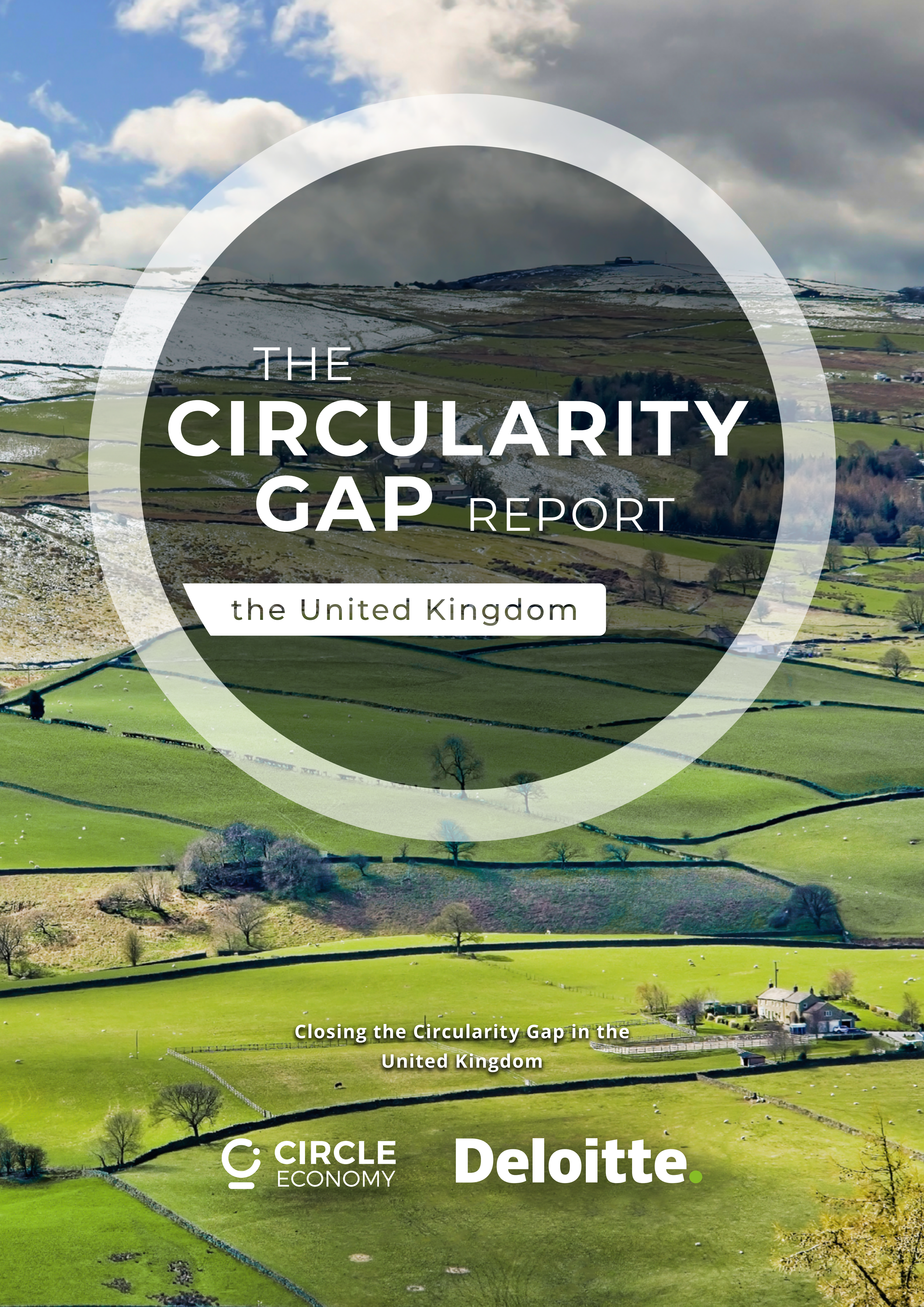


THE CIRCULARITY GAP REPORT

the United Kingdom

Closing the Circularity Gap in the United Kingdom

CIRCLE ECONOMY

Deloitte.

BEHIND THE COVER

The United Kingdom's beautiful landscape reminds us to draw inspiration from nature in the transition to a circular economy. Just as we cycle through the seasons each year, with the winter fading away and the sun bringing new life, it's time for the people of the United Kingdom to usher in a new season—and a new economic system.

To develop this report, we have held a series of stakeholder consultation meetings consisting of several roundtables. A diverse group of attendees were consulted, including members of the public, private and third sectors, as well as academia.

CIRCLE ECONOMY

We are a global impact organisation with an international team of passionate experts based in Amsterdam.

We empower businesses, cities and nations with practical and scalable solutions to put the circular economy into action. Our vision is an economic system that ensures the planet and all people can thrive.

To avoid climate breakdown, our goal is to double global circularity by 2032.

In collaboration with:

Deloitte.

Deloitte is an international professional services network comprising over 333,000 specialists who provide audit and assurance, consulting, financial advisory, risk advisory, tax, and related services to clients in over 150 countries. Its purpose is to make an impact that matters.

To build the sustainable future we need, at the speed we need to build it, we have to work together in new, more ambitious and impactful ways. Deloitte's goal is to convene the private sector, public sector and society to inform and enable actionable strategies that will improve circularity, in a way that benefits businesses, society, and the planet.

IN SUPPORT *OF THE CIRCULARITY GAP REPORT THE UNITED KINGDOM*

DIANE CROWE
Head of Sustainability at Reconomy Group

'The *Circularity Gap Report the United Kingdom* helps us understand the current landscape for material use in the UK, as well as the impact it has. Importantly, the report is also clear about the needed collaborations between Government, regulators, businesses and individuals to transition to more circular systems that can make impact reduction an easy, commercial and mainstream choice.'

PROFESSOR FIONA CHARNLEY
Co-Director at the Exeter Centre for the Circular Economy and UKRI Circular Economy Hub

'The circular economy presents us with a framework to tackle global challenges; however, transformation will only be achieved through new interdisciplinary relationships between businesses, Government, academia and society. The *Circularity Gap Report* provides evidence, examples and a clear direction of travel on which to build these partnerships and make this exciting vision a reality.'

MAYA DESOUZA
Circular Economy Campaign Director at Business in the Community

'This report highlights the importance of a circular economy by showing the close link between material use and carbon emissions. It shines a light on how a different approach to using resources is a key lever for decarbonisation, and that reducing the footprint of products and activities from a specific set of sectors can substantially reduce carbon emissions.'

LIBBY PEAKE
Head of Resource Policy at Green Alliance

'Seeing the UK's Circularity Gap outlined for the first time is alarming. Warning signs are being ignored as we allow the reckless use and loss of valuable resources, with over 90% of material use coming from virgin sources. We can't keep going at this rate, and the good news is we don't have to. Greater circularity is attainable and could drastically reduce the UK's material footprint. Political leaders know what to do, and this clear evidence should inspire them to take the steps needed.'

JACK BARRIE
Research Fellow at Chatham House

'The Circularity Metric has become key for measuring progress of the global circular economy transition. This report shows how far away the UK is from being a truly regenerative circular society—and therefore how exposed it is to the increasing volatility and competitiveness of global resource markets. It also provides the UK with a starting point, a marker in the sand, from which to move forward—as well as a compelling argument for why that journey should be started in earnest today.'

IAIN GULLAND
Chief Executive at Zero Waste Scotland

'The *Circularity Gap Report the United Kingdom* offers both an important warning of the dangers of climate inaction, and a path towards a more circular society. Assessing the Circularity Gap provides valuable insight into the state of the journey, and makes everyone's role in delivering positive change clear. We must implement policies that encourage circularity and systems change: to achieve sustainable production and consumption, the transformation to a circular economy is critical.'

WAYNE HUBBARD
CEO at ReLondon

'The report highlights the scale of our linear economy's impact on material use and carbon emissions, and shows how a circular economy can tackle such impacts. At ReLondon, we recognise that this transition will only be possible through collaboration—between national and local governments, private and third sectors, communities and citizens—and so we welcome the publication of this report. It will help build a shared understanding of both the current state and future possibilities for the UK economy, and inform the crucial shift to a circular economy.'

DANA HAIDAN
Chief Sustainability Officer at Virgin Media O2

'The *Circularity Gap Report* outlines the clear opportunity for Government, business and society in scaling the circular economy to help reduce waste and emissions. But realising the potential of more circular models will require systemic change and a joined-up approach, as well as clear measurement and metrics. The report provides a starting point, shaping our understanding of how to achieve this.'

MARTIN PAULI
Global Circular Economy Services Leader at Arup

‘The *Circularity Gap Report* reinforces the urgent need to accelerate the transition to a built environment that is designed, developed and operated based on circularity principles. This means that construction waste is eliminated, materials are circulated, and natural systems are regenerated. This will require greater collaboration across the construction value chain, the stimulation of green finance and scalable circular innovation and business models.’

JULIETTE WHITE
Vice President Global SHE and Sustainability at AstraZeneca

‘Transitioning to a circular economy is critical to tackle the interconnected climate and biodiversity crises. The path forward identified in the *Circularity Gap Report the United Kingdom* demonstrates that keeping materials in circulation at their highest value can reduce emissions and decrease pressures on natural resources whilst supporting the UK economy.’

CAROLINE RUSH
CBE, Chief Executive at British Fashion Council

‘The fashion industry is complex and has multiple touchpoints; we need engagement, commitment, and dedication by all actors across our fashion ecosystem to drive forward systems-level change in a concerted manner. The *Circularity Gap Report* successfully maps what’s needed to reach this vision and gives guidance on how to shape a circular economy in the UK. We are committed to playing our part to accelerate the transition to a circular economy in the UK and encourage everyone to play their part in positive change. It is now time to move from concept to action.’

ANNE-MARIE MALLEY
Sustainability and Climate Lead at Deloitte UK

‘The United Kingdom has a great opportunity to maintain its position as a frontrunner on climate action. This first *Circularity Gap Report* for the United Kingdom provides government and businesses with actionable steps to transition to a circular economy, and can be used as a baseline for future circular economy initiatives. Achieving net-zero by 2050 will require urgent action to develop a clear vision with government and business aligned on the systematic changes needed around product design, new business models and raising awareness to reduce resource consumption.’

EXECUTIVE SUMMARY

The United Kingdom's (UK) Circularity Metric sits at 7.5%—leaving a Circularity Gap of 92.5%. This means that the vast majority of material inputs to the UK economy come from virgin sources. By way of comparison, the current global Circularity Metric in 2023 sits at 7.2%. This *Circularity Gap Report* is the first to examine the material flows of the UK economy in this way. The analysis uncovers how materials—non-metallic minerals, metal ores, fossil fuels and biomass—are extracted, used and disposed of (see more on pages 32–33). The objective of the report is to highlight the role and importance of the circular economy and to present the opportunities that exist to reduce material consumption in the UK. The extraction and processing of materials, including fuels and food, are responsible for approximately half of global greenhouse gas (GHG) emissions, and over 90% of biodiversity loss and water stress.[1] Therefore, reducing material consumption is one of the key pathways for tackling the root causes of the climate, biodiversity and pollution crises.

A circular economy can decrease the UK's high rate of material consumption by keeping materials in use for longer at the highest value possible. As the UK economy becomes more circular, the Circularity Metric increases and the absolute tonnes of materials consumed decreases. As a nation, the UK uses over one billion tonnes of virgin materials per year; 15.3 tonnes per capita. This is above the global average of 12.2 tonnes per capita,[2] meaning that the UK is a disproportionately high user and consumer of virgin materials. Much of this can be linked to its imports of materials and products, which means that many environmental impacts are offshored. While the material footprint is high for the UK on average, it's worth noting the disparities in material use between the UK's constituent countries. Large volumes of extracted materials flow from resource-rich nations with low population densities—such as Scotland, Wales and Northern Ireland—to England, the country with the highest population density.

The UK is highly dependent on international trade to satisfy its demand for materials: this inflates its already large emissions profile. In 2019, 20% of the country's virgin material use originated from domestic extraction with the remaining 80% coming from the import of large amounts of materials and finished products. The UK also exports slightly more than half of its domestically extracted materials—predominantly non-metallic minerals and fossil fuels. The UK's consumption-based carbon footprint was 749 million tonnes of CO_2e in 2019, 54% of which resulted from the extraction and production of imported materials and products. These emissions embodied in imports are not directly targeted by the UK's net-zero goal. So, although there have been promising efforts to lower domestic emissions through decarbonising electricity generation, for example, other factors—such as the embodied carbon emissions within material imports, and the lower energy efficiency development of the UK's housing stock compared to peer European nations—result in high, inefficient energy use and GHG emissions.[3] Cutting the emissions embodied in imports while decarbonising domestic heat and transport systems are thus key avenues to boost the UK's circularity.

Material use and carbon emissions are tightly coupled, with a few sectors contributing the most to both. The top ten industries contributing to the UK's material footprint make up 45% of the total material footprint, and sit within four sectors: construction, agrifood, manufacturing and processing, and services.[4] Material use is intricately linked to GHG emissions: material-intensive sectors are also carbon-intensive. The top ten contributing industries to the UK's carbon footprint make up 38% of the total carbon footprint and sit within five sectors: transport, construction, services, energy and agrifood.[5]

Opening up the Circularity Gap. Although it may be assumed that 92.5% of virgin materials flowing through the UK economy are wasted, this isn't necessarily the case. Within the Gap are a range of circular and non-circular inputs as well as stock build-up:

- **20.6% of these materials find their way into long-lasting uses or applications (additions to stock),** such as buildings and infrastructure.
- **A further 15.6% are renewable/carbon-neutral biomass,** such as forest residues, food crops and manure.
- **An additional 41.7% of the virgin materials (29% of which are imported) are non-renewable inputs,** such as metals, rock, chemicals, glass and plastics.
- **13.0% comes from non-circular inputs,** such as fossil fuels for powering industry, transport and heating.
- **1.4 % is non-renewable biomass—biomass that is not carbon-neutral,** such as grass.*

In total, the inputs in the latter three bullets represent over half (56%) of the UK's material footprint—painting a picture of an economy that leaves a huge environmental imprint at home and abroad. The UK must focus on reducing these three elements while also boosting its Circularity Metric and ensuring that other indicators, such as additions to stock, are made as circular as possible.

A set of six 'what-if' scenarios, can tackle material use and lower emissions while narrowing the UK's Circularity Gap. These scenarios may also have positive impacts on health and wellbeing by encouraging healthier food and more active lifestyles, boost communities' resilience, improve biodiversity and soil health, support resilient supply chains and create decent new jobs. The six scenarios are: 1) Build a circular built environment, 2) Shift to a circular food system, 3) Champion circular manufacturing, 4) Rethink transport and mobility, 5) Welcome a circular lifestyle, 6) Tackle the UK's import footprint. Individually, the scenarios have a limited impact—but combined, they can almost double the Metric, bringing it up to 14.1%. They also have the power to cut the UK's material footprint by **40%**, and slash its carbon footprint by approximately **43%**.

** Note that these figures don't sum to total due to rounding.*

THE WAY AHEAD FOR A MORE **CIRCULAR UK**

UK business can play a major role in making the UK economy more circular, especially when using circularity as a driver for innovation, experimentation and collaboration. The current linear economy poses many business risks—and these are likely to increase over time. Businesses that can see a way to derive satisfactory profit from new services, products and operating models that reduce material consumption will be the long-term winners, but the vision to do so remains sporadic across most sectors. Achieving circularity is challenging for complex value chains, especially those that lack transparency and traceability, and those where products or services aren't designed for circularity or are inherently non-circular. Making a shift will require experimentation with new approaches and business models, for which collaboration across value chains and innovative pilots will be invaluable. This report outlines how companies can move from a position of compliance, to improved resilience and value creation—shedding linear risks and embracing circular benefits.

The circular economy must be considered a key pillar in UK and sector-level strategic business and economic plans. Reducing and maximising the value of material inputs to the economy will not only result in reduced environmental pressures but is a sound economic strategy to deliver cost savings, drive productivity growth, spur new regional, circular value chains and create jobs. This is acknowledged by the latest Net-Zero Independent Review, which recognises that reducing resource use and delivering a more circular economy is a priority for decarbonising the UK economy. This also entails redefining value. For example, the circular economy holds huge potential to contribute to the protection and enhancement of the UK's natural capital assets.

UK nations and local and regional initiatives will play a key role in the transition as promoters, facilitators and enablers. The UK already boasts a solid circular economy-related stakeholder ecosystem. Celebrating, strengthening and building upon these local initiatives and communities via support and collaboration will be a crucial complement to top-down action. Collaboration across sectors and disciplines together with facilitation of clusters, incubation spaces and networks where there is a gap is needed to maximise the potential of existing and future initiatives.

There is a huge opportunity for the UK—and a risk of missing out. While the UK exhibits a level of material consumption that surpasses the global average and well-exceeds ecological limits, it is well-positioned to take on the challenge of going circular. It is considered a frontrunner in climate action, being the first major economy to roll-out a legally binding commitment to achieve net-zero emissions. It is also advanced, by global standards, when it comes to circular economy-related policy. With decarbonisation agendas gaining prominence at different levels, a rich ecosystem of motivated stakeholders, and the circular economy gaining traction in both policy making and business strategies, the UK is already taking crucial first steps to leave linear behind. However, there is a need for a clear(er) vision, a detailed strategy and clear and ambitious targets for reducing material consumption and achieving greater, higher-value circularity. Decarbonisation is only one piece of the puzzle; the circular economy can deliver other environmental objectives, such as pollution and water stress reduction and biodiversity protection. Achieving net-zero by 2050 will require ambitious targets for cutting the UK's material footprint by half, at a minimum.[6]

THIS REPORT LAYS THE PATH FORWARD FOR A MORE CIRCULAR UK

To take the circular economy agenda forward, the report recommends leadership and action to:

- **Take a shared approach to circularity** across the UK by creating an integrated and inclusive circular economy approach;
- **Create a comprehensive set of indicators** and targets to guide and embed the transition;
- **Shape a level playing field** through a fit-for-purpose policy framework;
- **Upgrade product standards** to improve end products as well as intermediate materials;
- **Harness Government power** to drive action;
- **Encourage businesses** in key sectors to lead from the front;
- **Ensure action** is diverse and citizen-centric.

Moving forward, achieving all these objectives will require a systemic, holistic approach that goes beyond cycling. If approached in the right way, a circular economy can provide wider environmental, societal and economic benefits. This report advocates for an upgrade of the economic system, to one that focuses on providing wellbeing and a good quality of life for all UK residents, within planetary boundaries.

CONTENTS

1. INTRODUCTION

We are living in the Anthropocene: a new geological epoch where human activity has become the dominant driver of Earth system change and has caused increasing harm to the natural environment. As of 2023, many of the planetary boundaries that support life on this planet have been transgressed.[7, 8] Exponential growth in material extraction, which has more than tripled globally since 1970 to 100 billion tonnes a year,[9, 10] has driven this overshoot. As global material use has reached new heights, the Circularity Metric has dwindled from 9.1% to 7.2% within only six years.[11] For the UK, this figure stands at 7.5%. This means that 92.5% of the just over 1 billion tonnes of materials used to satisfy demand in the UK in 2019 came from virgin sources. By minimising material use and waste in the first place and keeping as many materials in circulation for as long as possible at their highest value, the circular economy is a means for reducing environmental impacts, increasing resilience and providing economic benefits. This analysis can act as a tool for decision makers—both in policy and business—to identify key (sectoral) drivers of material extraction and use and pinpoint levers to optimise materials management and enhance resource efficiency. It can also guide the creation of targeted circular strategies to unlock economic, social and environmental value.

This analysis examines the material flows of the UK economy: using 2019 as a baseline year (the latest for which data is available), it uncovers how materials—non-metallic minerals, metal ores, fossil fuels and biomass—are extracted, used and disposed of, as well as the key drivers of these processes. It also calculates the UK's Circularity Metric (secondary material consumption), which sits at 7.5%—slightly above the global average. The UK is considered a frontrunner in climate action, introducing the first legally binding commitment from a major economy to achieving net-zero emissions. It is also advanced, by global standards, when it comes to circular economy-related policy. However, there is a need for clear(er) vision, detailed strategy and clear and ambitious targets for reducing material consumption and achieving greater, higher-value circularity.

As a result, the *Circularity Gap Report the United Kingdom* aims to:

1. Provide a snapshot of how circular the UK is by identifying the Circularity Metric.
2. Identify how materials flow through the economy and how they may limit or boost the current Circularity Metric.
3. Spotlight possible interventions within significant sectors and value chains that can aid the UK's transition to circularity and reduce its material footprint.
4. Spotlight avenues for decision makers within government and business to revamp production and consumption patterns.
5. Communicate a call to action based on the above analysis, to inform future goal setting and agendas.

THE RISKS OF LINEARITY IN THE UK

From a materials perspective, the UK was the first nation to transform its economy through mass industrialisation, shifting from an agrarian (biomass-based) to a predominantly industrial (minerals-based) socioeconomic structure.[12] Today, the UK is a high-income economy and a major economic powerhouse.[13] It also boasts global political and cultural influence due to its strong diplomatic service and cultural output. However, despite its position in sectors such as finance, aerospace and life sciences, the country's economy faces challenging economic headwinds.

Over the past four decades, the UK has experienced a major structural shift in its economy, transitioning from material- and energy-intensive sectors to a more service-oriented economy.[14,15] This has also radically altered the material basis of its economy, as deindustrialisation and globalisation have reduced domestic environmental pressures (territorial greenhouse gas (GHG) emissions and domestic material extraction, for example). Outsourcing and international trade flows play a large part in reducing these environmental pressures:[16] as the UK has increasingly become a net importer of raw materials, the impacts of material extraction and GHG emissions embedded in imports have grown as a fraction of the UK's total material and carbon footprints.[17, 18] In 2019, approximately four-fifths of the UK material footprint and over half (54%) of the carbon footprint were generated abroad.[19] Like many high-income nations, the UK exports the environmental impacts of its consumption elsewhere.

Such dynamics attest to the increasing separation between environmental pressures and impacts associated with consumption. For instance, on a per capita basis, the UK relies on around 12.3 tonnes of raw materials extracted elsewhere in the world to satisfy its domestic material demand (15.3 tonnes per year). Imported emissions are also not included in net-zero targets. While deep reductions in domestic emissions have been achieved, the UK has experienced some of the sharpest global increases in GHG emissions embedded in trade (as a percentage of domestic production).[20]

CURRENT STATE OF PLAY: A SOCIAL, ENVIRONMENTAL AND ECONOMIC CROSSROADS

Since 2008, the *Climate Change Act*[21] has guided the UK's climate policy and set out emission reduction targets.[22] In June 2019, Parliament passed legislation to reduce the UK's net GHG emissions by 100% compared to 1990 levels by 2050, with a 78% reduction target by 2035. Identifying the right resource efficiency and circular economy strategies across the most impactful sectors will be critical for the UK to reduce its environmental footprint and achieve net-zero targets. The UK Government has started embracing the concept of the circular economy as a driver of industrial transformation[23] and (clean) growth,[24] with a focus on economic benefits such as productivity, competitiveness and resource security. It also views circularity as a means for achieving multiple environmental objectives such as decarbonisation, improved resource efficiency, and reduced pollution and waste. The *Environment Act*,[25] another key piece of legislation passed in 2021, includes circular strategies across multiple dimensions: resource efficiency and waste reduction are included as one of four priority areas, for example. Through this Act, the Government has been granted comprehensive powers that can ensure the advancement of a circular UK economy.

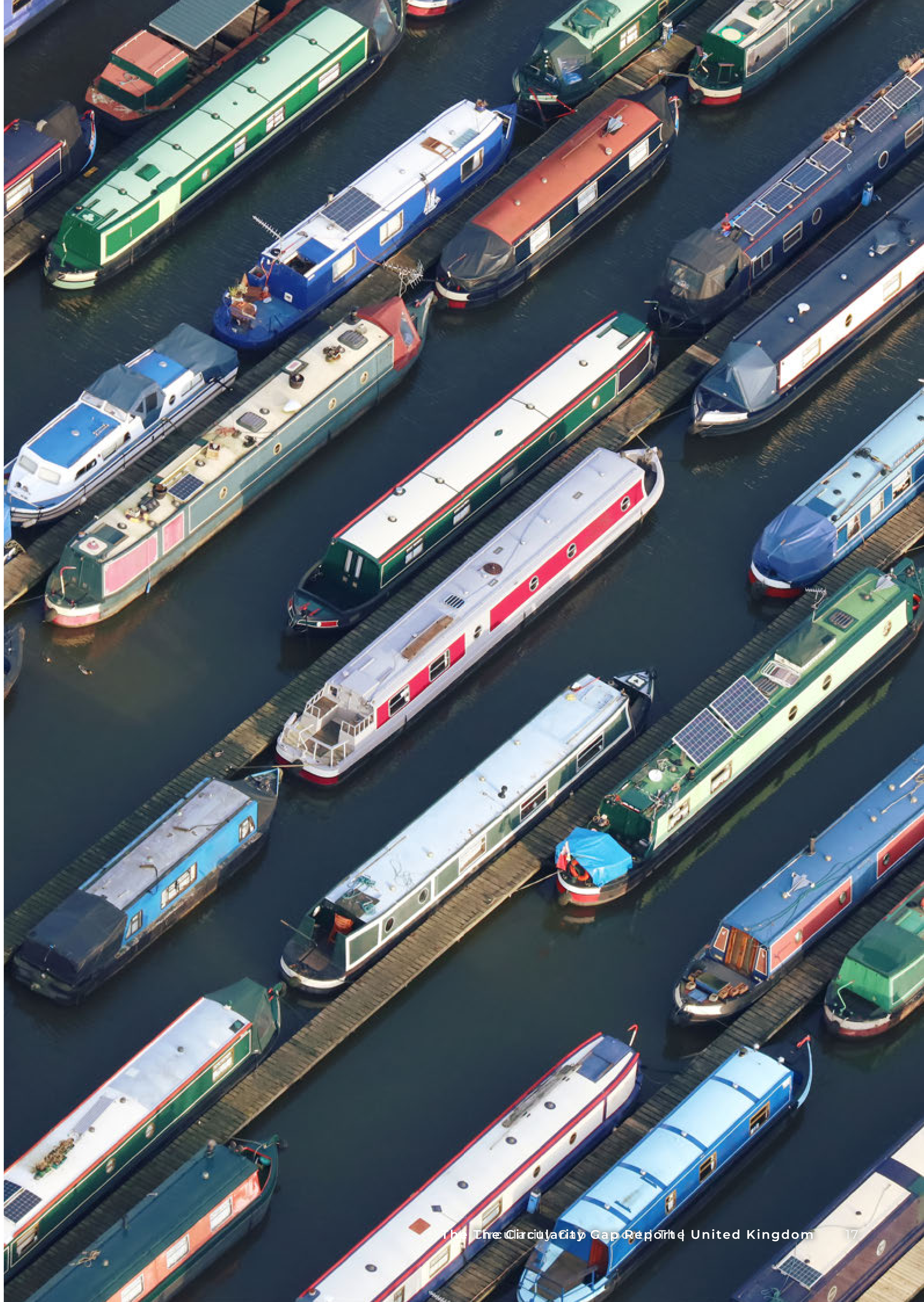
Across the UK's four constituent countries, there has been significant movement towards circular approaches.[26] For instance, Scotland has had a circular economy strategy since 2016,[27] and is working on a *Circular Economy Bill*.[28] Wales' *Beyond Recycling*[29] strategy aims to minimise waste and keep materials in use to support a circular transition, while Northern Ireland is developing its owncircular strategy.[30] Importantly, both Wales and Northern Ireland have committed to targets that aim to reduce resource use to remain within planetary boundaries. In England, the *Waste Strategy for England*,[31] *25 Year Environment Plan*[32] and the draft *Waste Prevention Programme*[33] all include interventions that aim to foster the circular economy, and outline ways to reduce pollution, tackle waste crime and encourage recycling and resource management. The UK's *Critical Minerals Strategy*[34] and *Net Zero Strategy*[35] also call for an acceleration of the circular economy, with the move towards extended producer responsibility and deposit return schemes supporting this. While the UK's circular economy policy landscape is better developed than many countries, it still needs a clear, ambitious vision for tackling material use.[36]

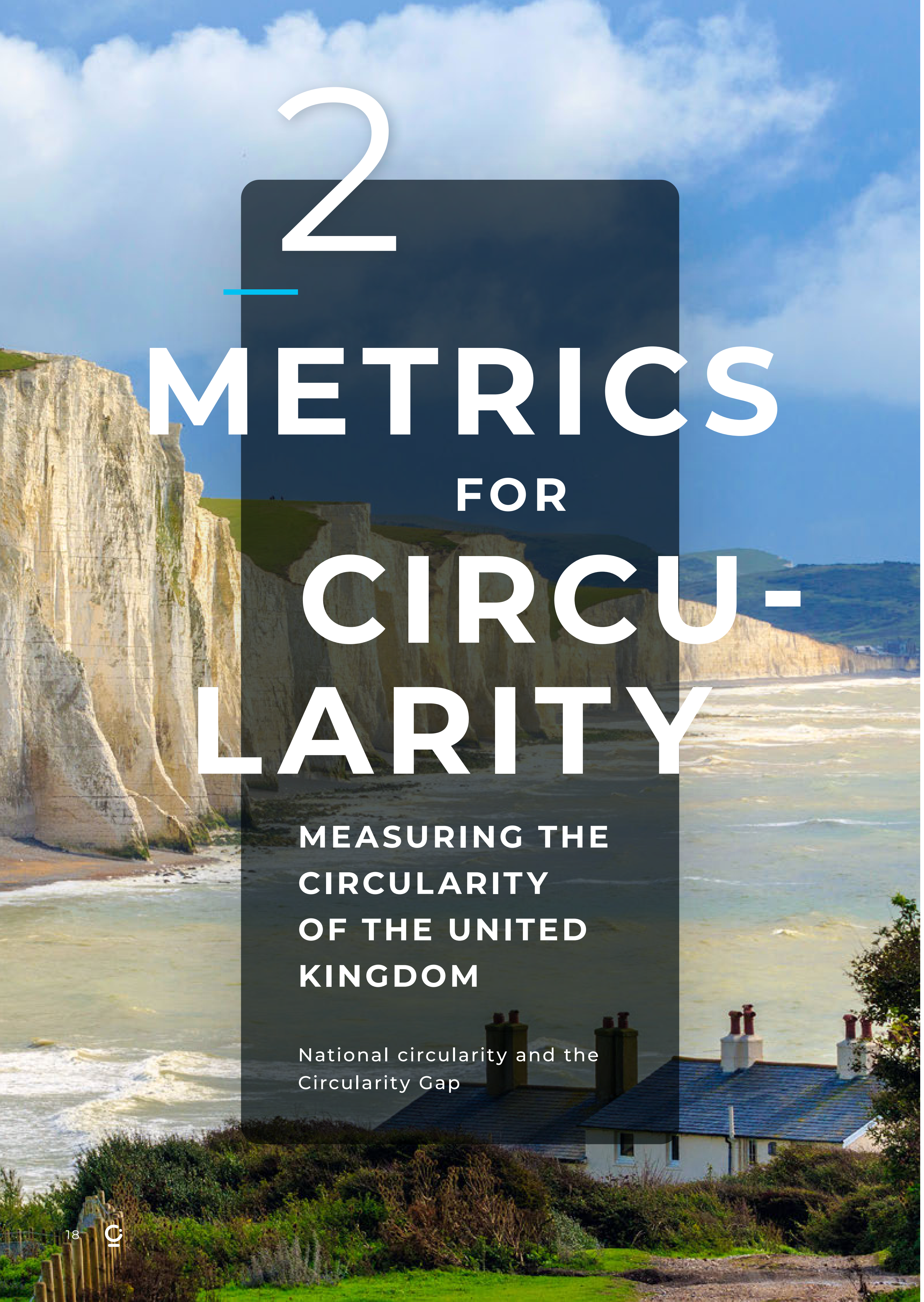
Up until now, policy has largely centred on end-of-the-pipe solutions, such as improved waste management and energy performance. Encouraging innovation and investment to enhance the design of systems and products, extending lifespans, rethinking business models, and altering production and consumption patterns to cut total material consumption and emissions must be given more attention moving forward. In the past, many circular economy policies came under the jurisdiction of the EU. Now, with the UK's exit from the EU, there is an opportunity for both the UK as a whole and the devolved administrations to design their own policies and regulatory frameworks. Businesses can also set their targets and strategies to capitalise on these policy tailwinds and the economic opportunities that the transition presents.

AN ECONOMY FULL OF POTENTIAL: CIRCULAR ECONOMY AS A MEANS TO AN END

The circular economy is a means to an end goal: an ecologically safe and socially just space. In the case of the UK, this will require optimising the transformation of materials into social value to bring the UK economy within planetary boundaries. The UK is well-positioned to achieve and benefit from this transformation. The country has a rich stakeholder ecosystem of environmental think tanks and non-profit organisations, as well as academia and private sector representatives, all working to promote the circular economy on many different levels.[37] This ecosystem can be leveraged to accelerate planning and action to position circular economy approaches as a key pillar in sector-level strategic economic and business plans. Secondly, there are many initiatives at the national and local level that serve as a solid basis from which to build upon. Thirdly, advancing the circular economy offers huge potential in terms of transforming the basis of economic activity[38] and boosting employment[39, 40]—two core political goals in the UK.

This report presents six scenarios that can help the UK significantly cut its material and carbon footprints, advance resource efficiency and substantially increase material circulation in the economy, progress towards the Sustainable Development Goals, unlock new economic opportunities, and bring the country from theory to action: the kind of systemic shift needed to realise a circular economy.





2 METRICS FOR CIRCULARITY

MEASURING THE CIRCULARITY OF THE UNITED KINGDOM

National circularity and the Circularity Gap

Measurements are critical to understanding the world around us. In the first edition of the global *Circularity Gap Report*, in 2018, Circle Economy launched the Circularity Metric for the global economy. The analysis in this report adapts the Metric to a national level and applies it to the UK. This section explains how this report has assessed the UK's circularity, introduces supporting metrics that help to quantify the material flows that contribute to the country's Circularity Gap, and highlights how these metrics can continue to change based on data availability. These insights provide an initial assessment of material flows and circular opportunities to help shape a starting point for the UK's circular journey. By measuring circularity in this way, governments—and other actors, including businesses—can track their circular performance over time and put trends into context, as well as engage in coordinated goal setting.

THE CIRCULARITY METRIC EXPLAINED

To measure circularity with one figure, we have to reduce the complexity of material flows. This analysis takes the socioeconomic metabolism of a nation—the way in which materials flow through the economy and are used over the long-term—as the starting point. This approach builds on and is inspired by the work of Haas et al. (2015)[41] and mirrors the approach applied in all other national *Circularity Gap Reports*. Taking an 'X-ray' of the economy's material use, this report considers six fundamental dynamics of what the circular economy transition aims to establish and how it can do so. This translates into two core objectives and four strategies, based on the work of Bocken et al. (2016):[42]

- **Objective one:** Resource extraction from the Earth's crust is minimised and biomass production and extraction is regenerative;
- **Objective two:** The dispersion and loss of materials is minimised, meaning all technical materials have high recovery opportunities, ideally without degradation and with optimal value retention; emissions to air and dispersion to water or land is prevented; and biomass is optimally cascaded.

The four strategies we can use to achieve these objectives are:

- **Narrow flows—Use less:** The amount of materials (including fossil fuels) used in the making of a product or in the delivery of a service are decreased. This is through circular design or increasing the usage rates of materials and products. **In practice:** Sharing and rental models that increase product utilisation whilst decreasing the number of products needed, material lightweighting (mass reduction), multifunctional products or buildings, energy efficiency, digitisation rather than physical product.
- **Slow flows—Use longer:** Material use is optimised as the functional lifetime of goods is extended. Durable design, materials and service loops that extend life, such as repair and remanufacturing, both contribute to slowing rates of extraction and use. **In practice:** Durable material use, modular design, design for disassembly, reuse, repair, remanufacturing, refurbishing, renovation and remodelling over building new structures and products.
- **Regenerate flows—Make clean:** Fossil fuels, pollutants and toxic materials are replaced with regenerative sources, thereby increasing and maintaining value in natural ecosystems. **In practice:** Regenerative and non-toxic material use, renewable energy, regenerative agriculture and aquaculture.
- **Cycle flows—Use again:** The reuse of materials or products at end-of-life is optimised, facilitating a circular flow of materials. This is enhanced with improved collection and reprocessing of materials and optimal cascading by creating value in each stage of reuse and recycling. **In practice:** Design for recyclability (both technical and biological), design for disassembly, reuse and recycling.

While each of the four strategies are important, their deployment may lead to potential overlaps or even anti-synergetic effects. For more information on how these strategies affect each other in practice, refer to Appendix B on page 94.

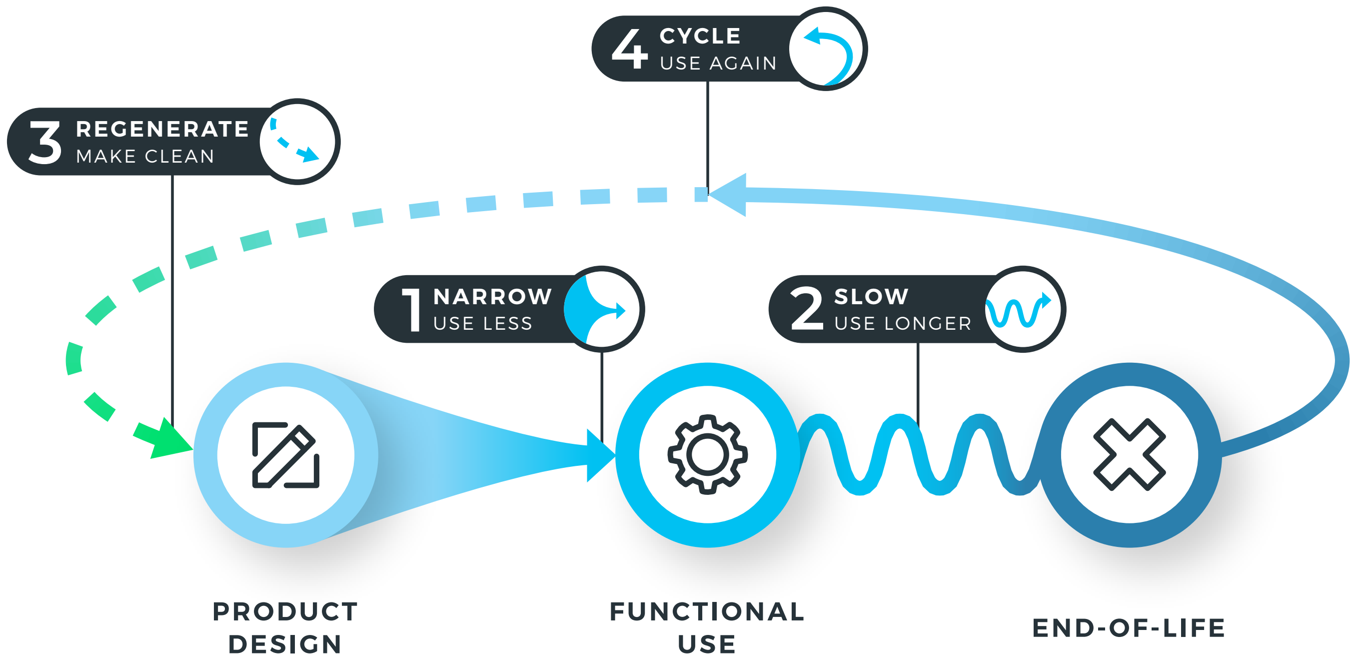


Figure one depicts the four flows to achieve circular objectives: narrow, slow, regenerate and cycle.

Ultimately, strategies to narrow, slow, regenerate and cycle material flows can lead to a lesser amount and variety of materials being used to provide for similar societal needs. In materials having longer lifespans and being reused more effectively, the total amount of materials used by the economy will drop—reducing environmental impacts as a result. For the Circularity Metric to capture this crucial process, we measure the share of materials that are cycled back into the global economy after the end of their useful life (secondary materials) as part of the total material consumption.

The Circularity Metric, an 'input-focused' metric, captures circularity in one number. Communicated as a percentage, it is a relative indicator of how well global or national economies balance sustaining material-based societal needs and wants with materials that already exist in the economy. The value of this approach is that it allows us to track changes over time, measure progress and engage in uniform goal-setting, as well as benchmark countries' circularity against each other as well as at the global level. Additionally, it provides direction as to how the UK can embrace its circular potential.

DYNAMICS INFLUENCING THE CIRCULARITY METRIC

Applying the Circularity Metric to the global economy is relatively simple, largely because there are no exchanges of materials in and outside of planet Earth. For countries, however, the dynamics of trade introduce complexities to which we must adapt our Metric, resulting in certain methodological choices.[43] These are:

1. **We take a consumption-based perspective.** This means that we only consider materials consumed domestically, and exclude exports from our accounting.
2. **We use demand-based indicators.** This allows for a re-allocation of environmental stressors from producers to final consumers, which ensures that resource depletion is allocated to countries based on their roles in driving production through their consumption. This ensures transparency for countries with high import levels and highlights the importance of reducing consumer demand.
3. **We consider imports and exports in terms of their Raw Material Equivalents (RMEs).** This allows us to more accurately interpret the true impact of finished and semi-finished products. Learn more about RMEs on page 27.
4. **We include waste imported from abroad for reuse in our calculation of the Circularity Metric.** We give 'credit' to the national economy for using secondary materials recovered from former 'waste' over virgin ones.

For a more detailed explanation of these choices, please refer to Appendix C, on pages 94–95.

INSIDE THE UK'S CIRCULARITY GAP

We account for 100% of inputs into the economy in our Circularity Metric Indicator Set, which includes Circular inputs, Linear inputs and Stock build-up. This allows us to further refine our approach to closing the Circularity Gap in a particular context and answer more detailed and interesting questions: how much biomass is the UK extracting domestically and how sustainable is it? How dependent is the UK on imports to satisfy the basic needs of the population? How much material is being added to the UK's stock, such as buildings and roads, every year? The categories that follow are based on the work of Haas et al. (2020).[44]

CIRCULAR INPUTS

Socioeconomic cycling rate (7.5%)

This refers to the share of secondary materials in the total consumption of an economy: this is the Circularity Metric. These materials are items that were formerly waste but now are cycled back into use, including recycled materials from both the technical (such as recycled cement and metals) and biological cycles (such as food, paper and timber). In the UK, secondary material use weighs in at 82.6 million tonnes—7.5% of total material use. This is slightly higher than the global average of 7.2%.[45] Metal ores and biomass represent 18% and 16% of the 82.6 million tonnes, respectively. While non-metallic minerals—almost entirely from construction and demolition waste—account for nearly two-thirds (63%). However, construction and demolition waste often become recycled aggregate for backfilling—a low-value application. A crucial objective, therefore, is to preserve materials' value and aim for higher-value practices, such as reuse.

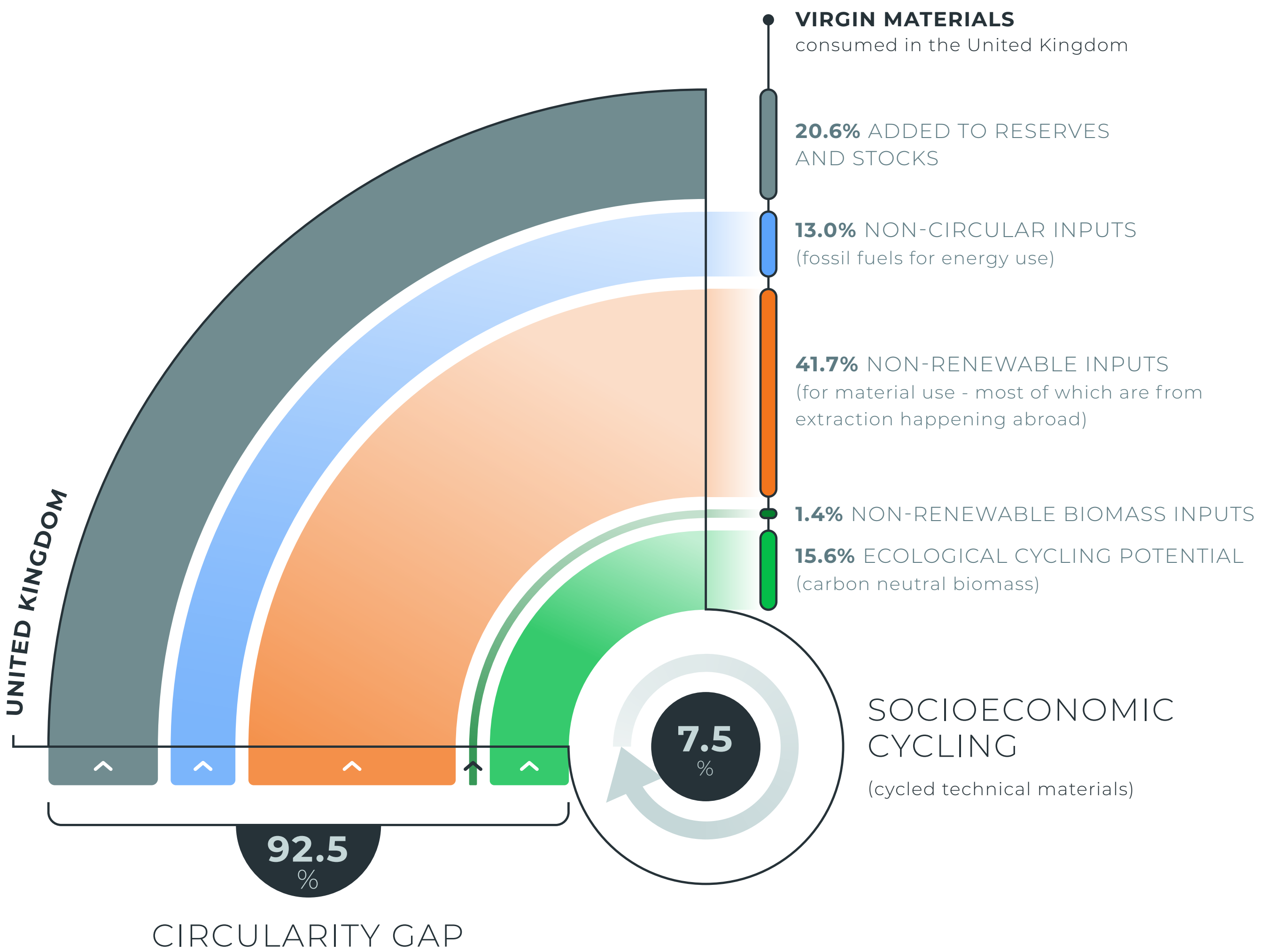


Figure two shows the full picture of circular and non-circular materials that make up the UK's Circularity Gap.

Ecological cycling potential (15.6%)

Ecological cycling concerns biomass such as trees, manure, food crops and products, or agricultural residues flowing through an economy, while biomass *products*, such as timber and wood, are considered part of the Circularity Metric. To be considered ecologically cycled, biomass should be wholly sustainable and circular: it must, *at the very least*, guarantee full nutrient cycling—allowing the ecosystem's biocapacity to remain the same—and be carbon-neutral. Because detailed data on the sustainability of primary biomass is not available, estimating Ecological cycling potential needs to rely on a broader approach: if the amount of carbon that comes from land use and land cover-change (LULCC) emissions matches the amount of carbon consumed by the economy through primary biomass, then all consumed biomass can be considered carbon-neutral.[46]

WHY DON'T WE INCLUDE ECOLOGICAL CYCLING POTENTIAL IN THE CIRCULARITY METRIC?

While carbon neutrality is a necessary condition for biomass to be considered sustainable, it is not the only condition: nutrients must be fully circular as well. As of yet, methodological limitations exist in determining nutrient cycling. To this end, in line with past *Circularity Gap Reports*, we have excluded Ecological cycling potential in our calculation of the UK's Circularity Metric, even though this could boost the country's circularity rate to just over **23%**. For all nations, we take a precautionary stance with the exclusion of nutrient cycling. This is due to the fact that the accuracy of the impact on the Metric cannot be guaranteed. For example, biomass extracted in the UK cannot be tracked to its final end-of-life stage, so it is not possible to ensure that the nutrient cycle is closed. If the nutrient cycle were to be closed—and sustainable biomass management were the norm—circularity could significantly increase.

LINEAR INPUTS

Non-renewable biomass inputs (1.4%)

This metric indicates biomass inputs that are not carbon-neutral. As long as LULCC emissions are positive, a share of biomass is certainly not carbon-neutral as not all CO_2 is being sequestered through consumption (CO_2 embedded in biomass in Domestic Material Consumption). For the UK, such biomass represents around 1.4% of the total material footprint (15 million tonnes), largely due to emissions from peatlands. Currently, UK land-use emits more GHGs than it removes. Recent changes in the inventory to account for peatland emissions mean that the Agriculture, Forestry and Other Land Use (AFOLU) sector is now estimated to be a net emitter, having previously been estimated to be a net sink under the previous methodology.[47]

Non-renewable inputs (41.7%)

Non-renewable inputs into the economy—those that are neither fossil fuels nor non-cyclable ecological materials—include the metals, plastics[48] and glass in consumer products. These are materials that potentially *can* be cycled, but are not. The UK's Non-renewable input rate stands at 41.7% (around 462 million tonnes). However, it should be noted that the majority of this stems from extraction happening abroad for materials and goods imported into the UK.[49] All net extraction abroad is allocated under Non-renewable inputs.[50]

Non-circular inputs (13%)

This category centres on fossil fuels for energy use. Fossil-based energy sources, such as petrol, diesel and natural gas, are inherently non-circular: they are burned and emitted into the atmosphere as GHGs. As they combust and disperse, circular economy strategies such as cycling are not applicable as the loop cannot be closed. However, circular strategies that narrow and regenerate flows will inherently reduce emissions. At 13% (around 144 million tonnes), the UK's rate of Non-circular inputs is significant. Broken down by fossil fuel type: coal and other solid energy materials, such as peat, account for the smallest share (6%), natural gas accounts for over a third (36%), whilst the bulk comes from crude oil and natural gas liquids (55%). Despite increasing decarbonisation efforts, the UK's economy is clearly still very fossil-fuel dependent—especially for powering transport, industry and space heating. However, there have been advancements between 1990 and 2019 in reducing the share of fossil fuels in total energy consumption (from 92% to 80%)[51] and reducing overall energy consumption (a drop of 13%), as well as in increasing the share of renewables in total energy consumption (from 1% to 13%).[52]

STOCK BUILD-UP

Net additions to stock (20.6%)

The vast majority of materials that are 'added' to the reserves of an economy are net additions to stock. Countries are continually investing in new buildings and infrastructure—to provide housing and roads, for example. This stock build-up is not inherently bad; many countries need to ensure that the local population have access to basic services, as well as build up infrastructure globally to support renewable energy generation, distribution and storage capacity. These resources do, however, remain locked away and are not available for cycling—therefore weighing down the Circularity Metric.[53] By employing circular strategies, such as lifetime extension, we would expect to see the rate of stock build-up decrease. At 20.6% of total material consumption (around 228 million tonnes), the UK's **stocking rate** is slightly lower than other countries that have had this indicator measured. In absolute terms, net stock additions per capita in the UK are 3 tonnes per person per year, compared to 2.9 in Scotland and 6.2 in Northern Ireland. In Sweden, per capita net stock additions are much higher: 10 tonnes.

NATION	SOCIOECONOMIC CYCLING	NON-RENEWABLE BIOMASS INPUTS	NON-CIRCULAR INPUTS	NON-RENEWABLE INPUTS	NON-RENEWABLE INPUTS	NET ADDITIONS TO STOCK
Sweden	3.4%	36.3%	-	7.4%	13.1%	39.8%
Northern Ireland	7.9%	22.9%	0.9%	16.6%	17.9%	33.7%
Scotland	1.3%	16.2%	1.8%	14.9%	42.5%	21.1%
Poland	10.2%	14.2%	1.4%	18.7%	20.1%	35.3%
Switzerland	6.9%	10.7%	0%	9.2%	40%	33.3%
UK	7.5%	15.6%	1.4%	13%	41.7%	20.6%

Table one provides comparisons between countries that have a Circularity Metric Indicator Set.

PRACTICAL CHALLENGES IN QUANTIFYING CIRCULARITY

Providing a baseline measurement circularity based on material flows offers many advantages, not least that it can be used as a call to action and can guide legislative action and targets. But the circular economy is full of intricacies, and capturing it in one number is difficult without making some crucial simplifications. However, these simplifications do result in limitations that must be considered.

1. **There is more to circularity than (mass-based) cycling.** As seen from the examination of the four flows, there are other important aspects to circularity: namely, using less, using longer and regenerating natural systems.
2. **The Metric focuses on one aspect of circularity.** We focus only on material use, without examining other factors such as biodiversity loss, pollution, toxicity and so on.
3. **Data quality isn't alway consistent.** Data on the end-of-life stage can vary between countries and can often be weak.
4. **We consider relative, not absolute, numbers.** This means that if cycling increases at a faster rate than material consumption, the Metric will improve—even if the ultimate goal is for consumption to decrease.
5. **Achieving 100% circularity isn't feasible.** There are technical and practical limits to cycling, and some materials will always be required for stock build-up. Some materials, like fossil fuels, are also inherently non-circular and cannot be cycled.

For more detail on each of these points, please refer to Appendix D, on pages 95–96.

For a more exhaustive look into the methodology behind the Circularity Gap, you can visit our website:

circularity-gap.world/methodology

IF CONTINUED STOCK BUILD UP IS INEVITABLE—SHOULD IT BE CONSIDERED PART OF THE 'GAP'?

Stock build up will continue to be necessary as the UK's population grows, demand for new housing increases and renewable energy infrastructure develops, for example. For these reasons, it may be argued that Net additions to stocks should not be considered part of the Circularity Gap. If all the materials locked into stock were not considered as part of the full Indicator Set, the Circularity Metric would increase substantially.

Nevertheless, the Circularity Metric is ultimately a measure of what is cycled—not just what is circular—and materials added to stock can't be cycled for potentially decades, if not more. What's more, the circularity of materials added to stocks cannot be ensured: it is not always clear which portion of these materials are designed and used with cycling in mind or to what extent they are regenerative and non-toxic, for example. The bottom line is that the built environment consumes a huge volume of materials: its impact on the UK's overall consumption should not be ignored, especially given crucial resource depletion and decarbonisation concerns. The role of circular strategies in optimising Net additions to stock for circularity —and decreasing material consumption overall—is critical.

3 SIZING THE UNITED KINGDOM'S MATERIAL FLOWS

The resource reality of meeting societal needs

The UK has high material consumption and is only 7.5% circular: there is an excess of materials flowing through its economy, and the vast majority of these come from virgin sources. This chapter dives into the country's socioeconomic metabolism, exploring how materials are used—and at which proportions—to meet various societal needs and wants. Key themes have emerged that illustrate how the country uses materials: the UK exhibits low domestic extraction, heavy extraction and greenhouse gas (GHG) emissions originating abroad and embodied in international trade flows, and a heavy negative trade balance in recyclable waste.

MEASURING THE UK'S MATERIAL FLOWS AND FOOTPRINTS

This analysis takes the socioeconomic metabolism of the UK—the way in which materials flow through the economy and are kept in long-term use—as the starting point for measuring its level of circularity. To ensure our data is in line with the reality of the United Kingdom, Deloitte LLP and Circle Economy coordinated with the Office of National Statistics using 2019 data from the UK Government and Eurostat.

Figure three provides a schematic depiction of the socioeconomic metabolism of the UK. It depicts the amounts of materials (clustered into four key material groups) embodied in the inputs and outputs of highly aggregated industry groups. Due to the level of detail and intricacy of how materials flow through an economy, not all flows in all sectors have been visualised. The left side illustrates the four dominant domestic extraction material groups in the UK: non-metallic minerals (sand, gravel and limestone, for example), metal ores (iron, aluminium and copper, for example), fossil fuels (petroleum and coal, for example) and biomass (food crops and forestry products, for example). It also shows the volume of materials entering the national economy through **imports**. These are represented in terms of Raw Material Equivalents (RMEs)—the entire amount of material extraction needed, anywhere in the world, to produce a traded product. Together, the domestic extraction and the **RME of imports** comprise the total inputs (raw material input, which does not include secondary material inputs) of a national economy.

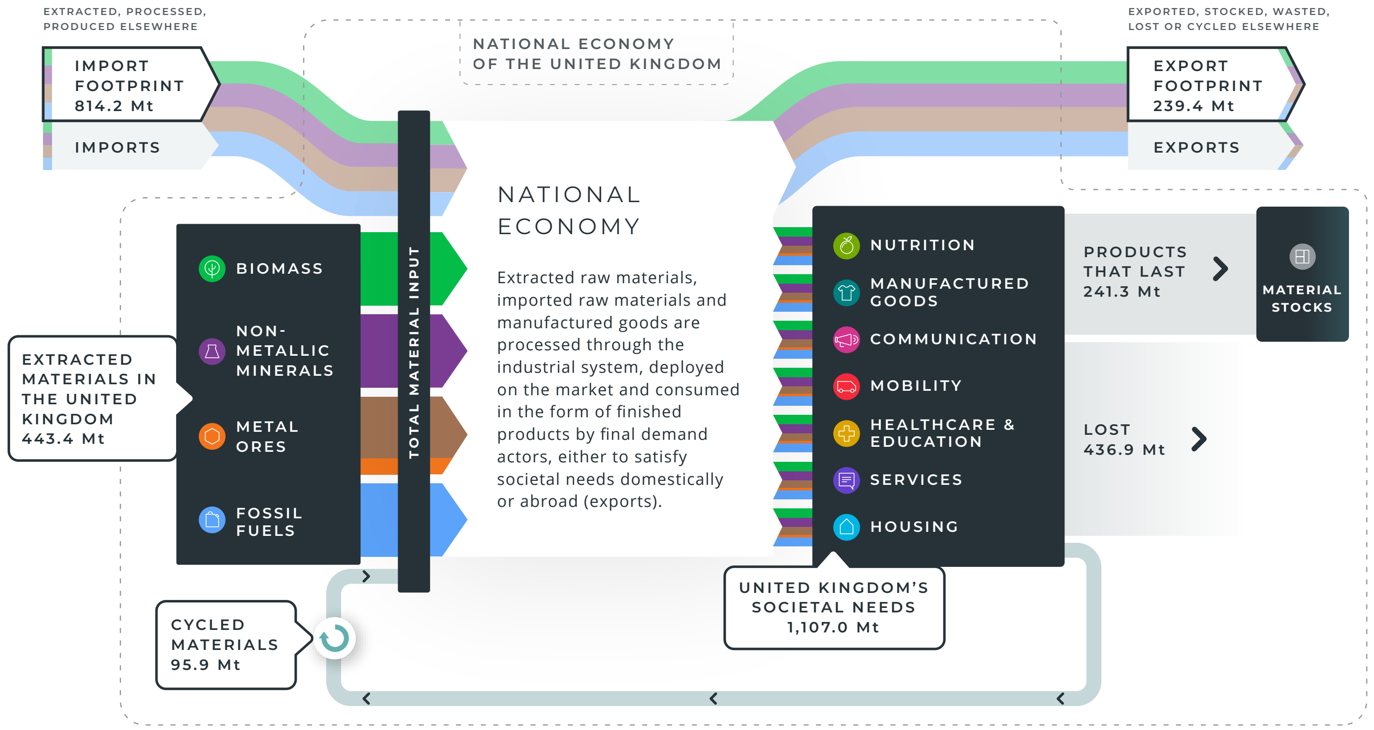


Figure three shows a schematic overview of the socioeconomic metabolism of the UK.
Note: material stock and cycled material flows are not scaled to proportion.

Once in the economy, extracted or traded raw materials—as well as traded or domestically produced components, semi-products and products—undergo operations that either transform them into end products or make them part of the production process of another end product. Beginning with ***extraction***, the resources are ***processed*** (from metals into ores, for example), which are manufactured into products in the ***produce*** stage. The finished products satisfy societal needs and wants such as Nutrition, Housing and Mobility, or they are exported. Of these materials entering the national economy every year, the majority are utilised by society as short-lived Products that Flow—reaching their end-of-use typically within a year, such as an apple, food packaging or a standard toothbrush. At end-of-use, materials from **Products that Flow** are typically either lost or cycled back into the economy. The remaining materials enter into long-term stock—referred to as **Products that Last**. These are products such as capital equipment, buildings and infrastructure.

SEVEN SOCIETAL NEEDS & WANTS

Societies require materials to operate. In fulfilling people's needs, three connected spheres need to be taken into account: 1) how materials are put to work, to 2) deliver social outcomes, via 3) provisioning systems. Provisioning systems comprise physical systems such as road infrastructure, technologies and their efficiencies,[54] and social systems, which include government institutions, businesses, communities and markets.[55] Provisioning systems are the essential link between biophysical resource use and social outcomes. For example, different forms of transportation infrastructure (railways versus motorways, or car-sharing versus car ownership) can generate similar outcomes, but at very different levels of material use: this is how the circular economy can allow us to thrive with minimal environmental impact.

On the next page, we describe the seven key societal needs and wants and which products and services they include, as well as the volume of materials it takes to fulfil them from the UK's total material consumption of just over 1.1 billion tonnes. Since various products can be allocated differently, here we make explicit choices. For example, 'radio, television and communication equipment' can be classified either as part of Communication, or as Manufactured Goods. We decided to subsume it under 'Communication'. Since previous *Circularity Gap Reports*, we have also reallocated infrastructure to various appropriate societal needs: it is no longer purely allocated under 'Housing', meaning that comparisons with past analyses are no longer accurate.

SEVEN SOCIETAL NEEDS & WANTS

NUTRITION

259 million tonnes (23% of total material consumption)

Agricultural products such as crops and livestock are used to create food and drink products. These tend to have short life cycles in our economy, being consumed quickly after production.

HOUSING

244 million tonnes (22% of total material consumption)

This includes the construction, maintenance and renovation of housing with materials such as concrete, steel and timber.

MANUFACTURED GOODS

162 million tonnes (15% of total material consumption)

Manufactured goods include appliances, clothing, cleaning agents, personal-care products and paints, and more. These generally have short to medium lifetimes in society. Textiles also consume many different kinds of resources such as cotton, synthetic materials like polyester, dye pigments and chemicals. Manufactured goods belonging to other societal needs, such as vehicles and capital equipment for healthcare, are not included in this category.

SERVICES

152 million tonnes (15% of total material consumption)

The delivery of services to society ranges from education and public services, to commercial services like banking and insurance. This typically involves the use of commercial buildings, professional equipment, office furniture, computers and other infrastructure.

MOBILITY

150 million tonnes (14% of total material consumption)

A considerable volume of materials is used for mobility. Two material types are particularly used: the materials used to build transport technologies and vehicles like cars, trains and airplanes, as well as infrastructure like roads and railways; plus, predominantly, the fossil fuels used to power them.

HEALTHCARE & EDUCATION

113 million tonnes (10% of total material consumption)

With an expanding, ageing and, on average, more prosperous population, healthcare services are increasing globally. In addition to buildings, typical products used include capital equipment such as X-ray machines, pharmaceuticals, hospital outfittings (beds), disposables and homecare equipment. Similarly, the provision of education requires buildings and teaching tools, such as computers and projectors.

COMMUNICATION

28 million tonnes (2.5% of total material consumption)

Communication is an increasingly important aspect of today's society, provided by a mix of equipment and technology ranging from personal mobiles to data centres. Increased connectivity is also an enabler of the circular economy, where digitisation can make physical products obsolete or enable far better use of existing assets, including consumables, building stock or infrastructure—smart metres and teleconferencing instead of in-person meetings, for example.

** Figures may not sum to total due to rounding.*

Key takeaways

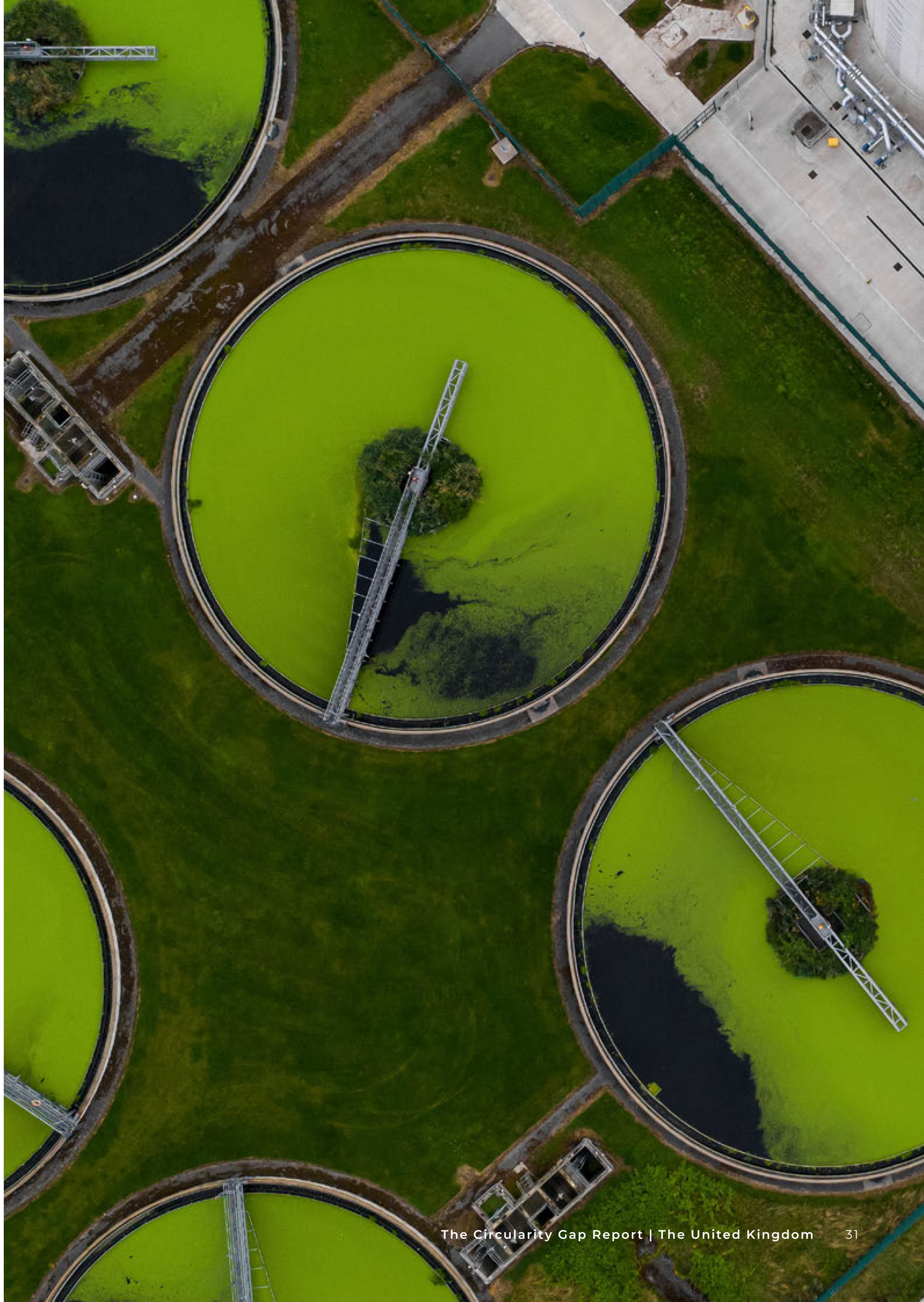
- Domestic extraction amounts to **451 million tonnes**, or 6.7 tonnes per capita per year. This is largely non-metallic minerals.
- The UK's total import footprint is **814 million tonnes**, while its export footprint is **239 million tonnes**.
- The UK's total material consumption is around **1,108 million tonnes**, comprising just over 1 billion tonnes of virgin materials and 83 million tonnes of net secondary materials.[56]
- Of all the waste treated in the UK, around **56.5% is technically recycled**, while 5% is incinerated and 24% is landfilled. The remaining 15% is treated in wastewater treatment plants or spread on land.
- The UK exports much more recyclable waste (**15.1 million tonnes**) than it imports (**1.8 million tonnes**).
- The UK exhibits low recycling rates for chemical and medical waste (0.6%) and animal and vegetal waste (3.4%), moderate rates for traditional recyclables (13%) and mixed ordinary waste (14%) and very high rates for mineral waste (**68%**). Recycling rates for other countries for which we have done this analysis are summarised in Table two.

The diagram on pages 32–33 shows how materials move through the UK economy, from extraction to processing to production to the provision of goods and services. Finally, these reach their End-of-Life. Knowing what happens to products and materials after their functional use in our economy is essential for identifying and addressing opportunities for a more circular economy. For more detailed information on how our model classifies different waste types, and how this waste is processed, refer to Appendix E on page 96.

Five different waste streams, detailed in Table two, contribute to the Circularity Metric. Of all these waste types, mineral waste, recyclables, and animal and vegetal waste are most prevalent, respectively claiming 71%, 21% and 5% of the total waste treated in the UK (by weight). Better recycling rates for chemical and medical waste, animal and vegetal wastes, mixed ordinary waste and recyclables, therefore, would be key avenues for the UK to boost its Metric.

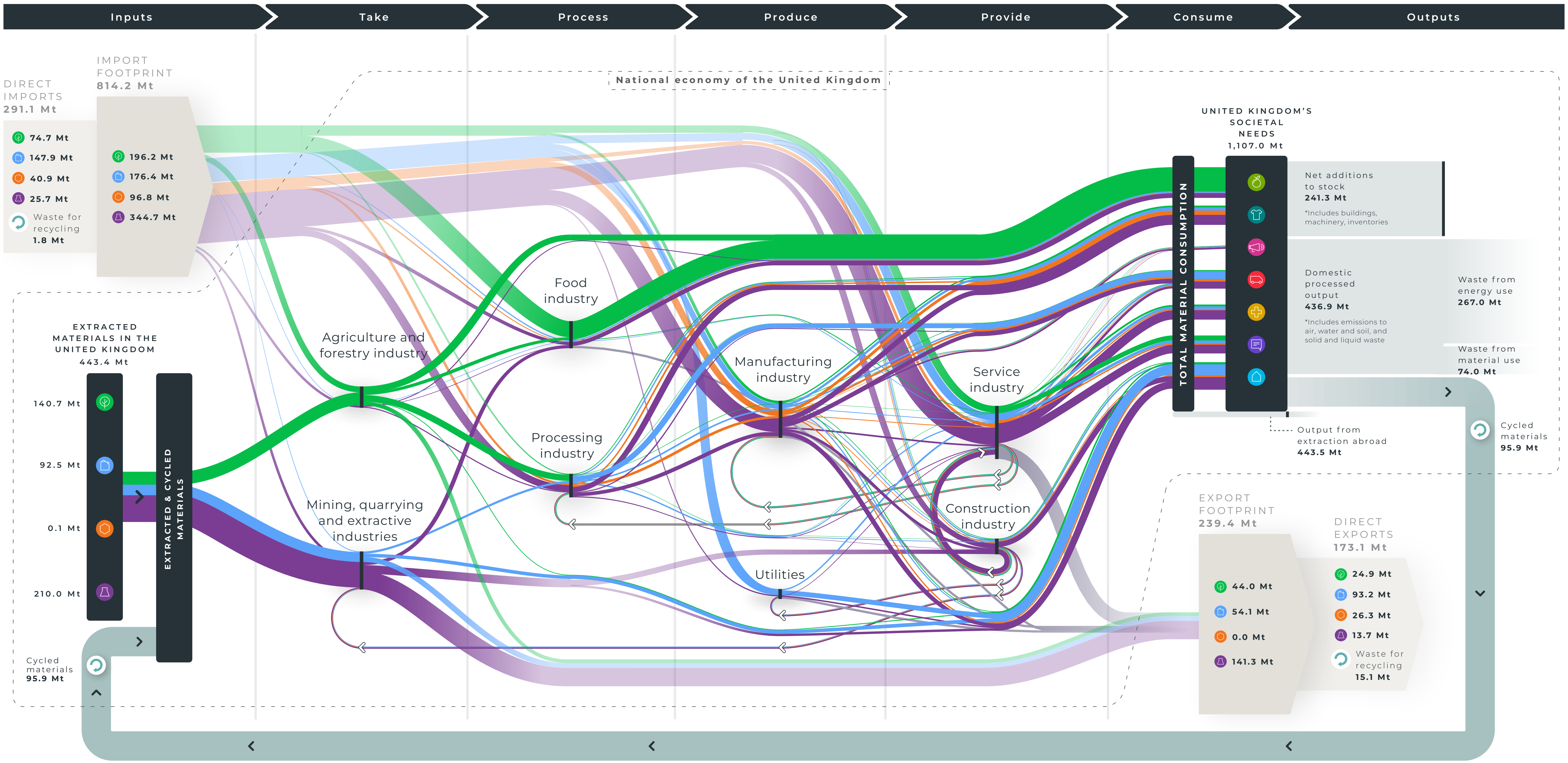
WASTE STREAM	UK	SCOTLAND	NORTHERN IRELAND	POLAND
Chemical & medical waste	0.6%	2%	50–60%	80.4%
Traditional recyclables	13%	48%	62%	93.1%
Mixed ordinary waste	14%	38.2%	13%	37.1%
Animal & vegetal waste	3.4%	100%	100%	96.2%
Mineral waste	68%	17.4%	65–73%	71.7%

Table two shows waste management rates for various countries for which we've completed this analysis.



X-RAY OF THE UNITED KINGDOM'S ECONOMY

Figure four shows an X-Ray of the UK's economy: the materials that feed into meeting key societal needs.



Mismatches between inputs and outputs at the sector level are due to a cut-off for small flows set at 0.5 Mt in order to preserve image clarity.

The grey flows represent a "virtual" reallocation of resources embodied in exports originating from take industries (e.g. mining and agriculture) that should rather be attributed to Process, Produce or Provide industries.

THE NATIONAL MATERIAL AND EMISSIONS PROFILES

The UK economy is highly import-dependent, with a material- and carbon-intensive profile. This is largely because of: 1) systemic inefficiencies in how materials are used to satisfy societal needs, and 2) highly material- and carbon-intensive international trade flows, such as imports. The lion's share of material and emissions impacts stem from five sectors: Agrifood, Construction, Manufacturing and processing, Services, and Transport and mobility. There is also a strong interlinkage between the UK's material and carbon footprints.

LOW RAW MATERIAL SELF-SUFFICIENCY

In 2019, the UK's domestic extraction totalled 443 million tonnes. This amounted to 6.6 tonnes per person, almost half the global average of 12.3 tonnes per capita, per year. However, there are significant differences between nations within the UK: domestic extraction per capita is far higher in Scotland (22.8 tonnes)[57] and Northern Ireland (14.5 tonnes).[58] Data for Wales is not yet available.

By material group, roughly half (49.5%) of total domestic extraction can be attributed to non-metallic minerals (210 million tonnes), with the remainder composed of biomass (141 million tonnes, or about 31% of the total) and fossil fuels (93 million tonnes, or 20% of the total). Domestic extraction of metal ores is negligible (about 1 million tonnes).[59] Non-metallic minerals dominate domestic extraction, given their relatively diverse and hefty deposits across the UK.[60] For example, aggregates such as crushed rock, sand, gravel and brick clay are quarried and mined UK-wide and used for construction. Meanwhile, the extraction of industrial minerals such as limestone and gypsum serve a range of industrial purposes.[61] Biomass extraction is also substantial and dominated by food products: mainly for animal feed (grazing and straw), cereal and grain crops (such as wheat and barley) and vegetable products (such as sugar beets). The UK has relatively large fossil fuel resources, too: coal, natural gas and oil. However, domestic coal production has been in structural decline for decades, despite the recent decision to approve the first new coal mine in thirty years.[62] Oil and natural gas reserves and production are declining, although they still represent a significant portion of the UK's consumption patterns.[63] These are concentrated in the North Sea: Scotland extracts over four-fifths (81%) of all fossil fuels in the UK—and nearly all of its crude oil.

Importantly, less than half of domestic extraction (47%) is used to satisfy final domestic demand: the remaining 53% is exported. By material group, the main materials exported by the UK are: 141 million tonnes of non-metallic minerals (60% of the total export footprint), 54 million tonnes of fossil fuels (23%) and 44 million tonnes biomass (18%). The key export destinations are the EU and the rest of Europe (24% of total domestic extraction), Asia and the Pacific (15%), the Americas (11%), and Africa (2%). There are far lower shares of domestic extraction used to satisfy own final demand in Scotland (20%) and Northern Ireland (34%), than for the UK as a whole (47%).[64] This may suggest that England is a densely populated 'consumption centre' within the UK, where raw materials flow from material-rich 'peripheral' areas to satisfy demand. For example, around 80% of North Sea oil is exported outside of the UK, while most of the gas produced comes to shore to be consumed domestically, particularly for heating, electricity generation and to power industry. Trade flows thus play a key role in (re)arranging and (re)structuring material flows, and shifting environmental impacts both within the UK, as well as between the UK and the rest of the world.

	UK TOTAL	UK PER CAPITA	EU AVERAGE PER CAPITA	GLOBAL AVERAGE PER CAPITA
Domestic extraction	443 million tonnes	6.6 tonnes	10.3 tonnes	12.2 tonnes
Material footprint	1,025 million tonnes	15.3 tonnes	17.8 tonnes	11.9 tonnes
Carbon footprint	749 million tonnes	10.8 tonnes	9.5 tonnes	5.5 tonnes

Table three shows a comparison of national and global figures for material extraction and consumption, as well as emissions.

LARGE MATERIAL AND CARBON FOOTPRINTS, BUT POSITIVE TRENDS

As a high-income country, the UK has large material and carbon footprints. Satisfying the UK's demand drives extensive extraction and emits GHGs not only domestically, but also abroad. Moreover, the country's material footprint is intricately linked to its carbon footprint—and both are closely linked to international trade flows.

MATERIAL FOOTPRINT

This analysis estimates the UK's total material footprint in 2019 to be approximately 1,025 million tonnes—15.3 tonnes per person. Overall, the UK is a net importer of (raw) materials: its material footprint is more than double its domestic extraction (443 million tonnes). Broken down by material group, non-metallic minerals account for the lion's share of the material footprint with 422 million tonnes (**41%** of the total), biomass contributes 292 million tonnes (**28.5%** of the total), fossil fuels 214 million tonnes (**21%**), and metal ores 97 million tonnes (**9.5%**).[65] The UK is responsible for 1.1% of the global material footprint, despite representing 0.9% of the population. It also overshoots the global consumption average of 12.2 tonnes per capita per year. And while the material footprint well-exceeds the estimated sustainable level of 8 tonnes per capita,[66] the UK fares substantially better than other high-income economies: Australia (39.0), the USA (33.9), Canada (33.5), Germany (22.1), Japan (18.3) and France (16.3), for example. Material footprints also differ among UK nations based on local consumption patterns and the structure and efficiency of the economy, with income levels and population density also playing a crucial role. There is a strong correlation between per capita GDP growth and per capita material footprint,[67] and population density has a significant impact on regions' consumption.[68] England is the most densely populated of the constituent countries and houses the majority of the UK's population: this allows materials to be used more intensively, lowering the per capita figure. Scotland, Wales and Northern Ireland have much lower population densities, and thus higher material footprints per capita: 21.7 tonnes for Scotland[69] and 16.6 tonnes for Northern Ireland,[70] for example.

Key material-intensive sectors

The top ten industries contributing the bulk of the UK's material footprint stem from four sectors: Construction, Agrifood, Manufacturing and processing, and Services.[71] Together, these account for 463 million tonnes, or 45%, of the UK's total material footprint.[72]

- Within the **Construction** sector, the building industry is the single largest contributor: it accounts for 88 million tonnes, or 8.5% of the UK's total material footprint. Non-metallic minerals account for two-thirds of the industry's material footprint due to the sheer mass of construction materials.
- **Agrifood** accounts for 110 million tonnes (10.5% of total material footprint). Key contributing industries are the Processing of food products (45 million tonnes or 4% of the UK's total material footprint), the Cultivation of vegetables, fruit, and nuts (34 million tonnes or 3%) and Cattle farming (31 million tonnes or 3%). Biomass flows (87 million tonnes or 80%) dominate the sector's footprint.
- **Services** account for 149 million tonnes or 14.5% of the UK's total material footprint. Key contributing industries include Health and social work (63 million tonnes or 6% of the UK's total material footprint), Hotels and restaurants (50 million tonnes or 5%), and Public administration and defence (36 million tonnes or 3.5%). Broken down by material group, non-metallic minerals (76 million tonnes) and fossil fuels (25 million tonnes) respectively contribute 51% and 17% of the sector's material footprint.
- **Manufacturing and processing** accounts for 116 million tonnes or 11.2% of the UK's total material footprint. The top three industries here are Petroleum refinery (50 million tonnes or 5% of the UK's total material footprint), Manufacture of motor vehicles, trailer and semi-trailers (34 million tonnes or 3%), and Chemicals (32 million tonnes or 3%). Once again, the breakdown by material group reveals the heavy contribution of fossil fuels (53 million tonnes) and non-metallic minerals (43 million tonnes) to the sector's material footprint: 46% and 37%, respectively.

How other global regions contribute to the UK's material footprint

Approximately 80% of the UK's material footprint comes from materials extracted overseas. This analysis finds Asia & Pacific (led by China and India), the EU, and the Americas (dominated by the USA) to be the main contributors. Trends also show an increased reliance on imports of raw materials across supply chains to satisfy UK demand. See Table four for more information.

Evolution and trends revealed by the national material footprint

Firstly, the UK is increasingly a net importer of (raw) materials: while in 1990 domestic extraction accounted for just under half (47%) of the material footprint,[73] by 2019 this had fallen to around one-fifth (20%). This means that the UK is becoming increasingly dependent on international trade flows to satisfy demand—indicating further offshoring of environmental impacts. Secondly, there have been significant changes to the material footprint's makeup by material group: positively, fossil fuel use fell by around two-thirds (-67%) from its peak in 1999, while the consumption of non-metallic minerals has become the most prominent material, remaining largely stable as a percentage (50%) from 2000 onwards.[74] Thirdly, while estimates vary, the UK's material footprint probably peaked in 2004 at about 1,450 million tonnes—around 30% higher than the 2019 figure. The current figure, however, still tops that of 1990. This, interestingly, indicates that material demand did not fully recover from the 2008 financial crisis, while technological improvements have also reduced the material intensity of domestic production and supply chains that end in the UK.

How the material footprint links to economic output

In decoupling material consumption from economic performance, two methods can be distinguished. *Relative decoupling* is when GDP grows at a faster pace than growth in material use, while *absolute decoupling* would mean achieving GDP growth while decreasing material use. While both cases entail an increase in the efficiency of material use, only absolute decoupling lowers environmental pressures. Notably, the UK has already achieved absolute decoupling: while GDP per capita grew by 47% between 1990 and 2019, raw material consumption declined by 4% over the same period.[75] However, it's important to note that the reduction in the material footprint is modest compared to the growth in GDP—and because the material footprint tends to fluctuate, the country may shift back to relative decoupling. On the global level, there is still a strong coupling between GDP growth and raw material consumption. And ultimately, no evidence currently suggests that environmental pressures have been reduced at the scale needed to bring the global economy within planetary boundaries.[76, 77, 78]

	ASIA & PACIFIC	EU & REST OF EUROPE	THE AMERICAS	AFRICA
Contribution to material footprint (tonnes)	417 million tonnes	199 million tonnes	140 million tonnes	12.2 tonnes
Contribution to material footprint (%)	40%	19%	14%	6%
Largest contribution by material group (%)	1. Non-metallic minerals (55%) 2. Fossil fuels (21%)	1. Non-metallic minerals (41%) 2. Biomass (34%) 3. Fossil fuels (22%)	1. Metal ores (30%) 2. Biomass (29%) 3. Fossil fuels (25%)	1. Biomass (43%) 2. Non-metallic minerals

Table four shows how global regions contribute to the UK's material footprint.

CARBON FOOTPRINT

This analysis calculates that, at **749 million tonnes of CO_2e**, the UK's carbon footprint is double its territorial emissions (375 million tonnes of CO_2e).[79] This means that approximately half of the UK's carbon footprint is 'externalised': emissions are produced abroad and embodied in the products imported into the country, a phenomenon also known as 'carbon leakage'.[80]

In the UK, the share of GHG emissions embedded in trade, as a percentage of domestic production, has risen sharply—at a rate among the highest in the world.[81] While the country houses 0.9% of the world's population, its carbon footprint claims 2.1% of the (anthropogenic) total: on a per capita basis, this amounts to 10.8 tonnes of CO_2e per person, per year. But carbon footprint inequality in the UK is extreme: the top 1% of earners have emitted the same amount of GHG emissions in a single year as the bottom 10% over more than two decades.[82] Breaking down the carbon footprint: four-fifths (**635 million tonnes CO_2e**) correspond to industrial activities, whilst one-fifth (**114 million tonnes CO_2e**) are directly attributable to UK households, through activities such as household heating and private transport.

Key carbon-intensive sectors

As for the material footprint, a few key industries concentrate the bulk of the UK's consumption-based carbon footprint.[83] The top five sectors are: Transport, Construction, Services, Energy and Agrifood.[84] Together, these account for approximately 281 million tonnes of CO_2e (roughly 38% of the UK's total carbon footprint).

- **Transport,** accounting for around 67 million tonnes of CO_2e (8.9% of the total UK carbon footprint), is a major source of GHG emissions in the UK. Air transport, which generates 45 million tonnes of CO_2e (6.0%) of the total UK carbon footprint, is the single largest contributing industry.[85] Sea and coastal water transport accounts for 22 million tonnes of CO_2e (2.9% of the total carbon footprint).
- The **Construction** sector is highly carbon-intensive. The Building industry is the second largest single industry, contributing almost 40 million tonnes of CO_2e (5.3%).
- A combination of three **Service** industries account for 89 million tonnes of CO_2e (11.8% of the total UK carbon footprint). Health and social work represent around 37 million tonnes of CO_2e (4.9%), Public administration and defence almost 29 million tonnes of CO_2e (3.8%), and Hotels and restaurants around 23 million tonnes of CO_2e (3.1%). It is important to note that the main source of emissions from these industries is the use of fossil fuels, particularly natural gas, for heating (public) buildings.
- Just two industries from the **Energy** sector account for approximately 45 million tonnes (6.1% of the total UK carbon footprint). Despite coal's contribution to electricity generation being at a historic low, electricity generation by coal does still account for almost 18 million tonnes of CO_2e (2.4%). Petroleum refinery accounts for around 27 million tonnes of CO_2e (3.7%).
- Finally, two industries from the **Agrifood** sector account for almost 40 million tonnes of CO_2e (5.3% of the total UK carbon footprint). Processing of food products contributes 19 million tonnes of CO_2e (2.5%), while Landfill of food waste contributes 21 million tonnes of CO_2e (2.8%). Food waste landfilling is the largest contributor to total emissions from landfilling.

Crucially, although ranking in a slightly different order and despite a few outliers, the large sectoral overlaps shows the strong correlation between the material and carbon footprints: a low-carbon and resource-light economy are not only complementary, but mutually reinforcing.

How other global regions contribute to the UK's carbon footprint

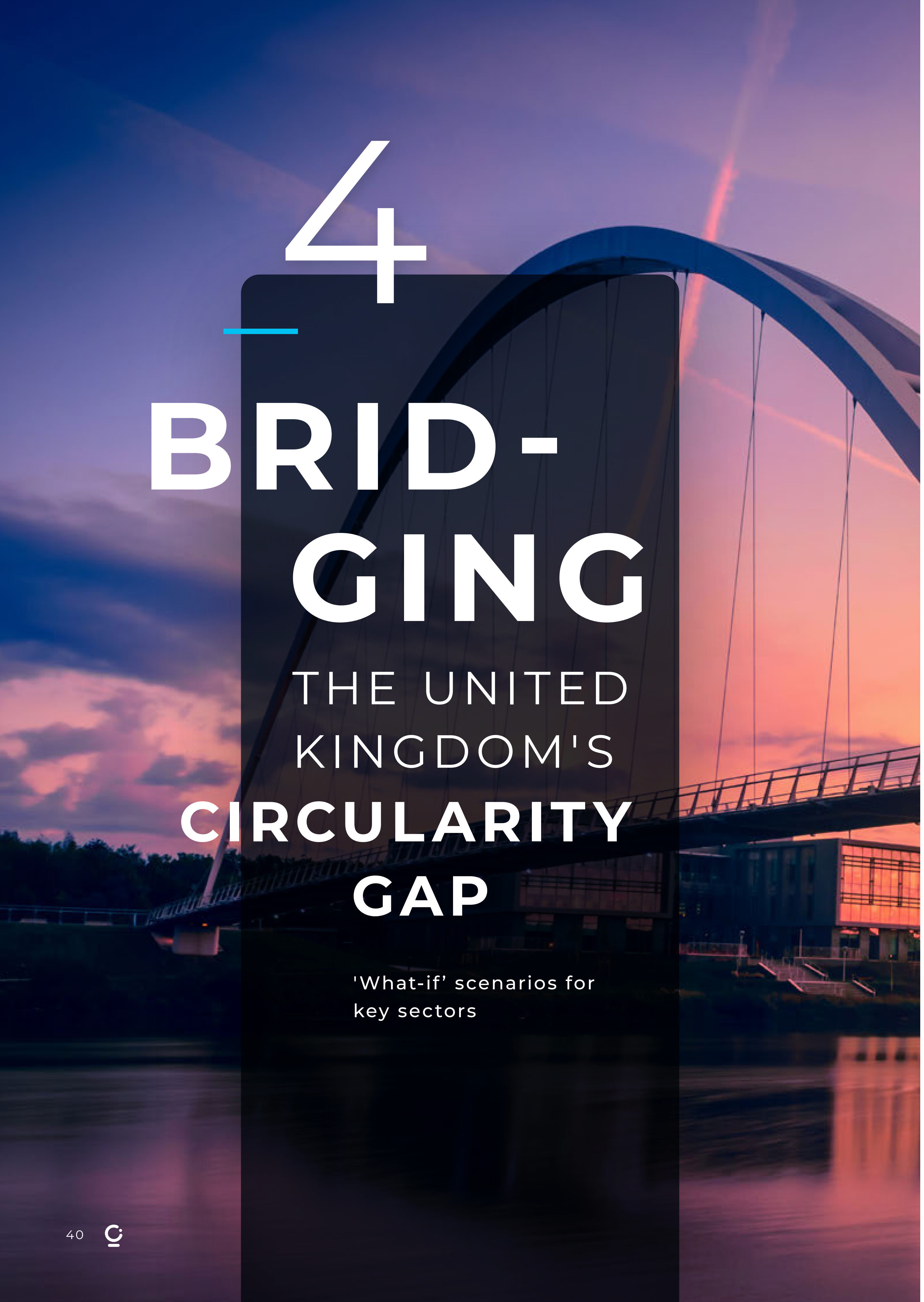
GHG emissions embedded in imports—from extraction and processing abroad—account for **345 million tonnes of CO_2e**, almost half of the total consumption-based footprint. The main regions of origin are Asia & Pacific (mainly China and India) with 167 million tonnes of CO_2e (22% of the total UK carbon footprint), the EU and the rest of Europe with approximately 117 million tonnes of CO_2e (16%), the Americas (mainly the US) with 37 million tonnes of CO_2e (45%), and Africa with 22 million tonnes of CO_2e (3%).

Evolution and trends revealed by the UK's carbon footprint

Firstly, the current difference between territorial and consumption-based emissions is a huge departure from 50 years ago: on average, between 1970 and 1986, consumption-based emissions were only 0.2% higher than territorial emissions.[86] The UK economy has become less carbon-intensive: while the UK's territorial emissions likely peaked in the early 1970s, its carbon footprint probably peaked in 2004, at around 1 billion tonnes CO_2e.[87] As of 2019, the carbon footprint dropped by 30% compared to its peak. It is important to highlight that this positive shift has occurred despite—not because of—outsourcing and deindustrialisation. The wider gap between territorial and consumption-based GHG emissions is due to structural economic changes that occurred after the late 1980s: shifting from material- and energy-intensive manufacturing sectors to a more service-oriented, comparatively less-carbon intensive economy, alongside technological developments, improvements in energy efficiency and stricter environmental policy.[88] Via international trade, the UK is increasingly responsible for generating GHG emissions abroad: while territorial emissions have decreased, as has the carbon footprint of the UK economy as a whole, GHG emissions embedded in imports have grown significantly as a share of the total.[89] Also importantly, the total amount of GHG emissions generated directly by UK households through heating and transport have largely remained unchanged since 1990, while air transport shows the highest increases.[90]

How the carbon footprint links to economic output

Similar to the material footprint, there are two ways to decouple the carbon footprint from economic performance: *relative* and *absolute*. The UK is one of the few countries in the world to have achieved *absolute decoupling* of economic growth from its carbon footprint, as with its material footprint.[91] While GDP per capita grew by 47% between 1990 and 2019, the UK's carbon footprint declined by 14% during the same period. However, while territorial emissions have dropped by 44% since 1990, changes to the UK's energy mix have dominated this decline. Reductions now need to be extended to the rest of the economy if long-term net-zero commitments—as well as other environmental objectives such as resource efficiency—are to be met in time.[92] Given the tight coupling between GDP growth and carbon emissions prevalent worldwide, the UK has made encouraging progress—but this has not happened at the pace necessary to relieve environmental pressures.[93]



4 BRIDGING THE UNITED KINGDOM'S CIRCULARITY GAP

'What-if' scenarios for key sectors

After presenting the UK's Circularity Metric and Indicator Set, deep diving into the country's material footprint and investigating the key themes of the economy, it's possible to explore pathways for change. In this chapter, our analysis crafts six scenarios across key sectors to explore the 'what-if', ultimately sketching a future of a more circular UK that's both resource-light and low-carbon. They serve as an exploration of a potential path forward but also outline which sectors and interventions could be the most impactful in terms of steering the material and carbon footprints, as well as the Circularity Metric.

BRIDGING THE CIRCULARITY GAP: 'WHAT IF' SCENARIOS

In the *Circularity Gap Reports*, scenarios are largely free from the constraints of law or political realities. They are deliberately non-time-specific and exploratory. This approach allows us to freely imagine what society could look like with truly transformational change: a close to fully circular economy. The action plan laid out below indicates which interventions—in which sectors—are most impactful for three key indicators: the material footprint, the carbon footprint and the Circularity Metric. Additional environmental and social co-benefits are also explored. The scenarios are informed by and developed based on the ultimate aims of slowing, narrowing, cycling and regenerating material flows, as described on page 19.

The scenarios span six key areas and sectors that represent key leverage points for the UK's economy, using 2019 as the baseline year for the analysis. These scenarios are 1) Build a circular built environment, 2) Shift to a circular food system, 3) Advance circular manufacturing, 4) Rethink transport and mobility, 5) Welcome a circular lifestyle, and 6) Tackle the UK's import footprint. The scenarios explore changes in the links between 1) the economic and financial dimension (monetary flows, financial transactions and capital accumulation), 2) the material and biophysical dimension (aggregate material throughput, infrastructure and stock expansion), and 3) the sociocultural dimension (desires, efficiency and productivity).

Measuring the effects of the suggested interventions in terms of their effect on the Circularity Metric and material and carbon footprints is a simplification that sometimes ignores other relevant aspects of the equation, such as additional ecological parameters. However, this analysis still provides value by contributing to the dynamic debate on where the UK can place its bets for enhanced circularity and reduced material consumption and waste.

SCENARIOS	MATERIAL FOOTPRINT	CARBON FOOTPRINT	IMPROVED CIRCULARITY METRIC
1. Build a circular built environment	- 10.1%	- 19.2%	9.3%
2. Shift to a circular food system	- 8 %	-6.4%	8.7%
3. Advance circular manufacturing	- 5.1%	- 3.3%	8.7%
4. Rethink transport & mobility	- 7%	-8.4%	8%
5. Welcome a circular lifestyle	- 13.2%	- 11.5%	8%
6. Tackle the UK's import footprint	- 8.3 %	- 3.3 %	8.1%
Combined impact	- 40%	-43%	Increases to 14.1%

Table five shows a summary of results for each scenario. For a more detailed version of this table, please refer to Table six on pages 64–67.

1. BUILD A CIRCULAR BUILT ENVIRONMENT

The impact of the built environment is enormous: construction and operation activities account for approximately a third of material consumption, carbon emissions and solid waste generation worldwide.[94, 95] In the UK, the expansion of the built environment—which for this analysis includes residential and commercial buildings and excludes infrastructure—claimed around one-fifth (20.6%) of total material consumption in 2019. At the same time, construction is a crucial economic sector for the UK economy: it accounts for 6% of the country's economic output, with a GVA of £125 billion.[96] The 343,000 registered construction businesses employed 2.4 million people (7% of all the jobs in the UK),[97] distributed evenly across the UK.[98, 99] Circular economy strategies provide an opportunity to cut material use and emissions in the sector while creating new business and employment opportunities. The way stocks are designed and built is fundamental to determining the size and nature of future material flows.[100] Buildings and infrastructure act as huge banks of often-reusable materials. If buildings are designed to maximise energy efficiency, material flows used for heating and cooling will be narrowed. Material choice is also a critical factor in reducing buildings' embodied carbon and material intensity.[101] Revamping the entire construction ecosystem, from material choices to building practices, as well as shifting to more sustainable and inclusive urban planning will be crucial for realising a more circular—low-carbon and resource-light—UK.

To this end, this scenario comprises three interventions that explore how the UK can optimise its building stock expansion, create a low-carbon, energy-efficient building stock, and scale resource-efficient building processes.

INTERVENTIONS		MATERIAL FOOTPRINT	CARBON FOOTPRINT	CIRCULARITY METRIC
1.1	**Optimise building stock expansion**	- 5.6%, down to 967 million tonnes	- 7.7%, down to 691 million tonnes of CO_2e	+ 1.4 p.p. to 8.9%
1.2	**Create a low-carbon, energy-efficient building stock**	- 4.9%, down to 974 million tonnes	- 12.1%, down to 658.5 million tonnes of CO_2e	+ 0.4 p.p. to 7.9%
1.3	**Shift to resource-efficient building practices**	- 1.1%, down to 1,017 million tonnes	- 2.1%, down to 734 million tonnes of CO_2e	+ 0.05 p.p. to 7.55%
	Combined impact	**- 10.1%, down to 921 million tonnes**	**-1 9.2%, down to 605 million tonnes**	**+ 1.8 p.p. to 9.3%**

Building a circular built environment could bring many **co-benefits** beyond the environmental: retrofitting, for example, can serve to increase energy efficiency and cut energy consumption,[102] which in turn can increase resilience by reducing dependence on foreign materials, cut costs for households and hedge against price volatility. Additionally, if designed strategically, retrofitted housing can help tackle multiple issues—from health inequalities to affordability—improving standards in homes, cutting costs and improving wellbeing.[103] For example, lower energy and heating bills can help lift people out of fuel poverty, while improved ventilation and solutions for draughts and dampness can address health concerns. Employing circular strategies for the built environment—such as off-site construction, the use of new materials and better material management, and renovation and retrofitting—can also spur job creation and create new business opportunities.[104, 105] One study, for example, projected that favouring housing renovation and repair work by reducing the VAT rate from 20% to 5% could create upwards of 95,000 jobs in the UK, both in construction industries and across the wider economy.[106] Another found that upgrading all of the UK's homes to meet EPC 'C' standards for energy efficiency over the next several years could sustain as many as 500,000 retrofit-related jobs.[107]

1.1 OPTIMISE BUILDING STOCK EXPANSION

Our first intervention targets the UK construction sector's material use through strategies that **narrow** material flows and **cycle** materials. Optimising new builds and increasing the reuse of building materials (steel, concrete and timber, for example) and components (doors and window frames, for example) will reduce the demand for virgin material inputs. At the same time, this intervention presents a range of strategies to increase building occupancy, which will cut the total number of new buildings needed—ultimately **narrowing** material flows. Additionally, as empty properties tend to deteriorate more quickly due to insufficient maintenance, boosting occupancy can also make buildings last longer, thereby **slowing** material flows.

The country's societal need for Housing consumes 244 million tonnes, or around 24% of total material consumption, for construction and maintenance practices. The number of households in every country in the UK is increasing[108]—partly explained by the fact that the share of people living alone has increased by 8.3% in a decade.[109] An expected 6.6 million homes will be added to the existing housing stock of approximately 29 million homes by 2050. At the same time, soaring housing prices have made it hard for people to find and access affordable housing,[110] pushing the country into a housing crisis.[111] Planning is also crucial for realising more sustainable, inclusive and affordable (new) homes, places and neighbourhoods, but its potential is yet to be exhausted.[112]

Since 2000, the UK has built an average of around 178,000 new homes per year.[113] At the same time, more than 50,000 buildings are demolished each year,[114] although demolitions are decreasing and change-of-use of existing buildings is increasing.[115] While the Government's efforts have (so far) mostly focused on expanding home building to ease prices and meet housing demand,[116] more can be done to fully optimise the UK's existing housing stock.[117] For instance, the overall rate of under-occupation in England in 2019–20 was 38%, with around 9.1 million households living in under-occupied homes: those with two or more spare bedrooms.[118] Covid-19 also saw a decreased demand for office and commercial spaces.[119] These spaces could be used more optimally—especially because continuous expansion of the housing supply comes with negative environmental consequences and does not necessarily improve affordability.[120, 121, 122] For example, while urban areas cover just 7% of UK land, their coverage has increased 30% by area between 1990 and 2019,[123] driven by urban sprawl and resulting in the loss of green belts.[124]

1.2 CREATE A LOW-CARBON, ENERGY-EFFICIENT BUILDING STOCK

This intervention comprises two strategies: deep retrofitting practices and the large-scale deployment of low-carbon energy management and heating technologies, such as heat pumps and smart metres. These will serve to **narrow** material flows, particularly fossil fuels. Retrofitting activities should use secondary and non-toxic materials to the greatest extent possible, **cycling** and **regenerating** flows. Material choice is important, as carbon embodied in certain materials may generate knock-on effects, counteracting benefits from improved energy efficiency.

Buildings don't only drive high material consumption in the construction phase: the use phase also exhibits substantial material use, especially of fossil fuels. They are thus also major carbon emitters. In the UK, buildings contribute almost one-third (30%) of territorial emissions. Of this, emissions from heating are responsible for the largest portion at 23%—comparable to the emissions from all private road transport vehicles.[125] The UK's housing stock is one of the oldest in the world and thus is among the least energy efficient in Europe.[126,127] Though figures vary from year-to-year, home heating was responsible for around 30% of total energy consumption[128] and 17% of total UK territorial GHG emissions in 2019,[129] largely because around 85% of UK homes use gas-fired boilers for heating.[130] Furthermore, 85% of the UK's energy-inefficient housing stock is expected to be standing in 2050.[131] Retrofitting is thus a key circular strategy to reduce the energy demand of existing buildings.

But retrofitting is a customised—rather than standardised—process and, therefore, can be slow, cumbersome and costly. Despite some energy efficiency improvements over the last decades, progress has flat-lined since 2013 when the Government cut support for insulation.[132] Similarly, scrapping the *Zero Carbon Homes Plan* in 2015[133] has meant that the 1 million homes built since then will have to be retrofitted to meet net-zero commitments.[134] However, this is already improving with the recent consultation on the *Future Homes Standard* and *Future Buildings Standard*,[135] which provide a pathway for highly efficient homes and buildings in the coming years. Nonetheless, poor thermal insulation and energy performance are posing social difficulties: inflated energy bills and adverse impacts on wellbeing took hold during pandemic lockdowns, for example.[136] Now, the ripple effects of the war in Ukraine have created a perfect storm: high dependence on fossil fuels, low uptake of insulation, and sharp increases in energy prices (which are international and volatile in nature) have driven up energy bills, pushing up to half of UK households into fuel poverty.[137, 138]

Achieving net-zero will require a nearly complete decarbonisation of the UK housing stock by 2050.[139] This colossal task will need strong policy drivers and the right financial regulatory solutions and incentives[140, 141] as well as the build-up of the construction sector's capability and capacity to deliver the scale of retrofits needed, particularly in terms of recruitment and skills development.[142] To this end, and as part of the *Heat and Buildings Strategy*,[143] the Government plans to roll out a combination of energy efficiency measures (such as large scale retrofitting), technologies (such as smart meters), and low-carbon heating solutions (such as electric heat pumps), for example.[144, 145] Additionally, all new homes built after 2025 will require low-carbon heating systems and gas boilers will be phased out (although there is no clear date yet for this).[146] Investments in insulation, renewables and cleaner heating technologies, such as solar powered heat pumps, are also being financially incentivised.[147, 148] However, the scrapping of the *Green Homes Grant*—a voucher scheme to subsidise energy upgrades to homes in England—jeopardises the Government's aim to increase heat pump installations to 600,000 per year until 2028.[149, 150] Although decarbonising UK public buildings is costly and challenging,[151] it will be essential to achieve climate ambitions[152, 153]—and can provide a wealth of other benefits, from boosting buildings' value to cutting maintenance and operational costs.

1.3 SHIFT TO RESOURCE-EFFICIENT BUILDING PRACTICES

This intervention focuses on scaling material-efficient construction practices—thereby cutting material input and waste—in an effort to **narrow** flows.

Construction is the most wasteful sector (by mass) in the UK: around 138 million tonnes of materials were wasted in 2018.[154] While most construction and demolition waste is recovered—particularly for heavy waste streams such as concrete and bricks—it is largely downcycled to produce aggregate, for example, losing value and complexity. Strategies that preserve value—such as waste prevention and reuse—must be prioritised. Waste is generated at all stages of the construction process—from the extraction of materials to manufacturing to the building phase—not only at the end-of-life. For example, traditional building practices result in up to 20% of materials procured ending up as on-site waste. In the UK this is estimated at between 7 and 12 million tonnes a year.[155]

The circular economy can prevent construction materials, products and components from becoming waste in the first place, for example through circular design (i.e. deconstruction and disassembly), reduction of surplus materials (for example, via optimised procurement), and resource-efficient construction practices (i.e. off-site construction).[156, 157] Modern methods of construction (MMC), such as modular construction practices, reduce waste through off-site manufacturing and incorporate circular design that enables reuse, for example. Combining modular design with sustainably-sourced timber[158] amplifies this potential. Prefabricated in a factory and then efficiently assembled on site, timber construction is price competitive and is more time-efficient than traditional building practices. These circular and sustainable approaches are increasingly taking hold in the UK, with an extensive business ecosystem developing.[159, 160]

Policy support is key to incentivising a large-scale shift to more sustainable construction practices. For example, the IEA estimates that updating building codes coupled with education and training for key actors—such as architects, engineers and contractors—could reduce demand for both cement and steel by up to a quarter.[161] In terms of improving building practices, the Government's policy has focused on supporting the use of innovative and secondary materials for the production of construction materials (such as glass, ceramics and secondary steel) as well as the advancement of new building techniques and the uptake of latest technologies for construction that reduce waste and GHG emissions.[162]

PARTNERSHIPS TO DISRUPT UK CONSTRUCTION AND HOUSING

- The **Circular Building Toolkit** is a set of guidelines and resources developed by Arup and the Ellen MacArthur Foundation, which aims to help professionals design buildings that have a smaller environmental footprint and mainstream a circular built environment.[163]
- The **Construction Innovation Hub** is a research organisation and partnership platform of over 600 organisations from industry, academia and government.[164] It carries out a range of activities related to circularity, including research and development for new building materials and methods that have a lower environmental impact.
- **Ilke Homes** and **Octopus Energy** have announced they have teamed up to offer sustainable housing and energy solutions to UK households. Their **modular buildings and renewable energy scheme**, which adds solar panels, battery storage and air source heat pumps to modular homes with no bills for householders, aims to provide residents with low-cost, zero-carbon homes that are powered by 100% renewable energy.[165]

2. NURTURE A CIRCULAR FOOD SYSTEM

The global food system is the largest driver of environmental damage worldwide.[166] It barrels past several planetary boundaries,[167] from climate change to biodiversity loss,[168] contributing one-third of total GHG emissions[169] and taking hold of nearly 40% of total landmass to grow crops, graze livestock and produce animal feed.[170] The UK is no exception. The expansion and intensification of more industrialised land-management for agriculture makes farming the main driver of land use change and natural biodiversity loss in the UK (farming claims about 70% of all national landmass[171]). According to an Environment Agency report, the UK is one of the 'most nature-depleted countries in the world.'[172, 173] This has significant environmental consequences: 11% of domestic GHG emissions in the UK come from agricultural land use, with methane stemming from livestock production being the main source.[174] The UK's agrifood sector has substantial economic importance: it contributes £120 billion in annual value, provides employment for over 4 million people[175] and is valuable for trade.[176, 177] The UK is a net importer of food: roughly half (48%) of the food consumed is imported while only 20% of UK-produced food is exported.[178] This imported food contains embedded emissions from its production, which are estimated to be considerably higher than UK's territorial agricultural emissions, contributing to over one-third (35%) of the UK's total carbon footprint.[179, 180]

A more circular food system is one where agricultural production optimises the use of all biomass, waste is minimised by closing nutrient loops, and soil health and biodiversity are enhanced. It is also one where sustainable diets are the norm—and human health and communities' livelihoods are protected. Changes to the food system can range from the farm to the fork: this scenario looks at both. To this end, this scenario comprises two interventions to cut food's impact: endorsing a balanced diet as well as adopting more sustainable food production, to enable the UK to substantially reduce its environmental footprint both domestically and abroad.[181]

INTERVENTIONS		MATERIAL FOOTPRINT	CARBON FOOTPRINT	CIRCULARITY METRIC
2.1	**Endorse a balanced diet & cut food waste**	- 7.4%, down to 949 million tonnes	- 4.8%, down to 713 million tonnes of CO_2e	+ 1.2 p.p. to 8.7%
2.2	**Shift to more sustainable food production**	- 1.1%, down to 1,013 million tonnes	- 1.0%, down to 742 million tonnes of CO_2e	+ 0.1 p.p. to 7.6%
	Combined impact	**- 8%, down to 943 million tonnes**	**- 6.4%, down to 701 million tonnes of CO_2e**	**+ 1.2 p.p. to 8.7%**

Shifting to a more circular food system would also bring numerous environmental and social **co-benefits**. Limiting calorific intake and shifting to more plant-based diets could have positive impacts on health.[182, 183, 184] More sustainable agriculture practices could also improve air and water quality,[185] in addition to building the resilience of the food system by benefiting soil health and biodiversity, in the UK and abroad.[186, 187] Importantly, given that roughly half of food consumed in the UK is imported, action to reduce demand in UK food-related material and carbon footprints would improve the physical balance of trade and have an impact at a global scale.[188]

2.1 ENDORSE A BALANCED DIET & CUT FOOD WASTE

This intervention centres on food consumption: limiting caloric intake to 2,700 per day and favouring plant-based diets would serve to both **narrow** and **regenerate** material flows. We also consider strategies that can cut down avoidable food waste: preventing unnecessary or excess food production, for example, which **narrows** flows. All unavoidable food waste—such as inedible peels, pits and bones—should be **cycled**.

Diets

Dietary choices have a substantial impact on both human health[189, 190] and the environment:[191, 192] research shows that the healthiest diet for the planet and people is very low in meat and high in plant-based protein and whole grains.[193, 194] On average, the UK diet exceeds the recommended amounts of saturated fat (mostly from meat, cheese and butter) and sugar (from sugar-sweetened drinks and desserts), while fruit, vegetable, fibre and oily fish intake are below recommended levels.[195] More than six in ten UK adults were overweight or obese in 2019,[196] and 13% of deaths in the UK are related to unhealthy diets.[197] However, it is important to highlight that disparities across socioeconomic groups are wide and growing.[198] But the trend in dietary choices is positive: over the last two decades, the British diet has become healthier, with increased intake of fruits and vegetables and decreased meat consumption.[199, 200]

Unhealthy diets are also largely unsustainable. Consumer preferences for animal protein directly affect the amount of land required to produce food in the UK. For example, livestock requires around 80% of UK agricultural land (roughly half (48%) of all UK land),[201] despite providing less than 20% of calories and 40% of the protein consumed.[202] Accounting for overseas production, UK meat imports require more productive land than the total area of the UK.[203] At the same time, because land is scarce in the UK, ineffective food production means less available supply for nature regeneration and carbon removals (such as wood and peatlands restoration), although there are opportunities to do both.[204] This is crucial to boost the circularity of biomass, which would impact the UK's performance in terms of ecological cycling potential.

A shift to more sustainable diets could be prompted by (1) introducing (mandatory) labelling and information about the environmental impact from food and drink and (2) tax incentives (such as carbon and/or health-based taxes on foods such as those in place through the sugar tax),[205, 206] to make more sustainable food more affordable and to cut food waste.[207] From a policy perspective, carbon and health taxes are most effective in designing sustainable food policies when combined.[208] However, it should be noted that there are broader cultural and societal elements at play, such as socioeconomic disparities, which would also require shifts as well as the need for a balanced approach that ensures fairness in incentivising behaviour change.

Food waste

The UK produced around 9.5 million tonnes of food waste in 2018, 70% of which can be considered avoidable:[209] this represents a market value of around £19 billion and an associated 25 million tonnes of GHG emissions.[210] Households are responsible for the vast majority of food waste: around 70% (6.5 million tonnes), with around 14% of all food and drink bought by households ending up wasted, equivalent to over 15 billion meals.[211] This level of waste points to a systemic mismatch between supply and demand, especially when considering that one-tenth of the UK population is food insecure.[212] But progress is being made: between 2007 and 2018, avoidable food waste per capita decreased by almost one-third,[213] with surplus food redistribution increasing more than threefold between 2015 and 2021.[214] However, it's worth noting that this solution does not address the root causes of food waste generation or food insecurity.[215]

2.2 SHIFT TO MORE SUSTAINABLE FOOD PRODUCTION

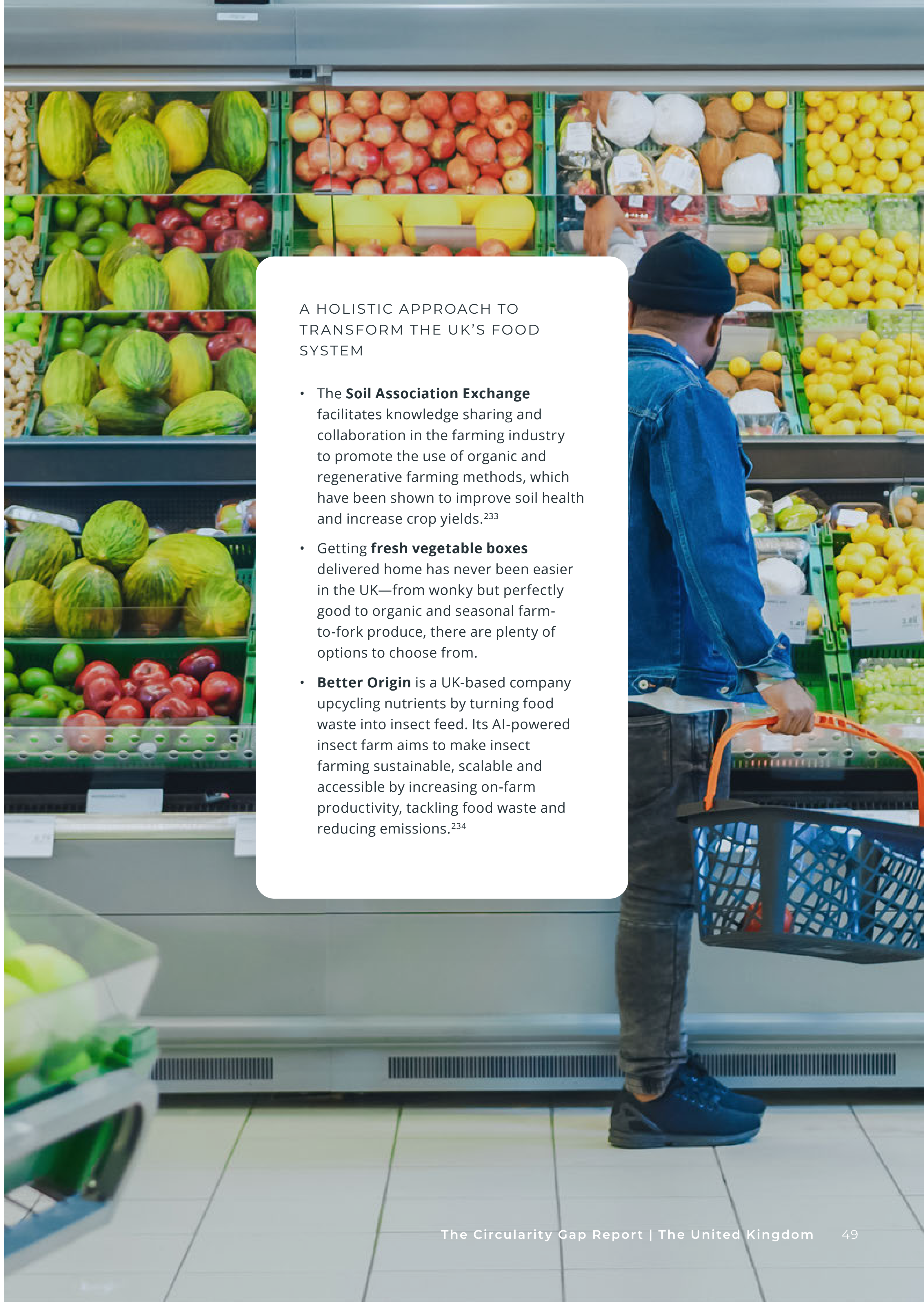
This scenario's second intervention tackles food production. We explore the impact of a shift to organic, local and seasonal food production—strategies that will **regenerate** and **narrow** flows by reducing the need for synthetic fertilisers, lowering transport distances and lessening dependence on greenhouse-grown foods (and thus reducing fuel consumption for heating). While the UK's topography, climate and soil vary widely—making changes in agricultural practices challenging—we can envision a food production system that works alongside nature, protects biodiversity and cuts emissions and chemical inputs.

A range of environmental pressures—from climate change to pollution—pose risks for soil health, water availability and agricultural productivity. They also endanger food sovereignty and societal health and wellbeing.[216, 217] Intensive farming practices are one of the main causes of soil degradation and organic carbon storage loss[218] as well as deep imbalances in nutrient cycles.[219] In 2020, just under 3% of farming land in the UK was farmed organically (or was in conversion),[220] well below the EU average of 9.1%,[221] and a drop of one-third compared to 2010.[222] Delivering net-zero, resilient and sustainable agriculture in the UK will require a deep transformation in land use, including the release of 9% of agricultural land by 2035, and 21% by 2050.[223] In recent years, the UK's agricultural sector has built a strong knowledge-base and new regulatory framework and infrastructure for pollution control, for example for slurry, providing hope for further emissions reductions.

Improving soil health and protecting biodiversity will also require a transformation of how UK farms use synthetic fertilisers. Currently, nitrogen (over) use and low efficiency of synthetic fertilisers result in a wide range of environmental problems, from soil degradation and acidification to water eutrophication and biodiversity loss.[224] In Britain, fertiliser usage per tonne of produce declined by 53% between 1985 and 2019.[225] Subsequently, ammonia emissions have also declined by around 20% between 1990 and 2020[226] (although in some countries, such as Northern Ireland, they have actually increased).[227] Alternatives exist for sustainable pest management (such as biopesticides), as well as for organic fertilising (such as animal waste and compost) that contribute to nutrient cycling.[228] Improving the nitrogen cycle through enhanced efficiency in the use of fertilisers is also key for making farming practices more sustainable.

A fundamental reform of UK agriculture is critical for tackling the nature and climate crises, but the transition must be fair.[229] Change is moving in the right direction: UK farmers are increasingly recycling waste materials, improving nitrogen fertiliser application and improving energy efficiency.[230] Society-wide there is an increasing appetite for local produce, local food production and more sustainable land use management.[231] Policy could better support this shift: farmers could receive support for making the transition, for example, in the form of information and skills training as well as payments for carbon storage and technological upgrading. Low-carbon farming regulations and support for local produce and local food production are also in place.[232]

** Note: The impacts of shifting to more sustainable farming methods appear to be quite modest: due to the nature of our methodological approach, we were unable to provide a detailed assessment of changes in land-use management, which would play a key role in advancing circularity and diminishing environmental pressures.*



A HOLISTIC APPROACH TO TRANSFORM THE UK'S FOOD SYSTEM

- The **Soil Association Exchange** facilitates knowledge sharing and collaboration in the farming industry to promote the use of organic and regenerative farming methods, which have been shown to improve soil health and increase crop yields.[233]
- Getting **fresh vegetable boxes** delivered home has never been easier in the UK—from wonky but perfectly good to organic and seasonal farm-to-fork produce, there are plenty of options to choose from.
- **Better Origin** is a UK-based company upcycling nutrients by turning food waste into insect feed. Its AI-powered insect farm aims to make insect farming sustainable, scalable and accessible by increasing on-farm productivity, tackling food waste and reducing emissions.[234]

3. ADVANCE CIRCULAR MANUFACTURING

The UK was the world's first industrial powerhouse, dominating the global industrial landscape until the end of the 19th century and claiming large shares of global manufacturing output and world trade in manufactured goods. However, services now play a much bigger role in the UK's economy.[235] Nonetheless, manufacturing is still vital, particularly in terms of output, employment and wages, and exports and innovation, with the automotive, aerospace and life sciences industries concentrating the bulk of the sector's production. The sector directly accounts for around 10% of GDP, contributing £170 billion to the overall economy. It also provides approximately 9% of jobs—around 3 million direct jobs—as well as an estimated more than 5 million jobs across the value chain. The UK's industrial and manufacturing base is a crucial facet of the UK's environmental strategy: due to its sheer size and production capacity, it holds the potential to be a key driver for a prosperous and sustainable future.[236, 237] Enacting a circular economy in the UK can drive the UK to transform its national productive capabilities and rebuild its industrial base, building resilience and security, creating highly skilled jobs and cutting structural costs (related to energy and raw materials).

To this end, this 'what if' scenario highlights how to advance material efficiency by making better use of (metallic) waste in industrial processes, and extending product lifetimes through various R-strategies. It is also worth noting that the UK's manufacturing and industrial base includes other important industries—such as chemicals, cement, food and drink, ceramics, glass, and paper and wood products, for example—that are out of scope for this scenario. These highly energy-intensive sectors may also advance resource efficiency and decarbonisation via an increased use of secondary materials, cutting edge technological industrial processes, hydrogen deployment and industrial heat recovery projects, for example.[238]

INTERVENTIONS		MATERIAL FOOTPRINT	CARBON FOOTPRINT	CIRCULARITY METRIC
3.1	**Implement resource-efficient manufacturing**	- 1.8%, down to 1,006 million tonnes	- 1.1%, down to 741 million tonnes of CO_2e	+ 1.2 p.p. to 8.7%
3.2	**Employ R-strategies for machinery, equipment and vehicles**	- 3.3%, down to 991 million tonnes	- 2.3%, down to 732 million tonnes of CO_2e	+ 0.1 p.p. to 7.6%
	Combined impact	**- 5.1%, down to 973 million tonnes**	**- 3.4%, down to 724 million tonnes of CO_2e**	**+ 0.3 p.p. to 7.8%**

While the impact of these interventions may appear modest in comparison with previous scenarios, their adoption would also bring a range of social and economic **co-benefits**: increased resilience against supply chain disruptions and price volatility, reduced energy consumption and demand due to efficiency gains, reduced waste generation, and lower material input as materials are kept in use, for example. Scaling the uptake of R-strategies could also induce greater private sector involvement in the circular economy and boost industrial sectors, creating new opportunities for businesses, incentivising innovation and laying the groundwork for longer-term resilience and competitiveness.

3.1 IMPLEMENT RESOURCE-EFFICIENT MANUFACTURING

This scenario's first intervention centres on improving manufacturing's material efficiency—both during the initial stages, where materials are formed and in the final stages, where products are created. Reducing the need for metal inputs, such as steel and aluminium, by improving industrial processes will serve to **narrow** flows. Gains in material efficiency should be integrated into the early stages: cutting yield losses involves making the most of technological advances to get more from less. Further along the value chain, where metals will be used to make a vehicle or machinery, for example, process improvements will bring similar benefits. Reducing scrap material—a by-product of standard procedure—would also boost efficiency and reduce the need for virgin material inputs, further **narrowing** flows. All unavoidable scrap can also be reused, **cycling** flows.

Although the UK mines little and has low metal production, it is an important stakeholder in the industry. For example, the London Metal Exchange is the world's largest marketplace for trading metals.[239] On average, the UK produces approximately 7 million tonnes of steel, consumes around 12 million tonnes of steel products annually and produces 11 million tonnes of scrap steel.[240] Nevertheless, the UK's metal sector is still highly import-dependent: 41 million tonnes from abroad in 2019, namely the EU and China. The UK steel industry has also faced multiple challenges over recent decades.[241] The current lack of resilience in the supply chain for virgin metals may motivate the application of circular economy strategies—such as scrap optimisation—in the manufacturing sector. Scrap metal recycling has significant environmental and economic advantages.[242] For example, scrap steel uses far less energy, and thus generates a fraction of the GHG emissions—resulting in cost savings for processors. Circular strategies provide an opportunity to domestically recycle up to around 6 million tonnes of scrap steel that would otherwise be exported overseas. The UK's many important industries, such as automotive, aerospace and machinery, could provide sufficient demand for more domestic metal recycling. While increasing domestic recycling would require investment for greater steelmaking capacity, it would also offer employment opportunities and emissions reductions.[243, 244] In addition, cutting-edge industrial processes—such as lightweighting through material substitution, additive manufacturing[245] and near net shape (NNS) manufacturing—can also reduce material inputs and reduce emissions and waste.[246, 247] However, due to a current lack of domestic infrastructure and technologies for scrap processing, such as electric arc furnaces, 80% of the UK's metal waste is sent overseas—despite the country having no domestic extraction of metal ores. The most recycled metals by weight are iron and steel, although there is potential to recycle other high-value metals that the UK lacks such as aluminium, copper and zinc.

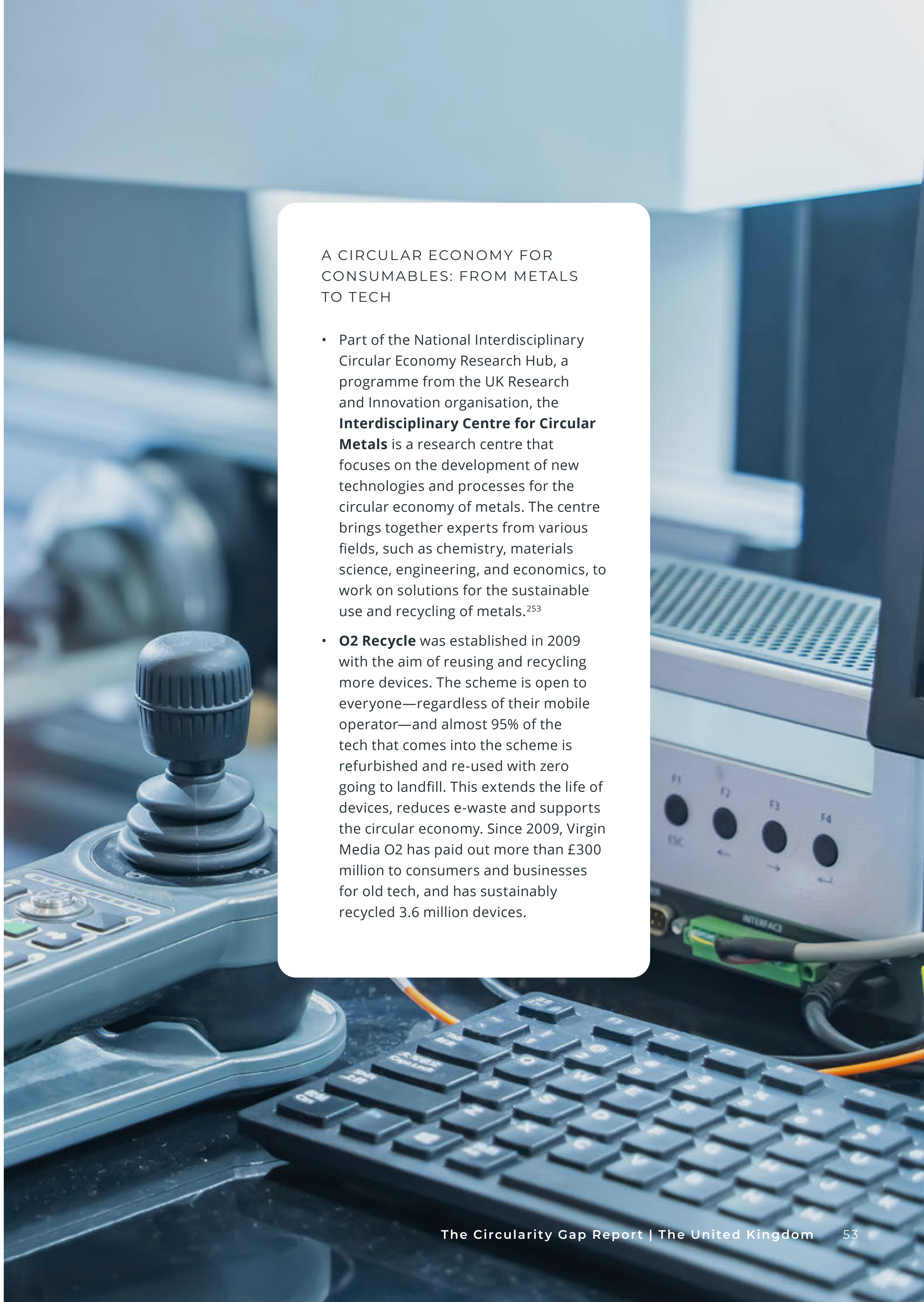
3.2 EMPLOY R-STRATEGIES FOR MACHINERY, EQUIPMENT AND VEHICLES

This intervention employs various R-strategies[248] (see text box on page 52) for the manufacturing of machinery, equipment and vehicles. Remanufacturing and refurbishment practices can be leveraged to extend product lifetimes, therefore **slowing** flows. The UK could also benefit from a shift to more circular supply chains, making use of leasing or other Product-as-a-Service (PaaS) systems as an alternative to ownership-based models. In a ownership-oriented system, the aim is to maximise the number of products sold. PaaS circumvents this and therefore contributes to **narrowing** flows. Incorporating circularity in the early phases of design, both at the process and material levels, will also be crucial to enable high-value circular practices.

While the circular economy is often associated with lower-value strategies such as recycling, much potential lies in strategies higher up on the waste hierarchy, such as remanufacturing, repair and reuse. To maximise the environmental, economic and social potential of the circular economy in the UK's manufacturing sector, strategies that preserve product functionality and extend lifetimes need to be at the core of a future national circular economy strategy. The economic potential of R-strategies in this sector is also significant. For instance, in the EU, the market value of remanufacturing could reach £25.5 billion by 2030.[249] Industries such as aerospace, automotive, electrical and electronic equipment, medical equipment, machinery and heavy-duty equipment hold the most potential.[250] Other R-strategies like repair and reuse also provide significant opportunities for the UK to boost its circularity and cut material use and emissions, by retaining the value of materials and complexity of products while stimulating innovation and creating jobs. For example, remanufacturing, repair and reuse activities could create over 450,000 new UK jobs by 2035, helping to offset job losses generated by offshoring and automation[251] if properly incentivised and met with ambition from the Government. To deliver on these opportunities, several challenges need to be addressed: strengthening R&D facilities, boosting industry-academic relations, building up technological and physical infrastructures, and investing in the development of the necessary (industrial) skills.[252]

WHICH R-STRATEGIES DO WE CONSIDER—AND WHAT DO THEY MEAN?

- **Remanufacturing:** A procedure in which all components of a product are completely disassembled down to their smallest parts, are fully inspected and then reused for an entire new life cycle.
- **Refurbishment:** A procedure to improve the quality of a product up to a specified quality.
- **Repair:** The reparation of parts of a product that limit its performance and the maintenance of parts that can help to prolong its useful life. This can happen at the inter-industry level or be performed after consumers purchase a good. Similarly, upgrades can be carried out to improve a product's functionality and extend its useful lifetime: this goes beyond repair and implies an improvement to a product, for example, by increasing mechanical-, electrical- or ICT-related inputs, depending on the product.
- **Reuse:** The extension of a product's lifetime, that therefore displaces the sale of new goods. This assumption stems from the fact that products are often still usable—even without additional repair and maintenance—but reach their end-of-use early due to consumer attitudes and behaviours.



A CIRCULAR ECONOMY FOR CONSUMABLES: FROM METALS TO TECH

- Part of the National Interdisciplinary Circular Economy Research Hub, a programme from the UK Research and Innovation organisation, the **Interdisciplinary Centre for Circular Metals** is a research centre that focuses on the development of new technologies and processes for the circular economy of metals. The centre brings together experts from various fields, such as chemistry, materials science, engineering, and economics, to work on solutions for the sustainable use and recycling of metals.[253]
- **O2 Recycle** was established in 2009 with the aim of reusing and recycling more devices. The scheme is open to everyone—regardless of their mobile operator—and almost 95% of the tech that comes into the scheme is refurbished and re-used with zero going to landfill. This extends the life of devices, reduces e-waste and supports the circular economy. Since 2009, Virgin Media O2 has paid out more than £300 million to consumers and businesses for old tech, and has sustainably recycled 3.6 million devices.

4. RETHINK TRANSPORT & MOBILITY

In the UK, the transport and mobility sector is the largest emitter of domestic GHG emissions: just over a quarter of territorial emissions in 2019, with passenger cars and road transport as the highest contributors.[254] Since 1990, transport has experienced little overall change: there has been just a slight (4.6%) reduction in emissions, primarily due to fuel efficiency improvements being partially offset by an increased volume of road traffic.[255] Additionally, due to accessibility and price (rather than choice), transport use correlates with socioeconomic status within the UK.[256] As part of the decarbonisation and 'levelling up' agendas, the Government is pursuing ambitious objectives to transform the UK's transport and mobility system by making it more sustainable and inclusive. So far, decarbonisation for small passenger vehicles is already progressing—but reaching net-zero for air, train and sea travel will require profound behavioural change and further innovation backed by heavy investment. Where electrification isn't possible, alternative technologies—such as hydrogen and alternative fuels—should be considered.

This 'what if' scenario provides a reimagination of transport and mobility in the UK by modelling two interventions: reducing or avoiding travel or the need to travel by rethinking the transport and mobility system, and driving cleaner mobility forward using new technologies that tackle vehicle production and use. Ensuring the optimisation and decarbonisation of all transport across the UK—from cars and trains to aeroplanes and ferries—will require broader and more systemic change.

INTERVENTIONS		MATERIAL FOOTPRINT	CARBON FOOTPRINT	CIRCULARITY METRIC
4.1	**Reduce or avoid travel, or the need to travel**	- 4.1%, down to 983 million tonnes	- 9.2%, down to 680 million tonnes of CO_2e	+ 1.2 p.p. to 8.7%
4.2	**Drive cleaner mobility forward**	- 2.9%, down to 995 million tonnes	+ 1.0% up to 757 million tonnes of CO_2e*	+ 0.1 p.p. to 7.6%
	Combined impact	**- 7%, down to 953 million tonnes**	**- 8.4%, down to 686 million tonnes of CO_2e**	**+ 0.5 p.p. to 8%**

** The carbon footprint would increase by a slight 1%: a 2.4% decrease from lightweighting offset by a 3.4% increase from electrification. The reason for this is two-fold: supply chain emissions from renewable energy sources being much higher than for fossil fuel ones, and limitations in the modelling approach to better estimate emissions reductions during use phase—while the real benefit of electrification lies in the reduction of tailpipe (household) emissions. Therefore, it's expected that the impact of this intervention in the carbon footprint could be far greater than it appears.*

The UK could also experience a range of environmental, societal and economic **co-benefits** from embracing these strategies: improved air quality, less noise, and increased and safer room for amenities and green spaces, for example. Improving interregional and intercity connectivity can provide economic benefits by boosting regional productivity and encouraging multiple economic centres. Taking these steps can also have multiple co-benefits for health and wellbeing: more active transport and reduced sedentarism would boost physical activity, thereby contributing to outcomes such as less obesity.[257] A flexible, hybrid-mix of work-from-home and office time could also positively influence productivity, health and wellbeing, as well as bring social benefits. However, potential downsides such as adverse economic impacts for local and regional economies,[258] diminished collaboration and social interaction, as well as fair distribution of extra costs by employers and employees, should also be considered and addressed.[259]

4.1 REDUCE OR AVOID TRAVEL, OR THE NEED TO TRAVEL

This scenario's first intervention explores the benefits of decreasing or avoiding travel or the need for travel by rethinking the transport and mobility system. This will ultimately require UK residents to embrace a more car-free lifestyle, cut down on air travel and continue to work-from-home where possible. Doing so could cut the need for private car ownership and use as well as fuel consumption, both serving to **narrow** flows. Increasing public transport (train and bus) coinciding with and causing a significant reduction in private car ownership and use will offset the expected decrease in material use to a degree.

Air travel

UK citizens rely heavily on air travel: British passports are used for one in 12 flights globally.[260] International aviation emissions have more than doubled since 1990,[261] while air transport was the single largest contributing industry to the UK's carbon footprint (7%) in 2019. However, while this analysis calculates flights per capita in the UK to be 4.4 in 2019, inequality in air travel is vast: just 15% of the UK public were responsible for 70% of flights.[262] Furthermore, current policy recommendations would still allow increasing numbers of passengers to use air travel in the UK, leading to 30 million tonnes of carbon dioxide to be emitted in 2050.[263] The Government has placed some priority on making alternatives to air travel cheaper while providing better services to meet demand, yet the perceived threat to the competitiveness of the UK economy from reduced air travel[264] has meant that little changes have been made thus far.

Car travel

In 2019, there were 491 passenger vehicles per 1,000 people in the UK, a figure that has slowly increased since 2011.[265] While this is below the European average (560 passenger vehicles per 1,000 people),[266] the increasing rate of car ownership is still problematic—many car journeys are taken solo and most cars are parked for huge amounts of the time. In Great Britain in 2019, over four-fifths (84%) of passenger kilometres travelled by road were by cars, vans and taxis.[267] Active transport also remains low compared to other forms of transport. What's more, socioeconomic status indicators—including income and location of residence—align with excess car travel: the top 5% of car users contribute 5.7 times more emissions by travelling 4.8 times more often than the national average.[268] This contributes significantly to congestion (particularly in major cities such as London) which could cost the UK economy a predicted £14.5 billion by 2030. By rationing the top quintile (20%) of car users' mileage in the UK, emissions could be reduced by over a quarter.[269]

Public transport and Mobility-as-a-Service

In England in 2019, the number of private transport journeys was nearly ten times higher than that of public transport journeys.[270] Improvements to the UK public transport system have the potential to boost Mobility-as-a-Service and reduce reliance on cars and air travel—subsequently cutting emissions. Cities, and inclusive urban design, have a big role to play in this,[271] as urban planning can increase interregional and intercity connectivity. However, improving public transport to reduce car ownership will only prove effective if it is easier to switch between different public transport networks (intermodal travel) and if the costs of trains are reduced in comparison to car use and air travel. Public transport remains one of the most efficient forms of shared mobility—but there are strong links between transport and inequality. For example, higher-income residents are more likely to use trains and cars, and less likely to use bus services. The opposite is true for those with lower incomes including ethnic minority groups, young people who are unemployed or are students, elderly people or women.[272] Furthermore, despite car traffic remaining lower than pre-pandemic levels, public transport use has also fallen. And despite an early cycling boom,[273] current trends in cycling are unclear.[274] Other measures, such as demand-responsive transport and on-demand mobility[275] such as car clubs, car sharing schemes and single day car insurance, can provide flexible, fast, safe and cheap mobility solutions at scale. This shouldn't come at the expense of public transport, but rather complement it.

Hybrid, flexible work

Avoiding travelling in the first place can also dramatically reduce environmental impacts. The percentage of workers in the UK that carry out any work from home increased from roughly a quarter (24%) to over a third (36%) between 2011 and 2020, whilst those who work *mainly* from home jumped from 8.4% to 36%. This trend was accelerated by covid-19-induced lockdowns[276] that increased flexwork as well as part-time and self-employment, all of which contribute to decreased individual travel. There continues to be strong support for a hybrid work model in many fields.[277] However, full-time teleworking may not always reduce travel as workers may engage in more business or personal travel, counteracting the benefits saved from not commuting.[278] Additionally, hybrid flexwork could increase inequalities because the benefits of such work models are not equally distributed.[279, 280] As demonstrated by the pandemic, there are also plenty of essential jobs that cannot be done remotely.

For these strategies to become a reality, necessary incentives need to be put in place. The increased provision of local services through mixed-use planning (i.e. shops and facilities as part of new developments) can remove the need for cars: for example, 20-minute neighbourhoods. A tax on excess car use, integrated payment systems to ease intermodal connectivity to stimulate a return to public transport, and investments in infrastructure such as improving pedestrian and cycling environments that prioritise active mobility could also be viable options.[281, 282]

4.2 DRIVE CLEANER MOBILITY FORWARD

While focus should ideally centre on reducing transport and mobility—especially by car and air—and developing new mobility systems, as explored in our first intervention, clean new technologies are also needed. This intervention comprises several strategies that tackle the production and use phase of vehicles. The UK has an opportunity to **narrow** material flows by prioritising small(er), more lightweight, fuel-efficient vehicles, thereby cutting material and fuel use. This could include private cars, public transport vehicles and freight transport. Moving towards the future, all new vehicles for public and private transport should also be electric: this would cut fossil fuel use, **narrowing** flows, and **regenerate** flows if the vehicles were to be powered by renewable energy. However, it is also worth emphasising that electric vehicles still consume large volumes of materials—and especially critical minerals[283] such as lithium, cobalt and nickel for batteries, for example. This intervention must be understood in the context of the previous one—i.e., a substantial reduction in the fleet size—to prevent certain trade-offs and knock-on effects.

This intervention is well-aligned with the UK's *Road to Zero Strategy*,[284] which aims to build a fully electric vehicle fleet by 2050. The Government has also mandated that the sale of new petrol, diesel and hybrid cars and vans will come to an end from 2035 onwards.[285] The decarbonisation agenda in the UK promotes the shift to electric and ultra-low emission vehicles (ULEVs), with sales growing rapidly.[286] But there's still a way to go: the vast majority of vehicles registered in the UK are powered by internal combustion engines, with greener alternatives only representing a small fraction of the total number of cars on the road. On the production side, the strong automotive manufacturing base in the UK leans towards greener technology: over £10 billion has been invested in electric vehicles and batteries since 2010.[287] The industry is currently transforming to deliver fully electric vehicles by 2030 whilst navigating the challenges that this poses.[288] Nonetheless, decarbonisation is a necessity and offers plenty of opportunities for manufacturers and suppliers of batteries and electric motors.[289]

Despite an increasing will to switch to electric vehicles in the next decade, high upfront costs and a lack of sufficient infrastructure (such as rapid public recharging points) remain key hurdles for a shift to electric vehicles at scale.[290] These barriers must be overcome to reach the 2035 targets to phase out sales of petrol and diesel vehicles.[291] Even where infrastructure is in place, issues remain around network interoperability, and ease of access to UK charging facilities for drivers. In the long term, transitioning to EVs will require policy action on important issues, such as the type of electricity used to meet the increasing demand, the sourcing and supply of materials for batteries, and the recyclability of the batteries, for example. Moreover, other technologies such as hydrogen[292] can complement electrification, not only for road transport[293] but also for shipping and aviation.[294, 295] Policy drivers to stimulate these changes could include sound fiscal incentives (such as levies on emissions and vehicle weight) and tighter fuel economy and emissions standards, subsidies for the purchase of more sustainable (private and commercial) alternatives, and investments in the deployment of a reliable and affordable charging network (cities play a key role here), for example.[296] The selection of policy drivers should be guided by social equity and inclusiveness, promoting affordability and convenience to avoid social backlash and ensure a just and fair transition from fossil fuel to electric vehicles.[297]

DRIVING FORWARD ON-DEMAND MOBILITY AND SUSTAINABLE TRANSPORT

- Launched in 2017, **ArrivaClick** operates on a demand-responsive basis, meaning that routes and schedules are determined based on the real-time needs of passengers, rather than following a fixed schedule.[298] Passengers can book rides through a smartphone app and are then picked up and dropped off at designated locations. The service is currently available in several towns and cities in the UK, including Ashford, Liverpool and Manchester.
- **Wrightbus** is a Northern Ireland-based bus manufacturer that focuses on hydrogen fuel cell technology.[299] It successfully rolled out the world's first double-decker hydrogen-powered buses in 2020 in Aberdeen, Scotland. Its buses are a more sustainable and viable alternative to traditional diesel ones, as they produce zero emissions and tout a higher efficiency as well as a longer range than battery electric buses.

5. WELCOME A CIRCULAR LIFESTYLE

The dominant economic model has bred a damaging cycle: consumable goods are manufactured from raw materials, sold, used and largely discarded.[300] Waste is often created without regard for people or the planet. This system has emerged from an economic model that largely puts profit above people and cultural trends that glorify or prioritise ownership and revere material wealth. Tackling the triple crisis of climate change, biodiversity loss and pollution is a collective action problem. However, whilst policymakers and businesses are responsible for making sure that production is responsible and sustainable, individual consumption choices are also an effective way to induce that change, particularly for individuals with higher incomes.[301] Like other high-income countries, excessive convenience and consumerism[302] have led to a spike in individual material footprints and waste generation: for the average consumer, with limited time or energy to look for less impactful alternatives, waste is inevitable and is built into most products. Transitioning to circularity will require a better understanding of the relationship between social and material dimensions,[303] as well as a new consciousness of what we're consuming and for how long.

This 'what if' scenario explores the role of consumption in a circular economy,[304] examining the impact of a material 'sufficiency' lifestyle: having enough, but not too much.[305] This will require heavy consumers to buy and own less 'stuff'. We analyse the impact of shifting to a more circular lifestyle and mindset for goods such as clothing, electronics, packaging, household appliances and furniture, as well as activities like travel.

In addition to these impacts, other **co-benefits** would be prevalent: the UK would likely benefit from less waste, litter and pollution. In addition, more sustainable, community-based lifestyles could bring a range of societal benefits: more inclusive and resilient communities and a heightened sense of belonging due to improved social interactions, for example.

5.1 EMBRACE A 'MATERIAL SUFFICIENCY' LIFESTYLE

This scenario explores just one intervention: a low-impact lifestyle of 'material sufficiency' where high standards of wellbeing are still maintained and conscious living is prioritised over excess and wastefulness.[306] We examine a range of strategies aimed at minimising material consumption, **narrowing** flows, encouraging UK residents to use products for longer, **slowing** flows, and using eco-alternatives and recycling as much as possible to **regenerate** and **cycle** flows. Cutting the number of consumables in circulation—**narrowing** flows—is the most impactful strategy.

INTERVENTION		MATERIAL FOOTPRINT	CARBON FOOTPRINT	CIRCULARITY METRIC
5.1	**Embrace a 'material sufficiency' lifestyle**	- 13.2%, down to 890 million tonnes	- 11.5%, down to 663 million tonnes of CO_2e	+ 1.1 p.p. to 8.6%

In the UK, gearing consumption towards circularity could cut the material intensity of its economy, both nationally and abroad via the supply chains that deliver goods and services to UK businesses and households. This is particularly true for high-impactful products such as textiles,[307, 308] plastics[309] and electronics,[310] the consumption of which has skyrocketed in the past two decades. As opposed to the reliance on large-scale and unproven technologies alone to cut extraction, waste and emissions, a recent report by the House of Lords estimates that around a third of emission cuts will need to come from behavioural changes by 2035. This includes the adoption of low-carbon technologies, a shift to low-carbon products and services, and the reduction of material- and carbon-intensive consumption for both individuals and businesses.[311]

There is support for reduced material- and carbon-intensive consumption as well as greater sharing and repairing by individuals, as opposed to buying new *stuff*.[312] But information and incentives are often lacking. Government and businesses have critical roles to play: the Government needs to use the levers at its disposal to support and foster societal change through regulation, taxation and infrastructure development. Ingraining fairness in policy design is key to effective behavioural change and avoiding social backlash.[313] Businesses need to take enabling steps that help ordinary people reduce their material and carbon footprints by embracing circular business models and circular design, providing affordable alternatives that allow reduced consumption, and providing access to affordable repair and sharing services and systems, for example.[314] This could be realised through repair cafés, for example. Subsidies and grants for the development of these activities, as well as the effective implementation of 'right to repair' legislation, particularly for electrical and electronic devices, will also be important.

ENABLING CIRCULAR LIFESTYLES AND CULTURE THROUGH INITIATIVES AND NETWORKS

- As part of its efforts to build a circular business model, Currys has promoted the responsible use, repair and recycling of technology products. Its **Long Live Your Tech** initiative[315] offers services such as product repair, recycling and trade-in options. Its **Cash for Trash** programme allows customers to swap their tech for vouchers to use in store.
- Created in 2020, the **Community Repair Network** brings together community-based organisations that promote sustainable consumption and production by extending the life of products, reducing the environmental impact of manufacturing new products and providing social benefits to communities.[316] The organisations work together to repair and reuse household items, such as furniture and appliances, to reduce waste and provide affordable access to goods for low-income households.
- Many waste recycling centres in Wales also have **circular hubs**: areas designated for the collection of reusable items such as clothing, furniture and household goods. These items are then usually cleaned, repaired if necessary and then made available for the public to purchase at a reduced cost.

6. TACKLE THE UK'S IMPORT FOOTPRINT

Significantly improving the raw material efficiency and carbon intensity of supply chains is necessary for delivering a more circular (resource-light and low-carbon) UK economy. As a major open and highly-integrated economy, the UK is highly dependent on trade: the value of imports and exports represents around half of economic output.[317] During the past fifty years, as the UK deindustrialised, the import of finished goods grew in importance. As discussed previously in this report, the UK's high material footprint has partly been driven by extraction abroad to satisfy the country's demand: net extraction abroad (NEA) accounts for 29% of total material consumption (see page 93). This figure's size can be attributed to some of the UK imports having very high Raw Material Equivalent (RME) coefficients (see page 27), particularly for non-metallic minerals. Essentially, the country is carrying a hefty 'ecological rucksack': the weight of materials taken from nature to make a product, minus the weight of the product itself. This can be a result of the nature of the product—some mineral fertilisers, for example, require processes where a lot of other rock and mineral types are excavated as a side effect—or because of inefficient and highly impactful production processes carried out by trading partners. Unfortunately, due to a lack of granularity in traceability, it is not possible to pinpoint which products or trading partners are posing problems. This makes it infeasible to discern the influence of data quality and manipulation—such as scaling, interpolation and proportioning—on these results, nor to further identify more accurate reasons for them.[318] Tracking extraction taking place abroad is undoubtedly tricky: materials can either be embodied in goods eventually imported into the UK, or become waste and emissions through the production processes taking place in the country of origin. While the former are either consumed or added to stock in the UK, distinguishing between these various paths is impossible. However, a scenario was explored where changes in high-impact material flows coming from abroad are modelled.

In this scenario's only intervention, we explore the impact of shifting away from high-impact imports and building more resilient (domestic) supply chains by substituting the import of certain materials and increasing the efficiency of domestic industries.

INTERVENTION		MATERIAL FOOTPRINT	CARBON FOOTPRINT	CIRCULARITY METRIC
6.1	**Shift away from high-impact imports and build resilient supply chains**	- 8.4%, down to 939 million tonnes	- 3.3%, down to 724 million tonnes of CO_2e	+ 0.6 p.p. to 8.1%

By shifting away from high-impact imports, the UK could also reduce environmental impacts abroad by decreasing material extraction, pollution, GHG emissions and waste. Societal and economic **co-benefits** include strengthened socioeconomic resilience through reduced dependence on the most environmentally impactful foreign imports. New business and job opportunities could arise by reshoring the production of certain goods and service offerings, for example.

6.1 SHIFT AWAY FROM HIGH-IMPACT IMPORTS AND BUILD RESILIENT SUPPLY CHAINS

By shifting away from high-impact material imports, the UK could cut the overall material needs of the economy, while also cutting waste generation and emissions abroad—all serving to **narrow** flows.

The UK generally imports more goods than it exports.[319] Accompanying the UK's exit from the EU,[320, 321] the covid-19 pandemic, and the war in Ukraine, recent trends in the international trade flows of the UK show a reduction in the size of trade flows relative to GDP.[322] But despite recent turmoil, total international trade has grown over the last two decades.[323] Through its trade strategy, the Government has centred on exports and promoting UK companies on the international stage. By comparison, imports have received little attention. In 2019, UK imports of goods were valued at £542 billion, with most products coming from Germany, the US, China, the Netherlands and France. Precious metals, mechanical appliances, motor vehicles, electronic equipment, and mineral fuels top the list in terms of the goods flowing into the UK.[324]

There is ample potential for UK trade policy to drive and complement environmental objectives.[325] By influencing the supply chains of its imports, the UK can reduce the environmental impacts that it offshores. But global supply chains have become increasingly complex over the past decades, and making them more sustainable is no easy task, due to limited traceability for example. The UK's exit from the EU also creates long-term uncertainty for UK businesses' supply chains, particularly in terms of imports from the EU. Businesses may use this time of transition as an opportunity to increase supply chain resilience and become more flexible: the UK Government may incentivise businesses to locate their supply chains domestically, for example. Participating in overseas programmes and collaborating with international partners to increase financial stability may also serve to increase supply chain resilience, while businesses may do this by diversifying the locations of suppliers to distribute risk geographically.

ENGAGING ACROSS THE SUPPLY CHAIN TO DRIVE CIRCULARITY

- Established by the UK's Department for International Development (DFID) in mid-2019 and now run by the Foreign, Commonwealth and Development Office, the **Sustainable Manufacturing and Environmental Pollution (SMEP) programme** aims to support sustainable manufacturing and reduce environmental pollution in developing countries linked to supply chains ending up in the UK.[326] The programme focuses on working with local partners to improve the environmental performance of manufacturing industries and promote the use of cleaner technologies. The programme also aims to increase the capacity of local governments and organisations to address environmental issues and implement sustainable manufacturing practices.
- Several companies producing textiles and soap have **relocated production to Scotland for sustainability** reasons such as to reduce environmental impact (transport emissions and waste generation), shorten supply chains, and engage with local communities by supporting local suppliers.

COMBINED INTERVENTIONS

Individual interventions along a range of platforms have a limited impact on the material and carbon footprints and the Circularity Metric, but when we combine the interventions we see a substantial impact. However, it is important to note here the difference in relative impacts between the reductions in the material and carbon footprints, and the increases in the Circularity Metric. Firstly, as noted in Chapter two, the material and carbon footprints are presented as absolute figures, while the Circularity Metric is a relative figure, presented in proportion to a whole. Secondly, because material consumption and GHG emissions are strong proxies for environmental impact, reducing them is the primary goal for lessening environmental pressures—while increasing the Circularity Metric is a means of achieving these goals. Increasing materials' circularity in a socioeconomic system—in other words, replacing virgin with secondary materials—is just one way of reducing the overall material and carbon footprint (and thus environmental impacts). Reducing the overall demand for materials has a much more significant effect on lowering the material and carbon footprints, and requires fewer interventions. This is exemplified by the outcomes of our scenario analysis: the impact of cycling is limited compared to a reduction in consumption.

If we harness the cross-intervention synergies, the UK's **material footprint could be lowered by a remarkable 40%**, from 1,025 million tonnes to a mere 617 million tonnes. On a per capita basis, the material footprint could be reduced from 15.3 tonnes to around 9.2 tonnes per year, bringing the figure close(r) to what is a more sustainable level (8 tonnes per person per year).[327, 328] The combined scenarios also offer the potential for deep GHG emissions reductions: the **carbon footprint could be decreased by approximately 43%**, bringing it from 749 million tonnes of CO_2e down to 424 million tonnes of CO_2e. At the same time, the **Circularity Metric could almost double** (increasing to 14.1%). Please refer to the following table for further detail on the impact of each scenario and specific interventions. For more information on the methodology behind the combined scenario results, refer to Appendix G on page 99.

SCENARIOS, INTERVENTIONS & STRATEGIES

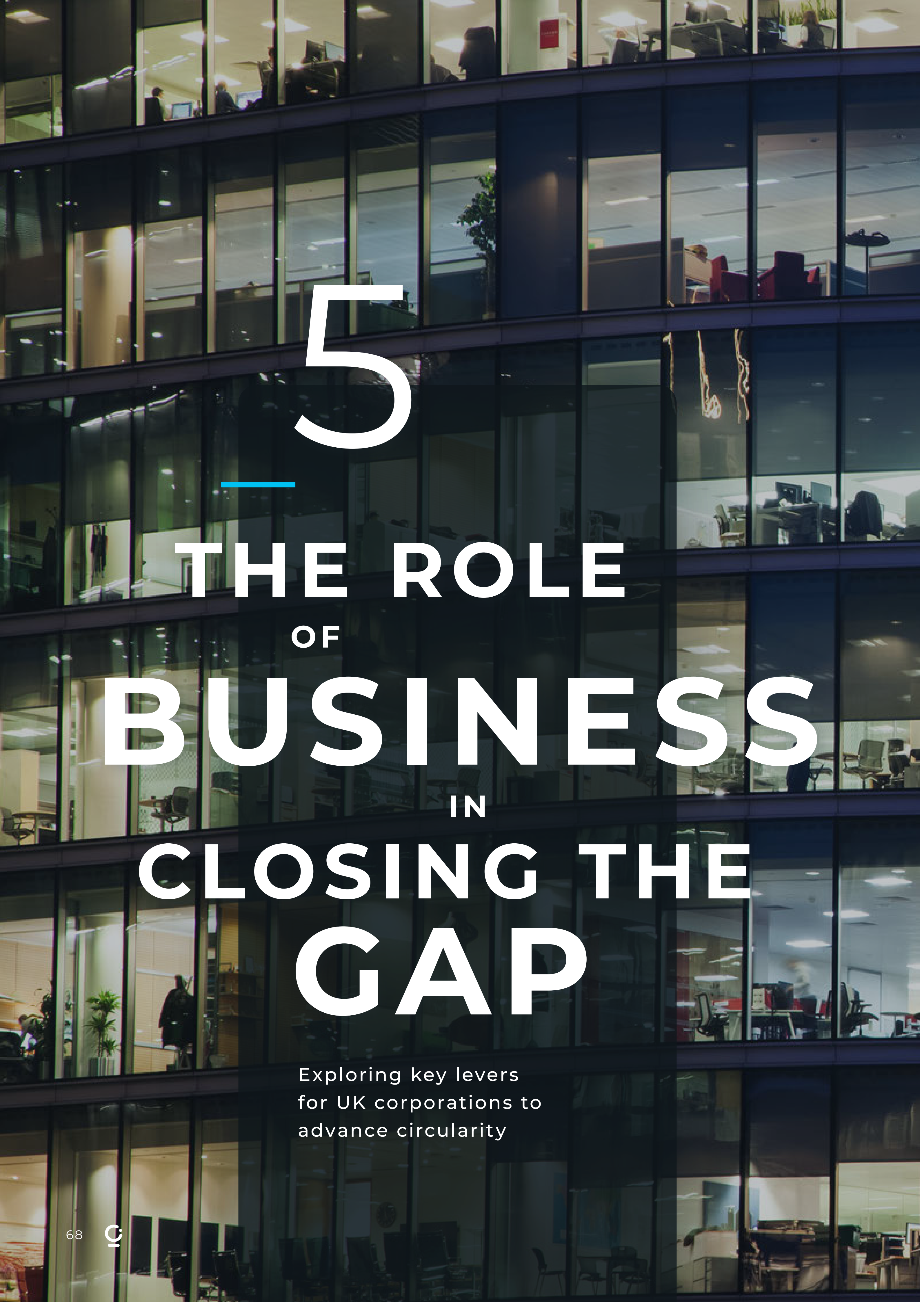
	INTERVENTIONS	STRATEGIES	IMPACT
1. BUILD A CIRCULAR BUILT ENVIRONMENT	**1.1 Optimise building stock expansion**	• Optimise housing stock expansion • Use secondary materials for new construction • Increase housing and commercial buildings occupancy	Reduction of material footprint by **10.1%**, decrease from 1,025 to **921 million tonnes**. Reduction of carbon footprint by **19.2%**, decrease from 749 to **605 million tonnes** of CO_2e. Circularity Metric rises from 7.5% to **9.3%**. Co-benefits: Reduction in energy consumption and waste, new businesses and job opportunities, reduced fuel poverty and increased wellbeing at home, increased availability of space for community use or renaturation.
	1.2 Create a low-carbon, energy efficient building stock	• Practise deep retrofitting of housing stock • Use energy efficient house appliances • 2-degree lower room temperature and smart metering	
	1.3 Shift to resource-efficient building practices	• Use lightweight and durable bearing elements • Reduce losses during construction processes • Prioritise local construction materials and supply chains	
2. NURTURE A CIRCULAR FOOD SYSTEM	**2.1 Endorse a balanced diet and cut food waste**	• Embrace a dietary shift towards a vegetarian diet • Cut avoidable post-consumer waste generation and maximise food recycling	Reduction of material footprint by **5.1%**, decrease from 1,025 to **975 million tonnes**. Reduction of carbon footprint by **3.3%**, decrease from 749 to **724 million tonnes** of CO_2e. Circularity Metric rises from 7.5% to **8.7%**. Co-benefits: Reduced energy consumption, value and employment creation, strengthened resilience and competitiveness.
	2.2 Shift to more sustainable food production	• Shift towards organic, seasonal and local food production • Reduce fertiliser use, heating fuels and transportation services	
3. ADVANCE CIRCULAR MANUFACTURING	**3.1 Implement resource efficient manufacturing**	• Improve industrial processes to reduce virgin inputs for key manufacturing industries • Reduce yield losses • Divert scraps	Reduction of material footprint by **5.1%**, decrease from 1,025 to **975 million tonnes**. Reduction of carbon footprint by **3.3%**, decrease from 749 to **724 million tonnes** of CO_2e. Circularity Metric rises from 7.5% to **8.7%**. Co-benefits: Reduced energy consumption, value and employment creation, strengthened resilience and competitiveness.
	3.2 Employ R-strategies for machinery, equipment and vehicles	• Increase the lifetime of machinery, equipment and vehicles • Increase remanufacturing, refurbishment, repair and maintenance, upgrade and reuse services	
4. RETHINK TRANSPORT AND MOBILITY	**4.1 Reduce or avoid travel or need to travel**	• Embrace a car free lifestyle and practise car-sharing to reduce car use • Improve modal shift and increase public transport occupancy • Encourage flexible, hybrid mix homeworking • Reduce air travel	Reduction of material footprint by **7%**, decrease from 1,025 to **953 million tonnes**. Reduction of carbon footprint by **8.4%**, decrease from 749 to **686 million tonnes** of CO_2e. Circularity Metric rises from 7.5% to **8%**. Co-benefits: Improved air quality, greater access to mobility through improved sharing and public transport systems.
	4.2 Drive efficient vehicles and electrify the fleet	• Prioritise smaller and lightweight vehicles • Electrify private cars, buses, and freight transport	

Table six shows a summary of results for each scenario.

SCENARIOS, INTERVENTIONS & STRATEGIES

	INTERVENTIONS	STRATEGIES	IMPACT
5. WELCOME A CIRCULAR LIFESTYLE	**5.1 Embrace a 'material sufficiency' lifestyle**	• Reduce textile consumption and prioritise circular textiles (reusing, repairing, DIY, donating, recycling) • Adopt a minimalist lifestyle for furniture and home appliances, increase reparation • Encourage non-market and community-based services • Encourage local travel and leisure • Prioritise recycled and digital over physical paper products	Reduction of material footprint by **13.2%**, decrease from 1,025 to **890 million tonnes**. Reduction of carbon footprint by **11.5%**, decrease from 749 to **663 million tonnes** of CO_2e. Circularity Metric rises from 7.5% to **8.6%**. Co-benefits: Improved wellbeing, less waste, litter and pollution, more inclusive and resilient communities.
6. TACKLE THE UK'S IMPORT FOOTPRINT	**6.1 Shift away from high-impact imports**	• Substitute highly-impactful imports with locally available alternatives • Increase efficiency in local industries	Reduction of material footprint by **8.4%**, decrease from 1,025 to **939 million tonnes**. Reduction of carbon footprint by **3.3%**, decrease from 749 to **724 million tonnes** of CO_2e. Circularity Metric rises from 7.5% to **8.1%**. Co-benefits: Reduced environmental degradation, waste and pollution abroad, strengthened resilience.
COMBINED SCENARIOS	**The power of combined interventions**	**This row** presents the baseline result for enacting all scenarios in combination with each other.	Reduction of material footprint by **40%**, decrease from 1,025 to **616 million tonnes**. Reduction of carbon footprint by **43%**, decrease from 749 to **427 million tonnes** of CO_2e. Circularity Metric rises from 7.5% to **14.1%**.

Table six shows a summary of results for each scenario.



5

THE ROLE OF BUSINESS IN CLOSING THE GAP

Exploring key levers for UK corporations to advance circularity

Over the past ten years, the circular economy has gained traction across companies around the world. The term is being seen more frequently in corporate job titles—and in some cases, has become integral to sustainability strategies. Whilst the theory of circularity is appealing, it is still fragmentally applied in practice. The application of circular principles offers significant potential for organisations to achieve corporate objectives, including value chain resilience, cost reductions, and net-zero targets whilst working towards the Sustainable Development Goals. It also provides a planet-positive option for consumers, who are increasingly seeking out more sustainable products. This chapter explores how companies across industries can bridge the implementation gap and become more circular; decoupling financial value creation from unsustainable consumption and production.

INTEGRATING CIRCULAR ECONOMY THINKING INTO ORGANISATIONS: KEY PRINCIPLES

The circular economy is based on decoupling material use from economic value, simultaneously tackling the triple planetary crisis of climate change, biodiversity loss and waste and pollution. Circular economy principles are key to achieving the Sustainable Development Goals on the whole, and particularly Goal 12 on sustainable consumption and production. The principles of circularity—narrow, slow, regenerate and cycle (see page 19)—as illustrated in depth in Chapter four can be used by businesses shifting towards circularity.

FINANCIAL, RISK AND REPORTING	With the exception of a few sectors, business risks related to the linear economy are not integrated into business planning and circular metrics and risks are not required for mandatory financial reporting. Uncertainty around the profitability and cash flow associated with circular business models hinders uptake and scaling. The drivers to move away from traditional linear business models that have been historically profitable are perceived as weak.
ORGANISATIONAL	Circularity needs to be managed across business functions given its implications on value chains, products and business models. This will require clear leadership and strategy from the top and delegated responsibilities across organisations to drive circular change, backed up with clear targets and KPIs.
OPERATIONAL	Most current business models are designed to sell products without retaining control of them, being responsible for extending their lifetimes or dealing with them at the end-of-life stage. Businesses that sell a wide range of products may need different circular solutions for each value chain rather than a single solution, making the process complex. Even changes that seem simple at surface level—such as material substitutions—are hampered by limitations, such as quality concerns for secondary raw materials, or supply of necessary components.
REGULATORY	The UK has made and is planning initial policy steps towards a more circular economy, including the introduction of a Deposit Return Scheme and a revamp of Extended Producer Responsibility (EPR). However, the current regulatory and fiscal landscape within which companies operate supports a linear economy with few incentives to reduce waste and little advantage for companies to ensure product life extension. The regulatory landscape is changing rapidly, but there is still uncertainty regarding how companies should react and adapt to these changes.
CULTURAL AND CONSUMER BEHAVIOURS	Consumers indicate a desire to be more sustainable, but they still want convenience and need to be confident in, for example, product standards and the economic value of repair before consumption patterns can support more circular business models.

Table seven outlines some of the challenges businesses may face in the transition to circularity.

CURRENT CHALLENGES FOR ORGANISATIONS

The UK economy currently operates within regulatory, fiscal and behavioural systems that are largely linear. Although this is changing, businesses can still face several challenges in the transition to circularity.

Despite the challenges summarised in Table seven on the previous page, there are many examples of circular business and operating models. There are several factors that support and/or incentivise progress on circularity, for example:

- Products with high intrinsic value or that contain critical raw materials that are scarce or experience market volatility.
- Products that can be refurbished and remanufactured as they retain high value, eventually making them more cost effective.
- Products that can technically be repaired, refurbished, reused and recycled including those supported through quality standards, tooling availability, technical capability and without impacting warranties.
- Products that are easily leased or rented and where customers are keen to do so.
- Regulations that lead to fiscal or legal obligations or opportunities to act, such as for packaging.
- Short and transparent value chains that support product take back.
- Companies that agree to commitments and targets, such as waste reduction targets.
- Products that do not become redundant for technological or aesthetic reasons.
- Products that are designed to allow for recycling.

MAKING THE CHANGE FROM LINEAR TO CIRCULAR

Moving from a linear to a circular business can seem like a massive transformation. However, companies can start by setting a baseline, and piloting new value propositions before moving towards a full-scale transformation.

1. Map material flows

Businesses can map material flows for their products, as this report does for the UK economy as a whole. The first step for an organisation looking to go circular is to understand how materials flow throughout its business, asking where they come from and where they'll go, while examining the percentage of circular versus non-circular materials in circulation, the supply risks and the environmental and social impact. By understanding this baseline, companies can discern key levers for change by highlighting hotspots of material use and waste along the value chain.

2. Create a circular value proposition

After identifying primary materials or products, companies can start by piloting a new value proposition, measuring its success and then scaling.

There are three types of value propositions a company can offer:

- **Circular product design:** this could include the use of renewable or recycled materials, designing for recycling, repair or upgradability, modular design, or the minimisation of material use. A full-scale overhaul of product design can be supported by a set of organisational circular design principles.
- **Circular services:** offering services to customers that will help them be more circular. This could include repair services, product take back, warrantees, recycling services, ongoing software support for devices, and upgrades.
- **Circular business models:** shift from selling products to offering them as a service, offer the sharing of assets, refurbishment, and sale of second-hand products, and change delivery methods by switching to reusable packaging, for example.

Each business has a different starting point: some start-up companies have based their entire offering on circular economy principles, for example, while other companies will consider incremental shifts in their current models. In some cases, policy and regulation—such as the plastic tax and EPR schemes for packaging—may instigate the first shift towards more circular thinking in an organisation.

3. Shift to a circular operating model

When undertaking any of these transformations—from the incremental to the fundamental—a company will need to consider its capabilities and how they can support circularity. In Figure five, the sphere of control maps the key capabilities a company will need to engage and develop to make the transition. A circular economy requires a systemic change: this means that many factors are often not fully under the control of one company. The sphere of influence maps the key collaborations a company will need to undertake along its value chain and throughout its broader ecosystem. The external drivers map some of the key drivers that push the company towards a more circular model.

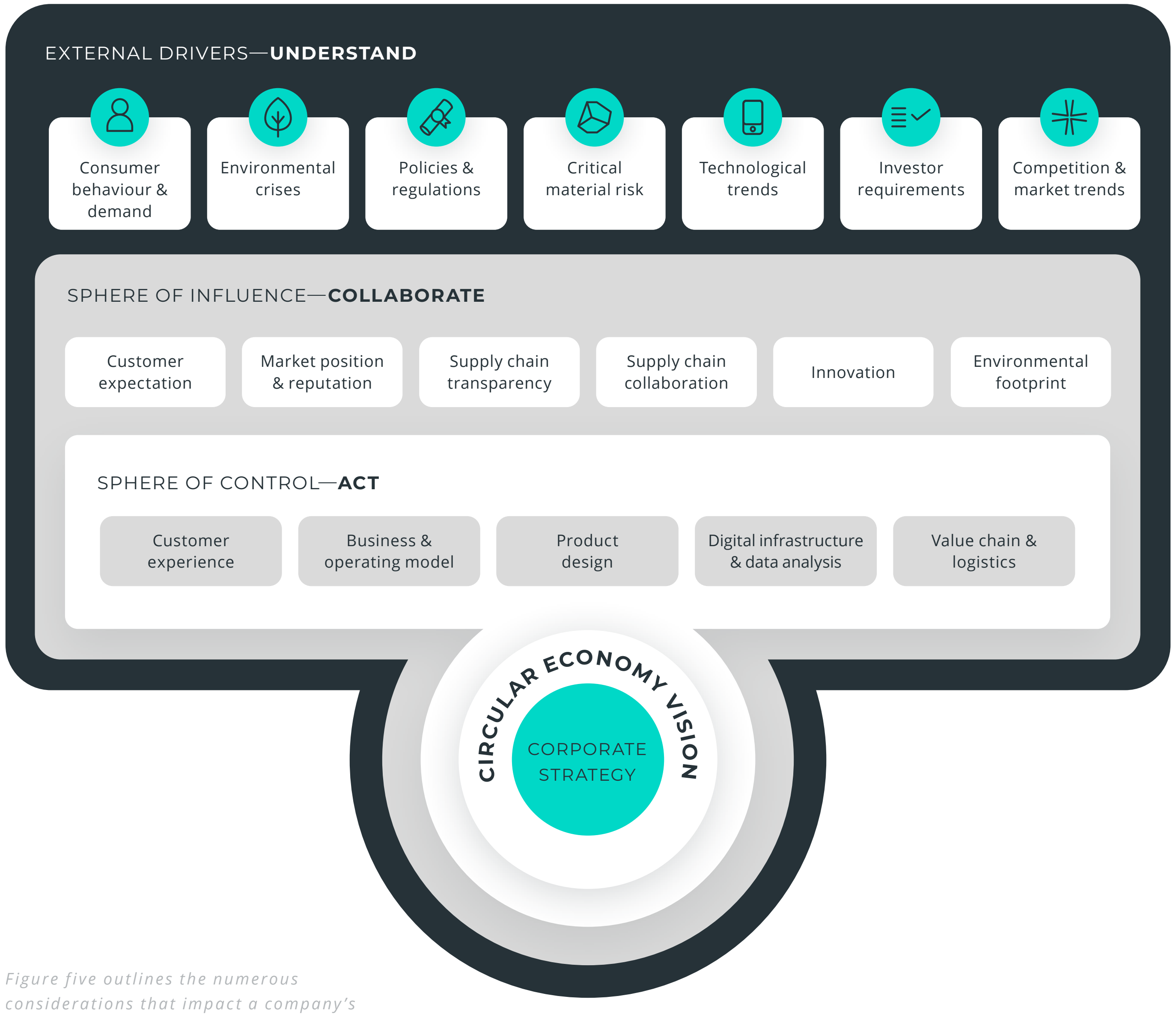


Figure five outlines the numerous considerations that impact a company's decisions about going circular (Image by Deloitte, adapted by Circle Economy).

MAINSTREAMING ACROSS THE BUSINESS

Whether establishing pilots or separate business units to test circular ideas, or looking for a more widespread transition to a circular economy, implementing circular principles in a business requires changes at the core of many business functions.

EXECUTIVE	• Provide top-level leadership in support of circular initiatives. • Establish governance and organisational structures to deliver the circular strategy • Identify appropriate metrics and KPIs to deliver the strategy, and ensure clear links and integration with other strategic objectives: business risk management and net-zero targets, for example. • Consider appropriate value chain partners to deliver circular objectives, and build these relationships.
FINANCE TEAMS	• Investigate and assess business cases for circular economy business models that require investment and have different cash flow patterns. • Support funding mechanisms to deliver circular objectives. • Engage with investors to gain buy-in for circular business models, or use circular strategies to promote investment opportunities. • Implement financial and alliance relationships to support the value recovery of materials and components, or the technologies and digital solutions that support this process.
PRODUCTION AND MANUFACTURING TEAMS	• Consider appropriate value chain partners to deliver circular objectives and collaborate across value chains. • Apply and scale technologies that support the delivery of circular strategies. • Ensure product take-back and optimal reuse and remanufacturing. • Ensure transparency and traceability across the value chain, • Design products and processes for zero waste and to meet business model aims, such as repairability for service-based models.
R&D TEAMS	• Focus R&D to develop products and processes that are designed for the chosen circular strategy. • Test new materials and changed designs to ensure that they align with material and product performance requirements and standards. • Develop and identify technologies that support the delivery of circular strategies, including cascading materials at end-of-life. • Develop and adapt machining and tooling to work with new materials and designs, as well as efficient packaging.
PROCUREMENT TEAMS	• Procure secondary raw materials from current or new suppliers, ensuring they are good quality and appropriately priced. Reduce overspecification where possible to lower unnecessary material use, particularly for infrastructure. • Capture required data from suppliers: for example, that which relates to material composition and component repair, as well as information to support recycling, provenance, by-products and footprints. • Develop the skills and capabilities needed to support reverse supply chains, and include this at the right stage in the procurement cycle.
MARKETING AND CUSTOMER RELATIONS TEAMS	• Promote customer behaviours in support of circular strategies including uptake for new products and services, whether business-to-consumer or business-to-business. • Support customers in the delivery of circular strategies, such as those related to take back, product longevity and recycling.
HUMAN RESOURCES	• Enhance awareness of circularity throughout the organisation through training, for example. • Upskill employees as needed to deliver circular ambitions. • Create a corporate culture, including the right incentives, that supports delivery of the chosen circular model.
INFORMATION TECHNOLOGY TEAMS	• Implement systems to capture and share product data, and encourage material traceability and value chain transparency. • Use technologies that support circular objectives such as resource efficiency, waste reduction, product and component longevity, take back and cascading. • Consider opportunities for extending the life of (electronic) equipment, considering refurbished products and reuse of component parts.
LOGISTICS TEAMS	• Develop take-back mechanisms internally and with eternal partners • Establish systems to capture the quality, volume and timing of returns to support product cascading. • Optimise vehicle utilisation and consider opportunities for circularity in fleet maintenance.
RPROPERTY AND FACILITIES MANAGEMENT	• Consider circularity criteria when commissioning buildings, fittings and fixtures. • Invest in furniture and office materials that are circular, such as refurbished products, recycled products, or those with contracts for repair. • Consider leasing models for large office equipment and explore opportunities for Products-as-a-Service (for printers, for example).

Table eight outlines examples of changes across organisational functions.

NEXT STEPS FOR BUSINESS

Each sector has its own challenges and barriers in the application of circular principles, and therefore each will have a different path forward. There are a number of actions that could be considered by all businesses as next steps on the transition towards a more circular economy:

1. Consider appropriate steps for your organisation, customers and value chain—and start piloting and scaling

The maturity of circular thinking within an organisation will clearly influence its next steps—so a baseline assessment will be crucial to provide clarity on how and where the circular economy is relevant. It will also give inspiration to develop and analyse pilots to test ideas and eventually scale ideas that work. Some initiatives may progress faster than others: for example, some businesses may be able to increase their secondary raw materials use faster than they could switch business models—although the latter may end up accelerating the circular economy transition at a faster pace.

2. Collaborate with others in the sector and with those in the circular economy space to identify a clear sector roadmap and address shared policy requirements from government

Clear sector-level visions and roadmaps can provide clarity on risks and a path forward, establishing what needs to be measured and what potential targets could be. Sector-level roadmaps can also direct public policy. A level policy playing field that removes incentives that favour the linear whilst establishing the fiscal and policy landscape that supports the circular economy is vital. Common standards, the development of underpinning infrastructure and clear disclosure guidelines are the foundations for scaling the circular economy transition.

3. Identify the knowledge, tools and systems that would support the transition across businesses.

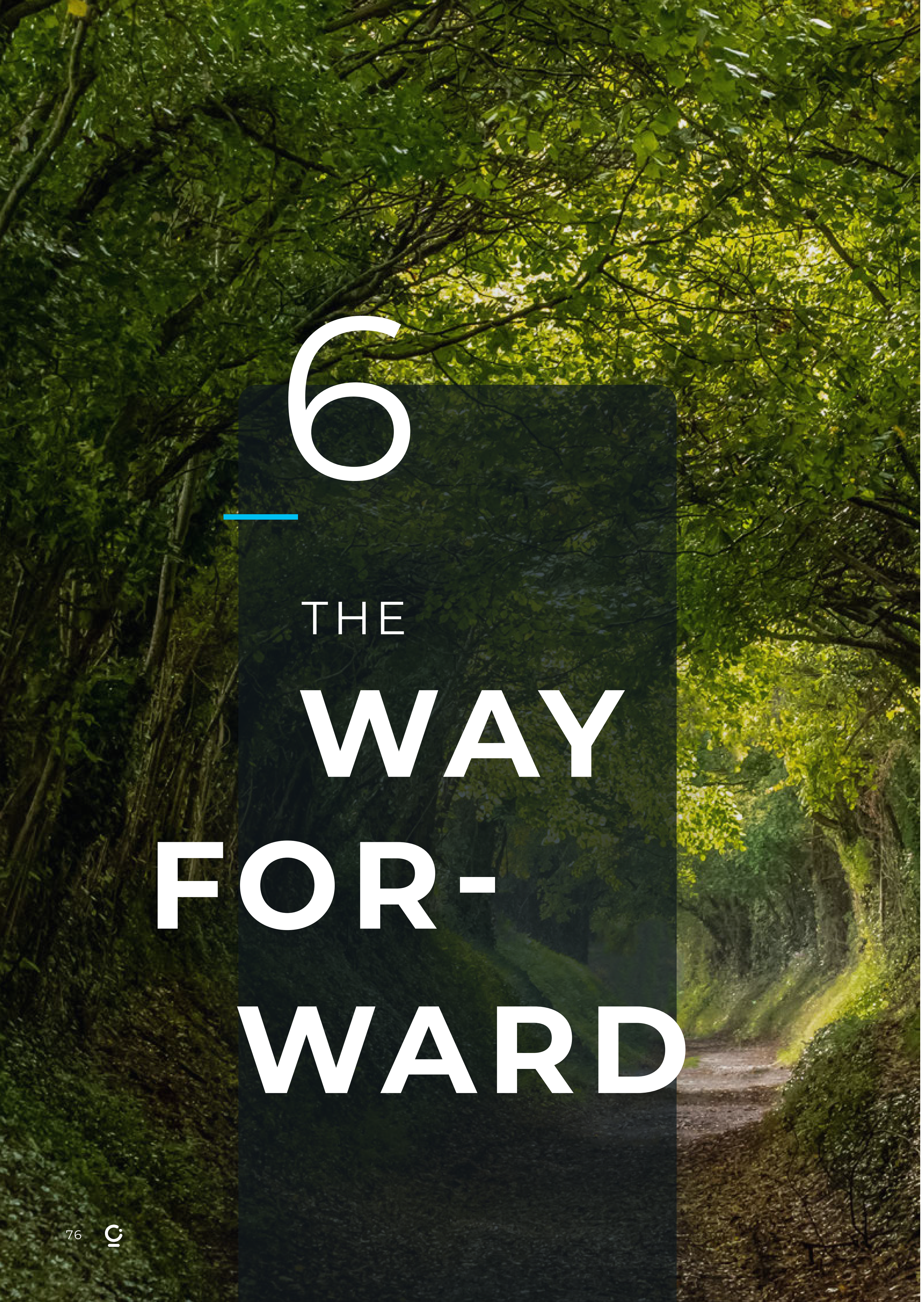
Building the knowledge and skills within each sector to understand, embed and innovate is needed. Supporting tools and systems will enable businesses to deliver on circular objectives, enabling science-based decision making and confidence in the practical delivery of circular objectives.

4. Channel finance to deliver a circular economy in the UK

Finance is critical to delivering circularity. For organisations, developing a solid business case will be critical to secure investment—an exercise made more complex by numerous product cycles, uncertainty over resource value over time and cash flow arising from service rather than product delivery models. Some investors are interested in the opportunities a circular economy may bring. Taking this lens across financial instruments and products will highlight opportunities to be exploited. As the circular economy is included as one of six environmental objectives in the EU taxonomy that assesses 'what is a sustainable activity', this aspect will become increasingly relevant. Companies will have to report whether they 'contribute substantially' or 'do no significant harm' for inclusion in ESG investment products.

5. Develop metrics that measure circularity interventions that support the delivery of carbon reduction and other business objectives

Metrics for circularity are becoming more widespread, generally based around production and consumption, waste management, secondary raw materials, innovation, and business competitiveness. An extension of targets to drive change at scale, similar to net-zero targets for carbon, would prioritise the reduction of resource use. Measuring embodied emissions, which are often tightly linked to consumption, may also help serve this aim.



6 THE WAY FORWARD

The UK economy has transformative potential: it can substantially cut its material and carbon footprints, while more than doubling its Circularity Metric. This report provides insight into how the country can substantially cut its material and carbon footprints (by around 40%) and almost double its Circularity Metric, bringing it from 7.5% to 14.1%. The six scenarios provide illustrative examples of how the UK could structurally reshape its economy, swapping out linear, materials- and emissions-intensive processes for solutions that efficiently use materials: maintaining their value, minimising waste and regenerating natural systems. This transformation, if done well and designed with this purpose in mind, can also contribute to the country's broader social goals: providing for the needs of UK society within planetary boundaries. In all, behaviour change is not essential just for achieving environmental aims, but also for delivering wider societal benefits. There is a need to fundamentally transform production patterns and challenge current lifestyles to shift towards a fair consumption space for all.[329, 330]

The circular economy is crucial to reducing the environmental impacts of the UK economy, at home and abroad. The net-zero and circular economy agendas are not only complementary, but mutually reinforcing. For the UK to become climate neutral, it must also become resource-light. Decarbonisation is only one piece of the puzzle; the circular economy can deliver on environmental objectives such as pollution and water stress reduction, and biodiversity protection. Achieving net-zero by 2050 will require ambitious targets for cutting the UK's material footprint by half, at a minimum.[331] As resource policy is devolved, these targets are already emerging from some constituent countries' governments: Northern Ireland, for example, has set a goal to halve its material footprint, while Wales has said it will achieve 'one planet resource use'. Additionally, while territorial emissions have dipped by 44% since 1990, changes to the UK's energy mix have dominated this decline. Reductions now need to be extended to the rest of the economy if long-term net-zero commitments—as well as broader environmental objectives—are to be met in time.

The circular economy must be a key pillar of strategic business and economic plans. Reducing and maximising the value of material inputs to the economy will not only reduce environmental pressures, but also deliver cost savings, drive productivity growth, spur new regional and circular value chains, and create jobs. This will also entail redefining *value*. For example, the circular economy holds huge potential to contribute to the protection and enhancement of the UK's natural capital assets, worth at the moment approximately £1.2 trillion,[332] and contribute to the growth of the annual output of the environmental goods and services sector (EGSS), estimated to be worth £89 billion.[333] Moreover, advancing the circular economy also brings economic benefits and builds the resource resilience of the UK due to enhanced material security and stronger supply chains.[334]

UK nations and local and regional initiatives will play a pivotal role in the transition as promoters, facilitators and enablers. The UK already boasts a solid circular economy-related stakeholder ecosystem. Celebrating, strengthening and building upon these local initiatives and communities via support and collaboration will be a crucial complement to top-down action. Enabling environments at the local level—such as the regional circular economy hubs operating in London—can help shape a circular neighbourhood approach that encourages behaviour change.[335] Similarly, learning from and capitalising on established dedicated industry verticals, such as the circular fashion ecosystem piloting in Leeds,[336] provides a path to engagement and ownership by all actors. Collaboration across sectors and disciplines together with facilitation of clusters, incubation spaces and networks where there is a gap is needed to maximise the potential of existing and future initiatives.

The UK has a huge opportunity—it should not risk missing out. The UK is well-positioned to take on the challenge of going circular. With well-formed goals for decarbonisation, a rich ecosystem of motivated stakeholders, and the circular economy gaining traction in both policy-making and business strategies, the UK is already taking its crucial first steps to leave linear behind. Many areas are rife with potential: boosting recycling rates for chemical and medical waste, animal and vegetal wastes, mixed ordinary waste and recyclables are key low-hanging fruits which could serve as avenues for the UK to raise its Circularity Metric. At the same time, there's ample scope to tap into the potential of high-value circular activities not captured by the Metric, such as repair, reuse and remanufacturing, unlocking new economic and business opportunities. The circular economy transition can serve to tackle multiple objectives—mitigating climate breakdown, building resilience, improving productivity, and shaping a more dynamic economy. On its journey forward, the UK must embrace bold action: the risk of missing out on the opportunities a circular economy could bring is one too great to take.

RECOMMENDATIONS AND NEXT STEPS TO BRIDGE THE CIRCULARITY GAP THROUGH LEADERSHIP AND ACTION

1. TAKE A SHARED APPROACH TO CIRCULARITY

Levels of ambition vary across the UK's four constituent countries, with each boasting its own starting point, needs, legislation and approach. Create an integrated and inclusive circular economy approach that aligns with the broader net-zero strategy and is complemented by clear, transparent reporting and monitoring on progress. Support intragovernmental efforts across the UK and strengthen public-private partnerships for shaping a shared vision. This will include strengthening regional and global knowledge to transition towards circularity and reduced consumption.

2. CREATE A COMPREHENSIVE SET OF INDICATORS AND TARGETS TO GUIDE THE TRANSITION

Ingrain reductions in the material footprint, consumption-based emissions and waste into targets and national policy-making to drive change at the scale, scope and speed needed. Integrate resource consumption metrics with net-zero targets, building on the Climate Change Committee's 6th carbon budget.[337] Measure success with comprehensive indicators backed by extensive data gathering at the sector- and business-level. Include indicators regarding circular employment in sector-specific targets to enable and support the transition.

3. SHAPE A LEVEL PLAYING FIELD THROUGH A FIT-FOR-PURPOSE POLICY FRAMEWORK

The Government, particularly His Majesty's Treasury, can encourage and support demand for circular goods and services. Redesign the fiscal framework to incentivise impactful change, through the taxation of virgin material use and the reduction or elimination of VAT rates on circular practices such as product repair and retrofitting, for example. Develop a UK taxonomy to guide capital flows towards circular economy activities.

4. UPGRADE PRODUCT STANDARDS TO IMPROVE END PRODUCTS AS WELL AS INTERMEDIATE MATERIALS

So far, product standards have been almost exclusively limited to energy efficiency, but their potential is far greater. The Government can use the powers given by the new *Environment Act* to shape stricter standards for repair, disassembly and ecolabelling, including resource efficiency standards for non-electronic products for the first time. Advancing the right to repair also holds great potential to improve product durability and support high-value circular practices.

5. HARNESS GOVERNMENT POWER TO DRIVE ACTION

Transitioning to a circular economy requires active government engagement to drive change by reshaping markets and investing in long-term, enabling infrastructure projects. The Government can use its market power, for example through public procurement and targeted investments, while creating clear criteria for purchasing decisions to influence the market. Help businesses invest in the advanced infrastructure and technology needed to boost their operations' circularity. Focus on capacity building and knowledge sharing across various levels of government.

6. ENCOURAGE BUSINESSES IN KEY SECTORS TO LEAD FROM THE FRONTLINES

Businesses have the opportunity and ability to accelerate the transition by adopting more circular practices. From incorporating circular design principles and using sustainable materials to developing innovative business models and shortening supply chains, businesses are well-positioned to deliver impactful change.

7. ENSURE ACTION IS DIVERSE AND CITIZEN-CENTRIC

Citizens, businesses, government, NGOs and academia need to work collectively to enable consumers to radically change patterns of consumption through offering sustainable goods and services, raising awareness of the need and opportunities for change, and creating fiscal and policy drivers.

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50. Net Extraction Abroad (NEA) is the difference between the trade balance of products and the raw materials needed to produce them. The difference between the two represents the 'actual' or net amount of raw materials that are extracted abroad to satisfy domestic consumption (that is, as the net amount of those that are extracted domestically to satisfy demand abroad). A large NEA figure means that the country or region imports products with extremely high embodied resources (or large 'ecological rucksack') either because of their nature (for example, some fertilisers might require the excavation of a lot of other rocks and minerals for their extraction, just like metal ores) or because of the inefficient production processes carried out by trading partners (including the embodied impact of infrastructure). Unfortunately, pinpointing specific products or trading partners responsible for high NEA is

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APPENDICES

APPENDIX A: GLOSSARY

Circularity Metric & Circularity Gap The Circularity Metric measures the share of secondary materials over total material consumption of an economy in any given year (see also: socioeconomic cycling). The Circularity Gap refers to the opposite: the share of virgin materials over total material consumption. For more details see also socioeconomic cycling and total material consumption.

Consumption refers to the usage or consumption of products and services meeting (domestic) demand. Absolute consumption refers to the total volume of either physical or monetary consumption of an economy as a whole. In this report, when we talk about consumption we are referring to absolute consumption.

Cycling refers to the process of converting a material into a material or product of a higher (upcycling), same (recycling) or lower (downcycling) embodied value and/or complexity than it originally was.

Domestic Extraction (DE) is an environmental indicator that measures, in physical weight, the amount of raw materials extracted from the natural environment for use in any economy. It excludes water and air. [Source]

Domestic Material Consumption (DMC) is an environmental indicator that covers the flows of both products and raw materials by accounting for their mass. It can take an 'apparent consumption' perspective—the mathematical sum of domestic production and imports, minus exports—without considering changes in stocks. It can also take a 'direct consumption' perspective, in that products for import and export do not account for the inputs—be they raw materials or other products—used in their production. [Own elaboration based on Source]

Economy-wide material flow accounts (EW-MFA) are a 'statistical accounting framework describing the physical interaction of the economy with the natural environment and with the rest of the world economy in terms of flows of materials.' [Source]

Environmental stressor, in Input-Output Analysis, is defined as the environmental impact occurring within the region subject to analysis. There is therefore an overlap between the stressor and the footprint, as they both include the share of impact occurring within a region as a result of domestic consumption. This is how they differ: while the rest of the stressor is made up of impacts occurring within a region as a result of consumption abroad (embodied in exports), the footprint includes impacts occurring abroad as a result of domestic consumption (embodied in imports).

Emissions We differentiate between *territorial* and *consumption-based emissions*, as well as *industrial* and *household emissions*. **Territorial emissions** are calculated based on the traditional accounting method for GHG emissions, with a focus on domestic emissions, mainly coming from final energy consumption. **Consumption-based emissions** are calculated using input–output modelling to not only account for domestic emissions but also consider those that occur along the supply chain of consumption of goods and services. In this way, the embodied carbon of imported products is accounted for. At the same time, we also differentiate between emissions attributed to **industrial** activities, and those directly attributable to **households** through activities such as household heating and private transport.

Greenhouse gases (GHG) refers to a group of gases contributing to global warming and climate breakdown. The term covers seven greenhouse gases divided into two categories. Converting them to **carbon dioxide equivalents** (CO_2e) through the application of characterisation factors makes it possible to compare them and to determine their individual and total contributions to Global Warming Potential (see below). [Source]

High-value recycling refers to the extent to which, through the recycling chain, the distinct characteristics of a material (the polymer, the glass or the paper fibre, for example) are preserved or recovered so as to maximise their potential to be re-used in a circular economy. [Source]

Materials, substances or compounds are used as inputs to production or manufacturing because of their properties. A material can be defined at different stages of its life cycle: unprocessed (or raw) materials, intermediate materials and finished materials. For example, iron ore is mined and processed into crude iron, which in turn is refined and processed into steel. Each of these can be referred to as materials. [Source]

Material footprint, also referred to as Raw Material Consumption (RMC), is the attribution of global material extraction to the domestic final demand of a country. In this sense, the material footprint represents the total volume of materials (in Raw Material Equivalents) embodied within the whole supply chain to meet final demand. The total material footprint, as referred to in this report, is the sum of the material footprints for biomass, fossil fuels, metal ores and non-metallic minerals. [Source]

Material flows represent the amounts of materials in physical weight that are available to an economy. These material flows comprise the extraction of materials within the economy as well as the physical imports and exports (such as the mass of goods imported or exported). Air and water are generally excluded. [Source]

Net Extraction Abroad (NEA) represents the difference between the trade balance of products and that of the raw materials needed to produce them. The difference between the two represents the 'actual' or net quantity of raw materials that have been extracted abroad to satisfy domestic consumption.

Raw Material Consumption (RMC) represents the final domestic use of products in terms of RME. RMC, referred to in this report as the 'material footprint', captures the total amount of raw materials required to produce the goods used by the economy. In other words, the material extraction necessary to enable the final use of products. [Source]

Raw Material Equivalent (RME) is a virtual unit that measures how much of a material was extracted from the environment, domestically or abroad, to produce the product for final use. Imports and exports in RME are usually much higher than their corresponding physical weight, especially for finished and semi-finished products. For example, traded goods are converted into their RME to obtain a more comprehensive picture of the 'material footprints'; the amounts of raw materials required to provide the respective traded goods. When RMEs are high, it means a country is carrying a hefty '**ecological rucksack**': the weight of materials taken from nature to make a product, minus the weight of the product itself. [Source]

Resources include, for example, arable land, fresh water, and materials. They are seen as parts of the natural world that can be used for economic activities that produce goods and services. Materials are biomass (like crops for food, energy and bio-based materials, as well as wood for energy and industrial uses), fossil fuels (in particular coal, gas and oil for energy), metals (such as iron, aluminium and copper used in construction and electronics manufacturing) and non-metallic minerals (used for construction, notably sand, gravel and limestone). [Source]

Secondary materials are materials that have been used once and are recovered and reprocessed for subsequent use. This refers to the amount of the outflow which can be recovered to be re-used or refined to re-enter the production stream. One aim of dematerialisation is to increase the amount of secondary materials used in production and consumption to create a more circular economy. [Source]

Sector describes any collective of economic actors involved in creating, delivering and capturing value for consumers, tied to their respective economic activity. We apply different levels of aggregation here—aligned with classifications as used in Exiobase V3, a global, detailed Multi-regional Environmentally Extended Supply and Use / Input Output database. These relate closely to the commonly used European sector classification framework NACE Rev. 2.

Socioeconomic cycling is the technical term for the Circularity Metric. It comprises all types of recycled and downcycled end-of-life waste, which is fed back into production as secondary materials. Recycled waste from material processing and manufacturing (such as recycled steel scrap from autobody manufacturing, for example) is considered an internal industry flow and is not counted as a secondary material. In the underlying model of the physical economy used in this report, secondary materials originate from discarded material stocks only. The outflows from the dissipative use of materials and combusted materials (energy use) can, by definition, not be recycled. Biological materials that are returned back to the environment (for example, through spreading on land) as opposed to recirculated in technical cycles (for example, recycled wood) are not included as part of socioeconomic cycling. Energy recovery (electricity, district heat) from the incineration of fossil or biomass waste is also not considered to be socioeconomic cycling, as it does not generate secondary materials.

Socioeconomic metabolism describes how societies metabolise energy and materials to remain operational. Just as our bodies undergo complex chemical reactions to keep our cells healthy and functioning, a nation (or the globe) undergoes a similar process—energy and material flows are metabolised to express functions that serve humans and the reproduction of structures. Socioeconomic metabolism focuses on the biophysical processes that allow for the production and consumption of goods and services that serve humanity: namely, what and how goods are produced (and for which reason), and by whom they are consumed. [Source]

Total material consumption is calculated by adding Raw Material Consumption (material footprint) and secondary material consumption (cycled materials).

APPENDIX B: HOW THE FOUR CIRCULAR STRATEGIES WORK TOGETHER

There are potential overlaps between some of the four circular strategies: narrow, slow, regenerate and cycle. For example, slow and cycle interventions often work together. By harvesting spare parts to use again, we are both cycling—by reusing components—and slowing, by extending the lifetime of the product the components are used for. And ultimately, slowing flows can result in a narrowing of flows: by making products last longer, fewer new replacement products will be needed—resulting in decreased material use. There are also potential tradeoffs between the four strategies to be acknowledged. Fewer materials being used for manufacturing—narrow—means less scrap available for cycling. Similarly, if goods like appliances and vehicles are used for longer—slow—their energy efficiency falters in comparison with newer models, preventing narrowing. Using products for a long time—slowing flows—decreases the volume of materials available for cycling: this can have a significant impact on material-intensive sectors like the built environment, where boosting the availability of secondary materials is particularly important. What's more: some strategies to narrow flows, like material lightweighting, can result in decreased product quality and thus shorter lifetimes—making it more difficult to slow flows.[338]

APPENDIX C: DYNAMICS INFLUENCING THE CIRCULARITY METRIC

Applying our Circularity Gap methodology to countries is complex, and has required us to make a number of methodological choices. In a bid to generate actionable insights for national economies, and to enable comparison between countries, our *Circularity Gap Reports* take a consumption perspective: we consider only the materials that are consumed domestically, and allocate responsibility to consumers by excluding exports. However, there are some limitations to our approach: the more 'open' an economy is the more susceptible to the limitations of both the material flow analysis and input-output analysis, the latter in particular. Some of these limitations include difficulties in calculating the import content of exports.

Secondly, most production is ultimately driven by consumer demand for certain products or services. In an increasingly globalised world, the chain that connects production to consumption becomes more entangled across regions. Demand-based indicators—applied in this analysis—allow for a re-allocation of environmental stressors from producers to final consumers. This ensures transparency for countries with high import levels and also supports policies aimed at reducing or shifting consumer demand, at helping consumers understand the material implications of their choices, or at ensuring that costs of, and responsibilities for, resource depletion and material scarcity are allocated to entities and regions based on their roles in driving production processes through consumption.

Thirdly, when considering what residents of the UK consume to satisfy their needs, we must apply a nuanced lens to the direct imports; meaning we work out the full material footprints of the products. To account for the material footprint of raw materials is straightforward, but this is not the case with semi-finished and finished goods. To represent actual material footprints in imports and exports, we apply so-called RME (Raw Material Equivalents) coefficients in this study. As an open, high-income economy with trade equal to 63% of its GDP (2019),[339] doing so in the case of the UK is more complex than for a smaller, less integrated economy.

Finally, the Circularity Metric represents a country's efforts to use secondary materials; this includes waste collected in another country and later imported for domestic use, opposite the case of the UK, which has a heavy negative trade balance in recyclable waste. The total amount of waste recycled in treatment operations is therefore adjusted by adding waste imports to—and subtracting waste exports and by-products of recovery from—the amount of waste recycled in domestic recovery plants. When we adjust the volumes of recycled waste in treatment operations using imports and exports of secondary materials, 'credit' for saving virgin materials is ascribed to the country that uses that secondary material—recovered from former 'waste'. This perspective is similar to national accounts' logic, in which most re-attributions are directed at final use. The UK's waste management sector will require heavy investment in domestic high-value reuse and recycling infrastructure, such as electric arc furnaces, deconstruction hubs and other sorting, recycling and reuse infrastructure, to encourage secondary materials to be kept within the UK economy. The market is not bound by geographical borders and materials can be transported wherever makes most logistical, environmental and economic sense, which currently means shipping some waste for incineration and recycling abroad.

However, it's also possible to take a more 'production-oriented' approach, in which 'credit' for recycling efforts is given to the country that collects and prepares waste for future cycling. This is, for example, the perspective taken by Eurostat in its calculation of the Circular Material Use Rate. For more information on this, refer to the methodology document.

APPENDIX D: PRACTICAL CHALLENGES IN QUANTIFYING CIRCULARITY

The circular economy is full of intricacies: quantifying it in one number presents a number of limitations. These are:

- **There is more to circularity than (mass-based) cycling.** A circular economy strives to keep materials in use and retain value at the highest level possible, with the aim of decreasing material consumption. The cycling of materials measured by the Circularity Metric is only one component of circularity: we do not measure value retention, for example. The Metric focuses on the end-of-use and mass-based cycling of materials that re-enter the economy but does not consider in what composition, or to what level of quality. As such, any quality loss and degradation in processing goes unconsidered.
- **The Metric focuses on one aspect of sustainability.** Our Circularity Metric focuses only on material use: the share of cycled materials out of the total material input. It does not account for other crucial aspects of sustainability, such as impacts on biodiversity, pollution, toxicity, and so on.
- **Lack of consistency in data quality.** Whilst data on material extraction and use are relatively robust, data on the end-of-life stage can often be weak, presenting challenges in quantifying material flows and stocks.
- **Relative compared to absolute numbers.** The Circularity Metric considers the relative proportion of cycled materials as a share of the total material consumption: as long as the amount of cycled materials increases relative to the extraction of new materials, we see the statistic improving, despite the fact that more virgin materials are being extracted—which goes against the primary objective of a circular economy.
- **It is not feasible to achieve 100% circularity.** There is a practical limit to the volume of materials we can recirculate—in part due to technical constraints—and therefore also for the degree to which we can substitute virgin materials with secondary ones. Some products, like fossil fuels,

are combusted through use and therefore can't be cycled back into the economy, while others are locked into stock like buildings or machinery and aren't available for cycling for many years. Products that can be cycled, such as metals, plastics and glass, may only be cycled a few times as every cycle often results in lower quality and may still require some virgin material inputs. Because of this, reaching 100% circularity isn't feasible: this calls for a more nuanced approach to calculating circularity and setting targets.

APPENDIX E: WASTE MANAGEMENT

The UK's waste statistics report almost **215 million tonnes of waste**, out of which 67 million tonnes are soils and dredging spoils which should not fall within the EW-MFA system boundaries (and are therefore excluded).[340] Under the new system boundary definition, 144.6 million tonnes would show as 'reported' waste, whilst 25.4 million tonnes would be 'unreported'. Most unreported waste is made up of the recalculated amount of manure (14.7 million tonnes), the remaining are largely (10.7 million tonnes) crop residues. Out of approximately 170 million tonnes of end-of-life waste being treated (either reported or unreported), over half is technically recycled (about 96 million tonnes), while the remainder is lost indefinitely. Of the latter, 5% ends up incinerated (including energy recovery) whilst another 24% approximately is landfilled. The remaining 15% is composed mainly of waste from energetic use in the form of excreta from human food consumption which is treated in wastewater treatment plants or spread on land and is not accounted for explicitly in the socioeconomic cycling, but rather as a potential for ecological cycling (see page 22).

The difference is systems boundaries and in the indicators used explain the gap between 'technical cycling' (56.5%) and the traditional recycling rate obtained from existing waste statistics (57%). The low (0.5%) discrepancy between 'technical cycling' and existing waste statistics is a result of the relatively low contribution to recycling of waste streams excluded from system boundaries in comparison to their high(er) contribution to volume of waste treated.

The UK has a negative trade balance in recyclable waste. This means that it exports more recyclable waste (15.1 million tonnes), such as metals and plastics, than it imports (1.8 million tonnes).[341] End-of-life waste is one element of a larger indicator called Domestic Processed Output (DPO), which originates from both the material use and energetic use of products. DPO from energetic use (including food and feed) stands at 267 million tonnes: it is composed mainly of emissions to air (but also manure and combustion waste) and it is split into a biogenic part (126 million tonnes) and one of fossil origin (141 million tonnes). This, combined with 74 million tonnes of DPO from material use (end-of-life waste excluding recycled materials), adds up to a total DPO of 341 million tonnes. A small part (27 million tonnes) of this is dissipative uses and losses: materials that are dispersed into the environment as a deliberate or unavoidable consequence of product use. This includes fertilisers and manure spread on fields, or salt. These losses mostly originate from energetic use, but partially also from material use. Aside from materials going to waste, 241 million tonnes of materials are added to stock (Net additions to stocks) in the form of buildings, infrastructure, and machinery and equipment, for example.

Of the waste streams that do contribute to the Circularity Metric, and compared to other Northern European countries (see Table one), the UK has very low rates for the recycling of chemical and medical waste (0.6%), moderate rates for traditional recyclables (13%), moderate rates for mixed ordinary waste (14%), low rates for animal and vegetal waste (3.4%) and high rates for mineral waste (68%). Of all these waste types, mineral waste, recyclables, and animal and vegetal waste are most prevalent, respectively claiming 71%, 21% and 5% of the total waste treated in the UK (by weight). Better recycling rates for chemical and medical waste, animal and vegetal wastes, mixed ordinary waste and recyclables, therefore, would be key avenues for the UK to boost its Metric.

APPENDIX F: ASSUMPTIONS FOR THE SCENARIO MODELLING

Scenario one: Build a circular built environment

1.1 Optimise building stock expansion
In modelling this intervention, we examine a mix of supply and demand-side measures. To model housing stock regulation, we assume that throughout urban planning processes, fewer project approvals are given out that allow for construction with virgin materials, reducing new construction by around a third (32%). This restriction is set on three-quarters of the housing stocks. This could be achieved by regulatory and fiscal disincentives on virgin construction materials, thus supporting the uptake of secondary materials, for example. We also assume that all construction and demolition waste that is suitable for reuse—50% of the total—is cycled and used again for new construction. This could be enabled by incentivising the use of secondary materials, for example. In order to meet the demand for housing, we boost spending on housing renovation. This could be driven via targeted grants and tax breaks, for example. This is a static 'what-if' intervention that models the impact of long-term circular strategies—spanning 50 years or more—as if they would happen tomorrow without factoring in developments in the underlying socioeconomic trends, such as population changes or efficiency improvements. A combination of measures to increase average occupancy in both residential and commercial buildings were also modelled.

1.2 Create a low-carbon, energy-efficient building stock
Scenario one's second intervention focuses solely on the demand-side circular strategies. It models measures for maximising energy efficiency in the housing stock, such as deep retrofitting, as well as a greater use of energy efficient home appliances. A decrease in room temperatures of 2-degrees and more smart metering are also considered. We assume a 60% reduction in energy demand considering that deep retrofitting would help houses reach a 'passive house' standard of energy consumption. This assumption was applied to the portion of housing in need of renovation and retrofitting. It's worth noting, however, that deep retrofitting will come at the cost of extra materials and embodied carbon: it's essential that circularity is prioritised in design and material choices to ensure outcomes are beneficial. Through these measures we assume a 60% reduction in energy demand. This assumption was applied to the portion of housing in need of renovation and retrofitting. It's worth noting that deep retrofitting will come at the cost of extra materials and embodied carbon: it's essential that circularity is prioritised in design and material choices to ensure outcomes are beneficial.

1.3 Shift to resource-efficient building practices
For Scenario one's third and last intervention, three supply and demand-side strategies are combined. For the first strategy, we assume a reduction in virgin steel and aluminium consumption and also model an increase in services to construction to compensate for expected increases in the cost of demolition and assembly work. We also model two more strategies: a 15 to 20% reduction in on-site construction material losses, and an uptick in the use of local construction materials and supply chains.

Scenario two: Shift to a circular food system

2.1 Endorse a balanced diet and cut food waste
In modelling this dual intervention, we apply demand-side measures composed of three layers. First, the average per capita food consumption of UK residents is reduced to 2,700 calories per day from the current 3,400, as a proxy for adopting a balanced diet.[342] Second, avoidable post-consumer food waste (which is estimated at over two-thirds of the post-consumer waste in the UK)[343] is eliminated. We implicitly assume that this avoided waste is being recycled—whether as substitution to fodder crops, compost for nutrient recycling, or through anaerobic digestion. Third, an alternative diet composition scenario is explored to meet the above-mentioned caloric intake. The scenario is based on switching the baseline UK diet towards a vegetarian diet. The vegetarian diet considers eliminated consumption of meat products, matched by an equivalent increase in the calorific intake of cereals, fruits, vegetables and nuts.[344] We have used a vegetarian diet for this modelling but note that prevailing dietary advice recommends a diet low in meat consumption.[345]

2.2 Shift to more sustainable food production
This supply-side intervention assumes a shift to organic, seasonal and local farming—practically translating into reduced demand for synthetic fertilisers, heating fuels (for greenhouses, for example), and transportation services. We assume that output from organic farming remains the same as conventional farming, in part due to high variation between studies comparing the two methods.[346] Due to the nature of our methodological approach, we were unable to provide a detailed assessment of changes in land-use management: increased regenerative farming practices, such as agroforestry, or the role of biorefining and the production of sustainable biofuels, for example. It's worth mentioning that these can undoubtedly play a key role in advancing circularity and diminishing environmental pressures, however.[347]

Scenario three: Advance circular manufacturing

3.1 Implement resource-efficient manufacturing
In modelling this supply-side intervention, we consider a mix of strategies. We assume that metal inputs for specific products are reduced by 28% due to process improvements. We also model the impact of reducing yield losses and diverting scrap from the manufacturing industry, to other sectors, thereby reducing their virgin material use.

3.2 Employ R-strategies for machinery, equipment and vehicles
For this intervention, we first model a mix of supply-side measures. For remanufacturing and refurbishment, the overall volume of sales remains the same due to the redistribution and re-selling of the remanufactured/refurbished products, creating a new life cycle. The displacement of new sales is therefore modelled as a net reduction in the inputs needed to produce the same volume of product output. Implementing both supply and demand-side measures for repair, upgrading and reuse would yield greater benefits. This could include new business models based on servitisation (renting and leasing, for example) and more flexible supply chain management (reverse logistics, for example), where manufacturing companies can capture value by returning goods to upstream operations. For instance, companies that sell machinery may decide to rent or lease it out to customers, eventually repairing and/or remanufacturing it to extend its lifetime. For this strategy assume that the overall volume of sales is reduced, due to product lifetime extensions precluding the need for new purchases.

Scenario four: Rethink transport & mobility

4.1 Reduce or avoid travel, or the need to travel
This intervention models the impact of several demand-side measures. In modelling our first strategy, we assume that 40% of the urban population and 10% of the rural population adopt a car free lifestyle—meaning that kilometres travelled in both areas are reduced by the same percentages. Air travel is reduced by 54%: the number of flights per capita is decreased from 4.4 to 2. Additionally, around one-third of the mobility need is covered by active modes such walking or cycling, with the remaining portion covered by car sharing—resulting in an increase in average vehicle occupancy. This is partially mitigated by greater 'wear and tear' for vehicles due to higher utilisation. In modelling increased work-from-home, we assumed an equal reduction of 20% across transportation modes for commuting. Finally, in modelling a modal shift, we assume that purchases of motor vehicles are cut, along with demand for fuel, while the use of public transport such as trains and buses is optimised.

4.2 Drive cleaner mobility forward
In modelling our final intervention for transport and mobility, we examine a mix of supply and demand-side measures. We assume that the entire bus fleet and road freight, and half of car mobility, are electrically powered—keeping the demand for transportation constant.[348]

Scenario five: Welcome a circular lifestyle

5.1 Embrace a 'material sufficiency' lifestyle
For this intervention, we have separately modelled a range of strategies. The consumption of textiles is reduced, and for new purchases, items with recycled fibres or that are durable and high quality are preferred. We also assume that household appliances and furniture are minimal and purchased locally—and where possible, residents buy items that have been designed for reparability, with replacement parts available in case of breakage. Paper use is heavily decreased, by printing only what's needed, buying recycled paper and toilet paper, and increasing digitalisation (through e-books, for example). We also assume that exchanges within communities are heightened: people depend more on community members than commercial services, for rental, repair and reuse, for example. Finally, we assume that local cultural activities and home-based hobbies like gardening are preferred to long-distance travel.

Scenario six: Tackle the UK's import footprint

6.1 Shift away from high-impact imports and build resilient supply chains
In this intervention, we target the top ten UK industries in terms of their material footprint, by identifying the upstream drivers of material impacts by region—including Europe and the rest of the world—and driving sectoral output. These include a mix of extractive and processing industries such as mining and quarrying, cattle farming and manufacturing. We also examine the driving sectoral output: for example, most of the material footprint of imports for the UK's construction industry is accounted for by stone imports from the rest of the world. Some of the products that we have identified as suitable for shifting to domestic production are sand and clay, construction materials, coal, chemicals, timber, vegetables, cattle and cattle meat, and natural gas. We assume these are instead met through self-sufficient domestic production and increased efficiency—thereby cutting imports by 25%. Here, it's important to note that domestic production should go hand in hand with recommendations made in other scenarios: for example, coal should be phased out and cattle meat production should still decrease on the whole—but what is produced should be as circular, sustainable and local as possible.

APPENDIX G: MODELLING THE IMPACT OF COMBINED SCENARIOS

Overlaps between—and the sequentiality of—interventions mean that our combined scenario calculations, as laid out in Chapter four, yield different results than simply adding up the impacts of individually modelled interventions. In particular, the scenarios on repair, recycling, as well as fossil resource consumption, are applied across sectors, thereby also influencing industry-specific interventions on agriculture and construction, for example. Therefore, we prioritise interventions according to principles of the circular economy. We begin with strategies that aim to reduce inputs, secondly applying repair and reuse-focused strategies and only lastly applying those focused on recycling. We look at overlaps in terms of coherence, meaning that we exclude interventions that explicitly contradict each other. We also don't take anti-synergic effects into account: for instance, the reduced availability of waste for recycling stemming from improved manufacturing efficiency. The sequential application of interventions means that those applied further down will have a lower impact than earlier ones, when they target the same transactions between economic actors. By way of example: let's assume we model two interventions targeting investments in the construction services sector. The share of the investment to be reduced—as specified in the first intervention—will be applied to the original investment figures, while the second intervention will be applied to the reduced investment figure that has resulted from the application of the first intervention. It's worth noting that all scenarios are expected to have some rebound effects, yet for the most part we are unable to calculate these, aside from those outlined above.

ACKNOWLEDGEMENTS

Circle Economy would like to thank the funders, authors, contributors and interviewees for their contribution to the preparation of this edition of the *Circularity Gap Report United Kingdom*. Authors, contributors and interviewees have contributed to the report in their individual capacities. Their affiliations are only mentioned for identification purposes.

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Deloitte UK

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Version 1.0 (February 2023)