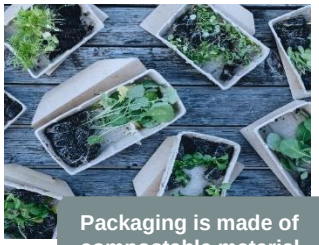


We welcome the ease in clear labelling

We value convenience and enjoy our habit of on-demand consumerism, but with appreciation for the environment and any potential impacts. We trust that any adverse impact of our packaging is mitigated through new technologies and systems. We are more knowledgeable on correct disposal routes for our packaging and, with clear labels and ease of access to recycling disposal units, recycling has never been easier. New packaging (such as edible packaging) is interesting and welcomed where there is a focus on convenience, but we take comfort in keeping many aspects of packaging as they were in 2020.

Technology: Reducing Adverse Impacts

Packaging design has changed a little, and we have a well-established and effective recycling system.



Packaging is made of compostable material

Our technology allows us to achieve Net Zero. Kerbside waste collection has improved to capture all materials and sends them to be recycled through new commercial-scale processes such as chemical recycling, which has reached an all-time high. The energy requirements for these processes are met through renewable energy. There is very little need for virgin materials due to this endless loop of recycling, with all packaging having a large percentage of recycled content requirement. Lesser used plastics have been phased out, to aid the initial transition to a recycling economy. Bioplastics are also widely recycled and new material is only used when recycled content is not obtainable. Further to this, the only new material being introduced into the system is compostable or edible, as these materials cannot be recycled, but are both locally and industrially returned to their original form. On top of existing collection technologies, drones are used to collect packaging from doorsteps and bring the materials to larger facilities, using artificial intelligence to identify different packaging types so they can be sorted for efficient recycling. We are also collecting plastics and other packaging from our oceans and reintroducing these materials into the recycling loop.

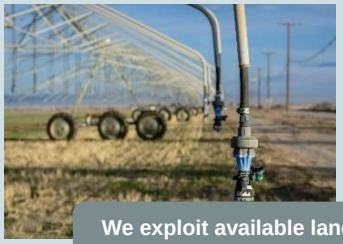
Recycling systems are efficient

Environment: Part-Regenerated, Part-Exploited

Less pollution and waste, but bio-sourcing has led to land exploitation.

This 'Consumption as usual' scenario allows the 2050 population to live within planetary boundaries without considerable need for change. (The planetary boundary is *"the threshold within which we can survive, develop and thrive for generations to come"*[63]) The environment will initially suffer, with landfill mining activities creating 'demolition sites' of ancient landfill areas. Biodiversity and care for the environment will decrease during this time when we are back-tracking on our waste (through landfill mining and ocean plastic extraction). Species will become extinct, habitats will be destroyed, and the effects of global warming will not cease, causing initial supply shortages for bio-based packaging materials (e.g., cardboard, bioplastics etc). As this is a gradual process to circularity through recycling there will be some losses but, ultimately, a more sustainable environment will prevail, with biodiversity levels increasing to where they were in the 20th century.

Land is gradually regenerating



We exploit available land for bio-material

[63] Fransen, B. (2021) What Are Planetary Boundaries, And Why Are They Significant. Available here 18 April 2022

[64] Edible packaging containing water: Available here 4 April 2022

4.2.2. What materials might we use?

Material

Recyclability is the focus of materials in this 2050 future, through using materials such as metals for their recycling durability. Bio-based packaging is also prevalent in this future, including bioplastics (such as polylactic acid), biodegradable and compostable plastics (e.g., from mycelium, seaweed), and edible packaging. Bio-coatings are also used for packaging designs (e.g., bio-coating sprays). Material used in this future include:

Plastic | Biomaterial | Glass | Paper | Metals

Innovation

Biomaterial is produced at scale. Chemical recycling and bio-waste stream recovery infrastructure is present all over the UK. Many fossil-based materials have been replaced by more sustainable options (e.g., replacing bubble wrap for delivery packaging with corrugated cardboard). Biological recycling (using microbes and enzymes) of plastics is also present, producing high quality recyclates that can be reused in packaging.

Light-weighting of packaging has become of high importance to aid the transport of goods by reducing haulage costs. Paper and plastics (including bioplastics) have been key in achieving this packaging characteristic, with more of a focus on recycled content.

Sourcing

Our primary source of material is the outputs from recycling plants, with most packaging reaching close to 100% recycled content. Where recycled material is not readily available, we can source materials from old landfill sites, where and when it is safe to do so. Plastics can also be retrieved from the copious quantities in the world's oceans. In extreme circumstances where virgin material is needed, surface mining is undertaken.

The bio-materials market is driven using bio-sources which cannot otherwise be used as a food source (or are a waste product of the food industry).

4.2.3 Path to the future

Drivers

Society's push for convenience is the key driver for this 2050 scenario, motivated by the lockdowns during the COVID-19 pandemic. Cardboard and lightweight plastics are used for delivery packaging for their lightweight properties and ability to combat security and repeat delivery issues by fitting through your letterbox – a recent innovation relating to last-mile delivery (final step of delivery from warehouse to customer)[65].

Large corporations have also seen the trend in conscious, but still convenient, consumerism. This is shown through changes in packaging design, e.g., PepsiCo Europe setting targets to eliminate fossil-based plastics in crisp bags by 2030 and Amazon scrapping single-use plastic in its delivery bags[66,67]. Packaging design will also become minimalistic, with less of a need for attractive packaging designs to draw in consumers as most shopping is done online, potentially causing the merging of primary and secondary packaging[68].

As well as the redesign of existing materials, new packaging materials are emerging. The bioeconomy is growing and, through programmes such as *The Circular Bio-based Europe Joint Undertaking* (CBE JU), there is no shortage of innovation emerging in the sector[69]. Research being undertaken is looking at the most sustainable methods to produce biomaterials, thereby future-proofing the industry and ensuring demand for packaging will continue to be met without the use of virgin fossil-based materials. In a similar vein, edible packaging is also in the development phase with the aim of reducing our reliance on plastics.[70]

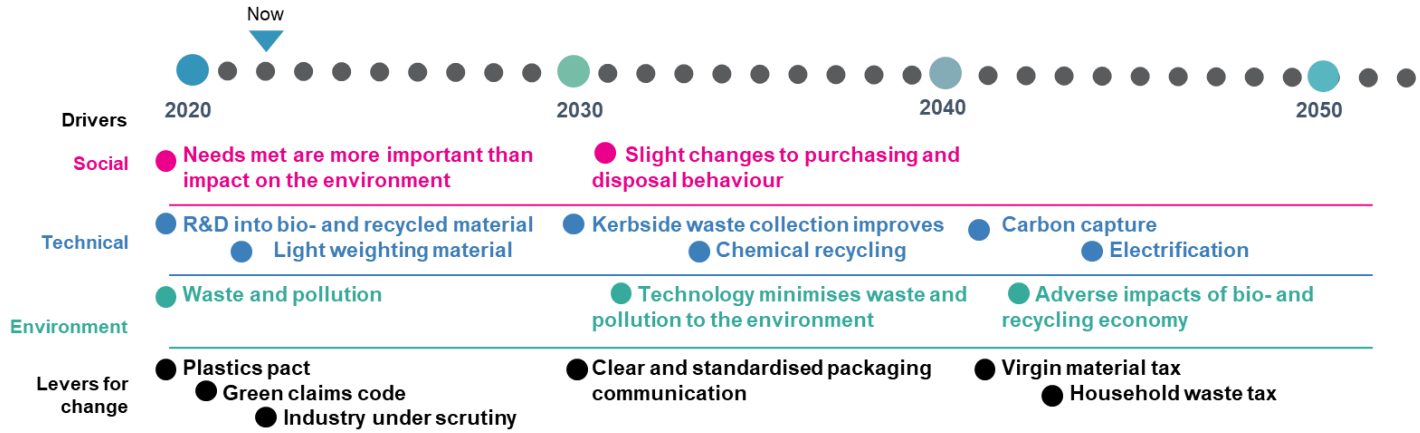
Further to innovation in new materials, there is a focus on recycling innovations to enable the continuous usage of materials in the current system – such as fossil-based plastics.

Chemical recycling technologies have the potential to recycle half of all global plastics packaging by 2040, and will limit the need for 'downcycling' of plastics as seen in current mechanical recycling processes.[71] There is still a degree of uncertainty over chemical recycling due to the associated increase in emissions and hazardous by-products, so an increase in mechanical recycling via improved waste collection services is the short term target, and is encouraged through the introduction of an Extended Producer Responsibility scheme for packaging in the UK from 2024.[72]

Levers for change

Looking at a short-term 2025 future, the UK Plastics Pact (run by the Waste & Resources Action Programme, WRAP) has set targets to reduce resource use and increase recyclability. Signatories include various major UK brands, thereby encouraging other businesses to follow suit. To meet these 2025 targets, research and innovation will drive fundamental changes to elements of the whole supply chain, from design and production to reprocessing of plastics at end of life[73]. The Green Claims Code which looks to limit 'green washing' by companies will enable transparency and consideration of the total impact of the packaging material[36].

Taxes also have a role to play when considering the shift in packaging materials, in both short- and long-term futures. The Plastic Packaging Tax came into force in April 2022, applying to plastic packaging containing less than 30% recycled plastic (including bioplastics), thus driving the industry laggards and indirectly motivating investment into efficient waste collection services and recycling infrastructure. Tax implementations such as this are likely encouraged by organisations such as The Ellen MacArthur Foundation, whose published piece on 'The New Plastics Economy Forecast' looks at the growth of plastics use towards 2050 and the potential damage to the environment this growth will cause.



[65] Huang, Rui, "Ecommerce in Rural Areas and Environmental Sustainability: The Last-Mile Delivery" (2017). WHICEB 2017 Proceedings. 50. Available here
[66] Wright, G. (2022) Amazon ditches single-use plastic delivery bags for recyclable paper. Available here 19 April 2022
[67] Packaging Europe (2022) PepsiCo Europe sets target to eliminate fossil-based plastic in crisps bags by 2030. Available here 19 April 2022
[68] Feber,D, Nordiggarden, D & Varanasi,S. (2019) No ordinary disruption: Winning with new models in packaging 2030. Available here 19 April 2022
[69] Bio-based European Joint (2022) What can CBE JU do for Europe? Available here 19 April 2022
[70] Patel, P. (2020) The time is now for edible packaging. Available here 19 April 2022
[71] Baily, G (2020) Can chemical recycling make plastic more sustainable? Available here 19 April 2022
[72] DEFRA (2022) Packaging and packaging waste: Introducing Extended Producer Responsibility Available here 19 April 2022
[73] WRAP (2022) UK Plastics Pack Signatory Gallery. Available here

4.2.4. Opportunities and challenges

Opportunities

As this future is similar to our current situation, it appears more realistic and acceptable to society in comparison to the other scenarios presented. Incoming EPR schemes encourage more recycled content. This should drive investment in recycling and material recovery infrastructure, or fund incentives for the public to correctly recycle (through deposit return schemes (DRS) or similar). The movement away from using virgin fossil material is possible through switching to bio-based materials and recyclates, with further potential to reduce environmental impacts by using waste as a resource.

Chemical recycling can lead to the creation of a new type of high-quality raw material supplier who can compete against companies that sell virgin raw materials. Raw material producers may also develop their own chemical recycling capabilities to maintain their market share.

Challenges

As this future is partly dependant on increasing the rate of recycling, numerous factors need to be addressed:

- Government targets and policy are limited in terms of motivating the industry to aim beyond targets.
    - Financial penalties on minimum recycling content will likely affect mainly smaller businesses, as larger corporations will either be in a financial position to pay or already have the infrastructure to achieve these targets.
- Public awareness/education is essential to increase correct waste disposal and recycling.
    - In the same vein, behavioural change is key but will be difficult to achieve and may need initial and significant financial incentives.
- The definition of what recyclability means is unclear, and there are no standard measurements nor verified reports to determine whether recycling systems are fully closed loops.

Likelihood of scenario

Developing processes and technology to manage our environmental impact is the most likely scenario. Industry is currently investing heavily in developing new material and feasible chemical recycling options. This is therefore the most likely future.

Scenario 3

4.3. Re(use)volution 2050

A society-driven reuse system for healthy living and clean environment. Packaging materials are becoming more durable than in 2020.

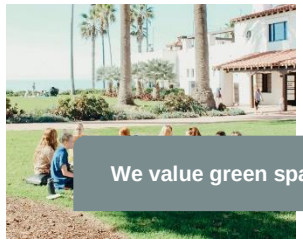
4.3.1. Socio-Techno-Environmental Landscape

Society: Altruistic Stewards

We are a community-oriented, collaborative, diverse and inclusive society.

Our priority is the community's wellbeing; therefore, we actively contribute to maintaining healthy living environments. We are conscious that our actions have an impact on others and the environment; therefore, we strive to live in symbiosis with one another and with the natural world. We live in a similar urban-rural built environment to that of 2020, except we have more communal green spaces that we use to maintain close contact with each other. What we saw as waste in 2020, we now see as resource – we are intrinsically motivated to circulate resources in use. Therefore, we reuse packaging when acquiring and consuming FMCGs and by doing so we can circulate it for use within the local economy. To be able to reuse packaging, we adopted new routines by incorporating new behaviours – we refill and recover reusable packaging, and we either reuse exclusively within our households or sequentially by sharing with other consumers. Economically, we live in a dematerialised system where our goal is to thrive together and have our needs met, rather than to grow individually and expand our materialistic wealth by continuously buying and disposing of new items in the same way we did 30 years ago.

We prioritise community wellbeing



We value green spaces

Refillable infrastructure is widespread

Technology: Internet of Reusables

Our systems are designed to circulate reusable packaging in the local economy, while allowing us to consume globally sourced goods.

2050 consumption systems are designed to facilitate packaging reuse for most types of FMCGs. Single-use packaging still exists but is rarely used and only for specific product types (e.g., pharma products), and is aided by recycling. Packaging is designed to facilitate acquisition and consumption over multiple use cycles; durable form design and long-life materials are used. Packaging standardisation is common to facilitate reuse across several brands and with various recovery and refill infrastructures. These infrastructures are widespread and therefore can operate in a local and shorter supply chain. Nonetheless, consumables are still produced in the global economy, meaning we can still acquire a wide range of FMCG brands.

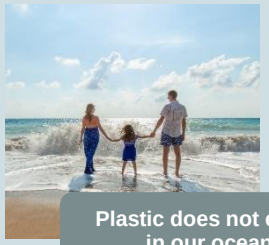
Packaging is more durable

Environment: Clean Healthy Living/World

We control the flow of packaging in the system and reduce industrial activity involved in packaging manufacturing.

The re(use)volution has resulted in a reduction of waste. The flow of packaging plastics into the ocean has stopped. The Circular Economy has been fully adopted and the reuse model is in full effect. We use products that retain their value and consumption has decreased.

There is less waste created



Plastic does not end up in our oceans

[74] Loop collection: Wadhera, C. (2021) Zero-waste shopping service to arrive in select Tesco stores. Available here. 4 April 2022

4.3.2. What materials might we use?

Material

There is a reduction in overall demand for packaging as consumers opt for refillable options, but there was an initial surge in demand for durable packaging. To facilitate the refill and reuse culture there is a focus on durable mono-materials and high-performance composites.

Overall, there has been a drastic reduction in the use of plastic packaging, and single use plastic packaging is no longer used. The dominant types of reusable packaging materials used are:

Plastic | Glass | Metals | Stainless steel | Tritan (BPA free plastic)

Reuse systems require a 'systems thinking' approach, as refill and recovery i needed. Innovations focus on durability through additives to common materials. Packaging is standardised and modular so that components can be easily replaced, and the same packaging can be used across different brands.

Emotionally durable design strategies are incorporated into packaging design to build resilient relationships between consumers and products. This results in products lasting longer and a decrease in consumption because consumers are invested in looking after products.

Sourcing

Although virgin material is still used, manufacturers are maximising the use of recycled content in new packaging products. Take-back schemes for refill systems have made it easy to collect material to be recycled. However, the main material value retention occurs at a product level through the reuse of packaging products.

[75] Unilever reusables: Peters, A. (2020) Giant brands love Loop's zero-waste packaging-and now it's coming to a store near you. Available here. 4 April 2022

4.3.3 Path to the future

Drivers

International climate movements such as *Extinction Rebellion protests*[76] and *Fridays for the Future*[77] have highlighted the need for societal action and to hold politicians accountable in reaching Net Zero and sustainability targets[78]. As a society we have chosen to eliminate our consumption of single-use packaging. We choose to opt for refill stations and reuse packaging. We view waste as a resource and choose single-use packaging that is recyclable. We have developed a sharing economy and live in communal spaces.

Innovators begin to focus on making reusable packaging last longer and making it recyclable, in line with consumer demands.

There is less pollution in the environment because we create less waste. The flow of plastics in the environment is closed and there is no leakage of plastic pollution into our oceans.

Urbanisation has still resulted in highly densely populated urban areas, but we have more communal and green spaces in cities, creating community and sharing spaces.

The current success of various reuse scheme such as Loop, Algramo, Coca-Cola in Brazil and PepsiCo's Sodastream brand is pushing other FMCG companies as well as supermarket chains to develop reuse strategies[79].

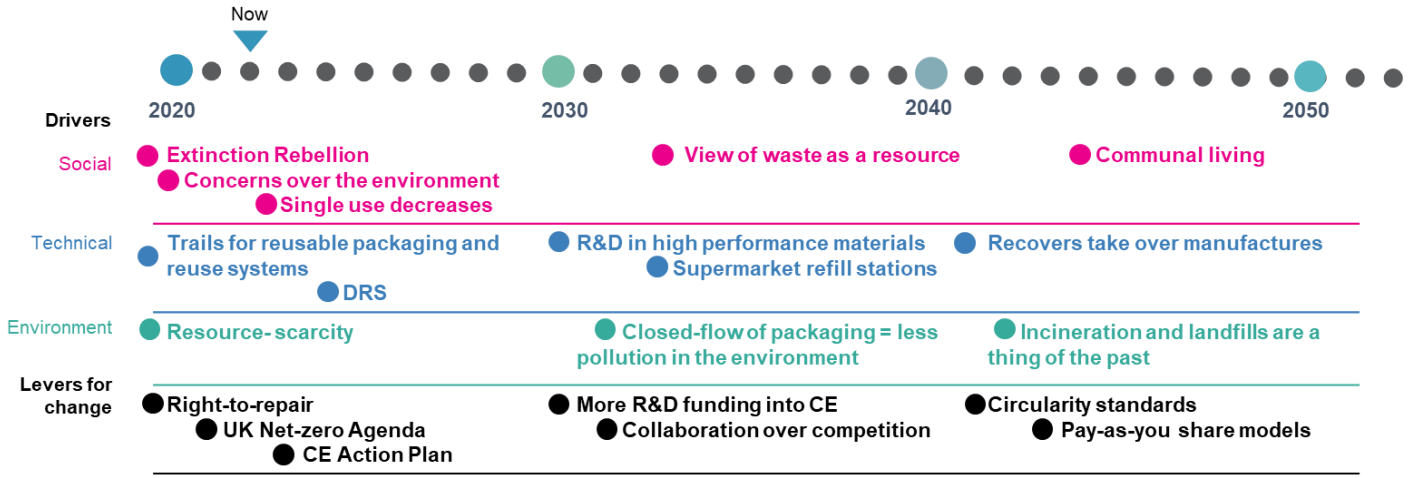
Levers for change

Access to information is readily available to the public, and we now understand the impact we have on our planet. We are more conscious of the choices we make regarding what products we buy and what packaging is used for these products.

Schemes such as the deposit return scheme (first in Scotland[80] and then the rest of the UK), and right-to-repair will encourage the packaging industry to adopt more circular business models and guides the consumers into seeing the inherent value in packaging materials. Legislation has forced the packaging industry to develop sturdier packaging as well as systems to collect and wash collected packaging.

Documents such as the UK Net Zero Agenda[81] and the Circular Economy Action Plan[82] provide targets for industry. Industries collaborate to reach these targets.

Supermarkets begin to adopt refill-and-return stations to maintain customer loyalty. Industries develop systems for collection and refill to make these more mainstream.



[76] Extinction Rebellion (2022) About us. Available here 18 April 2022
[77] Fridays for the Future (2022) What we do. Available here 19 April 2022
[78] Ares, E. (2020) The rise of climate change activism? Available here 5 April 2022
[79] World Economic Forum (2021) The Future of Reusable Consumption. Available here. 7 April 2022
[80] Zero Waste Scotland (2022) Deposit Return Scheme. Available here. 5 April 2022
[81] UK Department of Business, Energy and Industrial Strategy (2021) Net Zero Strategy: Build Back Greener Available here 18 April 2022
[82] European Commission (2022) Circular Economy Action Plan. Available here 19 April 2022

4.3.4 Opportunities and challenges

Opportunities

This future will result in the development of new markets and will shift market value to be across the lifecycle of packaging and not just at production and sale stages. Current business models such as subscription prefill services and platforms will grow and extend to markets not previously targeted. This could make reuse options more affordable.

Challenges

A future such as this requires consumer behaviour changes, and these changes are unlikely to be driven solely by the public. A key component of this is educating people on changing shopping habits.

The right kind of infrastructure and technology is needed to facilitate such a change. Affordability will be a major driving force in changing the way consumers shop, as sustainable options in 2020 are still only accessible for those with a higher disposable income.

This system will also require a lot more collaboration between different organisations and actors along the supply chain. Standardisation of packaging is needed to reduce complexity of take-back schemes and create efficient washing processes for used packaging. Standardisation will also give consumers the freedom to change brands instead of being locked into a single brand.

Reusable packaging will lengthen the lifespan of a package. A ‘reuse and keep’ mentality reduces the amount of available recyclable material. In a scenario where packaging is made of recycled content, there is a risk in suppliers not being able to meet demand. This could lead to recycling no longer being an industry priority.

There will be consumer concerns around packaging safety. People may be dissuaded from using reusable packaging as an aftermath of the COVID-19 pandemic. Education needs to be a top priority for this scenario.

Brand differentiation will be a challenge in the light of standardisation. Reuse systems require a level of standardisation across similar product categories; to ensure brands can keep their own brand identity, a level of branding on packaging is required. Organisations will have to collaborate to develop systems that deal with slight variances in packaging.

Likelihood of scenario

Big FMCG companies and retailers are already investing in R&D in this space, making it a likely option. Consumer demands for companies to be more plastic conscious is the main driving force behind the exploration.

Scenario 4

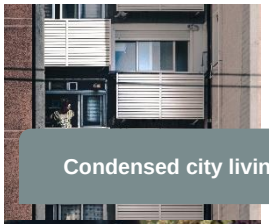
4.4. Doorstep to Fork 2050

We are a collaborative sustained society of minimalists. Systems are designed to produce and circulate resources and energy locally. We live in condensed communal areas and in symbiosis with the natural world.

4.4.1 Socio-Techno-Environmental Landscape

Society: Altruistic Minimalists

We are a collaborative sustained society of minimalists. We live in condensed communal areas.



Condensed city living

We choose to shop locally

As in the Re(use)volution scenario, we are a community-oriented, collaborative, diverse and inclusive society. We help each other by sharing resources, even in the face of scarcity. Our priority is community's wellbeing; therefore, we actively contribute to maintaining healthy living environments. We lead a minimalist lifestyle: our living environment has decreased in space since 2020. We now share living and recreational settings with each other. We are not materialistic, our goal is to sustain and have our needs met, rather than to grow individually and expand our material wealth by continuously buying and disposing of new stuff as we did 30 years ago. We care about our health and the health of our environment, but we strive to reduce our impacts and use less; we produce goods locally.

We utilise product-as-a-service (PaaS) offerings to fulfil our consumer needs through 'renting' consumer electronics, goods, and furniture.

Technology: Self-Sufficient Local Systems

Our technology enables us to produce and circulate resources in the local economy. Product-service systems are in the core of our living.

We rely on vertical farms to grown produce

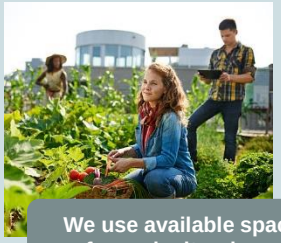
Agricultural technological advances in greenhouses have evolved. Fruit and vegetables can be farmed locally, in local communal gardens, vertical gardens, indoor farms and greenhouses. We consume a variety of different proteins (e.g., from insects) and there is no need for large tracts of land. Energy to run the greenhouses is supplied from renewable sources. There is no reliance on imports, and packaging is locally sourced. Recycling operations within the UK have increased, and no waste is exported to other countries.

We consume alternative forms of protein

[83] Local products: iStock images available here

Environment: Symbiotic Urban and Natural Living

Short-supply chains, sharing economy and local sustainable production in a condensed regenerative rural-urban world.



We use available space for agricultural use

In urbanised areas, homes are smaller but outdoor spaces are used as communal living areas. Our communal spaces contain local urban farms where we grow seasonal fruit and vegetables. We have built local repair capabilities through repair cafes and choose to repair products before replacing them.

We produce energy within our local regions

Manufacturing takes place within the same countries but is located on the outskirts of cities. Overall, our supply chains have shortened, decreasing the packaging needed for transport and the emissions released in transporting goods.

[84] Vertical gardens: Business Tech South Africa: available here

4.4.2 What materials might we use?

Material

Highly condensed living conditions and collaborative spaces have shifted our understanding of packaging needs. Short supply chains have limited the need for packaging, with the available packaging being reusable, such as durable mono-materials (i.e., plastic, metal, and glass) or bio-based (i.e., biodegradable, edible or compostable). Where materials are not single-use, they are reused and recycled at end-of-life.

Biomaterial | Glass | Paper | Metals

Innovation

We use little-to-no packaging – driving the 'naked product' trend, meaning the scope for innovation is limited. Any packaging used is regenerative, meaning it is compostable and can be used as fertiliser to grow new packaging material. Due to the short supply chains, less transit packaging is needed. Innovation into bio-based materials, especially compostable, edible, and regenerative materials, will be the focus.

Sourcing

Due to the overall reduction in packaging demand, materials are more likely to be sustained through local supply. Compostable packaging is used for local farming, with the potential to manufacture new packaging materials from the farm's produce. Materials used for reuse packaging applications will be sourced via recyclates and retained in a closed-loop recycling system.

4.4.3. Path to the future

Drivers

Environmental movements and concerns around well-being and diet have pushed consumers to make more local purchases. We support the local farmers and artisans instead of large supermarket chains. We purchase organic fruit and vegetables. At the same time the urban population is growing as we search for better opportunities in the big city or because our own areas have become uninhabitable because of droughts and rising sea levels. This has led to condensed living in cities.

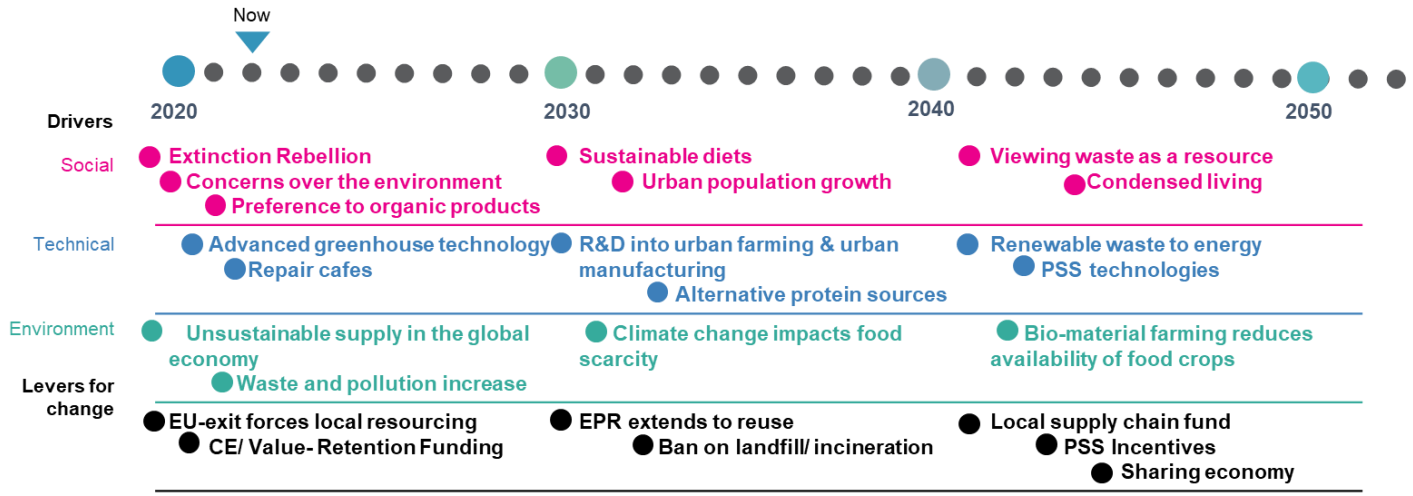
Advanced greenhouses have become more energy efficient, allowing us to grow produce in our own country and rely less on imports. This has allowed us to build resilient supply chains in an unstable world where drought and flooding are likely to disrupt food supply chains. Alternative protein sources such as insects have become more mainstream in the western world. Waste-to-energy processes have also become more efficient as we run out of land space for landfills. 'Products as a service' (PaaS) business models have become more mainstream, and technology has had a large influence on this. In such models, packaging aesthetics do not need to be priorities to encourage sales as there is a longer-term relationship between the consumer and manufacturer with multiple flows of products and parts during the service contract e.g., upgrades, repairs and maintenance. Reusable and durable packaging becomes a priority.

Global supply chains and imports have been proved to be unsustainable and risky. Our changing climate has also threatened our food supply chain and we begin to build internal capabilities to meet our food demands. Crops are being grown for biomaterial and biofuels, and this has also contributed to our food scarcity problems.

Levers for change

The long-term impacts of Brexit include the need to build internal capabilities to meet consumer demands. To meet internal demands and align with sustainability goals, the UK Government has issued funding for projects that relate to value retention and Circular Economy projects; this includes incentives around PaaS. Existing sustainability policies are expanded to include reuse.

There has been a ban on sending waste to landfill, which has led to the use of more compostable packaging options.



4.4.4 Opportunities and challenges

Opportunities

This scenario supports local economies by producing both consumables and packaging internally. This often relies on several small businesses instead of one main supplier which builds resilience in the supply chain. The short supply chains also make this a more sustainable option as there is a reduction in transport emissions and less of a reliance on fossil fuels.

Consumers can have a healthier diet of fresh and seasonal produce and less processed food. It is also healthier for wildlife, biodiversity, and soil health, as there is no mass production of food. We can become more adventurous with the meals we cook from scratch and are less likely to discard ‘wonky’ food. There is less food waste.

Through PaaS offerings, manufacturers can offer more value to customers and develop new revenue streams through subscription fees. For consumers, large capital expenses will transform into smaller operating expenses. This creates more accessibility for people in lower income groups.

Challenges

Currently, local farming in the UK is product-specific with it still being more sustainable to import fruit and vegetables than run our own greenhouses, because of the energy required to run them. The right energy supply is therefore key.

A change in consumer behaviour is required, as consumers will have to purchase food at markets and most likely bring their own reusable packaging to store fruit and vegetables. We will have to learn that only certain products are available at certain times as food supply will be seasonal.

Likelihood of scenario

A scenario that solely relies on local production within cities to meet consumers’ needs is unlikely, as there is a low probability of meeting all consumer needs through local farming in the UK. This is because farming technology (such for vertical farms and greenhouses) is not energy efficient enough to be developed at large scale. We would require energy supplies that are 100% renewable to ensure that the emissions released from local food production is less than that from imports.

Scenario 5

4.5. Augmented Circularism 2050

A society that continues to consume as we do today but with technological advancements that have incorporated circularity into everyday life. There is a high demand for critical raw materials and durable packaging.

4.5.1 Socio-Techno-Environmental Landscape

Society: Hedonistic Consumers

We value convenience, experience, and personalisation.

We associate consumerism with our own well-being, and this had led to stresses at work and to time becoming a valuable asset. For this reason, we value ease and convenience. Unlike an altruistic society, we have become resistant to finding fulfilment in nature and relationships, leading to a heavy investment in brands and the purchasing of goods and services. Green technology and e-commerce have given us unlimited access to next-day delivery with net zero emissions, and we cherish the experience of consuming. Our greatest joy comes from brands tailoring their offerings to us as individuals, with little concern over the end-of-life of these products. We trust science and technology to maintain resource supply and sustainable environments.

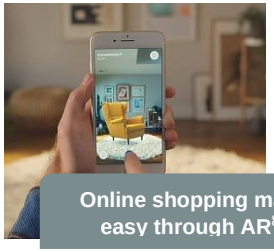
Interconnected and tailored shopping

Autonomous delivery to our door

Technology: i4.0 and Smart Packaging

Technological advancements have created ways of personalising goods and services offered to us through monitoring the way we consume.

In addition, technology has facilitated a more Circular Economy. We live in a society where Industry 4.0 (i4.0) dominates, meaning there is increased interconnectivity and automation. Reusability and reverse logistics have been incorporated into business models with the use of drones collecting reusable delivery packaging, RFID (radio frequency identification tag) tracking packaging through the supply chain using blockchain, and 3D printing of goods and food to create shorter supply chains. Rental Apps on our phones make it easier to access clothing, household tools and machinery with just a click of a button, while augmented reality (AR) allows us to preview products to decrease the rate of returns. The 'Internet of Things' has pushed a date-led economy where material supply and demand are anticipated, leading to further improvements in resource efficiency. There has been a significant investment in infrastructure across the supply chain, so that manufacturers can quickly respond to demand and incorporate the supply of recovered material into their processes. Information is freely exchanged between corporations and governments. Information on packaging is clear and standardised.



Online shopping made easy through AR[85]

Drones enabling reusable delivery packaging[86]

We use data as a key tool in driving a Circular Economy, as organisations can monitor in real time how close they are to meeting Circular Economy objectives and goals.

Environment: Enhanced Biodiversity

Technology enables us to continuously detect negative environmental impacts from our production and waste processes.

Our connected supply chain enables us to better detect leakages to the environment. We are therefore better able to understand where packaging ends up and make effective changes to stop these leaks. Using technology, we have successfully stopped the flow of plastics into the ocean. This data-driven society has provided us with information to restore our natural environments. We can use information in real time to understand environmental changes and harness technology to mitigate these changes.

Reuse options are convenient

[85] AR shopping: Early Metrics (2020) Augmented Shopping. Available here 20 April 2022

[86] Amazon drones: Amazon (2022) Amazon Prime Air. Available here 20 April 2022

4.5.2 What materials might we use?

Material

This future uses high-performance composites to enhance the reuse and durability of packaging. With new technologies to allow for easy collection of packaging, overall material use will be less than that of today's industry.

These new technologies also come with their own material demands, namely the use of critical raw materials (especially in printed circuit boards, PCBs). These are used in all smart packaging in the form of microchips found in RFID tags. The types of material required in this future are:

High performance plastics

Critical raw materials (CRMs)

Innovation

There is likely to be novel manufacturing technology, including the widespread use of 3D printing for replacement parts, removing the need for storage and delivery packing of mass-produced parts. Through advances in the 'Internet of Things', innovation will see new and interactive elements to our packaging, using blockchain technology and RFID to track and gather data on how to tailor our individual packaging needs. Autonomous delivery will be widespread to streamline reverse logistics to maximise packaging recovery.

High performance (e.g., moisture- or light-regulating) materials will enable an increased shelf-life of consumables[87] - such as plastic lids that absorb oxygen in plastic bottles.

Sourcing

There will be less waste due to increased reuse facilitated by new technologies. There will be sourcing issues in the short-to-medium term future – but this should plateau once circular business models are fully embraced. Packaging is reused multiple times, and this is facilitated through embedded packaging trackers to limit material loss from the system. There will be requirements for near-100% recycled content for packaging and a minimum use of virgin feedstock materials. However, most of the CRMs that are needed in the new technologies will be from virgin sources, though some can be re-extracted from landfills through urban mining.

[87] Emperchtinger, F. (2019) 5 things you should know about Smart Packaging. Available here. 6 April 2022

4.5.3 Path to the future

Drivers

Technology is the main driving force behind this scenario. Current innovations are already paving the way for autonomous delivery services to be used to deliver packages in Milton Keynes[88], with the streamlining of delivery systems using 'drone superhighways' to ensure same-day deliveries.[89]

Technology is becoming more affordable, with a 3D printer costing around £200 in 2020[90]; this will lead to shorter supply chains with products being produced on demand.

The COVID-19 pandemic has accelerated the trend of online shopping making it a very popular and convenient shopping method. Innovations in virtual reality and clothing shopping online has mimicked the in-person shopping experience and has given us the opportunity to 'try on' clothing before purchasing it[91].

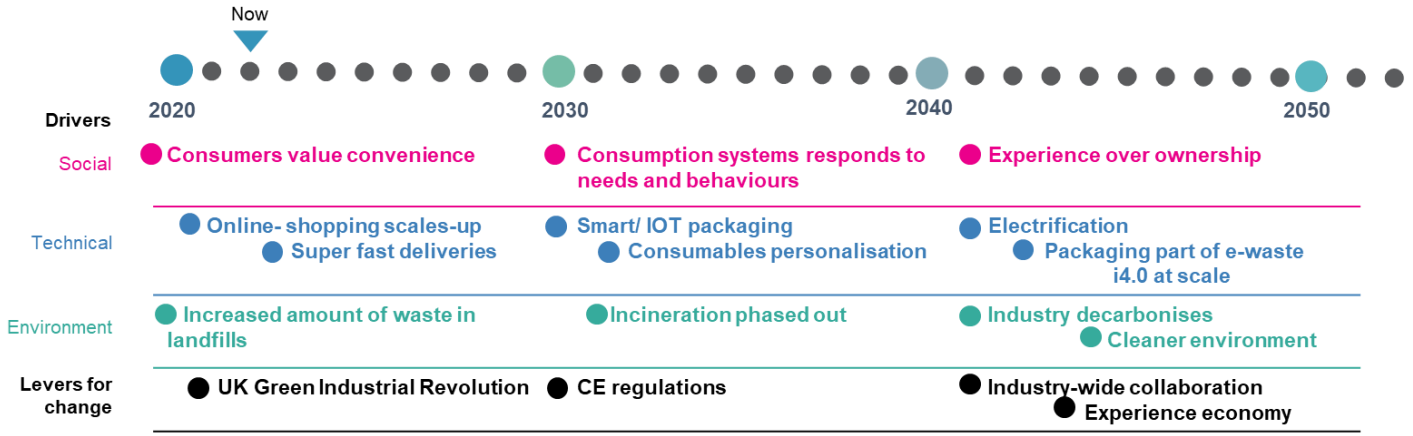
The collection of consumer data through our online purchases and social media activity has made it easier for companies to direct specific advertisements at us and to personalise product options.

The self-indulgent focus of society will also drive the use of smart packaging to create more personalised experiences. In a similar way to 'cookies' on web pages, data gathering through purchasing choices will enable packaging to be tailored to consumers' preferences.

Levers

Regulations and legislations on Net Zero and the Circular Economy will lead companies to find technology-driven solutions. Companies find that collaboration is key in meeting sustainability targets and begin to standardise collection processes and using digital tools to make these processes more efficient.

The UK Green Industrial Revolution takes place, where i4.0 concepts are used in conjunction with sustainability business models and Circular Economy practices. Tracking products and packaging across the supply chain has led to more collaboration between competitors as well as across the supply chain.



[88] Hern, A. (2020) Robot Deliver Food in Milton Keynes under coronavirus lockdown. Available here 6 April 2022
[89] The Engineer (2022) UK could be set for 165 mile drone superhighway. Available here 6 April 2022
[90] 3D Printer World (2022) How much does a 3D printer cost? Available here 6 April 2022.
[91] Mueller. S. (2020) The future of retail is contactless and immersive. Available here 6 April 2022

4.5.4. Opportunities and challenges

Opportunities

Technological advances would allow for more circular business models without consumers needing to completely change their habits. Rather, this scenario focuses on creating convenience as the main driving force behind societal changes.

Previously competitive organisations will need to collaborate with each other to develop a technology-enabled ecosystem.

Value-retention practices (e.g., reuse, recycling) reduce the reliance on imports and create more technology jobs in the UK.

Challenges

With the reliance on and vast increase in the use of technology, there comes a surge in energy demand. With the rising carbon emissions costs, there need to be significant improvements in the renewable energy infrastructure to manufacture and run all the necessary technology to enable this future,

With the recent Data Protection Act[92] controlling how organisations use data, there may be difficulties surrounding public perception and uptake of new technologies. Data gathering through packaging materials could be seen as too intrusive by consumers, limiting the scope of reach.

This future also relies on the public to treat packaging as a valuable commodity. As shown through the imposed plastic carrier bag charges[93], a behavioural shift can be achieved through placing a monetary value on an item previously seen as disposable by some consumers. Packaging used in this 2050 future will be designed with reuse and returns in mind, putting the responsibility on the consumer when drone collection is not possible. With a convenience-driven society, this could be a challenge to mitigate.

Many traditional packaging manufacturers will need to adapt new business models, invest in modern machinery, and upskill their workforces to deal with ‘SMART’ packaging.

Likelihood of scenario

The increase in online sales and rentals and quicker delivery times have paved the way for more automation in our delivery systems making this scenario more likely.

[92] UK Government (2022) Data Protection Act. Available here 20 April 2022

[93] DEFRA (2015) Carrier bag charges. Available here 20 April 2022

5. Summary and key takeaways

This research presents five future scenarios of what packaging material demand might look like in 2050. The presented scenarios were developed using qualitative futures research methodologies and are a selection of possible socio-techno-environmental landscapes that are likely to have a high impact on material demand. As scenarios, none of these are certain to occur by 2050; however, these scenarios give an indication of the type and scale of change the packaging industry and connected supply chain will likely face.

The main observations from the five scenarios are:

1. **Consumption of 2020 = 2050 Aftermath** showed a future in which we continue consuming, business-as-usual, in a linear economy, leading to material scarcity and resource shortages. Society and the environment are facing the extreme consequences of our industrial activity.
2. **Consumerism of 2020 in Part-sustainable 2050** showed a future in which steps have been taken for us to consume more sustainably, leading to material substitutions and technology development to mitigate the impact of our consumption-on-demand behaviours. Improved and more sustainable industrial activity takes place in some sectors, but with unintended negative effects in others.
3. **Re(use)volution** showed a future in which systems are designed to facilitate reuse. The materials we use are more durable and contain composite materials.
4. **Doorstep to Fork** showed a future in which systems are designed to produce and circulate resources and energy locally. There is less transport packaging required as consumers can purchase what they need locally; the packaging that does exist is made from biomaterials.
5. **Augmented Circularism** showed a future in which technology has optimised systems to incorporate circularity (and reuse) into our daily lives. All packaging is tagged with RFIDs, and IOT connects different parts of the supply chain so that we always know where packaging is. However, we require more critical raw materials to produce RFIDs, and packaging consists of durable composite plastics (for which recycling technologies have been created).

Given the high level of impact these scenarios are predicted to have, it is crucial for the different players in the packaging supply chain to begin planning how they can prepare for those futures, including steps that can be taken to increase or decrease the possibility of these scenarios being realised. For example, the ‘Consumption of 2020 = 2050 Aftermath’ scenario indicates that if we continue business-as-usual, society might face limitations to material supply and severe environmental consequences. In contrast, the ‘Re(use)volution’ scenario showed a future in which the packaging industry can have greater control of the flow of packaging materials, which facilitates a secure and controlled supply of resources and reduces waste.

Having a foresight into the future is key for policymakers looking to introduce legislative and regulatory mechanisms to help facilitate or prevent certain scenarios. Equally, leadership and collaboration across the supply chain are key to ensuring the path to the preferred future is supported and realised.

From the scenarios presented, experts believe that our future will consist of a combination of a ‘Part-sustainable 2050’ and a ‘Re(use)volution’. They believe that we will have more reuse and refill options but also have high chemical recycling rates and biodegradable and bio-based packaging. Ultimately this means that the types of material used and how we source raw materials for packaging will likely change substantially from today.

Appendix

Appendix A

Steps taken for data collection

- **Stage 1**: Review of academic, industry and public sector literature to collect data using PESTLE factors (political, economic, societal, technological, legal, and environmental) y that are anticipated to take place between 2020 and 2050. This enabled the research team to develop a comprehensive map of future events.
- **Stage 2**: Structured ideation session. The project team (comprised of behavioural scientists, product design engineers, circular economy specialists, packaging policy experts; N=8) and additional packaging industry experts (N=3) participated in a structured brainstorming workshop to collect additional data on the anticipated future events. This enabled the team to fill data gaps and map out dependencies of events used in further stages in describing the future scenarios.
- **Stage 3:** Qualitative open-ended interviews and surveys. The interview and survey participants were industry stakeholders and thought leaders across the packaging and materials sectors including policymakers (N=1), FMCGs brands (N=2), packaging manufacturers (N=3), retailers (N=3), waste management businesses (N=1), trade associations (N=2) and individuals with an overarching view of the supply chain (N=3). The interview and survey participants also imparted their expertise relating to the following packaging materials sectors: plastics, film, card, glass, and an overarching view of all packaging materials. The interviews lasted on average one hour and were conducted in a video-call, and surveys were administered online. The '7 Questions' method (an interview method used by the industry to gather intelligence about the future[7]) was used both in interviews and in surveys. Each question gathered data about the participant's vision of the future with respect to the different PESTLE factors as well as at a level of business operations in the industry at large and in the context of their own business. PESTLE is a macro-environmental framework that examines political, economic, sociological, technological, legal, and environmental factors that affect the packaging industry. The 7 Questions are included in this Appendix.
- **Stage 4:** Undertaking of industry workshop at the 2050 Future Packaging Material Demand event hosted by KTN and Innovate UK on 24 March 2022, at which the scenarios identified in this research were presented. The workshop was attended by stakeholders from the packaging sector and the Foundation Industries (N= 158) including a mixture of Academia, government, and research technology organisations. The workshop enabled the project team to collect data on the industry vision of what opportunities and challenges there might be in the alternate futures in the context of packaging material supply and demand, as well as how likely they foresee these futures to be. Workshop questions are included in Appendix B. In addition, workshop participants contributed to a voting poll attached in Appendix C.

7 questions used in stakeholder interviews

1. Looking back, are there any particular lessons – successes or failures – from the last 30 years that UK packaging industry can learn from when planning future activities?
2. What do you foresee are the biggest changes – positive or negative - that will happen for the UK packaging industry between now and 2050?
3. Describe what would be a favourable scenario for the UK packaging industry in 2050?
4. What do you think needs to happen between now and 2050 beyond business-as-usual to deliver the favourable scenario?
5. What are the priority actions the industry needs to take now (i.e., before 2030) to ensure the favourable scenario can be delivered?
6. What do you think would be an unfavourable scenario for the UK packaging industry in 2050?
7. If you had absolute authority, what would you do to achieve the favourable 2050 scenario?

Appendix B

Data analysis

The data, namely the influencers of change (i.e. trends, drivers and signals) gathered in the first three stages stage were mapped and thematically analysed to identify interrelated events that could take place in the next 30 years (i.e. paths to the future in Sections 4.1.3, 4.2.3, 4.3.3, 4.4.3 and 4.5.3) that might be influential on the socio-techno-environmental landscape of 2050 (in Sections 4.1.1, 4.2.1, 4.3.1, 4.4.1, 4.5.1).

As a result of this analysis, five scenarios were developed based on an established scenario development methodology[94]. The scenario-thinking approach used allowed us to capture a range of possibilities in rich detail[95]. Furthermore, to reduce bias, scenarios were developed independently by the two halves of the project team, after which the scenarios were compared and refined into the final set of five scenarios. The developed scenarios were analysed further to identify what materials might we use in 2050 based on the constraints of the foreseen socio-techno-environmental landscapes. In particular, a list of common packaging materials, packaging innovation and material sourcing were identified (in Sections 4.1.2, 4.2.2., 4.3.2, 4.4.2, 4.5.2).

Finally, the identified scenarios were qualitatively evaluated in terms the extent of their likelihood and their impact on material demand (in Sections 4.1.2, 4.2.2, 4.3.2, 4.4.2, 4.5.2). The likelihood of these futures was confirmed by participants in our industry event, through an online poll. The data gathered in fourth stage has been thematically analysed to identify the opportunities and challenges for material demand in each of the scenarios, as well as their perceived likelihood (Sections 4.1.4, 4.2.4, 4.3.4, 4.4.4, 4.5.4). The certainty and importance of these scenarios was determined by mapping them against 'level of uncertainty' and 'expected change in material required'. The likelihood of these futures was confirmed by participants in our industry event, through an online poll.

Appendix C

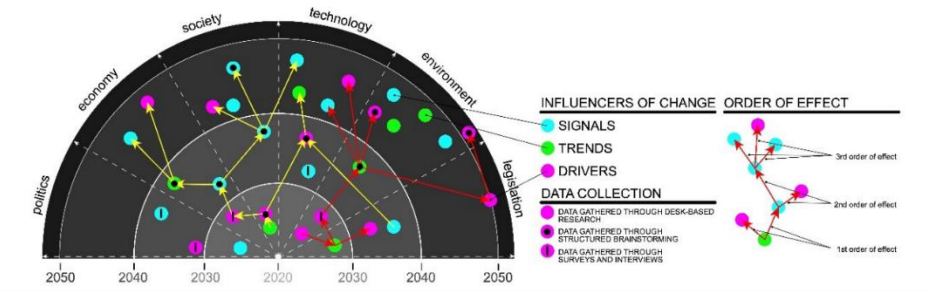


Figure 4: Basic outline of a futures map, used in developing the order of effect.

Workshop questions

1. How impactful (on material demand), certain and preferable is this future?
2. What are opportunities and challenges in this future for the industry?
3. How can the industry prepare for this future?

[94] UK Office of Science (2017) The Futures Toolkit. Tools for Futures Thinking and Foresight Across UK Government. Available here 6 April 2022
[95] Schoemaker. P.J.H, (1995), Scenario Planning: A Tool for Strategic Thinking. Available here 7 April 2022

Appendix D

Workshop voting poll

After the workshop, participants were asked three poll questions.

1. Which future is most likely to dominate?
2. Which future is most likely to impact your business?
3. Which future would you, as a consumer, prefer to happen?

The figure below shows the results of the first poll, along with commentary:

Key:	
Scenario 1	2020 business-as-usual = 2050 aftermath
Scenario 2	Consumerism of 2020 in part-sustainable 2050
Scenario 3	Re(use)volution 2050
Scenario 4	Doorstep to fork
Scenario 5	Augmented circularism

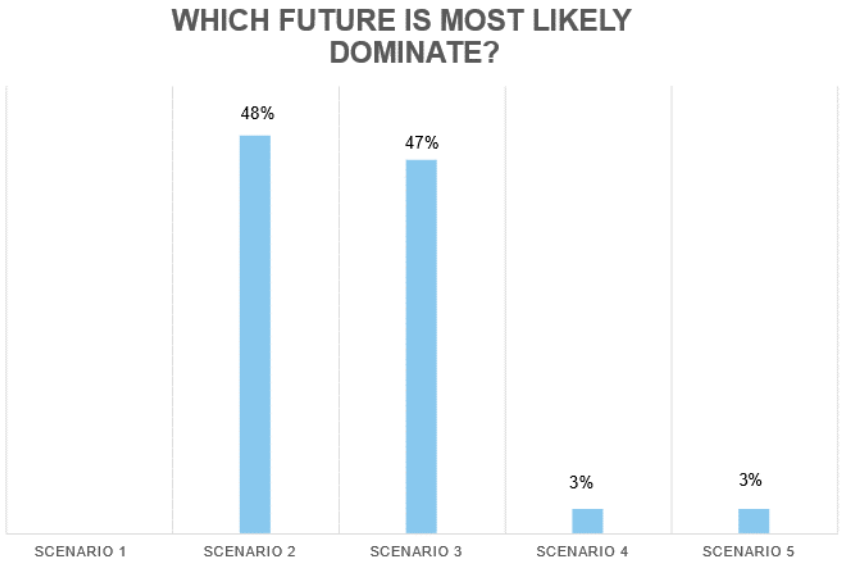


Figure 5: Poll on the most likely dominant scenario

Of the five scenarios, participants viewed either the second or the third as likely. Furthermore, participants commented that a future with aspects from both scenarios is likely.