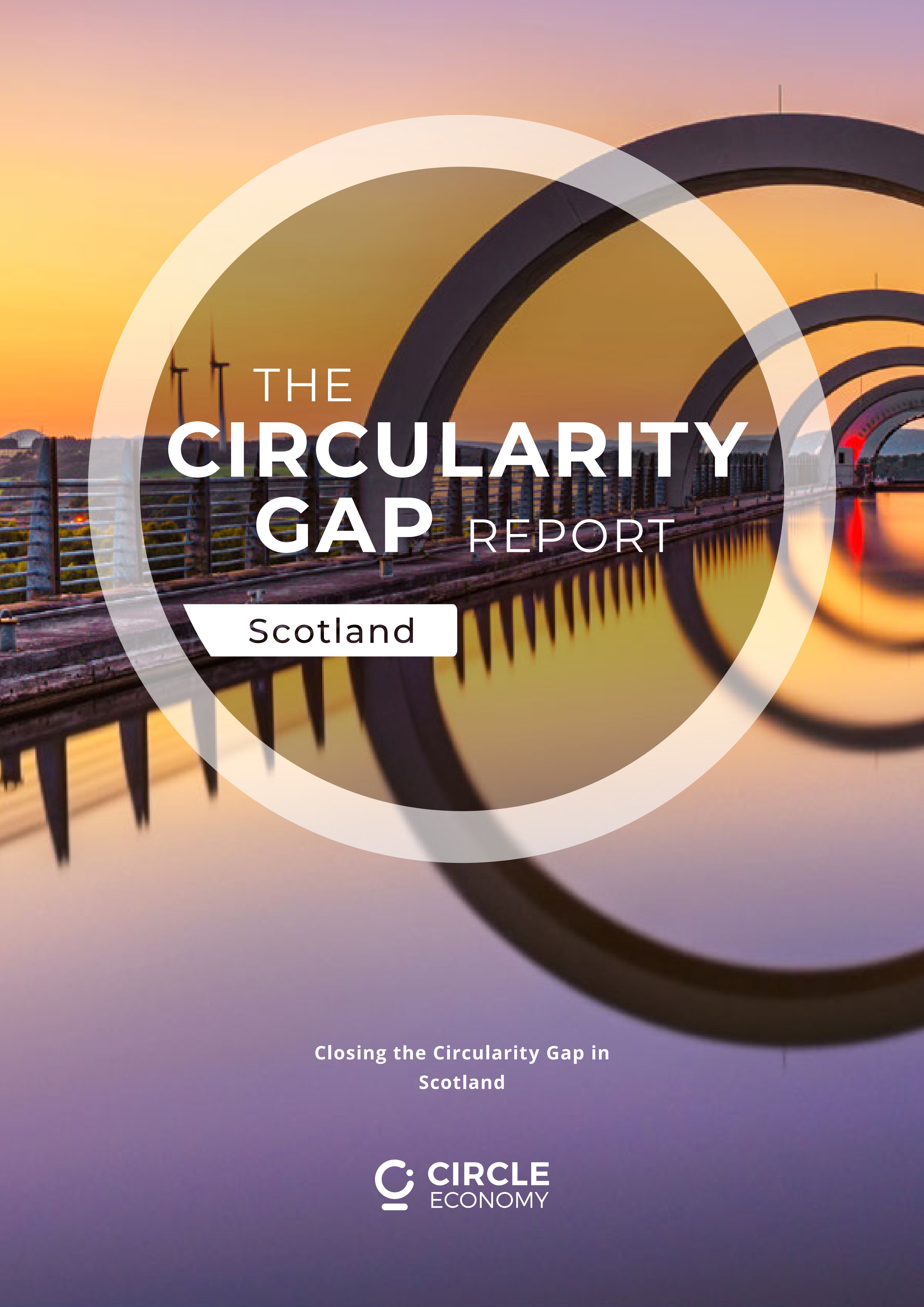

THE CIRCULARITY GAP REPORT

Scotland

Closing the Circularity Gap in Scotland

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.

Zero Waste Scotland, a not-for-profit environmental organisation funded by the Scottish Government, exists to lead Scotland to use products and resources responsibly, focusing on where it can have the greatest impact on climate change. Using evidence and insight, its goal is to inform policy, and motivate individuals and businesses to embrace the environmental, economic, and social benefits of a circular economy.

BEHIND THE COVER

The Falkirk Wheel—pictured on the cover—represents the transition from linear to circular. This can be literally interpreted: boats, for example, approach the rotating lift on a linear trajectory, before being carried upwards in a circular motion by one of the 21st century's most impressive structures. The arcs reflected in the water also form circles. There is also a more abstract interpretation: the lift connects the Forth and Clyde Canal with the Union Canal, representing the transition from the old linear system to a new circular system as the boats journey onto a new path.

This report is published as an affiliate project of the Platform for Accelerating the Circular Economy (PACE). PACE is a global community of leaders, across business, government and civil society, working together to develop a collective agenda and drive ambitious action to accelerate the transition to a circular economy. It was initiated at the World Economic Forum and is currently hosted by the World Resources Institute.

FOREWORD

This time last year, the eyes of the world were on Scotland, as world leaders and delegates met in Glasgow to find a way forward in tackling climate breakdown.

Since then, Scotland has had a laser-focus on its pursuit of a more sustainable and just future. This has included the launch of the *Circular Economy Bill* and Route Map consultations; as well as Zero Waste Scotland touring cities and towns during summer and engaging with the public on what a greener future looks like for them.

It's clear that there is a firm foundation of circularity intent with business innovation and community engagement taking root across the country.

One year on from COP26—almost to the day—we're now in the exciting position of launching Scotland's first ever *Circularity Gap Report*.

Zero Waste Scotland commissioned Netherlands-based pioneer Circle Economy to develop this landmark report to empower and guide our journey to a circular and zero waste economy.

The *Circularity Gap Report* doesn't just measure Scotland's current rate of circularity, providing a quantifiable baseline from which we can measure change—it also identifies bold interventions that will advance the country's circular efforts.

Implementing the scenarios means that Scotland could more than double its circularity and reduce its material footprint by over 40%, all while making significantly deeper contributions to its emissions targets.

For years, Zero Waste Scotland has brought the topic of consumption to the top of the climate change agenda, as it's an important point that's too often omitted from the conversation.

Around four-fifths (80%) of Scotland's footprint comes from the products and materials we manufacture, use and throw away. The average Scot also consumes more than double the sustainable level of material use, which academics agree would still allow for a high quality of life: around 8 tonnes per person per year.

It's evident our consumption is too high. When it comes to everything we consume—from flights to food and fashion to furnishings—buying and wasting less will help reduce our carbon footprint.

We need to change from a 'make, use, dispose' culture, referred to as the linear economy, to a more circular economy where we maximise the value of the products and materials we use to make them last as long as possible.

This is why our message has always been that, to truly end our contribution to the climate crisis, we need to rethink how we consume. Now we're going even further with a clear call to action: we must close the Circularity Gap.

Scotland is already respected across the globe for its circular economy efforts and, as the country's circular economy experts, I'm always proud of the work Zero Waste Scotland does to support businesses, projects, communities and citizens in embracing a more sustainable way of living.

This report can—and will—embolden our work and help us push ourselves even further.

Some solutions may feel daunting, as they will require structural change on a large scale, while others can be put into practice straight away. The important takeaway here is that we're now embarking on a new chapter in our circular economy transition.

We've come so far in the last few years and if any country is armed with the passion, innovation and determination needed to make real change, it's Scotland.

So let's take on the challenge... and close the Circularity Gap.

Iain Gulland

Chief Executive Officer, Zero Waste Scotland

EXECUTIVE SUMMARY

Scotland is only 1.3% circular—leaving a Circularity Gap of more than 98%. This means that Scotland almost exclusively uses virgin resources to satisfy its residents' needs and wants, such as for Housing, Nutrition and Mobility. In 2018, the country consumed 117.8 million tonnes of virgin materials—around 21.7 tonnes per capita. This is nearly double the global average, which rests at 11.9 tonnes. As a resource-rich country, domestic extraction soars at 125 million tonnes, or 22.8 tonnes per capita—a huge departure from the UK average of 5.5 tonnes per capita. Much of this relates to fossil fuels, a massive 74.5 million tonnes of which—primarily crude oil and natural gas—are extracted yearly, largely to service the power needs of the rest of the UK. While high per capita extraction and consumption rates are common for a high-income economy, Scotland rests near the top of this classification. Globally, the extraction and processing of materials, including fuels and food, is responsible for 50% of total greenhouse gas emissions and over 90% of biodiversity loss and water stress:[1] reducing material consumption is key to tackling the root causes of climate change and environmental degradation.

The material footprint behind Scotland's resource use lights the way forward. This report analyses how resources—metal ores, non-metallic minerals, biomass and fossil fuels—are used to meet Scotland's societal needs. Despite representing just 0.073% of the world's population, it consumes a total of 119.4 million tonnes of materials per year—0.1% of the globe's virgin material use. In other words, the Scottish economy is largely driven by overconsumption. And although successful efforts have been made to reduce landfilling and to decarbonise the electricity mix, Scotland still generates vast amounts of waste and relies heavily on fossil fuels to power transport and heat homes. Geographic, demographic and climatic factors are also key contributors to the hefty material footprint: extremely low population density and population dispersion in its vast countryside and many islands means that the materials used to build infrastructure and provide amenities and services are being used far less efficiently. Think of how much more frequently a city road is used compared to a country road: in material terms, the payoff is far greater—yet material use is the same. At the same time, the cold, damp climate demands greater energy use, and old buildings prove a challenge to heat efficiently.

High consumption, extensive extraction and a large emissions profile characterise the Scottish economy. Scotland's high material footprint is strongly tied to its trade profile: the country imports an abundance of materials and finished products from abroad—the net extraction of which accounts for more than two-fifths of its total material consumption. Taking domestic extraction into account (22.8 tonnes per person per year), Scotland's extraction footprint exceeds its total material footprint (21.7 tonnes per capita). Meanwhile, per capita extraction for fossil fuels alone, at 13.7 tonnes per person per year, exceeds the world average for total resource extraction, at 12.3 tonnes. High consumption and extraction tie into a similarly hefty consumption-based carbon footprint of 75 million tonnes of carbon dioxide equivalents (CO2e). This exceeds the country's territorial emissions—those produced within the country's borders—by 42%: much of Scotland's carbon footprint is 'externalised' and occurs as the result of extraction and production processes abroad, with greenhouse gas emissions embedded in imports.

The Agrifood, Services and Manufacturing industries are key contributors to Scotland's material footprint. Just four key sectors within the agrifood industry—processing of beef cattle, processing of food products, cultivation of vegetables, fruits and nuts, and cattle farming—represent nearly one-sixth of the material footprint. From beef and seafood to whisky and beer, Scotland's agrifood products are known around the world—yet they also drive extraction abroad: the country's topography and climate are less than ideal for crop cultivation, necessitating substantial imports for animal feed, for example. Coming just behind agrifood, the services industry contributes a little more than 13% of the material footprint: health and social work, hotels and restaurants, and public administration and defence consume vast quantities of materials and energy. Trailing slightly behind, the manufacturing of machinery and equipment, manufacturing of motor vehicles, trailers and semi-trailers and petroleum refineries combined account for nearly 13% of the material footprint. These processes—driven by the production of cement, chemicals, pulp and paper, and oil and gas refining and iron and steel works—also generate vast quantities of emissions and waste.

Opening up the Circularity Gap paints a picture of the Scottish economy. Scotland is 1.3% circular—but this doesn't mean the other 98.7% of materials flowing through its economy go to waste or are inherently 'bad'. The Circularity Gap comprises a range of elements: more than 20% of Scotland's material use (24.3 million tonnes) is 'locked' into stock in the form of buildings and infrastructure, for example. These materials will serve residents for decades before becoming available for reuse or recycling. It's crucial that elements of circular design—like longevity, reparability and cyclability—are employed now to ensure that high-value reuse and recycling can take place when these buildings reach their end-of-life phase. Another 16.6% of Scotland's material consumption is represented by renewable biomass with the potential for cycling: food crops, timber and wood products, for example. Inherently non-circular flows, such as fossil fuels, and non-renewable inputs represent approximately 15% and 45% of material use, respectively, while non-renewable biomass—biomass that is not carbon neutral—represents around 1.6%. In total, these three groups represent around two-thirds of Scotland's material footprint—painting a picture of an economy that leaves a huge environmental imprint abroad, and is still largely powered by fossil fuel dependence. Once again, much of this wasted potential for cycling can be linked to processes taking place beyond Scottish borders—yet is driven by Scottish demand, which externalises environmental burdens such as extraction, unsustainable production, waste and emissions. Scotland's goal shouldn't be to simply boost its 1.3% Circularity Metric—it'll also hinge on substantially reducing its high material footprint, particularly the share related to imports.

We present a set of circular strategies to close the Circularity Gap in Scotland. To bridge the Gap, this report explores seven 'what-if' scenarios that apply strategies to strengthen circularity, cut material use and emissions, and transform the Scottish economy. The scenarios are 1) Build a circular built environment, 2) Nurture a circular food system, 3) Champion circular manufacturing, 4) Rethink mobility, 5) Welcome a circular lifestyle, 6) Tackle Scotland's import footprint and 7) Advance circular decommissioning. Individually, the scenarios have a limited impact—but combined, they can increase the Metric by nine-fold, boosting it to 11.8%. Even more significantly: they have the power to cut Scotland's material footprint by more than 44%, bringing it down to 65.6 million tonnes, and slash its carbon footprint by nearly 43%, lowering it to 35 million tonnes of CO2e. These figures, however, are substantially influenced by our final scenario's potential impact; without it, the Metric increases to 4.2%. Chapter four of this report highlights the impacts of each individual scenario. Regardless, co-benefits would be numerous: improved health and wellbeing from healthier food and more resilient communities, improved biodiversity and soil health, and less pollution, for example.

Scotland's economy is full of potential—but there are limitations as to how much its Circularity Metric can be increased. Seven scenarios that fundamentally reimagine how Scotland builds, eats, gets around, makes things and shops must have a huge impact—but then, why does the Metric 'only' climb to 11.8%? Firstly, it's technically not feasible to aim for 100% circularity. Secondly, the structure of economic activity across borders in our highly complex and globalised world economy also makes circularity difficult to control within a single country. Scotland is particularly enmeshed in world trade: its consumption drives extraction and waste generation abroad as well as within its own borders, while demand from abroad, particularly the UK, also serves to drive up its material, extraction and carbon footprints. Scottish extraction is largely represented by fossil fuels, for example, which are inherently non-circular. What's more: attempts to control the circularity of imports shouldn't be overlooked, as this represents one of the key reasons for Scotland's high material footprint: to this end, circular imports are examined for the first time in a *Circularity Gap Report* in this release. Scotland may also embrace this opportunity to shift to more local production in as circular and sustainable a manner as possible. And as long as Scotland's current consumption patterns persist, large volumes of materials will be needed to sustain the lifestyles of its residents. For example: as long as there's a population to house, there will always be a substantial portion of materials locked into stock—and these are precluded from contributing to the Circularity Metric. Nonetheless, our global *Circularity Gap Report* has found that circular economy and consumption reduction measures can cut the material footprint by nearly half, while bumping the Metric from 8.6% to nearly 17%—enough to limit global warming to 1.5-degrees.[2] Implementing these measures in Scotland could potentially grow the Circularity Metric by a factor of nine (from 1.3% to 11.8%) and reduce both material use and consumption-based emissions nearly by half—a true metamorphosis for its economy.

The circular economy is a means to an end: a safe and just space for people and the planet. By narrowing its Circularity Gap and cutting material consumption, Scotland can serve this higher objective by relieving environmental pressures and resource depletion both domestically and abroad, while also transforming its social fabric. Currently, none of these objectives are being achieved: Scotland extracts and burns plenty of environment-harming fossil fuels and carries out unsustainable food production practices, transgressing planetary boundaries—and yet is marked by the highest rates of fuel poverty and food insecurity in the UK.[3 4] A comprehensive circular economy approach can have a transformative effect, providing wider environmental, economic and societal benefits. Circular strategies and business models can serve the objective of meeting residents' needs while diminishing environmental impact, by enabling greater access to and more even distribution of resources, for example. The circular economy is a means to achieving the defining goal of a world—and country—that is ecologically safe and socially just.

Realising a circular economy with and for people. Narrowing Scotland's Circularity Gap both hinges on and has implications for the structure of the economy and the labour market. The effective implementation of circular interventions can be best achieved via a combination of policy instruments, such as fiscal reform, regulations and consumer-oriented bottom-up interventions. Our analysis finds that shifting the tax burden from labour to resource use and pollution can potentially generate revenue exceeding €40.25 billion (£35 billion[5]). This revenue can be used to stimulate circular activities in the economy, namely through government spending in the form of fiscal incentives, subsidies, grants and investment in (enabling) infrastructure, boosting circularity in the built environment, agrifood, manufacturing and consumables industries. These investments can be parcelled out to support various circular strategies that can help Scotland use fewer, cleaner materials for longer, cycling them at end-of-life—creating socioeconomic benefits in tandem. What's more: putting the circular strategies we explore in this report into action could potentially create almost 60,000 new jobs, especially in labour-intensive sectors such as repair and maintenance activities and waste and material management. In order to alleviate certain undesired impacts—for example, short-term unemployment in industries that will be most penalised by taxation, such as oil and gas—there should be an emphasis on training for new skills to support workers in shifting away from declining linear activities.

The time for transformational change is now. Scotland is hailed as a world leader when it comes to environmental action: it boasts ambitious goals to reach net-zero, as well as a well-established circular economy strategy (*Making Things Last: A Circular Economy Strategy for Scotland*[6]) bolstered by supporting initiatives and programmes. The Scottish government is in the process of drafting a *Circular Economy Bill*. This presents a landmark opportunity to facilitate the transformational system change the circular economy requires. The Scottish government has also recognised the crucial role of circular strategies in the wider climate agenda: circular practices are already embedded in the *Climate Change Plan*[7] and the country recently introduced a Minister for Green Skills, Circular Economy and Biodiversity in August 2021. So while Scotland still has a way to go in cutting its large material footprint and extraction, it's well poised to take on the challenge. It can also benefit from a unique well of materials: decommissioned energy infrastructure can now act as a huge bank of precious materials that can feed into the clean energy transition, which will also be inevitably material-intensive. Scotland also benefits from a wealth of natural resources: traditionally fossil fuels, yes—but also minerals and biomass. At the moment, these resources are largely exported, while others with a high environmental footprint continue to be imported from around the world. Striking a balance between localising production and prioritising sustainable imports will be a crucial way forward for the country. This report can serve as a guide for making Scotland's economy more circular, a top priority—as without metrics and measurements, it can be hard to jump head-first into action. It lays out tangible insights to kick-off Scotland's journey to becoming a resource-light, low-carbon and thriving economy for all of its residents—as the country's bold goals demand a bold transformation. Fully embracing circular economy principles can help to achieve this bold shift.

This analysis presents a way forward for a Scottish circular economy. This report uncovers the key hotspots of Scotland's material use—revealing that the agrifood, manufacturing and services industries are large impact areas. Reducing their environmental impact will require strong leadership and close, proactive stakeholder collaboration—but also a shift in the 'rules of the game' that they currently play by. To this end, we firstly provide policy recommendations to enable a structural shift in the Scottish economy, powered by a radical rethinking of the fiscal and regulatory frameworks needed to make circular alternatives competitive on the market. Secondly, we note that implementing circular strategies will also require concrete, targeted (public) investments and spending to scale enabling and competitive infrastructure. Thirdly, given Scotland's heavy import footprint, striking a (better) balance between localising production and prioritising sustainable imports will be a crucial circular strategy. Finally, phasing out fossil fuel extraction while continuing down the path of electrification and decarbonisation will be vital to narrowing the Circularity Gap and contributing to a safe and just world. Moving forward, achieving all these objectives will require an approach that goes far beyond cycling, shaping a circular economy that provides wider environmental, societal and economic benefits. This is one that topples GDP-based growth as the North Star of development and instead focuses on providing a high quality of life within planetary boundaries, by cutting excess consumption as well as increasing materials' circularity.

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GLOSSARY

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 Scotland's 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), similar (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). [Source]

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 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. [Source]

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]

Resources include, for example, land, water, air and materials. They are seen as parts of the natural world that can be used for economic activities that produce goods and services. Material resources 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 already been used and recycled. 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. These relate closely to the 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. [Source]

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]

Territorial-based carbon footprint is based on the traditional accounting method for GHG emissions, with a focus on domestic emissions, mainly coming from final energy consumption. A **consumption-based carbon footprint** uses input–output modelling to not only account for domestic emissions but also consider those that occur along the supply chain of consumption (for example, accounting for the embodied carbon of imported products). [Source]

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

1. INTRODUCTION

We are living in the Anthropocene: a new geological epoch where human activity has become a major driver of change in the Earth system and has caused increasing devastation of and instability in the natural environment.[8] Our latest global *Circularity Gap Report* found that the world's economy has reached a staggering milestone: in the six years between two major climate conferences in Paris and Glasgow, we have collectively consumed more than half a trillion tonnes of materials—around 100 billion a year.[9] Meanwhile, our *Circularity Gap Report 2020*[10] reported that the global economy is only 8.6% circular: the vast majority of the resources we consume come from virgin sources, while waste is par for the course. Our linear 'take-make-waste' economy has made throw-away culture the norm, putting increasing pressure on the vital ecosystems and climate that our very existence depends upon. This report finds that Scotland's Circularity Metric sits at 1.3%—well below the global average. While the country is considered a frontrunner in environmental action—it boasts one of the world's most ambitious climate bills as well as well-developed plans for a circular economy—there is still a way to go in cutting material consumption and achieving greater circularity. With a material footprint of 21.7 tonnes per person per year, Scotland far exceeds the global average of 11.9 tonnes per person: it imports a wide array of goods with hard-to-control circularity from abroad, inflating its footprint. At 22.8 tonnes per capita, domestic extraction is also very high—and the vast majority is exported to meet societal needs abroad. Scotland exports most of the raw materials it extracts domestically, while importing vast amounts of raw materials embodied in imports. This resource-rich country has an important role to play in cutting pressure on natural resources whilst improving living standards for its residents, and already boasts the tools needed to get started. However, doing so will require using the tools Scotland has to instigate a deep systemic shift and total reimagining of how we extract, use and dispose of materials. This big shift is the circular economy.

THE RISKS OF THE LINEAR ECONOMY

With several systemic crises raging—from climate change and biodiversity collapse to resource depletion and rising sea levels—the Earth's natural life-support capacity is being pushed to its limits. Nature is essential for human existence and good quality of life. Ecosystems underpin socioeconomic production and consumption systems, playing a fundamental role in determining socioeconomic wellbeing.[11] In short, socioeconomic systems are embedded in nature. The high quality of life enjoyed in industrialised, high-income nations such as Scotland depends entirely on natural resources, from arable land and fish stocks to biodiversity and freshwater reserves. But natural resources are limited and vulnerable. Resource use conveys environmental (and social) consequences: the extraction, transport, processing, use and disposal of materials to satisfy societal needs and wants often provokes unavoidable and permanent environmental damage.[12 13] Although impacts vary by material and with technological developments, there is a clear link between aggregate mass flows and ecological impact.[14] Material use is thus a good proxy for measuring environmental degradation: the extraction and processing of materials, fuels and food, for example, contribute half of total global greenhouse gas (GHG) emissions and over 90% of biodiversity loss and water stress.[15] Within this context, it is crucial to reduce material use to sustainable and fair levels by optimising its efficient transformation into social benefits, especially by high-income nations which are responsible for the bulk of excess material use worldwide.[16]

And yet, global resource extraction has exploded during the past fifty years, more than tripling from 27 billion tonnes in 1970 to 92 billion tonnes in 2017.[17] The use of biomass, fossil fuels, metal ores and non-metallic minerals doubled between 2005 and 2015, increasing from 26.3 billion tonnes to 46.4 billion tonnes.[18] While this has fuelled economic development, it has come at a tremendous environmental cost, pushing the Earth system beyond a safe operating space and ultimately threatening human wellbeing.[19] Bringing socioeconomic systems within planetary boundaries will require the deliberate downscaling of global resource use—both material and energy use—especially by higher-income nations, while still focusing on equitably delivering human needs.[20]

THE LINEAR ECONOMY IN SCOTLAND

Scotland's economy heavily depends on the extraction of virgin resources and generates large volumes of waste: two characteristics core to the dominant linear economy. Like much of the world, Scotland functions within a damaging 'take-make-waste' paradigm marked by high consumption and fossil fuel use. The country's total material consumption—119.4 million tonnes—is putting immense pressure on natural ecosystems worldwide: with a large import footprint, Scotland is driving linear processes and contributing to environmental degradation elsewhere. Accounting for around one-third of the UK's landmass, Scotland boasts key natural resources from land to sea: oil and gas from the North Sea's bedrock, a range of mineral resources and abundant fishing stocks. It's unsurprising the country's economy is largely resource-based. Cutting resource extraction will have a crucial role to play in boosting Scotland's circularity: while the country is making progress in shifting away from fossil fuels—decarbonising its electricity mix through wind and hydro power, for example—truly transitioning to a circular economy will entail a deeper system shift that tackles consumption. All elements of the circular economy must be leveraged to preserve materials' value at the highest extent possible, eliminate waste and pollution, keep materials in use and regenerate natural systems.[21]

THE ROAD TO CIRCULARITY

Scotland is 1.3% circular: well below the global average, it faces a long journey to circularity. Of the 119.4 million tonnes of materials the country consumes, 98.7% are not cycled back into the economy: only 1.6 million tonnes are cycled back into the economy. 24.3 million tonnes are used to develop building stock or infrastructure, and a weighty 40.9 million tonnes are dissipated into the environment, or wasted in Scotland and abroad (see pages 32–33 for more information). The low Circularity Metric is only half of the story, however: it will be crucial to cut the high material footprint and boost circularity in tandem. While overconsumption is certainly a facet of Scotland's high material footprint, this is also inevitably tied to the country's population dispersion and overall low population density. Scotland houses an average of just 70 people per square kilometre, compared to the UK's average of 275,[22] with population density outside Scotland's 'central belt' well below 50 on average (mainly in rural and island communities).[23] This results in a less efficient use of the resources needed to provide social amenities and services: a city road, for example, is used at far greater intensity and frequency than a rural road. Material and emissions-intensive industries—construction, agrifood and manufacturing in particular—also play into the large footprint. While it's projected that Scotland's population will peak—and eventually begin to fall—within the decade, other trends, such as the rising prevalence of single-occupancy houses[24] and an ageing population imply that material use is only set to rise—unless circular strategies are employed. By minimising waste and pollution, keeping products and materials in use at their highest value and regenerating natural systems, a circular economy can allow Scotland to pivot away from its dominant linear model, serving the needs of its people while remaining within planetary boundaries.

Fortunately, Scotland has positioned itself as a frontrunner in this arena: its first *Zero Waste Plan*[25] was launched more than a decade ago, while the more recent strategies *Safeguarding Scotland's Resources: Blueprint for a More Resource-Efficient and Circular Economy*[26] and *Making Things Last: A Circular Economy Strategy for Scotland*[27] have emerged as part of efforts to cut waste generation and keep materials in the loop. Additional supporting initiatives, programmes and digital tools are abundant.[28 29] The Scottish government has also recognised the role circular strategies can play in the wider climate agenda, with such principles embedded in the *Climate Change Plan*[30] and net-zero goals. While the upcoming *Circular Economy Bill* is expected to give some direction, room remains for a more holistic approach with closer policy integration and coordination. Policy may be part of a 'whole government' approach, for instance including binding material reduction targets: this report spotlights just how effective such action could be for transforming Scotland into a resource-light and low-carbon society.

A SOCIAL AND ECONOMIC CROSSROADS

Scotland's end goal is a country where social needs are provided for within the planet's ecological limits—and a circular economy provides a means to this end. Currently, neither are optimally serviced. While Scotland performs quite well in wellbeing indicators, particularly those related to education and labour market participation,[31] performance in some fundamental issues leaves room for improvement. Crude oil and natural gas are extracted in large volumes, yet rates of fuel poverty are among the highest in the UK, for example: roughly one in four households struggle to keep up with energy costs.[32] Likewise, Scotland boasts a strong and productive agrifood sector, yet food insecurity affects almost one in ten people.[33] These examples do not imply causation but do highlight an imbalance in resource use. Resources are largely commodified in a system structured around profit and growth rather than equitable distribution within the means of the planet: too many residents struggle to meet basic needs, while in the meantime, environmental damage is still taking place, domestically and abroad. A deeper understanding that current production processes and consumption-driven lifestyles are unsustainable will be needed to spur a mindset shift—one that broadens perspectives around circularity beyond just improving resource efficiency and 'recycling more'. While Scotland has achieved relative decoupling—meaning that its GDP growth has outpaced its growth in material use—such gains in efficiency won't be enough to stave off climate and ecological breakdown if they're counterbalanced by rising extraction and consumption, both domestically and abroad. Notions of progress must shift away from GDP-based economic growth: social, economic and environmental justice considerations must become a crucial component of our definitions and understanding of wealth, prosperity, happiness and wellbeing.

The circular economy provides a new way of life, in which extracted resources are optimally transformed into social benefits for all of Scotland's residents, opening up room to shrink the material sphere of the economy and relieve environmental pressures while ensuring good lives for everyone. To this end, for the first time, this edition of the *Circularity Gap Report* will quantify the socioeconomic impacts of our circular interventions—highlighting how ambitious fiscal reform can enable the restructuring of the Scottish economy, discerning that the labour market is a key lever for accelerating the circular economy transition, and showcasing opportunities for job creation. This will further support the Scottish Government's aims for a Just Transition and Wellbeing Economy: a net-zero, resilient economy that tackles inequality and engages with those most likely to be affected by the transition—workers, trade unions, businesses, community organisations and youth among them.[34] [35] By placing circular economy and green skills under one Minister's remit, Scotland has already signalled the crucial role its people will play in transforming the economy. This report will pinpoint which strategies the skilled workforce would best be channelled towards and the financial and employment potential of pursuing these strategies.

AN ECONOMY FULL OF POTENTIAL

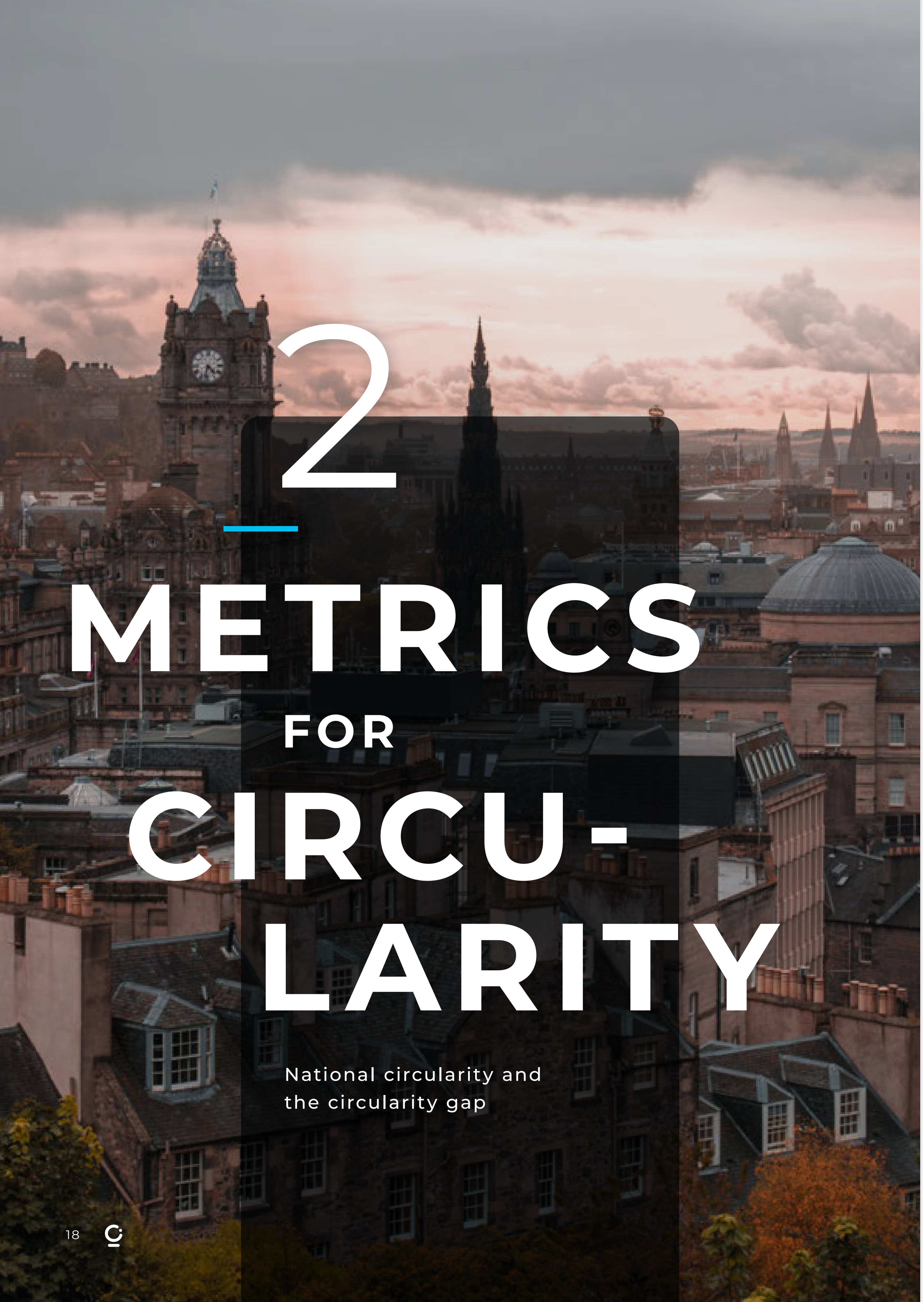
Scotland boasts ample opportunities to bump up its Circularity Metric and cut its material footprint—and is supported by a broad ambition and political will to do so. Initial efforts, such as the decarbonisation of the electricity mix and further attempts to electrify heat generation, have set a strong precedent for the systemic change needed in the years to come. Our analysis finds several avenues for boosting Scotland's Metric, from nurturing a more circular food system and rethinking the way housing is built and managed to tackling the foreign extraction feeding domestic demand. Combined, these strategies hold the power to cut material consumption by 44.3%, bringing it down to 65.6 million tonnes, and slash the carbon footprint (excluding direct emissions) by 43%, bringing it down to 35 million tonnes. These strategies could also boost the Metric from 1.3% to 11.8%.

Previous action has done well to set the stage for this transition: as of 2019, territorial GHG emissions had sunk 44% below their peak in 1990, owing to decarbonisation in the electricity supply mix and action among actors in construction and manufacturing.[36] However, further potential to cut emissions from power generation are minimal, emissions from land use, land-use change and forestry have actually increased over recent years, and the generation of emissions abroad continues to grow to satiate Scotland's rising consumption. The country's carbon footprint—a consumption-based measure—exceeds its territorial emissions by 42%, showcasing the extent of this pattern. Scotland has been labelled a climate leader; a title not undeserved due to laudable ambitions to reach net-zero by 2045—but future goals must consider the nation's carbon footprint rather than focusing solely on easier-to-control domestic emissions. A similar story emerges from examining waste statistics: recycling has increased steadily over the past two decades and landfilling has sunk to an all-time low, 63% lower in 2020 than in 2005[37]—yet incineration has grown by over 200% in the last decade,[38] a waste management option only slightly better than landfilling. The Scottish Government is currently reviewing the role of incineration in the waste hierarchy in Scotland and will make full recommendations in December 2022.[39]

The circular economy may provide a means to take control of less-than-ideal waste management and spiralling foreign emissions—and must become a core building block of Scotland's future environmental strategy. Coherent policy, strategic innovation and investment that tackles skills mismatches and supports digital infrastructure will be crucial to easing the transition,[40] helping develop supply chain capacity in sectors with marked potential: manufacturing, renewable energy and the bioeconomy, for example. This report presents seven scenarios that can help Scotland cut its material footprint by 44.3%, substantially increase its cycling power and bring the country from theory to action: the kind of systemic shift needed to realise a circular economy.

Aims of the *Circularity Gap Report Scotland*

1. Provide a snapshot of how circular Scotland is through the Circularity Metric.
2. Identify how materials flow throughout the economy and how they may limit or boost the current Circularity Metric.
3. Spotlight possible interventions within significant industries that can aid Scotland’s transition to becoming circular and reducing its material footprint.
4. Spotlight avenues for governments to create a shared vision with local businesses and consumers to encourage circular consumption.
5. Communicate a call to action based on the above analysis, to inform future goal setting and agendas.



2

METRICS FOR CIRCULARITY

National circularity and the circularity gap

Measurements are critical to understanding the world around us. As it becomes more urgent for us to adapt our socioeconomic system and become more circular, we need to provide a tactical approach for measuring the transition. In the first edition of the global *Circularity Gap Report*, in 2018, Circle Economy launched the Circularity Metric for the global economy. This analysis adapts the Metric to suit a national profile. This section explains how this report has assessed Scotland's circularity and introduces supporting metrics that help us understand the significant material flows that contribute to the country's large Circularity Gap. These additional insights allow us to formulate a plan for moving toward greater circularity: they provide an initial assessment by locating circular opportunities and priorities in material flows. By measuring circularity in this way, businesses and governments can track their circular performance over time and put trends into context, as well as engage in uniform goal-setting and guide future action in the most impactful way.

MEASURING CIRCULARITY: A MEANS TO AN END

The circular economy is a big picture and holistic idea. Ultimately, it is a means to an end—the end being a socially just and ecologically safe space, where our environment can flourish and people can thrive. Exactly *how* the circular transition can deliver more beneficial social and environmental outcomes is not a question with just one right answer, however. There is no simple straight-line solution and the feedback loops in the system run in all directions.[41] In particular, three connected spheres need to be taken into account: 1) how resources 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[42] and social systems, which include government institutions, businesses, communities and markets.[43] 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 social outcomes, but at very different levels of material use. This is how the circular economy can transform societies, allowing us to thrive with minimal environmental impact.

In this analysis, we take the socioeconomic metabolism of a country—how resources flow through the economy and are kept in long-term use—as the starting point for measuring and capturing its level of circularity. We also consider the importance of reducing consumption. This is because impact prevention through reduced demand is an important first step to take before exploring other mitigation options—a tenet reflected by a number of environmental management hierarchies wherein reductions of production and consumption, narrowing flows, is always the preferred and most effective strategy.

To ensure our data is in line with the reality of Scotland, we worked with Zero Waste Scotland using data from the Scottish Government, the UK Government and Eurostat.

MATERIAL FLOWS AND FOOTPRINTS

Societies consume materials and energy to maintain themselves. Figure one provides a schematic depiction of the socioeconomic metabolism of Scotland. It depicts the amounts of materials (clustered into four key resource 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, we are not able to visualise all flows and all sectors. Because the majority of materials flow through just a handful of sectors in an economy, we have limited our visualisation to show these. The left side shows the four resource groups as a result of direct domestic extraction. These are 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).

We also see on the left the volume of resources entering the national economy through **imports**. These are represented in terms of Raw Material Equivalents (RMEs)—the 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 (read more on this on page 32).

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 then processed (into metals from 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, these products' materials 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.

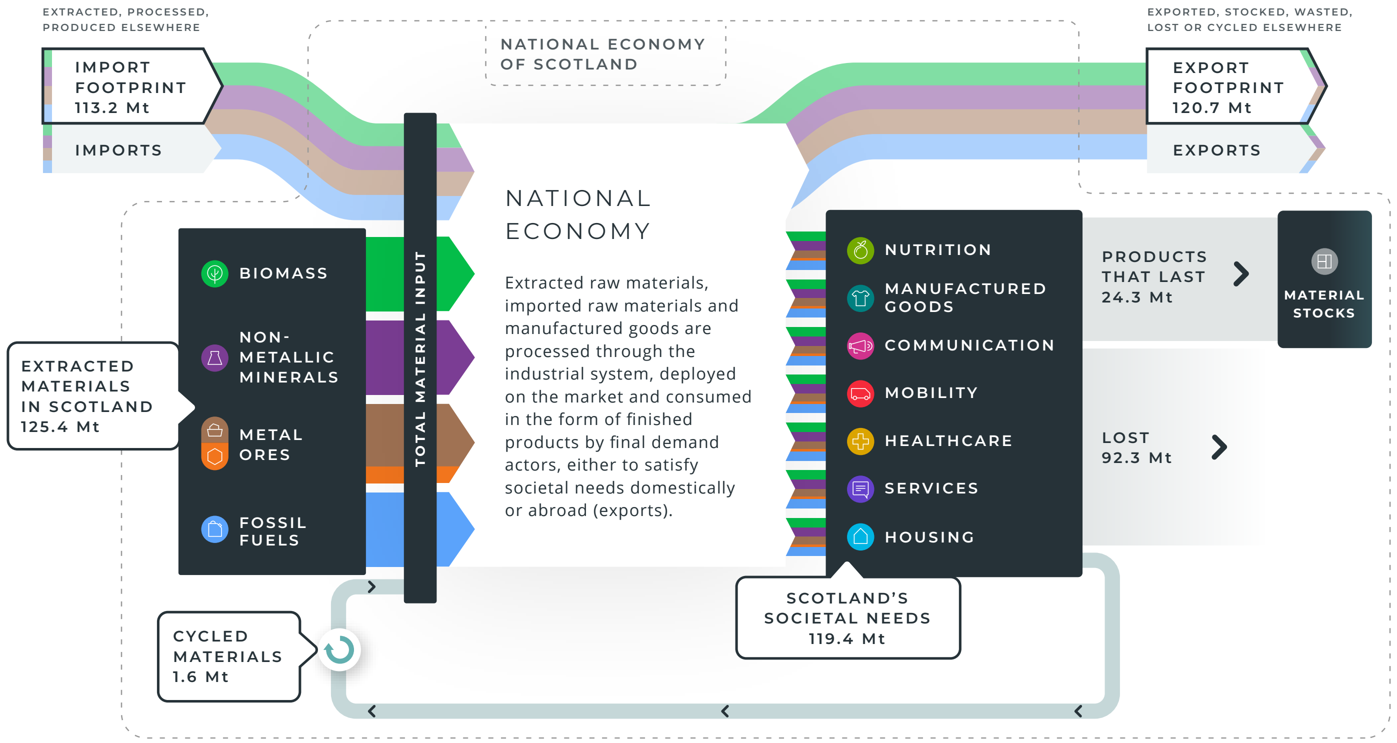


Figure one shows a schematic overview of the socioeconomic metabolism of Scotland. Note: material stocks and cycled material flows are not scaled to proportion.

THE CIRCULARITY METRIC EXPLAINED

In order to capture a single metric for circularity in an economy, we need to reduce this complexity somewhat. So, we take the metabolism of a national economy—how 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.[44] (2015) and continues the approach applied in all other national *Circularity Gap Reports*. Taking an 'X-ray' of the economy's resource and material use, we consider six fundamental dynamics of what the circular economy transition aims to establish and how it can do so. This translates into two objectives and four strategies, based on the work of Bocken et al. (2016).[45]

The core objectives are:

- **Objective one:** Resource extraction from the Earth's crust is minimised and biomass production and extraction are 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 are 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, material lightweighting (mass reduction), multifunctional products or buildings, energy efficiency, digitisation.
- **Slow flows—use longer:** Resource 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, repair, remanufacturing, refurbishing, renovation and remodelling over building new structures.
- **Regenerate flows—make clean:** Fossil fuels, pollutants and toxic materials are replaced with regenerative alternatives, 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 and products at end-of-life is optimised, facilitating a circular flow of resources. 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, recycling.

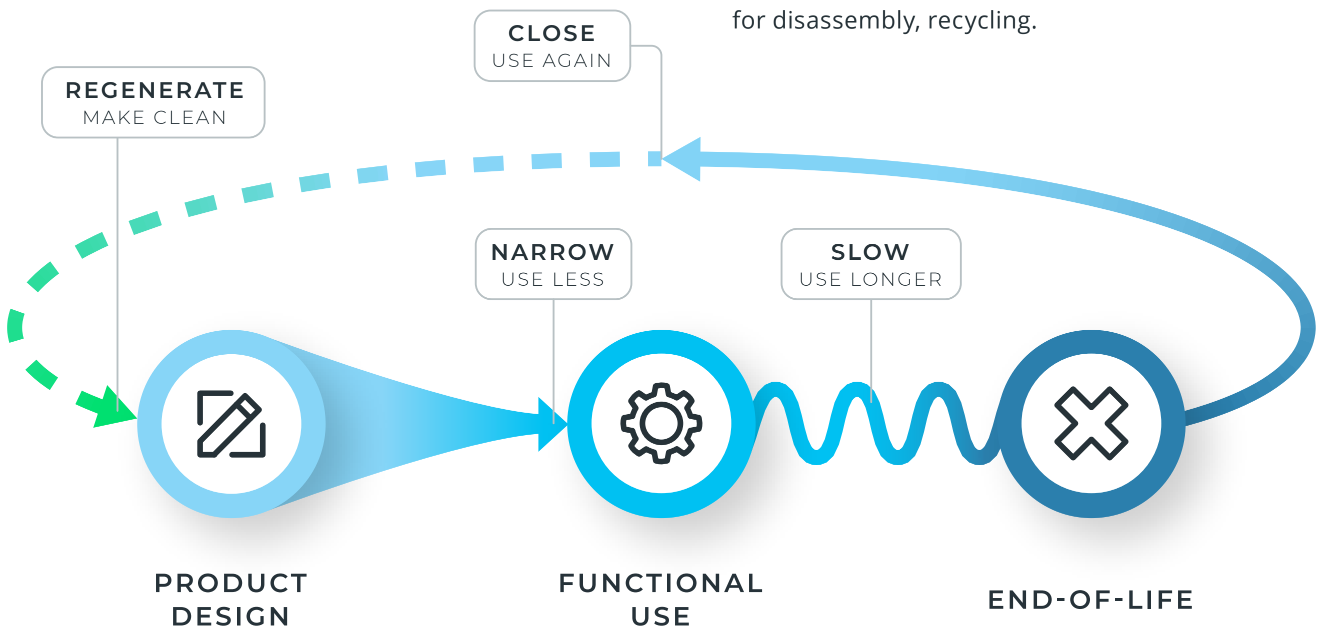


Figure two depicts the four flows to achieve circular objectives: narrow, slow, regenerate and cycle (here labelled 'close').

There are potential overlaps between some of these strategies: 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.

If we effectively deploy strategies focused on **narrowing**, **slowing**, **cycling** and **regenerating** the flow of materials, we may, ultimately, require a lesser amount and variety of materials to provide for similar needs. Because of this, fewer materials will be used by the economy, they will have a longer lifespan, and they can be reused more effectively and with less harm caused to the environment. For our Circularity Metric to capture this crucial process, we measure the share of cycled materials as part of the total material consumption of an economy. As such, it illustrates the current progress towards achieving the circular economy's ultimate goal of designing out waste through the four listed strategies.

Our Circularity Metric captures circularity in one figure. It is an 'input-focused' metric. Communicated as a percentage, it is a relative indicator of how well global or national economies balance sustaining 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. It can provide direction as to how Scotland can embrace its circular potential. Since its launch in 2018 at the World Economic Forum, the Circularity Metric has formed a milestone for global discourse on the circular economy.

INSIDE THE CIRCULARITY GAP

To accelerate the transition towards a circular economy, we need to use data and data-driven insights in the best way to support top-level decision making. At the same time, given the breadth and scope of a systems change towards a more circular economy, local and bottom-up grassroots initiatives are equally crucial to drive changes forward at the community level. To address the complexities and intricacies of a nation's economy, we aim to provide as much information and context on how individual nations can better manage materials to close their Circularity Gap. In our Circularity Metric Indicator Set, we consider 100% of inputs into the economy: circular inputs, non-circular flows and non-renewable inputs, and inputs that add to stocks. 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 Scotland extracting domestically, and is it sustainable? How dependent is Scotland on imports to satisfy the basic societal needs of the population? How much material is being added to Scotland's stock like buildings and roads every year? These categories are based on the work of Haas et al. (2020).[46]

Socioeconomic cycling rate (1.3%)

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 wood). In Scotland, this number is well below the global average of 8.6%, totalling only 1.3% of total material input.

Ecological cycling potential (16.6%)

Ecological cycling concerns biomass, such as wood, manure, food crops and agricultural residues. To be considered ecologically cycled, biomass should be wholly sustainable and circular: this means it must, **at the very least**, guarantee full nutrient cycling—allowing the ecosystem biocapacity to remain the same—and be carbon neutral. Because detailed data on the sustainability of primary biomass is not available, the estimation of the ecological cycling potential needs to rely on a broader approach: if the amount of elemental carbon from Land Use and Land Cover Change (LULCC)[47] emissions is at least the same as the carbon content of primary biomass in the total consumption of an economy, then all the consumed biomass can be considered carbon neutral.

Non-renewable biomass inputs (1.6%)

This metric indicates a biomass input rate that is not carbon neutral. As long as LULCC emissions are positive, there is going to be a share of biomass that is not carbon neutral because not all CO2 will be 'sequestered' through consumption (CO2 embedded in biomass in Domestic Material Consumption). For Scotland, this figure represents slightly under 2% of the total material footprint due to peat extraction and the changes in inventory accounting methods. 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 using the previous methodology.[48] Excluding inventory changes, land use emissions in Scotland rose by 0.4 million tonnes of CO2e in 2019, despite efforts to expand forest cover in Scotland during the last decade.

Non-circular flows (15.0%)

This category centres on fossil fuels for energy use. Fossil-based energy carriers, such as gasoline, diesel and natural gas that are burned for energy purposes and dispersed as GHG emissions in our atmosphere, are inherently non-circular. Here, circular economy strategies such as cycling are not applicable as the loop cannot be closed on fossil fuels—although the circular transition will inherently reduce emissions through 'narrow' and 'regenerate' strategies. At 15%, Scotland's rate of non-circular inputs is relatively high, spotlighting the fossil-fuel-dependent character of the economy, especially for space heating and to power transport and industry. This is in spite of great advancements in decarbonising its electricity mix.

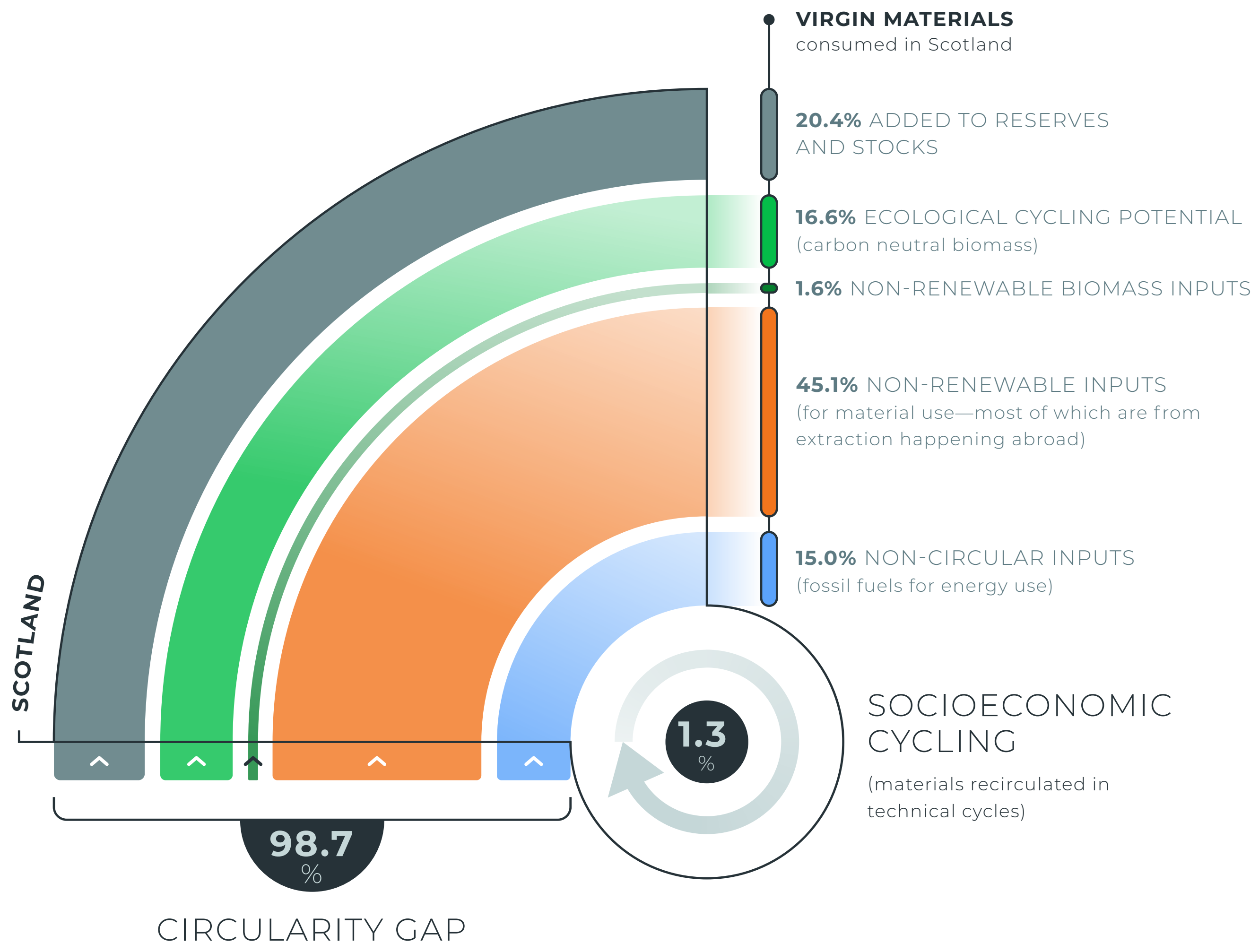


Figure three shows the full picture of circular and non-circular materials that make up Scotland's Circularity Gap.

Non-renewable inputs (45.1%)

Non-renewable inputs into the economy that are neither fossil fuels nor non-cyclable ecological materials include materials that we use to satisfy our lifestyles such as the metals, plastics and glass embodied in consumer products. These are materials that potentially *can* be cycled, but are not. Scotland's non-renewable input rate stands at a rather high 45.1%. However, it should be noted that the majority of this stems from extraction happening abroad for materials and goods and imported into Scotland. All of Net extraction abroad is allocated under Non-renewable inputs.

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 sufficient in itself: other nutrients such as nitrogen and phosphorus should be fully circulated back into the economy or the environment 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 in our calculation of Scotland's Circularity Metric, even though this could potentially boost the country's circularity rate to just under **20%**. For all nations, we take a precautionary stance with its exclusion, with the knowledge that its impact on the Metric may not be accurate. For example, we cannot track biomass extracted in Scotland to its final end-of-life stage, so it isn't easy to ensure that the nutrient cycle has closed. If this were the case, however—and if sustainable biomass management were to become the norm—circularity could significantly increase.

Net additions to stock (20.4%)

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 invest to ensure that their local populations 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 not available for cycling, and therefore weigh down the Circularity Metric. By employing circular strategies, such as lifetime extension, we could expect to see the rate of stock build-up further decreasing. At around 20% of total material consumption, Scotland's **stocking rate** appears to be only slightly lower than other countries for which this was estimated so far. Net additions to stock account for 86% of resources employed for material use and 45% of all processed resources—such as those used for energy. To compare, in absolute terms, net stock additions per capita in Scotland are 4.5, compared to 6.1 tonnes per person per year for neighbouring Northern Ireland and 10 tonnes per person per year in Sweden, primarily due to its higher population density.

CALCULATING INDICATORS BASED ON DOMESTIC MATERIAL CONSUMPTION PAINTS A DIFFERENT PICTURE OF MATERIALS AVAILABLE FOR RECIRCULATION

Together, Non-circular flows and Net additions to stocks represent 35% of material use, meaning that only 65% is available for recirculation. However, this figure is heavily influenced by the large volume of extraction occuring abroad. We allocate all extraction abroad to Non-renewable inputs—while it could also be part of Non-circular flows or Net additions to stocks, we don't have enough information to make this allocation. If we examine the indicator set based on Domestic Material Consumption instead of Raw Material Consumption, Net additions to stock rise to 36% and Non-circular flows rise to 26%, meaning that only 38% of all materials are available for recirculation. This figure can be considered more realistic, as it allows us to better allocate resources to the different indicators, in part due to a more complete data picture.

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

Stock build-up will continue to be necessary as Scotland's population grows 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. So why don't we do this?

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 many years. What's more, the circularity of materials added to stock 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 resources: its impact on Scotland's overall consumption should not be ignored, especially given crucial resource depletion concerns. The role of circular strategies in decreasing material consumption—and Net additions to stock on the whole—is critical.

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.[49]

In a bid to generate actionable insights for the economy and consumption on the ground, and to enable comparison between countries, our *Circularity Gap Reports* take a consumption perspective: we consider only the materials that are consumed domestically. However, there are some limitations to our approach: the more 'open' an economy is, the more susceptible it is 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 the demand of consumers for a certain product or service. 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.

So, why is it imperative to reduce consumption? Global resource extraction has exploded over the past several decades, triggering severe environmental consequences. Impact prevention through reduction in demand is an important first step before exploring other mitigation options. This is reflected also by environmental management hierarchies (for example, the waste hierarchy established in the EU Waste Framework Directive),[50] wherein the reduction of production and consumption is always the preferred and most effective strategy.

Thirdly, when considering what residents of Scotland 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. A motor vehicle, for example, may weigh 1 tonne when imported, but all the materials used to produce and transport it across global value chains can be as much as 3.4 tonnes. 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 87% of its GDP (2018),[51] doing so in the case of Scotland 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. 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. Whilst Scotland's waste management sector has been investing heavily in domestic reuse and recycling infrastructure, the market is not bound by geographical borders and materials can be transported wherever makes logistical, environmental and economic sense. Difficult-to-recycle materials and those that arise in smaller quantities can often be bulked and then transported for treatment in regional facilities.

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.

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

circularity-gap.world/methodology

PRACTICAL CHALLENGES IN QUANTIFYING CIRCULARITY

Providing a year-zero baseline measurement of the circularity of a national economy based on resource flows offers many advantages, not least that it can be used as a call to action. But the circular economy is full of intricacies, and therefore, simplifications are necessary, which result in limitations that must be considered. Some detail needs to be shed for the benefit of having an updated and relevant figure of circularity to guide future legislative action.

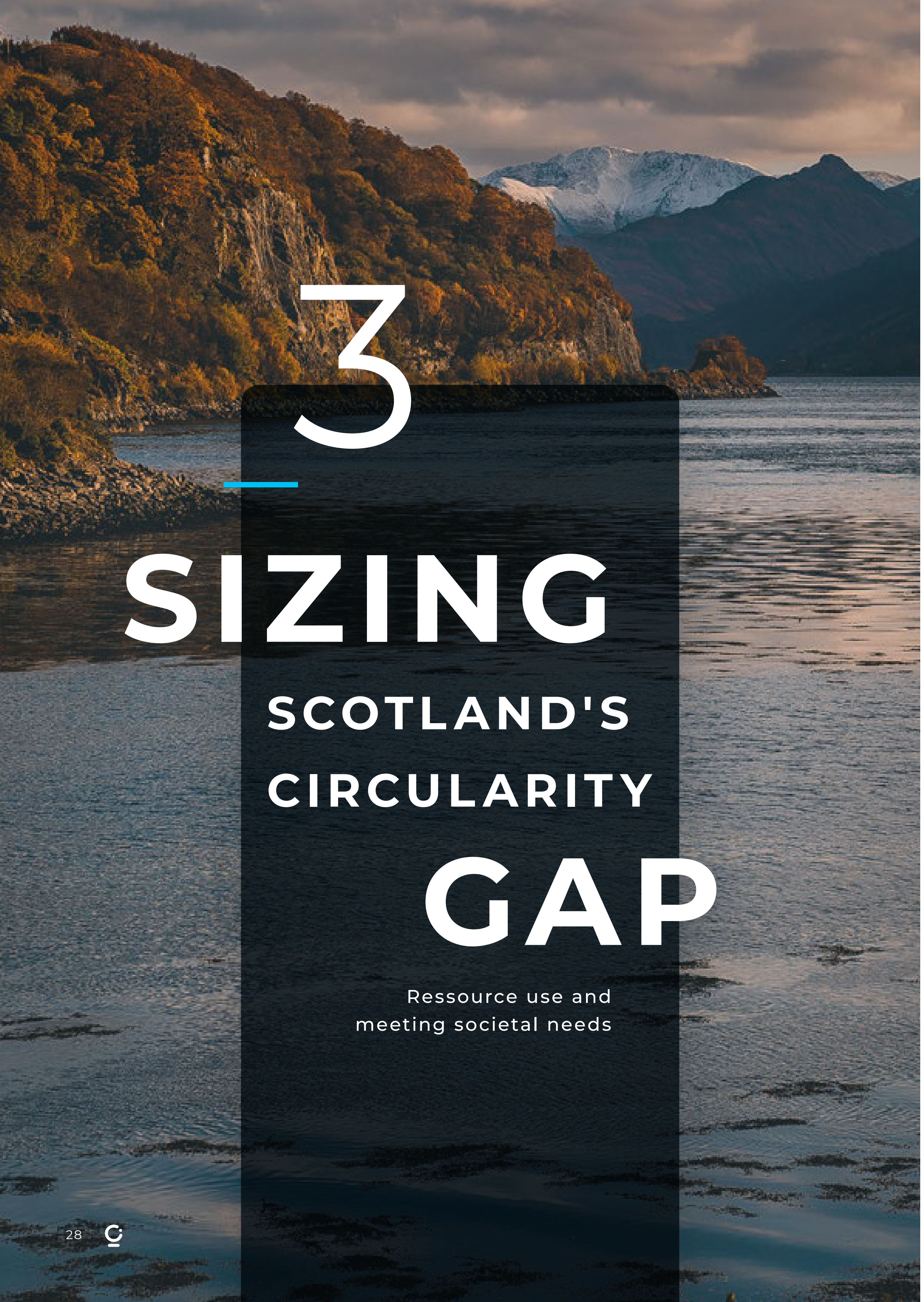
There is more to circularity than (mass-based) cycling. A circular economy strives to keep materials in use and retain value at the highest level possible, with the aim of decreasing material consumption. The cycling of materials measured by the Circularity Metric is only one component of circularity: 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 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.



3 SIZING SCOTLAND'S CIRCULARITY GAP

Ressource use and meeting societal needs

Scotland is 1.3% circular: the vast majority of materials flowing through its economy 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. Our analysis reveals Scotland's large material footprint and highlights how its economy drives vast extraction, both domestically and abroad. Key themes have emerged that illustrate the country's resource use: Scotland presents a material- and carbon-intensive profile, primarily driven by domestic extraction heavily dominated by fossil fuels, and heavy resource extraction and emissions abroad embodied in imports. On a sectoral level, the Agrifood, Manufacturing and Services industries comprise the largest portions of the country's material flows.

GLOBAL CIRCULARITY: FROM BAD TO WORSE

The *Circularity Gap Report 2020* identified that, for the first time in history, more than 100 billion tonnes of materials are entering the global economy every year. But as global resource use has reached new heights, the Circularity Metric has wilted from its 2018 rate of 9.1% to 8.6% in 2020. The reasons for this on the global stage are threefold: growing rates of virgin material extraction driven by an expanding global economy, which in turn leads to low(er) levels of end-of-use processing and cycling—as well as the need for ongoing stock build-up to provide for a ballooning population. The most recent iteration of our *Circularity Gap Report* illustrates the extent of our resource use: in the six years between Paris and Glasgow, the global economy consumed close to half a trillion tonnes of materials, causing emissions to spiral upwards.

The consumption of resources varies across continents and geographies, however. In light of the analysis in the 2020 Report, we see that Scotland is the exemplification of the *Shift* country profile—alongside most other high-income countries in the global North (see text box). This means that it scores very highly on the United Nations' Human Development Index (HDI), between 0.8 and 1, but its Ecological Footprint—an indicator that accounts for human demand for biological sources—reflects its mammoth level of consumption. If everyone on Earth were to live like the average UK citizen we would require the resources of almost 2.6 planets.[52]

In this way, the classic profile of a *Shift* country is one of high impact: these countries produce 66% of gross domestic product (GDP), while having only 20% of the global population. They also consume the largest share of the more than 100 billion tonnes of materials used globally and are major world traders. The pressure is on them to shift away from over-consumption of the planet's resources in servicing their relatively affluent and comfortable lifestyles. Their role in terms of global circularity is also prominent—the true impact of *Shift* countries extends far beyond their national borders, with much of the environmental and social costs incurred elsewhere. Scotland is a classic *Shift* country: as a high-income economy, it consumes more materials and energy per capita than most of the world's countries in fulfilling its residents' needs and wants.

NOT THE SAME, BUT SIMILAR: DIFFERENT COUNTRIES, COMMON NEEDS

Despite clear divergences between countries, suitable circular economy strategies can be developed based on discernible common needs. Based on the two dimensions of Social Progress—indicated by an HDI score—and Ecological Footprint, countries fall into three broad profiles:

Build—A low rate of material consumption per capita means Build countries currently transgress few planetary boundaries, if any at all. But they are struggling to meet all basic needs, including HDI indicators such as education and healthcare. Country examples: India, Bangladesh, Ethiopia.

Grow—These countries are manufacturing hubs, hosting an expanding industrial sector and leading the way when it comes to building. This rapid industrialisation, and a growing middle class, have occurred concurrently with rising living standards. Country examples: China, Brazil, Mexico, Egypt.

Shift—Home to a minority of the global population, material consumption in Shift countries is ten times greater than in *Build*. Their extraction of fossil fuels is relatively high, as is their participation in global trade. So despite high HDI scores which result in comfortable lifestyles, these countries have a way to go in consuming resources in line with the planet's resources. Country examples: United States of America, EU Member States, Gulf nations.

SEVEN SOCIETAL NEEDS & WANTS

Here 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 Scotland's total material consumption of 119.4 million tonnes. Since various products can be allocated differently, here we make our choices explicit. 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

HOUSING AND INFRASTRUCTURE

The construction and maintenance of housing accounts for around 20 million tonnes (17%) of the total material consumption.

NUTRITION

Agricultural products such as crops and livestock require just under 32 million tonnes (26%) per year. Food and beverage products tend to have short life cycles in our economy, being consumed quickly after production.

MOBILITY

A considerable share of total material consumption is taken up by the need for mobility: 16.3 million tonnes (13%). In particular, two resource types are used: the materials used to build transport technologies and vehicles like cars, trains and aeroplanes; plus, predominantly, the fossil fuels used to power them.

MANUFACTURED GOODS

Manufactured goods are a diverse and complex group of products—such as refrigerators, clothing, cleaning agents, personal-care products and paints—that generally have short to medium lifetimes in society. Textiles, including clothing, also consumes many different kinds of resources such as cotton, synthetic materials like polyester, dye pigments and chemicals. This accounts for 21 million tonnes (18%) of resources.

SERVICES

The delivery of services to society ranges from education and public services, to commercial services such as banking and insurance. The related share of total material consumption is the third largest, roughly 16 million tonnes (14%) in total, and typically involves the use of commercial buildings, professional equipment, office furniture, computers and more.

HEALTHCARE

With an expanding, ageing and, on average, more prosperous population, healthcare services are increasing globally. Buildings aside, typical products used include capital equipment such as X-ray machines, pharmaceuticals, hospital outfittings (beds), disposables and homecare equipment. This accounts for 11.3 million tonnes (9.5%).

COMMUNICATION

Communication is becoming an increasingly important aspect of today's society, provided by a mix of equipment and technology ranging from personal mobile devices 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. Total material consumption in this group is less intense, standing at 2.7 million tonnes (2.3%).

THE MATERIAL FOOTPRINT SATISFYING SOCIETAL NEEDS IN SCOTLAND

Domestic extraction

Figure four on pages 34–35 builds on the schematic material footprint diagram in Figure one on page 20. It dives into the socioeconomic metabolism of Scotland; linking how four resource groups (non-metallic minerals, metal ores, fossil fuels and biomass) satisfy the seven societal needs and wants shown on page 31. From left to right, the figure shows the domestic extraction of resources (Take) which amounts to **125.4 million tonnes**, mainly through the extraction of fossil fuels. These extraction processes result in raw materials like oil and gas. However, in a national context, domestic extraction represents only one of the inputs to the economy, which also includes directly imported products, weighing up at 38.5 million tonnes. Re-exports—products that are imported and without any processing are exported again—likely do not make up a significant part of Scotland's imports and therefore are not explicitly quantified in this study.

Material footprint

Considering not just the direct imports, but also the Raw Material Equivalents (RMEs), as previously introduced on page 19, we see that Scotland imports an additional 74.7 million tonnes of RMEs for a total import footprint of **113.2 million tonnes**. This means that Scotland's import footprint is in reality just about double the physical weight of its imports. The virgin materials typically undergo processing (Process), for example in the production of metals from ores, cement from limestone, or whisky from barley. Subsequently, these refined materials can be used for the manufacturing (Produce) and assembly of products like automobiles from metals, plastics and glass, or the construction of roads and houses. These finished products can, in turn, be distributed and delivered to provide services (Provide) and access to products that can satisfy societal needs and wants locally, or be exported. In 2018, Scotland exported some 100.2 million tonnes of final products with an associated RME of 20.5 million tonnes, resulting in an absolute export footprint of **120.7 million tonnes**. Knowing what happens to products and materials after their functional use in our economy (End-of-Life) is essential for identifying and addressing opportunities for a more circular economy. This is strongly tied to Scotland's material footprint—or virgin material consumption—of **117.8 million tonnes**. Factoring in its 1.6 million tonnes of secondary material use, Scotland exhibits a total material consumption of **119.4 million tonnes.**

Waste management

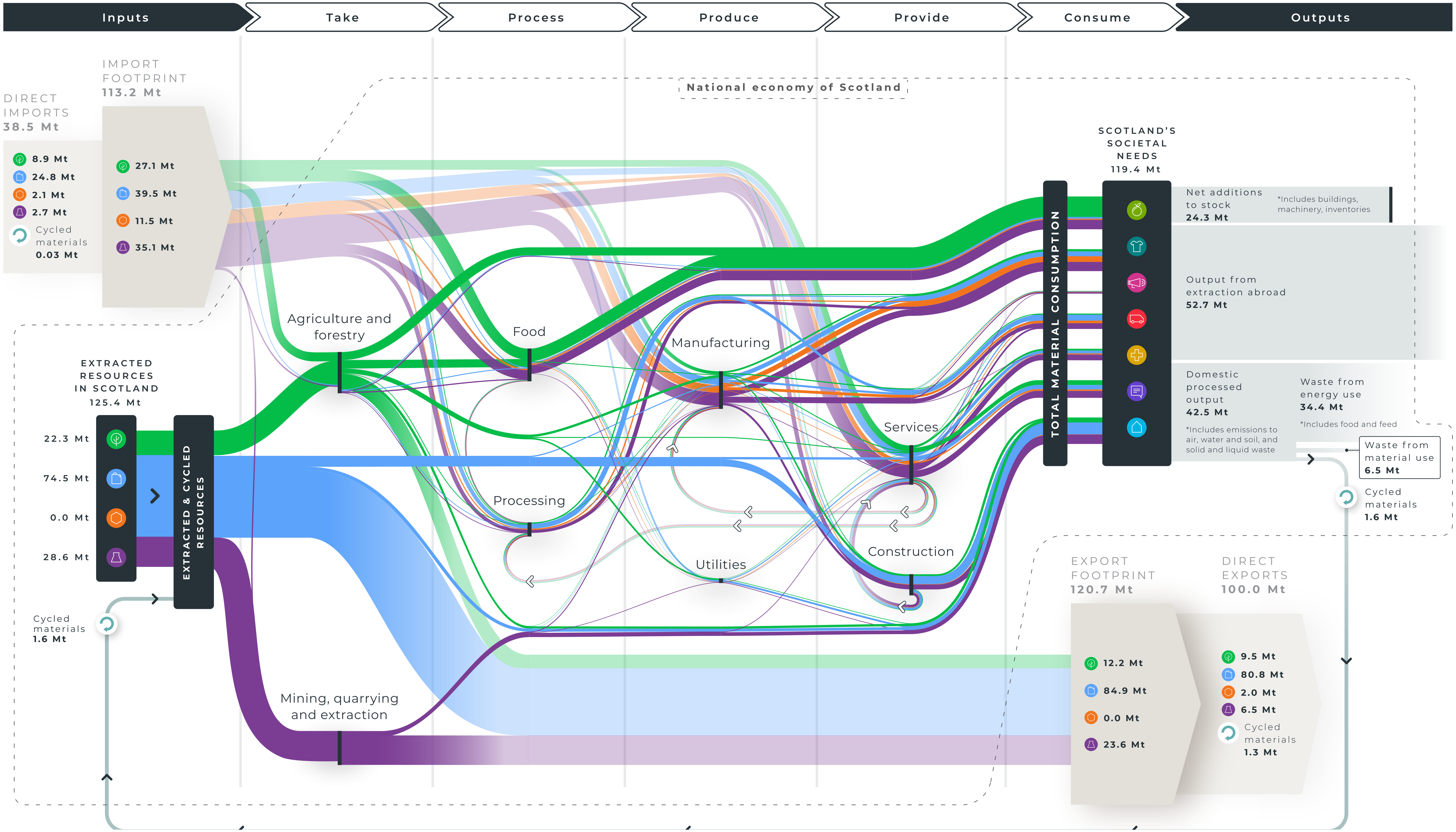
A considerable amount of the waste generated and treated belongs to waste streams that are not included in the systems boundaries of this analysis—and therefore should not be considered in estimating an economy-wide material cycling indicator[53] like our Circularity Metric. Under the new system boundary definition, 6.2 million tonnes of waste are classified as reported waste while another 3.07 would be classified as unreported. Almost all unreported waste is made up of manure (3 million tonnes),[54] with the remaining 0.1 million tonnes comprising fractions of crop residues. Of the 9.35 million tonnes of end-of-life waste that's treated (both reported and unreported), 30.3% is technical cycling of materials[55] (2.7 million tonnes), while the remainder is lost indefinitely. Of the latter, 6.7% ends up incinerated (including energy recovery) while another 32.1% is landfilled. The remaining 30.9% is composed of mainly 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 Circularity Metric. It is rather included as part of the Ecological cycling potential (see pages 22–24 for more information). About one-half of the waste that is recycled in Scotland belongs to waste streams that either don't fall within our analysis' system boundaries (such as sludges and liquid wastes from waste treatment, soils and dredging spoils) or do not fall under the definition of socioeconomic cycling (such as animal faeces, urine and manure). These differences in systems boundaries and in the nature of the indicators explain the gap between the rate of domestically cycled materials (30.3%), which feeds into the Circularity Metric,[56] and the traditional recycling rate obtained from traditional waste statistics (42%).[57] When it comes to trade in waste, Scotland's situation is underpinned by a highly negative trade balance in secondary materials: based on SEPA data,[58] the country is exporting 1.2 million tonnes more recyclable waste than it is importing, generating an import/export ratio as low as 2.5%. This, in turn, has a considerably negative effect on the Circularity Metric when a consumption-based perspective is taken, as less waste is re-entering the Scottish economy as secondary materials.

End-of-life waste is one element of a larger indicator called Domestic Processed Output (DPO), which can originate from both the material use and energetic use of products. DPO from energetic use (including food and feed) stands at 34.4 million tonnes, and is composed mainly of emissions to air, as well as manure and combustion waste. These emissions can stem from biogenic sources (16.4 million tonnes) as well as fossil fuel origins (17.9 million tonnes). Together with 6.5 million tonnes of DPO from material use (end-of-life waste excluding recycled materials), this adds up to a total DPO of 40.9 million tonnes. A small part (5.3 million tonnes), which originates mostly from energetic use, but partially also from material use, are so called 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.

Of the waste streams that *do* contribute to the Circularity Metric, and compared to other Northern European countries, Scotland has very low rates for the recycling of chemical and medical waste (2%), average rates for traditional recyclables (48%), moderate rates for mixed ordinary waste (38.2%), excellent rates for animal and vegetal waste (100%) and surprisingly low rates for mineral waste (17.4%). Of all these waste types, mineral waste, animal and vegetal waste, and recyclables are most prevalent, respectively claiming 29.8%, 17.4% and 13.4% of the total waste treated in Scotland (by weight). Better recycling rates for mineral waste and recyclables, therefore, would be key avenues for Scotland to boost its Metric.

X-RAY OF SCOTLAND'S ECONOMY

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



KEY THEMES OF THE SCOTTISH ECONOMY

Scotland's economy is resource-dependent and presents a material- and carbon-intensive profile. This can largely be attributed to two reasons: 1) high levels of domestic extraction (particularly of fossil fuels) and 2) the large import footprint, for all material groups but especially for non-metallic minerals and biomass. On a sectoral level, the Agrifood, Manufacturing and Services industries concentrate the largest shares of the country's material flows.

SCOTLAND DRIVES EXTENSIVE EXTRACTION, DOMESTICALLY AND ABROAD

Scotland is rich in natural resources, and is characterised by its material intensive industries: to this end, it exhibits very high levels of domestic extraction. A total of 125 million tonnes per year, Scotland's extraction is dominated by fossil fuels (**74.5 million tonnes**)—representing around 60% of extraction—with non-metallic minerals (**28.6 million tonnes**) and biomass (**22.3 million tonnes)** comprising the rest. No extraction of metal ores takes place domestically. Scotland's history and natural endowments point to this finding: the country was historically a coal-rich part of the UK—and as the industry began to decline, the discovery of hydrocarbons beneath the North Sea in the late 1960s shifted fossil fuel extraction to crude oil and natural gas. Although fossil fuel extraction has been on the decline since the advent of the 21st century—and has plateaued in the last decade—Scotland has held a crucial role in providing these fuels: it extracts 81% of all fossil fuels in the UK, and nearly all of its crude oil. Smaller-scale opencast coal mining and peat extraction also contribute to this mix. While extraction may be expected to slow in light of Scotland's bold intentions to reach net-zero, the UK government has recently announced plans to open new oil and gas wells in the North Sea to maximise production—a move deemed incompatible with current climate plans.[59]

In addition to its fossil reserves, Scotland is rich in a range of non-metallic minerals due to its varied geology: hard rock quarrying, sand and gravel extraction are most prevalent, while barytes mining, gold mining and silica sand extraction occur on a smaller scale.[60] The country's rich coastal waters,[61] expanding woodlands and forests,[62] peatlands[63] and vast grasslands—as well as its significant food and drink sector—indicate a rich bioeconomy and agrifood sector: biomass extraction includes some cereal crops (barely, wheat and oats, for example) and some vegetables, but primarily livestock farming, cattle and sheep in particular. As the relatively small forestry sector grows, timber production is also on the rise.

The extraction of these three key resource groups totals 125 million tonnes—or **22.8 tonnes** per person per year, more than quadruple the UK average of 5.3 tonnes per person per year and more than double the world average of 12.3 tonnes. Per capita domestic extraction for fossil fuels alone tops the world average for total extraction, at 13.7 tonnes per person, per year—while rates for biomass and non-metallic minerals represent smaller portions, at 4.4 and 5 tonnes per person per year. Foreign demand for Scottish resources is largely driving this mammoth extraction: only 20% satisfies the country's own final demand, with the remainder slated for export. Nearly 50% of total extraction—largely comprising fossil fuels with some non-metallic minerals—is exported to the rest of the UK, with the remaining 30% is sent abroad.

As only 20% of Scotland's domestic extraction is used within its borders, it follows that imports are high: just as foreign demand drives Scottish extraction, Scotland drives extraction abroad, which totals 60.3 million tonnes[64]—nearly half of the country's total material footprint. Roughly three-quarters of the extraction needed to satisfy Scottish final demand takes place beyond its borders, with international suppliers meeting its entire need for metal ores and a substantial volume of non-metallic minerals and biomass products. Scotland largely imports products with extremely high embodied resources: either due to their nature (for example, certain fertilisers which require heavy excavation of rocks and minerals) or due to inefficient production processes employed by trading partners.

LARGE MATERIAL AND CARBON FOOTPRINTS ARE LEAVING THEIR MARK

In spite of its well-known efforts in the environmental space, Scotland's material footprint exceeds planet-healthy levels at 117.8 million tonnes, or **21.7 tonnes** per person per year. This figure is high even for industrialised *Shift* countries and is comparable to the material footprints of Nordic European countries—which have the highest per capita material footprints worldwide. Sweden's material footprint amounts to 25 tonnes per person per year, while Finland's is 30.9 tonnes, and Norway's is 44 tonnes. While it sits considerably below the Norwegian average, Scotland's per capita consumption exceeds the UK's by around 35%, which stands at 18.2 tonnes[65] per person per year. Such a high per capita material footprint can partly be explained by a colder climate (requiring higher quantities of fossil fuels for space heating, for example) and, perhaps most importantly, very low population density (resulting in less efficient resource use per capita for civic amenities provision and infrastructure development, for example). Looking into Scotland's share of the global population compared to its per capita footprint shows the extent of its material use: the country represents 0.1% of the world's total material footprint, despite representing just 0.073% of the world's population.[66]

Scotland's decarbonisation efforts have brought some success: its carbon footprint has fallen sharply by 21% between 1998 and 2017.[67] For comparison, the UK's carbon footprint fell roughly 28%, but Norway's increased by 14%[68] during the same period.[69] It remains fairly high, at a total of **75 million tonnes** of CO2 equivalents (CO2e): 61.2 million tonnes of indirect emissions that relate to final consumption and 13.8 million tonnes of direct emissions generated by Scottish households, through activities from heating to transport. The average person in Scotland is responsible for 13.8 tonnes of greenhouse gas emissions per year—one-third more than the average UK resident, with a carbon footprint of 10.3 tonnes per capita. On global terms, Scottish residents are emitting more than double the world average of 5.5 tonnes. It is important to note that this figure excludes the massive amount of fossil fuels that Scotland exports. To add some further perspective, fossil fuel exports account for 124% of Scotland's domestic material consumption (DMC) or 72% of its material footprint in raw material equivalents (RME).

This is inextricably tied to—and driven by—Scotland's consumption footprint: its consumption-based carbon footprint is a substantial 42% larger than its territorial emissions. This means that much of Scotland's carbon footprint is 'externalised': emissions are spewed abroad and embodied in the products imported into the country. Of the total carbon footprint, 17% of emissions are embodied in imports from the UK, and 60% are embodied in products from the rest of the world—only one-quarter originate within Scotland's borders. Examining Scotland's territorial emissions serves to further highlight its position in our highly globalised world: less than half of emissions occurring domestically can be linked to consumption within the country—the rest are embodied in exports.

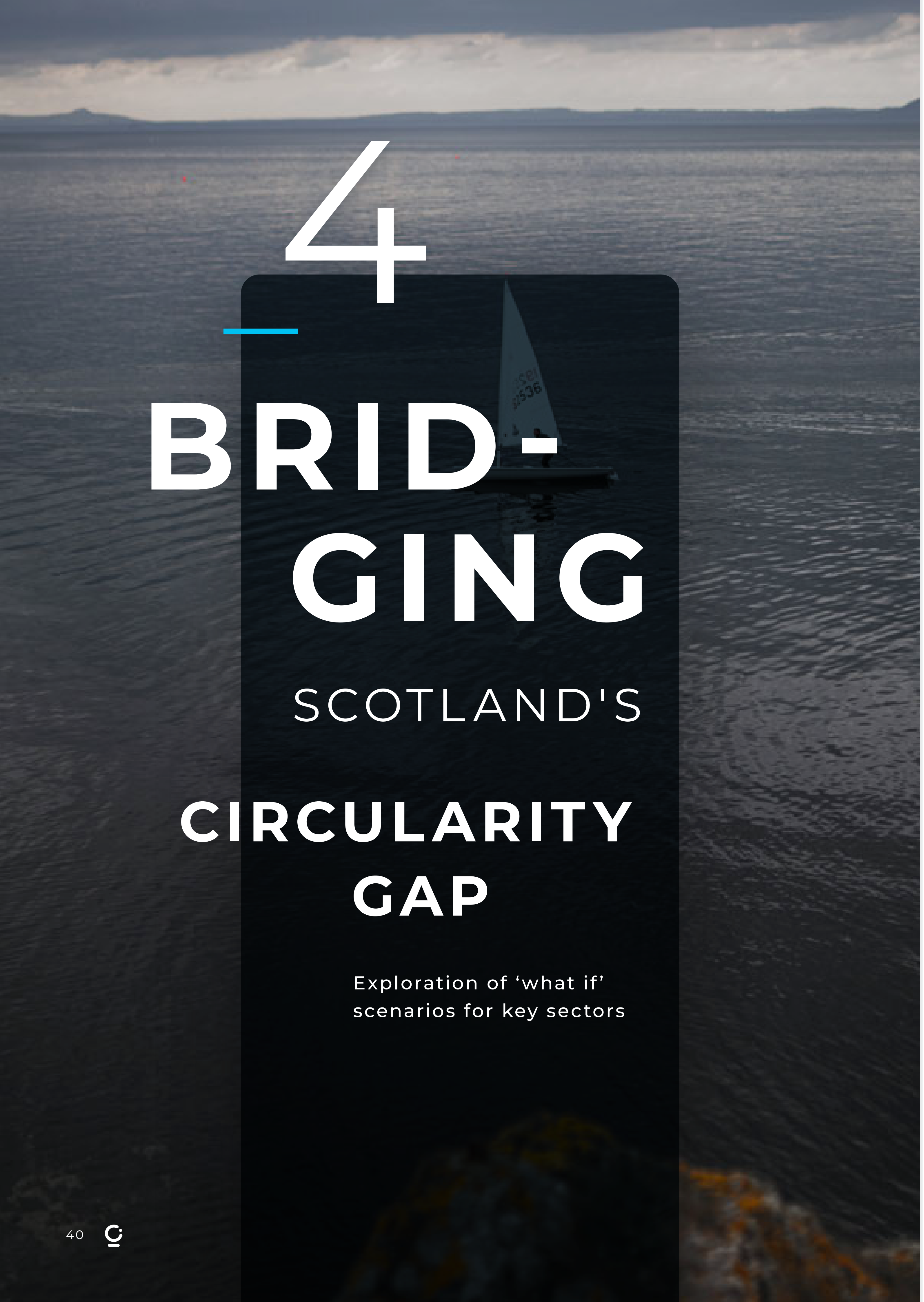
Nearly half of the country's consumption-based carbon footprint stems from high fossil fuel use in just ten sectors:[70] Air transport (7.4%), Construction (6.8%), Manufacture of machinery and equipment (5.9%), Health and social work (5.3%), Public administration and defence (5%), Manufacture of motor vehicles, trailers and semi-trailers (4.5%), Hotels and restaurants (3.7%), Petroleum Refinery (2.9%) and Processing of food products (2.9%). Oil (mainly for transport) and natural gas (for powering industry and for heating) are the two main fossil fuels behind Scotland's carbon footprint. Crucially, although ranking in a slightly different order, these ten sectors are also responsible for the majority of the material footprint: material use is inextricably tied to emissions. Cutting these sectors' material footprints through circular strategies will be a key means for emissions abatement in Scotland.

AGRIFOOD, MANUFACTURING & SERVICES EMERGE AS KEY INDUSTRIES OF THE SCOTTISH ECONOMY

Zooming into the composition of Scotland's economy, three industries stand out as key contributors to Scotland's material footprint: Agrifood, Manufacturing and Services. The top ten sectors of the Scottish economy—part of these three industries—account for around 40% of Scotland's total material footprint. The four key sectors of the agrifood industry together represent **14%** of the country's total material footprint: processing of meat cattle (4.1%), processing of food products (3.9%), cultivation of vegetables, fruits and nuts (3.4%), and cattle farming (2.7%). Scotland's agrifood industry is known throughout the world for the production of food and drinks—from beef and seafood to whisky and beer. Domestic extraction—in other words, agriculture—supplies around one-third of the biomass demanded by the sector: imports remain very important, especially for animal feed. This once again emphasises the country's sizable footprint for extraction abroad. What's more: the production of whisky, beer and fish alone creates 4.6 million tonnes of bio-based waste and by-products each year.[71] This highlights an opportunity for increased circularity: the high-value reuse or recycling of this waste, matched by improved resource efficiency, should be prioritised to achieve a more circular bioeconomy.[72]

The second key industry—manufacturing of machinery and equipment (5.4%), manufacturing of motor vehicles, trailers and semi-trailers (4.3%) and petroleum refineries (2.9%)—together contribute around **12.6%** of Scotland's material footprint. In Scotland, the manufacturing industry comprises resource-intensive sectors that consume vast quantities of virgin materials, energy and water—generating emissions and waste in the process. Key sectors are oil and gas refining, iron and steel works, and the production of cement, chemicals, pulp and paper, and food and drinks, among others.[73] While these all require vast quantities of materials, sectors linked to the production of metals and metal products stand out as the most material-intensive.[74]

Accounting for the energy consumption and the materials embodied in their use (buildings plus office equipment, for example), the three key sectors of the services industry make up a total of around **13.4%** of Scotland's **material footprint**: Health and social work (5.6%), Hotels and restaurants (4%), and Public administration and defence; and compulsory social security (3.8%). For instance, Scotland's 23,000 public sector buildings—including public administration offices, hospitals and health centres, libraries, primary and secondary schools, universities and research centres, museums, and more—are heavy energy consumers, and are largely heated with fossil fuels. Fortunately, the Scottish government is already taking steps to combat this, with goals to decarbonise public sector buildings by 2038 at the latest.[75] Other reasons for these buildings' material-intensive characters include food consumption (for schools and hospitals in particular) and the consumption of equipment—office and medical equipment, for example. Private sector buildings in the services industry—such as hotels and restaurants—present a similar picture: material-intensive buildings with high food consumption and appliance use.



4 BRIDGING SCOTLAND'S CIRCULARITY GAP

Exploration of ‘what if’ scenarios for key sectors

Now that we have presented how Scotland’s Circularity Metric and Indicator Set are derived, deep dived into the country's material footprint and investigated the messages it portrays, it’s time to suggest a remedy. For the chosen sectors, we have formulated scenarios that explore and entertain the ‘what-if’, allowing us to dream big and imagine a more circular, resource-light and low-carbon Scotland. They serve as an exploration of a potential path forward but also sketch which type of sectors and interventions could be most impactful in terms of steering the Circularity Metric and material and carbon footprints.

BRIDGING THE CIRCULARITY GAP: 'WHAT IF' SCENARIOS

In our *Circularity Gap Reports,* our scenarios have been largely free from the constraints of law or political realities: deliberately non time-specific and exploratory, their real-life materialisation did not inform our analysis. Through this approach, we are able to freely imagine what our society could look like with truly transformational change: a close to fully circular economy. Below, we present an action plan that allows us to 'dream big' and sketch which type of interventions and levers are most impactful in terms of driving forward the Circularity Metric, as well as impacting the material and carbon footprints.

We have funnelled our focus for the ‘what-if’ scenarios into seven areas and industries that represent key leverage points for Scotland's economy, using 2018 as the baseline year for our analysis. These scenarios are 1) Build a circular built environment, 2) Nurture a circular food system, 3) Champion circular manufacturing, 4) Rethink mobility, 5) Welcome a circular lifestyle, 6) Tackle Scotland's import footprint and 7) Advance circular decommissioning. By focusing on a few key sectors, we can dive deep and apply a diagnostic lens to identify where we can best apply interventions to increase the circularity and resource efficiency of Scotland and optimise the transformation of resource use into social benefits. 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).

The selection of the scenarios was based on quantitative and qualitative research, which allowed us to paint a picture of what we're able to model based on methodological limitations. In calculating the total impact of the scenarios on Scotland's economy, we can only measure the changes to the material footprint and the Circularity Metric, taking a mass perspective. We also measure changes to the carbon footprint; however, due to data limitations, we can only measure changes in indirect emissions (and not direct emissions). Although indirect emissions (61.2 million tonnes of CO_2e) represent roughly 82% of Scotland’s total carbon footprint (75 million tonnes of CO_2e), the fact that direct emissions (13.8 million tonnes of CO_2e) are excluded from our calculation for the footprint reduction means that some interventions' full potential is not captured. This is especially true for interventions targeting households. Hence, it is crucial to be aware that our reporting on changes in the carbon footprint only refers to changes in ‘indirect emissions’. Additionally, under each scenario, we also report the co-benefits of the chosen circular strategies beyond their impact on material flows. Our modelling capacity is continuously evolving and improving: this is reflected by the approach in this report and will continue to improve for future editions. For more information on our scenario modelling, you can refer to our Methodology document.

We are aware that measuring the effects of the suggested interventions in terms of their effect on the Circularity Metric and material and carbon footprints is a crude simplification which must ignore other relevant aspects such as additional ecological parameters. However, we see the value of this analysis in contributing to the dynamic debate on where to place our bets for enhanced circularity and reduced consumption in Scotland and beyond.

Our scenarios are informed and developed by the ultimate aims of slowing, narrowing, cycling and regenerating resource flows, as described on page 21, which provide a jumping-off point for the strategies needed to spur systemic changes.

1. BUILD A CIRCULAR BUILT ENVIRONMENT

Globally, the impact of the built environment is enormous: the societal need for housing demands 38.8 billion tonnes of materials—one-third of the global material footprint[76]—while construction and operation activities account for well over one-third all carbon emissions,[77] 40% of energy use and one-fourth of solid waste generation.[78] Circular economy strategies, however, provide an opportunity to cut material use in the industry. For example, practices upstream in the supply chain—such as design[79] and the manufacturing of building materials and components—can be employed to expand buildings' use and (re) cycle their materials, instead of sending them to landfill or incineration. Buildings act as huge banks of often-reusable materials: optimising this is key to ensuring a more circular, resource-light and low-carbon economy. Material choice is also a critical factor in reducing buildings' embodied carbon, and sustainable options are abundant: from rock wool insulation,[80] which makes use of slag waste from steel blast furnaces, to UK-manufactured Veka uPVC windows utilising recycled materials,[81] to wooden composite cladding using FSC certified wood reclaimed from post-industrial manufacturing.[82] Choosing materials wisely—and ensuring their value is optimised through multiple life cycles—will be crucial for realising Scotland's circular economy: the country's societal need for Housing—which is represented by both construction and maintenance practices—consumes 20.3 million tonnes, or 17% of the total material consumption.

The industry also plays a key role in the Scottish economy: it contributes around €24.7 billion (£21.5 billion) to the country's GDP and represents one-tenth of GVA,[83] also providing work to a substantial one-tenth of the workforce.[84] The construction industry is the most integrated in the Scottish economy: if £1 is purchased from this industry, £2.65 is generated in other industries of the economy.[85] The need for housing within the country is growing, with the total new supply increasing by roughly 20,000 new homes (or 15%) between 2018 and 2019.[86] As stock build-up continues, policy that puts environmental concerns front and centre—while still taking a systemic approach—will be crucial: Scotland's *Housing to 2040*[87] strategy aims to do just this, addressing both social and environmental issues through a holistic approach that considers practices such as off-site construction and stock decarbonisation, and concerns housing affordability and urban design. A well-functioning housing system shouldn't only tackle issues of community cohesion, inequality and fuel poverty—it also has the power to act as a catalyst for economic and environmental transformation. Prioritising circularity in construction—and gearing Scotland's €18.4 billion (£16 billion) investment package for housing towards such practices—hold huge potential to provide for Scottish residents while contributing to environmental action.

In this what-if scenario for the built environment, we explore opportunities for Scotland to optimise its building stock expansion, increase housing occupancy, and create a more resource-efficient building stock and more circular construction practices—allowing the country to both boost its circularity and cut construction's hefty material use.

1.1 OPTIMISE BUILDING STOCK EXPANSION

Our first intervention targets the Scottish construction sector's material use through strategies that **narrow** material flows and **cycle** materials. Slowing the rate of new builds means that less materials will be required by the construction industry—and improving the reuse of building materials (steel and timber, for example) and components (doors and window frames, for example) will further reduce the need for virgin inputs.

Scotland's housing stock is swelling: as of 2020, there were 2.51 million households and 2.65 million dwellings across the country—an increase of 6% and 6.6% over the past decade. Since the advent of the 21st century, the number of households has increased by 14%, owing to a growing population and a trend towards smaller households.[88] Residents are increasingly living alone: in the early 1970s, roughly 310,000 households were single-occupant—a figure that has since tripled. This can likely be tied to the country's ageing population—the elderly are more likely to live on their own, or in smaller households. These trends imply a projected increase in the housing stock: an estimated 12,000 new homes will be needed each year until 2028.[89] Circularity must be embedded in the construction industry to ensure this new construction has minimal impact: limiting the construction of new dwellings with virgin materials can be achieved by scaling secondary material, product and component use—either from construction and demolition waste, or decommissioned energy infrastructure. This will require both targeted investment and strong policy support, as well as the building of cost-effective, localised supply chains. Currently, the *National Planning Framework 4*[90] aims to encourage developers to minimise waste and carbon intensity, while the Construction Scotland Innovation Centre[91] enables net-zero and resource-light practices, for example. Research has also focused on advancing circularity in the construction, through supply chain-wide actions aimed at maximising the reuse of materials on site, for example.[92] The roll-out of new actions proposed for construction, ranging from the introduction of 'best practice' standards to a *Scottish Programme for Reuse of Construction Materials and Assets*, is a promising development.[93]

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 27%. This restriction is set on three-quarters of housing stocks. This could be achieved by implementing a tax on virgin construction materials, incentivising the uptake of secondary materials, for example. We also assume that all construction and demolition waste that is suitable for reuse—about 75% of the total—is cycled and used again for new construction. This could be enabled by subsidising the use of secondary materials, for example. In order to still meet the demand for housing, we boost spending on renovation and retrofitting and assume that these are performed to the maximum, which is about 41% of the total building stock. This could be driven via targeted grants and tax breaks, for example. As a result of retrofitting, we assume a decrease in energy consumption that is equal to passive housing levels. 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.

By limiting its building stock expansion and making it more circular, Scotland could cut its material footprint by a substantial 6.2%, bringing it down to 110.5 million tonnes. The carbon footprint would decrease by 3.6%, reaching 58.9 million tonnes of CO_2e (excluding direct emissions). In the case that we exclude unreported waste and consider three-quarters of waste suitable for reuse, the Metric could grow by 0.55 percentage points, reaching 1.9%.

1.2 INCREASE HOUSING OCCUPANCY

This scenario's second intervention presents a range of strategies to increase building occupancy. Doing so will cut the total number of buildings needed—ultimately **narrowing** material flows. Additionally, as empty properties tend to remain empty and therefore deteriorate more quickly due to insufficient maintenance, boosting occupancy can also make buildings last longer, **slowing** resource flows.

As of 2020, 4.3% of dwellings in Scotland were unoccupied—two-thirds of which remained empty for a year or more.[94] In the Scottish context, empty houses pose a number of problems as a lack of available and affordable housing are becoming serious social issues, and uninhabited buildings further tighten the housing supply and drive up prices. The increasing commodification of housing has also exacerbated the issue: housing is not considered a fundamental human right or social good, but rather an investment asset. Such investment decisions often fail to consider the negative impacts on community lives and neighbourhoods.[95 96] Empty housing also fuels virgin material use, as new building stock is needed to meet demand. Fortunately, the Scottish government has considerable room to determine housing development through budgetary commitments and legislative changes. Some action has already taken place in this arena: 2013 saw the introduction of an increased council tax for some empty properties in an effort to stimulate housing availability—with long-term empty properties facing a tax increase of 200%.[97] The Scottish Empty Homes Partnership, funded by the Scottish Government, also aims to put the country's privately-owned, long-term empty homes back into use through collaborations with local councils, landlords and community groups.[98]

To assess the impact of this intervention, we model a mix of supply and demand-side measures. We assume that the number of second homes and Airbnbs are regulated, matched by incentives for co-housing and multifunctional spaces: tax breaks, for example. For second homes and Airbnbs, we assume that around 5% of real estate's footprint could be cut by up to 85%, considering that these spaces have far lower occupancy than normal homes. Rather than assuming a proportional reduction in the stock of dwellings (since these dwellings would not simply 'disappear'), we modelled the impact of reducing monetary transactions from households to real estate services—in other words, rent—for that share of the residential stock, as rent is assumed to embody the annualised footprint of the constructed dwellings. For co-housing and multifunctional spaces, we assume a potential increase in occupancy of up to 25%, and a proportional decrease in the footprint of real estate services—along with cuts in electricity and heating fuel consumption as a result of increased occupancy. Increasing occupancy could be driven by a tax or levy on unoccupancy. By implementing this scenario, Scotland could expect a reduction of 5.6% in the material footprint, bringing it to 111.2 million tonnes, and 5.1% in the carbon footprint, bringing it to 58.1 million tonnes of CO2e. The Metric would increase by 0.1 percentage points, growing to 1.4%.

1.3 CREATE A RESOURCE-EFFICIENT BUILDING STOCK

This scenario's final intervention comprises two strategies: scaling resource-efficient construction practices—thereby cutting construction waste—in an effort to **narrow** flows, and implementing deep renovation practices, such as green retrofitting, repair and maintenance, which will serve to **narrow** and **slow** resource flows. Retrofitting activities should use secondary and non-toxic materials to the greatest extent possible, **cycling** and **regenerating** flows: material choice is important, as embodied carbon in certain materials may generate knock-on effects, counteracting benefits from improved energy efficiency.

In Scotland, the impacts of buildings' use phase and construction phase are broadly equal, when considering the embedded emissions 'locked in' during the construction process, and the emissions generated over a building's 60 year lifespan. The impact of inefficient or poorly insulated buildings are further exacerbated by the relatively cold, damp climate. What's more, nearly one-quarter of homes across the country were living in fuel poverty in 2019—with one-tenth living in extreme fuel poverty:[99] unable to keep their homes adequately warm at an affordable cost. Targeting support to address this is essential: for example, by improving the energy efficiency of homes (taking a 'fabric first' approach) and replacing fossil fuel heating systems with renewable alternatives—measures that will directly benefit those in fuel poverty by reducing energy costs in addition to generating emissions savings. Doing so will be crucial for meeting climate ambitions, particularly as occupied dwellings represent a substantial 15% of Scotland's territorial greenhouse gas (GHG) emissions.[100] The government is making strides in this area, already allocating substantial funding for heat and energy efficiency projects in social housing[101] and supporting building decarbonisation through the *Heat in Buildings Strategy*.[102] Embracing circular strategies will be a crucial component of achieving the government's aim: at least half of the building stock heated via an emissions-free system by 2030. It is also important to consider that for physical and material upgrades to be successful, changes and innovations in behaviour, regulation and society more generally will be crucial.[103] Regulations, for example, should simplify planning permissions for retrofitting processes, allowing people to adapt their homes with ease rather than moving to a different house.

For this intervention's supply and demand-side strategy for resource efficiency, we assume a reduction in virgin steel and aluminium consumption. We also model an increase in services to construction to compensate for expected increases in the cost of demolition and assembly work. A 15 to 20% reduction in on-site construction material losses, uptick in the use of local construction materials and supply chains, greater use of energy efficient home appliances (like washers, dryers and irons), a decrease in room temperatures of 2-degrees and more smart metering are also considered. This intervention's second strategy focuses solely on the demand-side, and models measures for deep renovation. We assume a 60% reduction in energy demand considering that deep renovation would help houses reach a 'passive house' standard of energy consumption. This assumption was applied to the portion of housing in need of renovation. 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. All together, this intervention could cut the material footprint by 5.2%, bringing it down to 111.68. The carbon footprint would decrease by 6.2%, to 57.4 million tonnes of CO2e. In all, the Metric would grow by 0.07 percentage points, to 1.41%.

Impact on Scotland's circularity:

Combined, the interventions for housing could decrease the material footprint by a massive 11.2%, bringing it from 117.8 million tonnes to 104.6 million tonnes. The carbon footprint would be similarly reduced by 11.5%, decreasing to 54.1 million tonnes of CO2e. The Metric could grow by 0.65 percentage points, bringing it from 1.3% to 2%. This scenario could also bring a range of social and economic co-benefits; retrofitting, for example, can serve to increase energy efficiency and cut energy consumption,[104] which in turn can increase resilience by reducing dependence on foreign resources 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.[105] 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.[106 107]

2. NURTURE A CIRCULAR FOOD SYSTEM

Globally, food systems are one of the biggest drivers of environmental damage, from climate change to biodiversity loss:[108] barreling past several planetary boundaries,[109] they contribute one-third of total GHG emissions[110] and take hold of nearly 40% of total landmass to grow crops, graze livestock and produce animal feed.[111] In Scotland, this figure is even higher: over 70% of the country's land—or roughly 6 million hectares—is used for agricultural practices.[112] However, while grassland types vary across the country's regions, having differing impacts on landscapes and wildlife,[113 114] generally poor soil quality and a rocky topography mean that much of the country's land is unsuitable for growing crops: the vast majority of agricultural land can be attributed to grazing cattle and sheep. Only a tiny portion (2%) of this is managed organically—and ever-prevalent, intensive land use is a prime driver of biodiversity loss.[115] Scotland's agrifood sector is a substantial employer and contributor to the economy: it boasts a strong presence in communities across the country—especially in rural areas, where it's the third largest employer.[116] It is also important for trade. Beer, whisky and fish represent the largest portion of agrifood products and also account for the bulk of the sector's exports: in 2021, Scotch whisky exports totalled a substantial €5.2 billion (£4.5 billion), claiming three-quarters of international exports of food and drink—the remainder of which was represented primarily by fish and seafood.[117] The agriculture and agrifood sectors, however, are not without impact. Grazing's prevalence means that forest cover is relatively low, claiming less than one-fifth of Scotland's land as of 2019—although the government aims to substantially boost this figure, while also prioritising peatland restoration, both of which will act as valuable carbon sinks and boost biodiversity. National policy for agriculture is also currently under development: expected in 2023, this policy ideally will balance the need for high-quality food production with stringent environmental standards that cut emissions and protect biodiversity while building resilience. Realising this will require both supply and demand side measures, ranging from more sustainable farming methods to shifting the dietary habits of Scotland's residents.[118] A 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 where sustainable diets (in other words, those that remain within the ecological limits of the planet) are the norm—and human health and communities' livelihoods are protected.[119]

Research identifies a shift towards healthier diets, substantial cuts in food loss and waste, and huge improvements in food production practices as key levers to make global food systems sustainable.[120] To this end, this scenario comprises two interventions to cut food's impact: through endorsing a balanced diet and cutting food waste, while adopting more sustainable food production, Scotland can both boost its circularity and substantially reduce its environmental footprint.

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 foods would serve to both **narrow** and **regenerate** resource 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—like inedible shells, peels or bones—should be **cycled.**

Dietary choices have a substantial impact on both human (mental and physical) health[121 122] and the environment,[123 124] with research showing that the healthiest diet for the planet and people is very low in meat and high in plant-based protein and whole grains.[125 126] On the whole, Scottish residents' have relatively poor diets high in fat, sugar, salt and alcohol—while comparatively low in whole grains, fruits, vegetables and fibre.[127] Meat consumption—well-known to have adverse environmental effects, and negative health outcomes if consumed in large quantities—exceeds that of neighbouring England, especially for lower socioeconomic groups, while there is a lower consumption of healthier foods such as fruits and vegetables.[128] Overweight and obesity figures are high, and have been on the rise for the last two decades,[129] resulting in a high occurrence of diet-related diseases such as diabetes and high blood pressure as well as excess mortality.[130] The social component cannot be ignored: the poorest diets tend to afflict lower-income residents (owing to a multitude of factors), and a large portion—nearly one-tenth—of residents are food insecure.[131] While some attention has been afforded to tackling obesity[132]—a tax on sugary drinks, for example[133]—progress has been slow and insufficient. Dietary goals must be tied to environmental ones, as the two are inextricably interlinked: and tides may be changing, with shifting mindsets and calls for action to improve the Scottish food environment providing encouragement.[134]

Food waste also poses a serious challenge: in 2014, it's estimated that Scotland wasted nearly 1 million tonnes of food and drink—three-fifths of which can be attributed to households.[135] This household waste represents a staggering €1.3 billion (£1.1 billion) unnecessarily spent on food and amounts to 1.6 million tonnes of CO2e emissions. Unfortunately, the majority of this waste (around two-thirds) is considered 'avoidable'—meaning it could have been eaten, such as leftovers or food that's past its best-by date.[136] Over the past decades, significant investments have been poured into improved infrastructure for households to improve waste management, which had a slightly positive effect between 2009 and 2014—and now, Scotland's *Food Waste Reduction Action Plan*[137] aims to deliver on ambitious targets to cut food waste by one-third compared to 2013 levels by 2025 and end landfilling of biodegradable food waste.

In modelling this intervention, we apply demand-side measures composed of three layers. First, the average per capita food consumption of Scottish residents is reduced to 2,700 calories per day, as a proxy for adopting a balanced diet.[138] Second, avoidable post-consumer food waste is eliminated, which is estimated at two-thirds of the post-consumer waste in the case of Scotland. 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 decreased consumption of meat products, matched by an equivalent increase in the caloric intake of cereals, fruits, vegetables and nuts.[139] These changes in dietary habits could be encouraged by the introduction of carbon and/or health-based taxes on food,[140] for example, the 2018 introduction of the 'sugary drinks' tax by the UK government. Other policy instruments, such as grants for dietary advice, and the wider provision of personalised nutrition advice through the healthcare system could also be used to support dietary changes. However, it should be noted that there are broader cultural and societal elements at play here, which would also require shifts.

If all Scottish residents were to embrace a vegetarian diet, the impact on both the material and carbon footprints could be substantial: reducing them by 9% and 6.4%, respectively. Moreover, the Metric could increase by 0.65 percentage points, to 2%.

2.2 ADOPT 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 reduced fuel consumption for heating them). While Scotland's topography, climate and soil make this challenging, we can envision a food production system as sustainable and low-waste as possible—one that works alongside nature, protects biodiversity and cuts emissions and chemical inputs.

86% of Scottish land has been designated 'Less Favoured Area':[141] an EU classification that recognises natural and geographic disadvantages for agricultural activities—as noted, the rocky topography and cool climate don't prove favourable for arable farming. Nonetheless, the country boasts about 5.6 million hectares of agricultural land comprising 51,000 farms. Only a small portion—around 4,600 farms—were dedicated to crop production, primarily for cereals.[142] 80% of farms raise livestock, from poultry and pigs to cattle and sheep, producing meat, milk and eggs. The sector as a whole contributes a substantial 16% of Scotland's territorial GHG emissions—half of which can be linked to livestock production, with a further one-third linked to soils.[143] However, cattle numbers have been on the decline since the mid-1970s and 2020 marked a 60-year low: a trend that has led to a 16% decrease in methane emissions compared to 1990.[144] Continuing along this path could see the advent of an agricultural system that benefits the environment, minimises resource use, protects biodiversity and sequesters carbon in soil and plants. Improving land use by prioritising organic production and boosting tree cover—through agroforestry, for example—could provide numerous benefits for the country, such as lower emissions and healthier soils.[145] Policy instruments that provide the needed economic benefits, such as tax incentives, could be used to promote sustainable farming practices: taxes on chemical fertilisers and pesticides, and subsidies and grants for switching to more sustainable agricultural practices, for example. But getting there will require robust farm-level support, extension services and technical advice: direct payments that support innovation, for example, or training for farmers to develop new skills.[146]

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.[147] 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.[148] If Scotland were to embrace these strategies, it could reduce its material footprint by a modest 1.8%, bringing it down to 115.7 million tonnes. The carbon footprint could shrink by 0.6%, to 60.8 million tonnes of CO2e, and the Metric could increase by a slight 0.03 percentage points, to 1.37%.

Impact on Scotland's circularity:

In calculating results for this scenario as a whole, we considered our first intervention's most impactful strategy—a vegetarian diet—as well as sustainable food production. All together, this scenario could bring substantial benefits: the material footprint could drop by 9.1%, bringing it down to 107 million tonnes, and the carbon footprint by 6.8%, bringing it down to 57 million tonnes of CO2e. The Metric could grow by 0.7 percentage points, up to 2%. Other studies, with a better methodological approach for measuring GHG emissions reduction in land-use management changes, have calculated a realistic 35% decrease in territorial emissions derived from agriculture by 2045 through the implementation of a combination of more sustainable agricultural practices.[149] Shifting to a more circular food system would also bring numerous co-benefits: a dietary shift to a plant-based diet—where animal products are replaced by healthy alternatives—could have positive impacts on health,[150 151 152] in addition to benefiting biodiversity and soil health.

3. CHAMPION CIRCULAR MANUFACTURING

Since the 19th century, Scotland has been hailed as one of Europe's industrial powerhouses, and is known to be a world leader in heavy manufacturing. Within the last 50 years, there has been a shift of sorts, with services playing a bigger role in the economy compared to heavy industry—but the latter remains a proud part of the country's heritage. The industry also remains a crucial facet of Scotland'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.[153 154] Employing around 170,000 people, the manufacturing industry accounts for more than half of the country's international exports, worth €21.3 billion (£18.5 billion), and is a significant investor in research and development.[155] However, less positively, the industry is responsible for nearly one-third of Scotland's territorial GHG emissions: highly-polluting industrial processes—oil and gas refining, iron and steel works, and the production of resource-intensive products such as cement, chemicals, pulp and paper, and food and drinks—are prevalent.[156] Disruptions stemming from the covid-19 pandemic, the UK exit from the EU, and increasing cries for sustainability are all posing challenges—but also providing opportunities for high-value, sustainable manufacturing. Across the industry, targets have been set to use resources more efficiently, cut carbon emissions, reduce energy use and waste and embrace industrial symbiosis. We envision a circular manufacturing industry for Scotland, where products and parts are reused at their highest value, design is aimed at optimising product lifetimes and current modes of production and sales are radically changed.

To this end, this 'what if' scenario for Scotland's manufacturing industry outlines opportunities to pivot away from linearity: we highlight how to advance resource efficiency by making better use of (metallic) waste in industrial processes, and how to extend product lifetimes through various R-strategies, from remanufacturing and refurbishment to repair and reuse. It is also worth noting that Scotland's manufacturing industry may advance circularity via industrial heat recovery projects and the development of district heating networks to utilise excess industrial heat;[157] however, we were unable to model these interventions.

3.1 IMPLEMENT RESOURCE EFFICIENT MANUFACTURING

This scenario's first intervention centres on improving manufacturing's resource efficiency—both during initial stages, where materials are formed, and 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 in early stages: cutting yield losses involves making the most of technological advances to get more from less. Further along the value chain, where the 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.

For the most part, Scotland's manufacturing industry comprises 'traditional' sectors, characterised by the production of goods with high metal content: machinery, equipment and manufacturing engineering, for example.[158] The metals sector in Scotland is largely dependent on trade: the country isn't a primary steel or aluminium producer, for example, yet it consumes a substantial amount of these materials to manufacturing other goods,[159] driving up the import footprint. Exports are also abundant: metals, metal products, computer and electrical equipment, machinery and equipment and transport equipment comprise roughly one-third total exports for manufacturing, contributing nearly 70,000 jobs.[160] The industry holds substantial potential for advancing circularity and progress towards net-zero: the reprocessing of materials and recycling of waste and end-of-life products can contribute deep cuts in virgin material and energy use. In Scotland, scrap from metal manufacturers, structural steel from demolition, metal packaging, decommissioned energy infrastructure, waste electrical and electronic equipment and end-of-life vehicles can all act as important sources for material reprocessing and recycling.[161] These processes are largely concentrated in industrial areas between Glasgow and Edinburgh.[162] There is already substantial activity around making manufacturing net-zero and circular in Scotland. For example, the new National Manufacturing Institute for Scotland (NMIS)—including the Advanced Forming Research

Centre[163] and the Lightweighting Manufacturing Centre[164]—is expected to become an integral and international centre for manufacturing expertise, with a focus on resource efficient and lightweight manufacturing.[165] Additionally, the Scottish Institute for Remanufacturing[166] stimulates and supports the remanufacturing community in Scotland and beyond. It provides a catalyst for collaboration between academia and industry to work effectively on joint projects and demonstrations, by identifying funding opportunities and providing a central hub of knowledge and expertise. This supports businesses in their development, allowing them to sustain remanufacturing business models. By developing the latest technologies available and taking advantage of Scotland's low-carbon electricity grid, improving the domestic circular management of scrap steel holds enormous potential to cut GHG emissions, create highly-skilled green jobs and increase the resilience of the steel industry.[167]

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. All together, this intervention could decrease the material footprint by 5.5%, bringing it down to 111.3 million tonnes, and the carbon footprint by 1.8%, bringing it down to 60.1 million tonnes of CO2e. All strategies combined would see an increase in the Metric of 0.08 percentage points, bringing it up to 1.42%.

3.2 EMPLOY R-STRATEGIES FOR MACHINERY, EQUIPMENT AND VEHICLES

Our second intervention employs various R-strategies[168] (see text box on page 51) for manufacturing machinery, equipment and vehicles. Remanufacturing and refurbishment practices can be leveraged to extend product lifetimes, therefore **slowing** flows. Scotland 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 product-oriented system, the aim is to maximise the number of products sold; PaaS circumvents this and therefore contributes to **narrowing** flows. Incorporating sustainable processes and materials in the early phases of design will also be crucial: lightweighting through material substitution, additive manufacturing and near net-shape (NNS) manufacturing, for example, both serve to cut waste and emissions.[169] For instance, additive manufacturing, similar to 3D printing, allows for flexible and highly material efficient production processes for material such as biochemicals, metals and ceramics in sectors such as aerospace, automotive and medical.[170] NNS manufacturing is a collection of industrial manufacturing techniques for materials such as ceramics, plastics and metals that allow for production processes that aim for a good or component to be produced as close to the final product as possible, thus reducing material inputs, waste material and (procurement, production, and waste disposal) costs.[171]

Scotland stands to gain a lot from embracing such strategies: one remanufacturing study carried out in 2015 estimated that the market potential for remanufacturing—for aerospace, energy, automotive, rail, medical equipment, ICT and electronics—is enormous: at the time, it employed around 17,000 people and boasted a value of around €1.3 billion (£1.1 billion).[172] As a high-value and high-impact but underexploited activity, the potential for growth in remanufacturing is high: both economically and to cut material input, energy use and emissions. It also offers opportunities to decrease manufacturing costs, build resilience against materials shortages and price volatility, enable shorter lead times and lessen the need for warehouse space—but gleaning the most from this potential will require systematic shifts in business models and supply chains. Already, the Scottish Institute for Remanufacturing is supporting manufacturing businesses in taking up remanufacturing.[173]

Other R-strategies like repair and reuse also provide significant opportunities for Scotland to boost its circularity and cut material use, by retaining the value of materials and complexity of products while stimulating innovation and creating jobs: the reuse sector is estimated to be worth around €281 million (£244 million) per year, and sustains over 6,000 jobs.[174] These strategies are also core elements of the country's national circular economy strategy. From a practical perspective, city councils are working to improve recovery at recycling centres, and encouraging repairability in public procurement.[175]

For this intervention, we first model a mix of supply-side measures for remanufacturing and refurbishment. The overall volume of sales would stay 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 example, 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, we assume that the overall volume of sales is reduced, due to product lifetime extensions precluding the need for new purchases. All together, this intervention could cut the material footprint by 5%, lowering it to 111.9 million tonnes, and the carbon footprint by 2.8%, bringing it down to 59.5 million tonnes of CO2e. The Metric could be boosted by 0.07 percentage points, reaching 1.4%.

Impact on Scotland's circularity:

Scaling resource-efficient manufacturing processes and implementing various R-strategies across the sector could decrease Scotland's material footprint by a massive 10.5%, lowering it from 117.8 million tonnes to 105.4 million tonnes. This Scenario would also result in emissions reduction of 4.6%, bringing indirect emissions to 58.4 million tonnes of CO2e. The Metric would rise by 0.3 percentage points, to a total of 1.6%. 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 volatility in prices, reduced energy consumption from efficiency gains, reduced waste generation and lower material input by keeping materials in use for greater time, for example. Scaling the uptake of R-strategies could also rouse greater private sector involvement in the circular economy, creating new opportunities for businesses, incentivising innovation and laying the groundwork for longer-term resilience and competitiveness.

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

- We understand **remanufacturing** as 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.
- We understand **refurbishment** as a procedure to improve the quality of a product up to a specified quality.
- We understand **repair** as the reparation of the parts that limit the performance of a product, and the maintenance of parts that can help to prolong the 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.
- We understand **reuse** to mean an extension of a product's lifetime, therefore displacing 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.

4. RETHINK MOBILITY

Getting people and products from one place to another is highly emissions- and material-intensive: around the globe, we're heavily dependent on cars, trucks, trains, ships and aeroplanes for every-day commuting, travel and freight shipping. Unsurprisingly, transport claims the largest portion of Scotland's territorial GHG emissions, representing around 37% of the total.[176] Scotland's new *National Transport Strategy*[177] aims to tackle this, setting out a vision and goals for the country's mobility system over the next two decades. Two key commitments include cutting car kilometres travelled by one-fifth, and phasing out the purchase of new petrol and diesel vehicles, both by 2030. Achieving these aims will require heavy investment in infrastructure—mobility hubs and electric vehicle charging stations, for example—to quickly implement technological advancements, as well as measure and instigate a society-wide modal shift towards more sustainable forms of transport. So far, decarbonisation for small passenger vehicles is already progressing; but reaching net-zero for air, train and sea travel will require further innovation backed by heavy investment. Where electrification isn't possible, alternative technologies—such as hydrogen and alternative fuels—should be considered. However, it's crucial to note that technical solutions alone won't be enough for Scotland to reach its net-zero goals; a shift in modes of transport and mobility patterns will be crucial, and future policy must reflect this, enabling behavioural change through infrastructure and urban planning that supports reductions in transport and car-free lifestyles.

This 'what if' scenario reimagines Scottish mobility, modelling two interventions to cut the material footprint and boost circularity. It boasts strategies such as embracing a car-free lifestyle, encouraging a modal shift, supporting flex work and prioritising efficient and electric vehicles. It's worth noting that this scenario only measures the impact of changes to private mobility—passenger vehicles in particular. Ensuring the optimisation and decarbonisation of all transport across Scotland—from buses and trains to ferries—will require broader and more systemic change.

4.1 EMBRACE A CAR FREE LIFESTYLE, IMPROVED MODAL SHIFT AND FLEX WORK

This scenario's first intervention explores the benefits of Scotland decreasing the need for mobility and rethinking mobility systems, ultimately enabling Scottish residents to embrace a more car-free lifestyle—and continuing to work from home where possible. Doing so would 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 overall shift away from private transport, further **narrowing** flows.

Scotland's geography influences the country's private vehicle use: the prevalence of rural areas and communities and low overall population density and population dispersion results in most journeys being made by car.[178] Car use exceeds the EU average—although car ownership lags behind the EU average, and the vehicle-to-population ratio rests somewhat below Britain's: 55 vehicles per 100 people, compared to Britain's 59. Roughly two-thirds of commuters get to work by car—with just 12% walking, 10% travelling by bus and 3% cycling. This is set to worsen: forecasts suggest that if current trends continue, vehicular travel will spike by 40% by 2037.[179] However, policy to counteract this is emerging: the UK's *Transport Decarbonisation Plan*[180] aims to, among others, improve public and active transport, while Scotland is set to reduce car use in terms of kilometres travelled by 20% by 2030,[181] and to invest in active travel infrastructure and create mobility hubs.[182] 80% of rural commuters use the car in comparison to 55% of urban work journeys:[183] considering the different conditions and needs of urban[184] and rural communities is also crucial when disincentivising car use for commuting. In this sense, introducing regulations such as 'low emission zones' in a fair manner can cut the number of cars within cities and towns, whereas focus can centre on improving public transport provision and internet connections in rural communities.[185] Incentivising public transport services and making them more reliable and affordable (via subsidising integrated ticket options, for instance) as well as clear public communication and messaging around sustainable mobility alternatives for encouraging active travel—such as cycling and walking—will be crucial in enabling a positive modal shift.[186] Promoting the extension of work-from-home models in the wake of covid-19 could also bring some environmental benefits: research has found that telework in Scotland can decrease emissions from commuting and office use, although this is partially offset by an increase in home emissions (from homes needing to be heated during the day, for example).[187] Improved urban planning could also serve to reduce the need for mobility, particularly for private vehicles, by improving public transport provision and walking environments, and providing services more locally and thus reducing and optimising resource use. It is also relevant to highlight that when it comes to current (unsustainable) models for urban mobility, a reliance on technical and digital 'solutions' often fails to address the root causes of the present state.[188]

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. Additionally, around one-third of the mobility need is covered by 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. In all, this intervention could decrease Scotland's material footprint by as much as 5.9% (primarily due to reduced fossil fuel demand), bringing it down to 110.8 million tonnes, and the carbon footprint by 2.6%, bringing it down to 59.6 million tonnes of CO2e. The Metric would grow by 0.08 percentage points, to nearly 1.4%.

4.2 DRIVE EFFICIENT VEHICLES AND ELECTRIFY THE FLEET

While focus should ideally centre on reducing mobility and transportation—especially by car—and developing new mobility systems, as explored in our first intervention, clean new technologies are also needed. This scenario's second intervention comprises a number of strategies that tackle the production and use phase of vehicles. Scotland has an opportunity to **narrow** resource flows by prioritising small(er), more lightweight, fuel-efficient vehicles, cutting material and fuel use. This could include private cars, public transport vehicles and freight transport. Moving toward 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 such as lithium, cobalt and nickel for batteries, for example. It is important that this intervention is understood in the context of the previous one—i.e., a substantial reduction in the fleet size—in order to prevent certain trade-offs and knock-on effects.

This intervention is well-aligned with the UK's *Road to Zero Strategy,*[189] which aims to build a fully electric vehicle fleet by 2050—and phase out new petrol and diesel vehicles by 2030. When compared to other European countries, the UK on average is doing quite well, boasting the third-largest ultra low emission vehicle (ULEV) fleet. There's still a way to go, however: ULEVs only represent a little more than 1% of the total number of cars on the road. Scotland's net-zero plans feature similar goals to shift to zero-emission vehicles. Electric vehicles are fortunately on the rise: sales of these cars made up one-fifth of all new vehicle purchases in late 2021,[190] an increase of 24% from the previous year. Newly-registered cars are also largely more efficient: emissions from new vehicles have dropped by more than one-fifth over the last decade. Nonetheless, the vast majority—98%—of cars operated on petrol or diesel in 2018, illustrating ample room for improvement.[191] Although the demand for electric vehicles is projected to surge over the coming decades, a number of factors will determine the environmental success of fleet electrification in Scotland: investment in recycling infrastructure for vehicle batteries, fit-for-purpose logistical and regulatory frameworks, and the building up of existing capability in technology design and manufacturing, for example.[192]

In modelling our final intervention for 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.[193] 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.[194] 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.[195] By creating a fleet of small, lightweight electric vehicles, Scotland could cut its material footprint by 4%, bringing it down to 113.1 million tonnes. The carbon footprint would decrease by a slight 0.5%: a 0.7% decrease from lightweighting offset by a 0.2% increase from electrification. This is because our methodology only considers indirect (supply chain) emissions—while the real benefit of electrification lies in the reduction of direct (tailpipe) emissions. Therefore, it's expected that the impact of this intervention could be far greater than it appears. In all, the Metric could increase by a small 0.06 percentage points, reaching 1.4%.

Impact on Scotland's circularity:

By realising these interventions for circular mobility, Scotland could cut its material footprint by 4.6%, bringing it down to 112.4 million tonnes. We also expect a reduction in emissions of 2.4%, bringing indirect emissions down to 59.7 million tonnes of CO_2e. This intervention could also boost the Metric by 0.07 percentage points, bumping it up to 1.41%. Scotland 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. Increased active transport and reduced sedentarism can also result in positive outcomes for human health due to increased physical activity, such as reduced obesity and overweight.[196] 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 diminished collaboration and social interaction, as well as fair distribution of extra costs by employers and employees, should also be considered and addressed.[197] The potential for direct and indirect benefits will depend on the exact magnitude of the intended changes, and the potential for overcoming conflicting effects.

5. WELCOME A CIRCULAR LIFESTYLE

Our current linear economy is largely consumption driven—but excessive materialism has been found to damage individual wellbeing, as well as the environment. Our dominant economic model has bred a damaging cycle: consumable goods are manufactured from raw materials, sold, used, and then, largely, are discarded:[198] waste is created without regard for people or planet. This system has emerged from an economic model that puts profit above people and cultural trends that glorify or prioritise ownership and revere material wealth. While businesses and regulators are responsible for making sure that products are produced sustainably, individual consumption choices are often the best way to induce that change. To this end, this scenario explores the impact of shifting to a more sustainable, community-based lifestyle that reduces individual consumption and prioritises sharing models over ownership. Like other high-income *Shift* countries, Scotland's society is largely based on consumerism. Supermarkets offer a broad array of plastic-packaged ready-meals, for example, while retailers offer hundreds upon hundreds of ever-changing, often low-quality garments to keep up with the latest trends—a huge change from previous generations. This has caused 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,[199] 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,[200] examining the impact of a material 'sufficiency' lifestyle: having enough, but not too much. This will require heavy consumers to buy and own less 'stuff'. We analyse the impact of shifting to a more circular mindset for goods like clothing, food and its packaging, and household appliances and furniture, as well as activities like travel.

5.1 EMBRACE A 'MATERIAL SUFFICIENCY' LIFESTYLE

This scenario explores just one intervention: a low-impact lifestyle that values minimalism and conscious living over excess and wastefulness.[201] We examine a range of strategies aimed at minimising consumption, **narrowing** flows, encouraging residents of Scotland to use products for longer, **slowing** flows, as well as 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: the needed shift is one to a lifestyle of 'material sufficiency' where high standards of wellbeing are still maintained.

Current consumption patterns of household goods, such as clothing, furniture, paper products, and household appliances—driven by consumer choices and deeply ingrained in habits and culture—generate environmental pressures both in Europe and abroad.[202] [203] In Scotland, consumption of goods (such as textiles) and services (transport and travel) represent a significant part of average weekly household expenditure.[204] Adjusting and gearing this consumption towards circularity—cutting consumption and improving the environmental profile of the products still consumed—holds great potential. It could cut the resource-intensity of the Scottish economy, both nationally and abroad via the supply chains of household goods and services. For example, fashion's impact has gained notoriety in recent years: it requires vast volumes of water and energy to produce, and creates massive waste. An estimated €161million (£140 million) worth of used clothing—approximately 350,000 tonnes—goes to landfill per year in the UK. Consumption is also on the rise: UK households are spending more on clothing each year, although the trend is slowing.[205] Yearly, the average UK household's new and existing clothing equals the weight of more than 100 pairs of jeans—with embodied CO2 emissions equivalent to driving a modern car more than 9,500 kilometres.[206] What's more: on average, nearly one-third of households' wardrobes haven't been worn for at least a year. Cutting each garments' carbon, water and waste footprints by up to 10% would be relatively simple, requiring just three additional months of active use per item. Shopping second-hand also presents a valuable opportunity to cut clothing's impact: already, two-thirds of UK consumers buy pre-owned clothing—and there's a willingness to wear more, especially if a better range of options were made available.[207]

The production of household appliances in Europe requires vast amounts of materials (predominantly metals like steel and copper as well as plastics). They also consume plenty of energy and water during usage, and, given their low recyclability and less-than-ideal options for disposal, generate environmental impacts throughout their entire lifecycle.[208]

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. Producers and consumers should be encouraged, for example via tax incentives, to reuse and repurpose their clothes each season, rather than discarding old and selling and buying new items—an action with substantial environmental impact that will also positively impact budgets. 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. Tax breaks on repair services (such as reduced VAT, which is already the case in some European countries) as well as stricter standards and incentives to design for repairability and disassembly could enable these changes. 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. This could be realised through repair cafés, tool libraries or other realisations of the sharing economy. As an example, in 2021, the Scottish Government and Zero Waste Scotland funded the establishment of a nation-wide sharing library and repair café network, delivered by Circular Communities Scotland. It aims to significantly increase sharing and repair facilities across the country, in order to reduce consumption and offer Scottish communities sustainable and affordable alternatives to buying new.[209] 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. Finally, we assume that local cultural activities and home-based hobbies like gardening are preferred to long-distance travel. It's worth noting that while our model focuses on community-based repair services, there are a number of other opportunities for systemic change. Businesses, for example, will have a crucial role to play in adopting and scaling more circular business models, while also incorporating circular principles in their product design. Offerings should focus on affordability and convenience, and give customers the opportunity to have their small goods—from kettles and toasters to hair dryers—repaired, in order to prevent new purchases.

Impact on Scotland's circularity:

In total, this scenario's sole intervention could reduce the material footprint by 14.6%, a huge 17.16 million tonnes, bringing it down to 100.7 million tonnes; cut the carbon footprint by 14%, bringing it down to 52.6 million tonnes of CO_2; and boost the Metric by 0.2 percentage points, increasing it to 1.54%. Other environmental co-benefits include Scotland enjoying 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.

6. TACKLE SCOTLAND'S IMPORT FOOTPRINT

As discussed previously in this report, Scotland's high material footprint has largely been driven by extraction abroad to satisfy the country's demand: Net extraction abroad (NEA) accounts for over two-fifths of total material consumption, according to our analysis (see page 24 for more information). This figure's size can be attributed to Scottish imports' extremely high Raw Material Equivalent (RME) coefficients (see page 19), particularly for products classified as non-metallic minerals. Essentially, this means that 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 production processes carried out by trading partners. Unfortunately, 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.[210] Tracking extraction taking place abroad is undoubtedly tricky: resources can either be embodied in goods eventually imported into Scotland, 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 Scotland, distinguishing between these various paths is impossible. However, we are able to explore a scenario where we model a change in high-impact material flows coming from abroad. In this scenario's only intervention, we explore the impact of shifting away from high-impact imports by substituting the import of certain materials and increasing the efficiency of domestic industries.

6.1 SHIFT AWAY FROM HIGH-IMPACT IMPORTS

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

Scotland has a relatively open economy[211] that is closely integrated with the rest of the UK[212] and Europe. International trade has grown over the last two decades—however, through its trade strategy, government emphasis has centred on exports and the need to promote Scottish companies on the international stage. By comparison, imports have received little attention.[213] In 2019, the country's imports were valued at €27 billion (£23.5 billion), with most products coming from Norway, the US, China, Germany and the Netherlands.[214] Natural gas, mechanical and electronic equipment, power generating and industrial machinery, petroleum products and related materials, and transport equipment top the list in terms of the goods flowing into Scotland.

In this intervention, we target the top ten Scottish industries in terms of their material footprint, by identifying the upstream drivers of material impacts by region, whether it's within the UK or from the rest of the world. As explained in Chapter three, 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 Scotland'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, industrial machinery and equipment, construction materials, chemicals, timber, cattle and cattle meat, and natural gas and related services. 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, cattle meat production should still decrease on the whole—but what is produced should be as circular, sustainable and local as possible.

Impact on Scotland's circularity:

This scenario's sole intervention would see a reduction in the material footprint of a huge 10.1%, bringing it down to 106 million tonnes. The carbon footprint could be cut by 4.7%, lowering indirect emissions to 58.3 million tonnes of CO2e, while the Circularity Metric could grow by 0.25 percentage points, boosting it up to 1.6%. By shifting away from high-impact imports, Scotland could also reduce environmental impacts abroad by decreasing extraction, pollution, emissions and waste. Societal and economic co-benefits include strengthened ecological and economic resilience through reduced dependence on the most environmentally impactful foreign imports. New business and job opportunities can also arise by reshoring the production of certain goods and service offerings.

7. ADVANCE CIRCULAR DECOMMISSIONING

Decommissioning describes a collection of processes aimed at dismantling and taking (industrial) equipment and infrastructure out of use once it has reached its end-of-life. In this sense, decommissioning is tightly linked to an economy's materials stock: ultimately, it concerns the management of these materials once existing assets reach their end-of-life. Decommissioning is a growing opportunity for Scotland's economic and industrial strategy—and has kicked off following the launch of the *Oil & Gas Decommissioning Action Plan*[215] in 2016. A year later, the creation of the Decommissioning Challenge Fund[216] was announced as a means to align and support all activities tied to effective, high-value and large-scale decommissioning of offshore energy projects. These projects are rife with opportunity: analysis estimates that Scottish decommissioning activities for oil and gas alone could create an additional €9.5 billion to €13 billion (£8.3 billion to £11.3 billion) over the next decade, and could potentially support up to 20,000 jobs.[217]

While circular principles such as refurbishment and lifetime extension would usually take top priority, a number of economic, environmental and political concerns suggest that decommissioning is the most appropriate option for some assets, such as oil and gas infrastructure and nuclear power plants. Indeed, large-scale decommissioning in Scotland has mostly centred on the country's vast oil and gas infrastructure. Scotland also currently has three nuclear sites at advanced stages of decommissioning.[218] In addition, the majority of Scotland's hydropower capacity was developed in the years following the second World War, up until the 1960s[219]—and many plants are now reaching their end-of-life. Ensuring that these assets are appropriately managed in this phase is a key avenue for advancing circularity: if well-planned, circular decommissioning can provide a 'bank' of valuable materials such as concrete, steel, iron and copper for reuse. Scotland can tap into the potential of its large-scale energy infrastructure, from power plants to offshore oil and gas platforms, that make up its material bank.[220] However, to date, decommissioning has primarily followed a linear model, with little regard for social and environmental factors. Circular decommissioning requires substantial knowledge, expertise and financial resources—in addition to the development of new supply chains and collaboration between various actors, from regulators to operators.

In this scenario, we therefore explore the impact that the recovery and reutilisation of decommissioned materials from energy infrastructure—hydropower and oil and gas—could have on construction works and for metal recycling.

7.1 OPTIMISE CIRCULAR ENERGY INFRASTRUCTURE DECOMMISSIONING

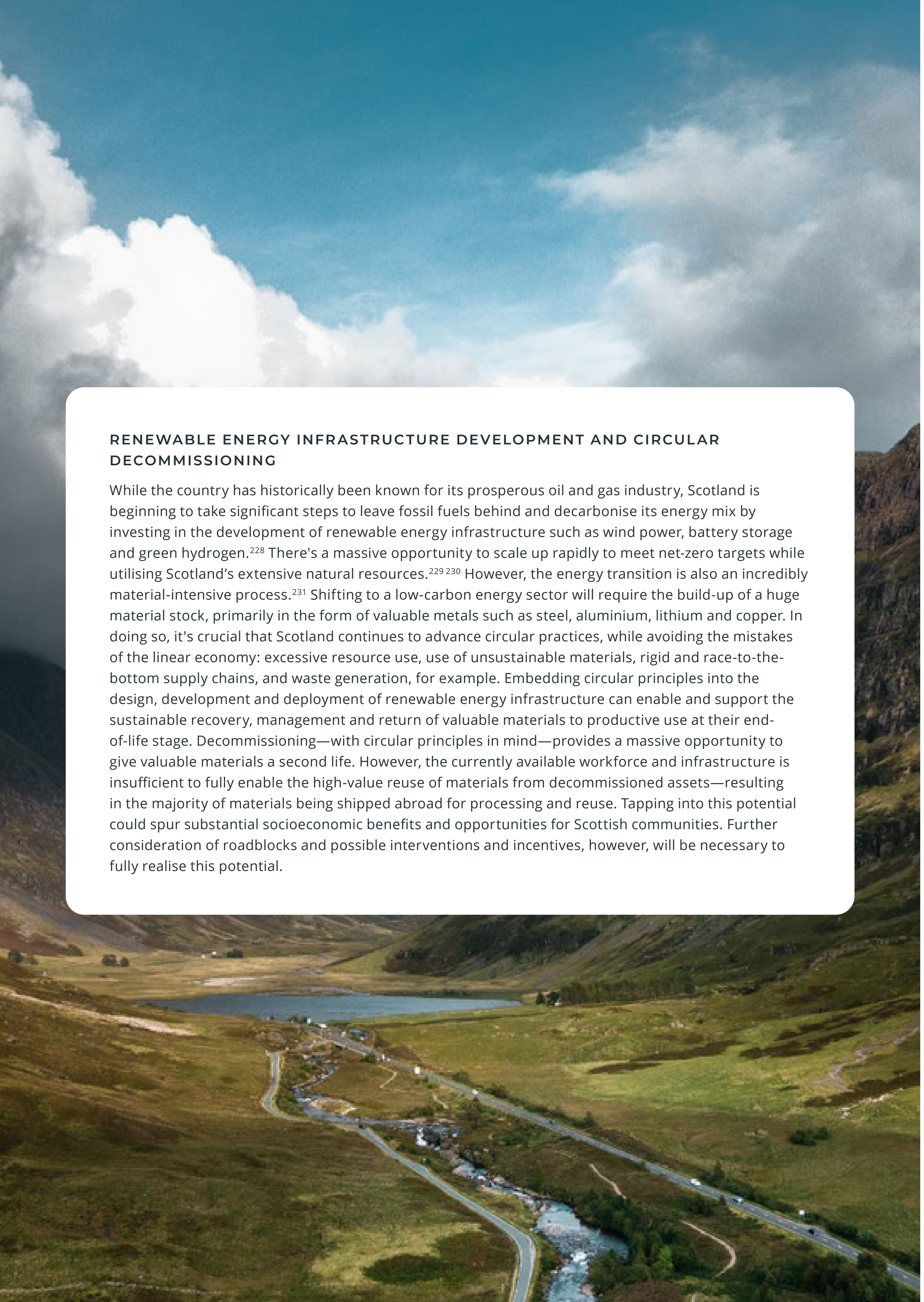
In this scenario's only intervention, we model the impact of reusing valuable materials from decommissioned energy infrastructure, such as hydropower and oil and gas, **cycling** flows. Doing so will also cut energy use and reduce the need for virgin materials for future infrastructure projects, thereby **narrowing** flows.

In Scotland, energy infrastructure is composed of huge amounts of concrete, iron and steel that could become available for reuse through decommissioning. As Scotland progresses along this trajectory, it will be crucial to develop detailed material inventories and new supply chains to ensure the process is smooth and cost-effective—and that materials are reused at their highest value. Currently, little is processed and reused domestically, despite the substantial environmental and economic benefits this would provide.[221] For reuse, repurposing and remanufacturing to take place at scale—and to optimise and enhance value and material recovery—better domestic management of decommissioned materials will be crucial. Making this a reality will require investment in infrastructure as well as in innovation and creativity, in addition to close collaboration between various stakeholders: from decommissioning operators and waste processors to supply chain contractors and local communities.[222]

For this intervention, we model the impact of two strategies. We assume that more than 70 million tonnes of concrete will become available from decommissioned hydropower infrastructure alone by 2030—equalling around 7 million tonnes per year between 2020 and 2030. In 2018, the UK's construction industry demanded 176.2 million tonnes of aggregate, with Scotland claiming 12.16 million tonnes of this.[223] Based on this, we assume that decommissioned concrete could meet roughly 60% of the construction sector's yearly aggregate demand, if a one-to-one substitution takes place. Our second strategy analyses potential use for decommissioned steel. By 2030, we assume that more than 1.1 million tonnes of scrap steel will be made available from decommissioned energy infrastructure.[224] This will amount to approximately 110,000 tonnes of steel per year. Given that Scotland's construction sector demands 163,000 tonnes of steel annually,[225] decommissioned materials could provide a substantial 56% of this need. In all, our analysis estimates that materials from decommissioned energy infrastructure—specifically steel and concrete—could provide around 56% and 60% of the construction sector's yearly material needs, respectively, if we assume 100% reusability.[226] In line with Scenario 1.1, we assume that 75% of the total decommissioned materials would be suitable for reuse, and that material volumes are a good proxy for substitution based on monetary value.

Impact on Scotland's circularity:

This supply-side scenario could cut Scotland's material footprint by 3.1%, bringing it down to 114.1 million tonnes, while slashing its carbon footprint by 0.3%, decreasing indirect emissions to 61 million tonnes of CO2e. The Metric could increase by a substantial 4.9 percentage points, bringing it up to 6.2%. At the same time, it must be noted that the amount and uncertainty around the figures on secondary materials available for cycling is higher for this scenario than for the previous ones, and thus shouldn't be compared. Still, this scenario could also bring economic benefits through the creation of new value chains and job opportunities for Scottish businesses and residents, especially if higher value applications for decommissioned materials are increased.[227]



RENEWABLE ENERGY INFRASTRUCTURE DEVELOPMENT AND CIRCULAR DECOMMISSIONING

While the country has historically been known for its prosperous oil and gas industry, Scotland is beginning to take significant steps to leave fossil fuels behind and decarbonise its energy mix by investing in the development of renewable energy infrastructure such as wind power, battery storage and green hydrogen.[228] There's a massive opportunity to scale up rapidly to meet net-zero targets while utilising Scotland's extensive natural resources.[229 230] However, the energy transition is also an incredibly material-intensive process.[231] Shifting to a low-carbon energy sector will require the build-up of a huge material stock, primarily in the form of valuable metals such as steel, aluminium, lithium and copper. In doing so, it's crucial that Scotland continues to advance circular practices, while avoiding the mistakes of the linear economy: excessive resource use, use of unsustainable materials, rigid and race-to-the-bottom supply chains, and waste generation, for example. Embedding circular principles into the design, development and deployment of renewable energy infrastructure can enable and support the sustainable recovery, management and return of valuable materials to productive use at their end-of-life stage. Decommissioning—with circular principles in mind—provides a massive opportunity to give valuable materials a second life. However, the currently available workforce and infrastructure is insufficient to fully enable the high-value reuse of materials from decommissioned assets—resulting in the majority of materials being shipped abroad for processing and reuse. Tapping into this potential could spur substantial socioeconomic benefits and opportunities for Scottish communities. Further consideration of roadblocks and possible interventions and incentives, however, will be necessary to fully realise this potential.

COMBINED INTERVENTIONS

Individual interventions along a range of platforms have a limited impact on the Circularity Metric and the material and carbon footprints, 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 good proxies for environmental degradation, reducing them are primary goals 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). Limiting 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.

In our broad 'what-if' image for the economy, if we harness the cross-intervention synergies, Scotland's material footprint could be lowered by a remarkable 44.3%, from 117.8 million tonnes to a mere **65.6 million tonnes**. On a per capita basis, the material footprint could be reduced from 21.7 tonnes to around 12 tonnes per year, bringing the figure close(r) to what is suggested to be a sustainable level (8 tonnes per person per year).[232 233] The combined scenarios also offer the potential for deep emissions reductions: the carbon footprint (excluding direct emissions) could be decreased by 43%, bringing it from 61.2 million tonnes of CO2e down to **35 million tonnes** of CO2e (excluding direct emissions). At the same time, the Circularity Metric could swell by 10.5 percentage points, increasing from 1.3% to 11.8%. These figures, however, are substantially influenced by Scenario seven's potential impact, due to the high volume and nature of secondary materials. For this reason, the combined scenario results can be read in two ways: one including Scenario seven's impacts, and one excluding them. Please refer to Table one, pages 64–67, for both sets of results.

Overlaps between—and the sequentiality of—interventions mean that our combined scenario calculations 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.

SCENARIOS, INTERVENTIONS & STRATEGIES

1. BUILD A CIRCULAR BUILT ENVIRONMENT

INTERVENTIONS	STRATEGIES	IMPACT AND MATERIAL FOOTPRINT
1.1 Optimise housing stock expansion	• Limit housing stock expansion • Use secondary materials for new construction	Reduction of material footprint by **11.2%**, decrease from 117.8 to **104.6 million tonnes**. Reduction of carbon footprint by **11.5%**, decrease from 61.2 to **54.1 million tonnes** of CO2e. Circularity rises from 1.3% to **2%**. 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 Increase building occupancy	• Apply regulatory measures to increase occupancy in second houses and holiday lets • Increase co-housing and multifunctional space incentives	
1.3 Creat a resource-efficient building stock	• Practise deep renovation and retrofitting of housing stock • Reduce losses during construction process • Prioritise local construction materials and supply chains	

2. NURTURE A CIRCULAR FOOD SYSTEM

INTERVENTIONS	STRATEGIES	IMPACT AND MATERIAL FOOTPRINT
2.1 Endorse a balanced diet	• Embrace a dietary shift towards a vegetarian diet • Cut waste generation and maximise food recycling	Reduction of material footprint by **9.1%**, decrease from 117.8 to **107 million tonnes.** Reduction of carbon footprint by **6.8%**, decrease from 61.2 to **57 million tonnes** of CO2e. Circularity rises from 1.3% to **2%.** Co-benefits: Health benefits, increase in biodiversity and soil health.
2.2 Adopt sustainable food production	• Shift towards organic, seasonal and local food production • Reduce fertiliser use, heating fuels and transportation services	

3. CHAMPION CIRCULAR MANUFACTURING

INTERVENTIONS	STRATEGIES	IMPACT AND MATERIAL FOOTPRINT
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 **10.5%**, decrease from 117.8 to **105.4 million tonnes** Reduction of carbon footprint by **4.6%**, decrease from 61.2 to **58.4 million tonnes** of CO2e. Circularity rises from 1.3% to **1.6%.** 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 MOBILITY

INTERVENTIONS	STRATEGIES	IMPACT AND MATERIAL FOOTPRINT
4.1 Embrace a car free lifestyle, improved modal shift and flex work	• Practise car-sharing to reduce car use • Increase public transport occupancy • Encourage flexible, hybrid mix homeworking	Reduction of material footprint by **4.6%**, decrease from 117.8 to **112.4 million tonnes.** Reduction of carbon footprint by **2.4%**, decrease from 61.2 to **59.7 million tonnes** of CO2e. Circularity rises from 1.3% to **1.4%** 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 more lightweight vehicles • Electrify private cars, buses and freight transport	

5. WELCOME A CIRCULAR LIFESTYLE

INTERVENTIONS	STRATEGIES	IMPACT AND MATERIAL FOOTPRINT
5.1 Embrace a 'material sufficiency' lifestyle	• 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 • Reduced consumption of plastic products • Prioritise recycled and digital over physical paper products	Reduction of material footprint by **14.6%**, decrease from 117.8 to **100.7 million tonnes.** Reduction of carbon footprint by **14%**, decrease from 61.2 to **52.6 million tonnes** of CO2e. Circularity rises from 1.3% to **1.5%.** Co-benefits: Improved wellbeing, less waste, litter and pollution, more inclusive and resilient communities.

	INTERVENTIONS	STRATEGIES	IMPACT AND MATERIAL FOOTPRINT
6. TACKLE SCOTLAND'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 **10.1%**, decrease from 117.8 to **106 million tonnes**. Reduction of carbon footprint by **4.7%**, decrease from 61.2 to **58.3 million tonnes** of CO2e. Circularity rises from 1.3% to **1.5%.** Co-benefits: Improved wellbeing, less waste, litter and pollution, more inclusive and resilient communities.
7. ADVANCE CIRCULAR DECOMMISSIONING	**7.1 Optimise circular energy infrastructure decommissioning**	• Use decommissioned concrete available from large-scale hydropower infrastructure for recycled aggregate production • Use decommissioned steel from all energy infrastructure for construction	Reduction of material footprint by **3.1%**, decrease from 117.8 to **114.1 million tonnes.** Reduction of carbon footprint by **0.3%,** decrease from 61.2 to **61 million tonnes** of CO2e. Circularity rises from 1.3% to **6.2%** Co-benefits: Reduced waste, new business and job opportunities.

	INTERVENTIONS	STRATEGIES	IMPACT AND MATERIAL FOOTPRINT
COMBINED SCENARIOS (EXCLUDING SCENARIO SEVEN)	**The power of combined interventions**	**This row** presents the baseline result for enacting all scenarios in combination with each other, except for Scenario seven.	Reduction of material footprint by **40%**, decrease from 117.8 to **70.7 million tonnes.** Reduction of carbon footprint by **43%**, decrease from 61.2 to **35 million tonnes** of CO2e. Circularity rises from 1.3% to **4.2%**
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 **44.3%**, decrease from 117.8 to **65.6 million tonnes.** Reduction of carbon footprint by **43%**, decrease from 61.2 to **35 million tonnes** of CO2e. Circularity rises from 1.3% to **11.8%.**

5 TRANSFORMING THE SCOTTISH ECONOMY WITH AND FOR PEOPLE

Scotland's economy, labour market & society

Over recent years, a range of Scottish environmental policies have come to fruition, as the circular economy has been embraced including as part of calls for green recovery from the covid-19 pandemic.[234] To date, however, the evaluation of such policies has centred on environmental impact: monitoring, for example, their effectiveness in cutting resource use and greenhouse gas (GHG) emissions. Inquiry into socioeconomic impacts must be a core focus going forward, with closer attention given to policies that can provide the enabling conditions for socioeconomic impacts from actions on climate. These include policy frameworks such as fiscal measures, regulations and consumer-oriented bottom-up interventions. These frameworks should effectively channel funds towards investment in job creation, skills and infrastructure for circular activities. The effective implementation of circular strategies can reap broader socioeconomic benefits, for example for health, wellbeing and environmental justice. This Chapter's analysis finds that up to 59,000 new jobs will be needed in the short term to drive strategies for closing Scotland's Circularity Gap.

This report so far has presented an analysis of Scotland's material metabolism and identified which circular scenarios could be most effective in improving Scotland's circularity. In this chapter, we explore how these interventions can be implemented, and illustrate what their broader socioeconomic impacts could be.

If Scotland were to implement the interventions laid out in Chapter four without making any structural changes to the economy, we would theoretically expect a decrease in both physical and monetary output. This is because circular economy interventions aim to reduce, extend, and make material production and consumption more efficient. Here, we identify these reductions as imbalances between the 'what if' scenarios and the baseline state of the economy. In a reality not captured by our model, however, the implementation of circular interventions would be facilitated by enabling conditions: reforming policy frameworks, shifting employment to circular activities, embracing circular business models and tackling skill requirements in the labour market. Policy frameworks comprise fiscal reform, regulations and consumer-oriented bottom-up interventions.

To address these enabling conditions, we quantify the fiscal reform required to balance the socioeconomic outcomes of the circular scenarios presented in Chapter four. In other words, we consider how the theoretical decrease in monetary output can be offset by revenue flowing in from environmental taxation. We also consider how this additional revenue could be used to stimulate greater circular activities in the economy: government spending in the form of subsidies, grants and investment in infrastructure, for example. We label this flow of tax revenue to the circular activities in the economy 'circular investment potential'.

To this end, this chapter outlines the components of a fiscal regime where taxation is based on the material footprints of industries—and accordingly, larger subsidies are given to the activities and the employment that work towards mitigating this footprint. An example of this experimental policy approach has been demonstrated in the Ex'tax Project,[235] the outcomes of which revealed how fiscal reform in EU countries can shift the tax burden from labour to resource use and pollution, enabling a more circular, sustainable economy that supports environmental protection.

In Section 5.1, we review the aforementioned enabling policy instruments in more detail, primarily through the lens of the four flows: narrow, slow, cycle and regenerate. In Section 5.2, we use these four flows to parcel out the total 'circular investment potential' to stimulate circular activity and related employment in four key industries. To sufficiently allocate investment to each industry, we need measures of the waste generation volumes, recyclability metrics and other indicators that describe Scotland's capacity to handle secondary materials. The allocation of circular investments was based on a participatory approach involving local experts, rounded out by our in-house knowledge. In this section, we also quantify the 'employment creation potential' stemming from our circular scenarios and discuss how it differs from our previous estimation of the baseline circular activity in Scotland. We end this section with some examples of occupation and skills requirements per industry. Finally, Section 5.3 addresses a review of the broader socioeconomic context and potential effects of a shift to a circular economy that are more difficult to quantify yet important to not overlook.

For more details on our approach and a discussion of underlying limitations, please have a look at the Methodology document.

5.1 TRANSFORMING SCOTLAND'S ECONOMY THROUGH POLICY FOR A CIRCULAR ECONOMY

Policy frameworks are key to establishing the 'rules of the game': they set boundaries and incentives limiting the scope, and structure action for various actors within any economy, for businesses, consumers and government. Table two outlines the main forms of policy instruments and gives illustrative examples for each.

For the transition to a circular economy to be practically and effectively implemented, circular alternatives need to be able to compete with their 'business as usual' linear counterparts. This will require a change in the rules of the game—taxes and regulations may be imposed on linear goods, while subsidies (or other support mechanisms) may be given to circular goods and services. In this section we provide some pathways for achieving, at the very least, price parity between linear goods and services and their circular alternatives. The changes proposed, however, do not not only serve this goal, but provide a 'double dividend': keeping tax revenue neutral and GDP stable at 2018 levels.

Fiscal measures are commonly employed to steer investments and stimulate changes in production and consumption patterns, thereby correcting market failures and balancing out negative externalities. When designed and implemented with this intention, fiscal measures can effectively support decarbonisation goals and enable the transition to a more circular and sustainable economy.[236, 237, 238, 239, 240] Comprehensive and coordinated policy is key for advancing resource efficiency and delivering environmental improvement, while limiting unintended negative consequences or rebound effects.[241, 242, 243] The introduction of fiscal measures in the policy mix is most effective when combined with other instruments, such as **regulations**.[244] Alongside fiscal reform and regulation, **bottom-up interventions** that reshape social norms (such as community-based initiatives, local decision-making, and information campaigns) should be considered in the policy mix. Fit-for-purpose fiscal and regulatory frameworks can influence consumer behaviour and spur more sustainable choices.[245] It is crucial to encourage consumers to play a more active role in engaging with and maintaining more sustainable consumption patterns in the long-term,[246] enabling a shift away from a culture of consumerism and ownership of new and unused products towards less materialism.

In Scotland, recent studies have explored the potential of implementing fiscal environmental measures:[247] for example, simplifying the UK-wide carbon tax, making it more effective, and gearing the €13.8 billion (£12 billion) allocated annually to Scottish public procurement towards more sustainable endeavours. Some schemes have already emerged, including an incineration tax, Transient Visitor Levy (a tourist tax), and more robust Extended Producer Responsibility schemes. Recommendations have been made to shift the country's tax burden from labour towards resource use and emissions, including a gradual move to taxing the carbon footprint of products and not just territorial emissions. Payment and credit schemes, in the form of grants, subsidies and loans, have also been recommended to protect biodiversity, incentivise more sustainable land-use management activities, and to incentivise the electrification of economic activities.

In the rest of this section we discuss each of the four flows—**narrow, slow, cycle, regenerate**—within this context. We examine how policy instruments can be leveraged to realise 'what-if' scenarios, briefly discussed in Chapter four, in more detail.

POLICY INSTRUMENT	EXAMPLES
Fiscal measures	• Subsidies that support sectors that contribute to social resilience—like healthcare and social work—and those that cut the environmental footprint—like waste management. • Subsidies and grants to invest in enabling infrastructure and incentivise the development of new technologies that can boost material efficiency and improve production methods. • Taxes that address potential rebound effects of environmental policy. These effects can arise when the resource efficiency gains of a product are negated by increased demand for it (Jevons paradox),[248] or when the savings from reduced purchases of one good are re-spent on another good with a more negative environmental impact.[249]
Regulations	• Command-and-control instruments, such as direct legal restrictions (bans) on certain polluting activities. • Setting material standards, such as limits for virgin material use and minimum shares for secondary material use.
Bottom-up interventions	• Making repair services accessible, convenient and affordable. • Providing information on products' durability and repairability.

Table two displays examples of socioeconomic policy instruments that can enable circular strategies.

NARROW FLOWS: USE LESS

Reducing material flows—both for industrial production and final consumption—is a core tenet of the circular economy. Adjustments to resource prices by means of a virgin material input tax, a carbon tax, or other fiscal measures[250] can incentivise businesses to re-evaluate their production processes. Fiscal reform can help shift resource allocation and boost efficiency by narrowing material inputs and losses, and substituting virgin materials with secondary ones.[251] For example, taxes on the type and amount of packaging material for a product are proving to be an effective instrument to both increase material efficiency and reduce waste generation. When the prices and availability of packaging made from secondary materials are considered in the implementation of the policy, it is likely to prevent rebound effects and obtain longer-term positive effects.[252] These types of taxes would be particularly relevant for the sale of private vehicles, fuels, imported food over long supply chains and consumable products with low utility, as discussed in the scenarios in Chapter four. Similarly, as part of the Ecodesign for Sustainable Products Regulation, the EU has recently introduced a proposal to ban the destruction of unsold inventory, aiming to reduce production and waste.[253]

The introduction of a virgin resources tax[254] or the so-called Value Extracted Tax—which focuses on resource use, similar to the widely-used Value Added Tax (VAT) for consumption—could be instrumental in shifting the tax burden from labour to resource use and consumption, incentivising material savings and cycling.[255] This policy measure could expose business practices grounded in linearity to financial risk, therefore encouraging businesses to shift away from these practices and towards more circular business models. However, embracing this policy could lead to some undesirable socioeconomic effects, such as offshoring, which could entail a reduction in domestic employment in the short-term and poor working conditions for workers in other countries serving local consumption. Nevertheless, as the circular economy picks up momentum, a shift in the workforce would be expected either towards circular activities within the same sector, such as repair, or towards other sectors with fiscal advantages, such as services and social work. Accordingly, we consider that **narrow** strategies will mainly affect prices, without causing significant net jobs losses in the long-term.

SLOW FLOWS: USE LONGER

Tax breaks for services that extend product lifetimes can make repair services more affordable, boost the uptake of reuse amongst consumers, and help to effectively slow resource flows—boosting the durability of assets from buildings and infrastructure to capital equipment to every-day products. Introducing a tax break for labour combined with a tax break for replacement parts could help to ensure lifetime extension is prioritised over replacing goods with new products. These measures have already been considered by the European Parliament, as well as several EU Member States.[256]

In addition to—and in support of—fiscal reform measures, ecodesign regulations can be rolled out to increase products' repairability, durability and recyclability from upstream product development.[257] These regulations can take the form of improved standards for product design, well-developed common performance indicators, information concerning the availability and accessibility of repair services, and the extension of consumer rights like minimum guarantees on product repairs and replacements. Another important means to slow down the rate of waste generation—and the demand for new goods—is through regulatory surveillance mechanisms that flag and address planned (or designed) product obsolescence, a practice which has been introduced by France.[258]

Policies that **slow** flows are particularly relevant for the repair, maintenance, refurbishment and second-hand sales of vehicles, renovation and repurposing of buildings, and lifetime service extension for garments, electronics and furniture, as proposed in Chapter four.

In the long term, a delicate balance should be struck between policies that enable quick innovation, bringing better and more efficient products to the market on the one hand, and new initiatives that aim to optimise the embedded capital stock of products currently in use on the other hand.[259] This balance can be addressed by introducing mandatory targets for reuse and requirements for reuse in public procurement, as well as increased provision of information for both businesses and consumers, ensuring that reuse becomes more accessible and trustworthy.[260] Such fiscal and regulatory changes could enable circular business models such as Product-as-a-Service (PaaS), which could allow for better planning of maintenance, refurbishment of broken components and a reduction in products sitting idle in stock.[261]

In our analysis, we consider that the interventions that slow material flows will not have a significant negative effect on employment, as they mainly discount labour costs for the arrangement and execution of repair services while saving time on new sales. More generally, we consider **narrow** and **slow** strategies as a means for shifting linear practices towards more quality-oriented production services. This shift has implications for the re-skilling of personnel working in retail and manufacturing industries. This is discussed in further depth at the end of this chapter.

CYCLE FLOWS: USE AGAIN

The recovery and cycling of waste is not an economically attractive activity within the current policy framework and market architecture: in other words, our economy isn't set up to optimally use waste as a resource. This has spurred discussion on appropriate taxation schemes 'to get the economics right' in governmental debates, including the European Commission, especially in regards to the valorisation of resources embedded in products in the final use stage. To help make these processes economically viable, secondary materials should be priced lower than virgin materials. This could occur through a raw material resource tax, to increase the price of virgin materials, in combination with subsidies and fiscal advantages for the recycling sector to decrease the price of secondary materials. For example, raising taxes on landfilling and incineration to an appropriate level could make waste management options with higher potential for value recovery more economically desirable.[262]

Within the context of Chapter four, we examine **cycle** strategies in the context of recycling construction materials and demolition waste, metallic parts in vehicles, and organic waste. We consider **cycle** strategies to be the most promising for job creation, as the collection, sorting and recycling of materials requires a larger workforce to meet the ever-increasing demand for waste disposal services, even in the presence of technological advancements in the waste management sector.[263] The tax revenue raised from the waste taxation should be then channelled into investments in human resources, equipment and infrastructure to boost the services of and support better working conditions in the waste management sector. Apart from investments in appropriate waste treatment facilities, this strategy will also require funding to create informative processes: digital platforms for businesses to mine the secondary materials suitable for their production processes, for example.

REGENERATE FLOWS: MAKE CLEAN

Strategies that regenerate flows aim to sustainably maximise the share of material flows coming from renewable biomass, prioritise the least harmful resources (with respect to their local availability), and increase the quality of materials used in production processes. The circular bioeconomy holds enormous potential to increase the share of renewable biomass use.[264] For example, synthetic chemicals can be technically substituted with biochemicals, fossil fuels with biofuels, plastic packaging with bio-based packaging, and chemical fertilisers with organic ones. For this purpose, a deep knowledge of material properties and energy carriers is necessary to apply the most effective solutions in a given local context, to optimise the cascading use of biomass and maximise value. This could include public funding for research, development and demonstration activities, pilot projects and infrastructure development as well as fiscal incentives for the formation of integrated biorefinery clusters and anaerobic digestion activities that use and treat bio-wastes and residues, for example.

More generally, from a regulatory perspective, more robust eco-labelling for (organic) products[265] and mandatory environmental impact disclosure to investors, as recently proposed by the European Commission,[266] could also incentivise cleaner production and consumption processes. Carbon taxes have also gained prominence. Their inclusion in a well-designed mix of environmental taxes could serve to shift the economic burden from labour and service providers to the producers of goods with large embodied impacts, with the potential to minimise material and energy use.[267] Carbon tariffs on outbound trade flows, for example, have been observed to strengthen regional integration and to support decentralised activities, such as alternative energy use, small-scale production and sustainable agriculture[268 269]—while a well-implemented meat tax could serve to protect the environment, ensure an equitable future for livestock farmers and shape a more sustainable food system for all.[270]

The scope of this strategy, in relation to the scenarios presented in Chapter four, encompasses examples such as stimulating the market share of renewable energy and low-carbon vehicles, and reducing the input of chemical fertilisers in the agrifood industry. Product designers and researchers in scientific fields such as biology and chemistry need to strengthen their collaboration, assessing different types of impacts (or footprints) that industrial processes may have on material depletion, waste generation, GHG emissions, bluewater contamination and biodiversity loss. We assume that **regenerate** strategies hold the potential for net job creation, driven by the growing demand for renewable energy, for example.[271]

The relationship between circular strategies and policy instruments is summarised in the table on page 75.

CIRCULAR STRATEGY	TYPE OF FISCAL REFORM	TARGETED VALUE-ADDED ELEMENT	RATIONALE
Narrow	Tax on type and amount of raw material inputs	Taxes less subsidies	Disincentivising overconsumption and reducing the demand for products with high environmental footprints
Slow	Tax relief/break on labour, subsidies to process adjustment and re-skilling of employees		
Cycle	Subsidies for job creation in waste collection, treatment, and re-processing sectors	Compensation of employees	Enabling the additional workforce expected to meet the increasing demand for circular products
Regenerate	Subsidies for jobs creation in research and development of regenerative materials and renewable energy production		

Table three displays a proposed mapping between the four flows, their relevant policy instruments and the corresponding rationale.

5.2 IMPLICATIONS FOR CIRCULAR INVESTMENT AND EMPLOYMENT OPPORTUNITIES

In this section, we outline the circular investment and job creation potential for the circular scenarios presented in Chapter four. We also put forward examples of occupations and skills needed for Scotland to fully embrace circular activities.

We examine the four key industries for change addressed in Chapter four:

- **Agrifood**, including all agriculture, food supply chains, packaging and associated waste generation and treatment;
- **Mobility**, meaning the use of transportation services and the supply chain of vehicles and energy carriers;
- **Construction**, with a special focus on residential buildings, which also share common aspects with commercial buildings and infrastructure planning—for example, the policy landscape, material intensity and the prioritisation of preservation over new construction;
- **Consumables**, encompassing a wide range of manufactured product categories like electronics and textiles, for which the volumes of production and consumption (waste) can be reduced through servitisation and the adoption of a minimalist lifestyle.

Figure five outlines the investments needed in each industry to stimulate circular activity in line with the what-if scenarios. The allocation of circular investment is estimated to exceed €20 billion (£17 billion) for Construction and Consumables, and to amount to €1.5 billion (£1.27 billion) for Agrifood and Mobility. These numbers stem from the assumption that a reduction in economic output due to the scenarios' realisation is equal to the additional tax revenue to be invested in each sector. The disparity between monetary changes is due to the volume of transactions being much higher for Construction (high prices) and Consumables (wide range of products). For example, relevant policy instruments for Agrifood are those that can stimulate the uptake of **narrow** strategies, for example, reducing the (over) consumption of animal products, and **regenerate** strategies, for example, applying regenerative agriculture or shifting away from synthetic fertiliser use. This initial allocation is based on a participatory approach, as explained in the Methodology document. These figures demonstrate which investments are needed to boost circular activity across the four different industries, and highlight potential positive socioeconomic outcomes.

CIRCULAR JOBS CREATION POTENTIAL

The transition to circularity will inevitably result in changes to the labour market, while changes in the labour market will inevitably determine how effective and quick the transition will be. Our Circular Jobs Metric can help policymakers and other stakeholders tap into the employment potential of the circular economy by showing how jobs contribute to realising various circular strategies—and in which industries these jobs occur.

Job creation potential was calculated based on the circular investment potential allocated to the **regenerate** and **cycle** strategies (see the rationale in Table four), using the employment multipliers of the sectors relevant for those strategies to estimate the total number of new jobs stemming from the allocation processes. This is explained in more detail in the Methodology document. Based on this scenario analysis of environmental fiscal reforms, we estimate that about 59,000 new jobs could be created to stimulate the Scottish economy's circular transition.* Many of these jobs are expected to relate to the research and development sector, and activities within and in collaboration with the waste management sector.

In 2020, Circle Economy and Zero Waste Scotland produced a first baseline for employment related to circular activity and explored the implications of the transition to a circular economy for the Scottish labour market.[272] It presented a baseline measurement of the number and geographical distribution of jobs related to the circular economy in Scotland and explored the types of circular jobs, roles and skills associated with opportunity areas across three value chains: construction, bioeconomy and capital equipment. This was based on 2016 data and used the Circular Jobs Methodology, which was developed by Circle Economy in collaboration with Erasmus University Rotterdam (see the Methodology document). Following updates to this methodology by Circle Economy in collaboration with the United Nations Environment Programme and with the use of updated employment data from 2018, employment related to the circular economy in Scotland was found to have increased from 4.5% to 9.7%.[273] This can mainly be attributed to an expanding waste sector, which doubled in employment, and the consolidation of business models that favour the lifetime extension of products and stock. In this chapter, we propose ways to allocate circular investments and improve circular activities so that circular employment can swell to above 11%.

**Note that our model is not time sensitive.*

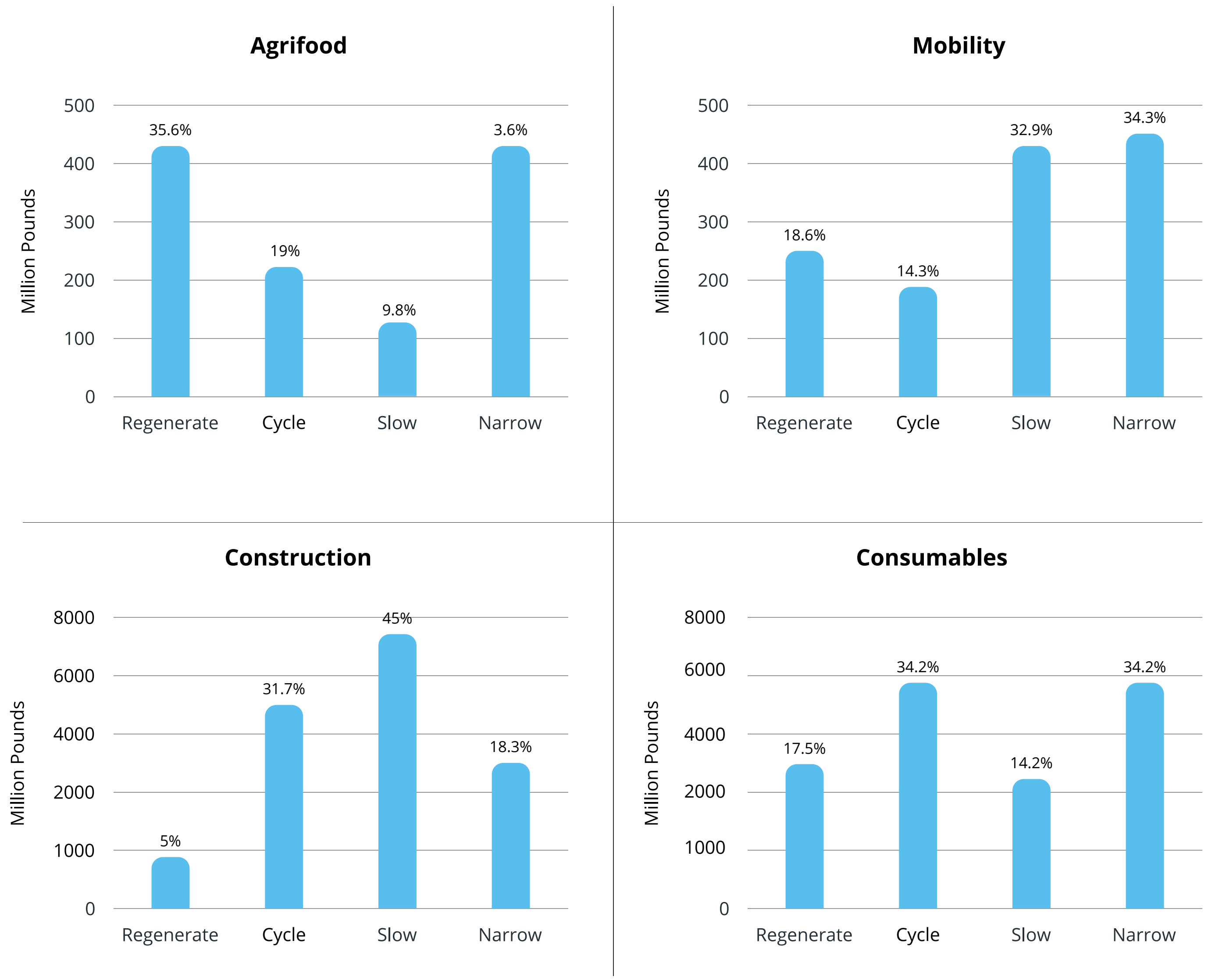


Figure five shows the investments needed in each industry to stimulate circular activity in line with the what-if scenarios.

POLICIES TO SECURE JOBS AND SKILLS FOR A CIRCULAR ECONOMY

Labour-focused policies can increase the circular activity indicator by creating new jobs in sectors that are core to the circular economy—such as waste management, repair and maintenance, and the production of renewable energy—while incentivising their collaboration with the other industries. In particular, the Scottish labour market holds massive potential for jobs creation in the waste sector, representing just 1% of the workforce in 2018. There is also a tremendous opportunity to increase knowledge on environmental topics at all levels due to a large education sector.[274] The education sector currently reveals the lowest score for circular activity in that year, suggesting a low interaction with core sectors, especially in the acquisition of educational equipment. Below, we discuss which activities need to be stimulated per key industry to both boost circularity in the labour market and the economy as a whole, including some of the occupations and skills key to these activities. This is summarised in Table four.

To support circular activity in the Agrifood sector, issues such as land productivity management and restoration will need to be addressed. Achieving **cycle** strategies in the sector will require skills in biology and chemistry to stimulate the valorisation of organic waste for energy recovery, bio-based packaging and other open loop recycling applications. The manufacturing sector, associated with Consumables and parts of Mobility such as vehicle production, holds massive potential for employment, especially in upstream activities around design expertise and life cycle assessments that reduce waste and/or improve cyclability in activities further down the value chain such as the collection of end-of-life products, their disassembly into mono-material components, and further sorting and subsequent re-processing to enter secondary material markets. These activities are usually underrepresented in the labour market, especially because of a high share of hard-to-recycle products that are destined to export, landfilling or incineration (not always with energy recovery). Moreover, Mobility will likely demand advanced expertise in material science and engineering to conduct research on and develop technologies for low emission vehicles. This could include low carbon next-generation biofuels, as well as energy storage technologies with high functionality and recyclability and low emissions. The latter options could be relevant to transport sectors that are more challenging to electrify, including marine and air transport.

Furthermore, the renewable production of electricity, waste management and other remediation activities are among the core sectors of the circular economy, and will likely require remarkable investments in infrastructure and jobs to meet the future demand for energy and waste services that would come with scaling circular activities across Scotland. Researchers for energy systems, bio-engineers and chemistry experts are examples of highly skilled jobs that would benefit from the subsidisation of the activities included in the **regenerate** strategy. Other types of technical and practical expertise are also relevant, such as energy technicians, product designers and architects, as well as water purification operators. While the renewable energy sector will imply a shift, at least in part, of workers from the non-renewable energy production sector, the amount of jobs that is required to build and maintain energy infrastructure is likely to display a net jobs gain. In the waste sector, a net gain is almost certain as the collection, disassembly, sorting, and actual recycling of materials is currently very low compared to the amount of waste generated.

Industry	Circular strategies	Policy instruments	Circular activities	Occupations and job profiles
Which industry?	Which circular strategies?	Which policies will drive the change?	Which activities will be primarly supported?	Examples of new occupations that will be needed
Agrifood	Regenerate	Subsidies for agronomy R&D and related initiatives	Land productivity management and restoration	Agronomists, agroecologists, environmental consultants, harvest operatives, rural surveyors, agricultural inspectors, and biosource advisers and planners
	Regenerate/ Slow	Subsidies for R&D in bio-refining activities	Research and development for biorefining for high-value (chemical) production	Biochemists, chemical process engineers, quality control managers, and environment health and safety managers
	Cycle	Subsidies for R&D in ecological cycling	Research and development for the use of organic waste for energy recovery (for example, anaerobic digestion)	Harvest operatives, technicians, plant managers, operators, system process engineers, biosource advisers and planners, and farm directors
	Narrow	Grant free consultation	Education on food conservation and waste prevention	Nutritionists, dietitians, logistics managers, and procurement managers
		Tax discount for workers in weather prediction	Prevention of yield losses due to climate change and extreme weather conditions	Harvest operatives, agricultural specialists, climate scientists, meteorologists, and geospatial technicians

Table four shows circular activities, and examples of occupations and skills per sector and strategy.

Industry	Circular strategies	Policy instruments	Circular activities	Occupations and job profiles
Which industry?	Which circular strategies?	Which policies will drive the change?	Which activities will be primarly supported?	Examples of new occupations that will be needed
Mobility	Slow	Tax break on labour	Repair, maintenance and upgrading of vehicles	Car manufacturing workers, mechanicians, repair technicians, and industrial designers
	Slow/Cycle	Subsidies for hiring/training in refurbishing and scrap metal sorting	Disassembly of vehicles, and evaluation of components as either functional, outdated or scrap to be sent to secondary material markets	Mechanicians, disassembly operatives, sorters, recycling operatives, cleaners, test engineers, circular equipment engineers, materials specialists, and logistics analysts
	Cycle	Subsidies for hiring	Re-processing of metals to create supply for secondary materials markets	Metalsmiths, procurement managers, material innovation specialists, and product developers
	Narrow	Fiscal incentives for workers and firms	Planning of infrastructure and transportation provision to reduce mobility demand	Urban planners, transport planners, procurement managers, architects, and civil engineers
	Regenerate	Subsidies for R&D in clean energy production and storing	R&D on technologies for energy storing with high recyclability and low emissions	Material scientists, product designers and developers, electronics and mechanical engineers

Which industry?	Which circular strategies?	Which policies will drive the change?	Which activities will be primarily supported?	Examples of new occupations that will be needed
Industry	**Circular strategies**	**Policy instruments**	**Circular activities**	**Occupations and job profiles**
Construction	Slow	Fiscal incentives based on low-impact material and energy inputs	Renovation and retrofitting activities with circular economy principles (for example, secondary materials and embodied carbon criteria)	Technicians, off-site workers (joiners, finishers, production assemblers), building managers, renovation and retrofit workers, and installers (insulation, roofs, windows, facades, ventilation systems, renewable energy)
	Slow & Narrow	Fiscal incentives for activities that extend building lifetimes	Repurposing and retrofitting of buildings; Design and construction of buildings with cyclability and reparability principles (for example, secondary materials, modularity, or easy-to-recycle virgin materials)	Architects, procurement authorities, designers, building managers, repair and maintenance operatives, and installers (insulation, roofs, windows, facades, ventilation systems, renewable energy)
	Regenerate	Subsidies for planning authorities and architecture studios with sustainability principles	Design and construction of buildings with bio-based materials; Regenerative urban design (for example, nature-based solutions and biomimicry)	Architects, digital developers, urban planners, urban metabolism experts, procurement specialists, and off-site workers
	Cycle	Subsidies for hiring/ training of deconstruction workers	Deconstruction and sorting of construction materials; Off-site construction; Closed-loop cycling of building materials	Material scouts, deconstruction auditors, deconstruction labourers, site analysts, procurement specialists, machinery handlers, and quality testers, and technical managers

Which industry?	Which circular strategies?	Which policies will drive the change?	Which activities will be primarily supported?	Examples of new occupations that will be needed
Industry	**Circular strategies**	**Policy instruments**	**Circular activities**	**Occupations and job profiles**
Consumables (focus on electronics, domestic appliances, and textile supply chains)	Slow	Fiscal incentives and subsidies for employee training	R-strategies implementation for products and capital equipment (for example, repair and maintenance, remanufacturing and reuse)	Technicians, reuse specialists, quality testers, high precision engineers, and logistics managers
	Cycle	Subsidies for hiring/training employees	Disassembly of products into reusable components and non-reusable components meant for cyclability	Remanufacturing engineers, technicians, and tailors with an understanding of reusable parts and the ability to sort waste materials
	Narrow/Slow	Subsidies for training employees and education	Modular design for durability and reparability	Designers, product developers, high precision engineers, fabrication specialists, and secondary materials procurers
	Narrow	Subsidies or grants for training for firms and workers	Monitoring and reducing the amount of material inputs and waste in the production processes of manufactured goods	Process planners, product developers, fabrication specialists, and material innovation specialists
	Regenerate	Fiscal incentives and subsidies for R&D for material recyclability	Prioritisation of bio-based materials in product design	Material innovation specialists, designers, product developers, procurers with knowledge in material science

CIRCULAR SKILLS AND A JUST TRANSITION FOR SCOTLAND'S LABOUR MARKET

The Scottish Government was among first in the world to declare a state of climate emergency. It swiftly presented the *Climate Emergency Skills Action Plan 2020–2025*[275] to ensure that Scotland's labour market will be adequately prepared to anticipate and enable the transition to a green and circular economy.

The workforce is a key lever for transformation towards a circular economy. But to tap into this potential, the right jobs and skills are needed: skills development is a crucial lever for achieving the employment and innovation potential of a circular economy. The adoption of circular strategies calls for skills to be applied to processes or business models involved in narrowing, slowing, regenerating, and cycling material flows. However, circular skills are largely missing in economies around the world: certain outdated education systems and inefficient feedback loops between industry, research and education, for example, hinder the ability to foster the skills and training a circular economy will require. All this is also impacted by three key global trends that are also shaping labour markets and further contributing to the skills gap: greening economies, digitalisation and longer working lives.

As detailed, the restructuring of the Scottish labour market will have profound effects on certain industries, with some experiencing a structural decline (fossil fuels, for example) while others will grow (materials management, for example). Within industries, some sectors might also experience relative decline (new construction, for example) while others will gain market share (renovation and retrofitting, for example). This will undoubtedly impact workers and skills requirements differently. For instance, workers' mobility will become especially important when regions and/or sectors experience a strong divergence between job creation and job losses. But it is not only a matter of job quantity: to ensure a just transition and avoid social backlash, elements such as the quality of employment of the new jobs and possible gender disparities are also essential to consider and attempt to address with enabling policies.[276]

To mitigate adverse effects, labour market reform focused on upskilling and retraining, such as through skills shift programmes, vocational education and lifelong learning, will be instrumental in ensuring the transferability of workers and their skills from declining to growing sectors of the economy.[277 278] In this sense, the design, planning and effective implementation of 'just transition funds', similar to those rolled out at the EU level the (such as the Just Transition Mechanism[279]) will be necessary to support and ameliorate the impact of communities and regions negatively affected by the transition. Regional and local contexts must be considered in any approach to redeploy workers from declining industries and sectors. These could take the form of a combination of grants to transform the productive base of these regions combined with public investments and an attractive investment framework for new private sector activities. However, the success of the transition will not only require political and economic support, but also close, multi-stakeholder collaboration and inclusive (participatory) decision-making processes. Particularly, the consultation and collaboration between key stakeholders such as regional and local governments, NGOs and non-profit organisations, industry associations, labour unions, employers and civil society.[280]

5.3 BROADER SOCIOECONOMIC EFFECTS

The social implications of the circular economy are becoming increasingly relevant when approaching, shaping and discussing its implementation, particularly the need for a just transition to a more circular economy. However, the links (and dynamics) between societal-level resource management strategies, environmental impacts and social impacts are not well established.[281 282 283 284] Recently, the social dimension appears to have gained attention by researchers looking to take a more holistic approach to circularity,[285] incorporating themes of employment, health and safety, and participation.[286]

It is also worth highlighting scale distinctions: social impacts can be of both a local and a global nature. In this report, we focus on the socioeconomic impacts at the national level for Scotland. This does not suggest that global social impacts and rebound or spillover effects should be omitted or overlooked when designing policy or setting targets that incorporate circular strategies. For Scotland to continue to take a leading role in setting ambitions for its circularity, building in mechanisms to acknowledge its responsibility in the global economy and supply chains will be crucial.

It is important to distinguish between **direct and indirect effects of environmental policy instruments on the socioeconomic sphere:**

- **Direct effects** are those that immediately follow a successful intervention scenario in which the footprint reduction yields a positive economic effect (such as improved land productivity) and society (such as better health, or illnesses reduction).
- As policy implementation can also impact businesses production processes and their workforce, other **indirect effects** can arise (such as rebound effects), for example, from a labour market reform that aims to boost circular activities and create new jobs to accelerate the uptake of circular strategies. In this sense, circular economy rebound effects include, for example, increases in material and energy efficiency per unit produced but increases in total production or consumption, thus offsetting any potential environmental benefits (such as material and/or energy savings).[287]

Scotland's transition to a circular economy will likely have a multitude of socioeconomic implications beyond those that can't be easily measured/quantified—benefits for human health, equality and social justice, for example. In this section, we discuss the potential socioeconomic implications that circular strategies could help bring about.

SOCIOECONOMIC RESILIENCE

Transitioning to a circular economy can lower resource demand and environmental impacts, while contributing to socioeconomic resilience. Building the systemic resilience of the Scottish economy doesn't just mean increasing capacity to jump back from a shock (such as covid-19 or a global financial crisis)—it also includes the ability to adapt to constant change: climate change and rising geopolitical tensions, for example. This can be seen as another key benefit of the transition.[288] Similarly, a more circular economy is also a more locally integrated economy, which provides value to local communities via shortened value chains, relocalisation and onshoring production, thus enriching local socioeconomic activities. In this sense, by becoming more self-reliant and autonomous against supply chain disruptions and instability, Scotland can also build greater resilience against forecasted resource constraints and price volatility.[289]

BENEFITS FOR HUMAN HEALTH

By radically changing production and consumption patterns, the circular economy can potentially deliver substantial direct and indirect benefits for human health,[290] for example by preventing the landfilling and incineration of waste, use of hazardous materials, and GHG emissions, thereby reducing pollution. Moreover, reducing congestion, air and noise pollution in major cities, such as Glasgow, Edinburgh and Aberdeen, combined with expanding urban green space, infrastructure and tree cover while enhancing biodiversity, can positively contribute to increased physical and mental wellbeing for the residents of these cities, especially when involving local communities in the design and management of urban nature interventions.[291 292 293] Similarly, as discussed in Chapter four, dietary shifts, towards healthier, more plant-based and high-nutrition foods, can have a positive impact on public health in the form of increased physical and mental wellbeing through reduced obesity and resulting health problems. This shift should be part of an entire transformation of the food system, from changes in farming techniques, practices to minimise food waste and education to influence dietary preferences.[294]

CULTURAL IMPACTS

The transition to a more circular economy can be stimulated by new cultural practices and norms that can also bring about social benefits.[295] For example, the increased adoption of a 'sharing economy' can lead to an enhanced 'sense of community' by increasing social interactions in day-to-day activities, via a shift in mindset from 'ownership' and 'individuality' towards 'sharing'.[296] This can provide people with more 'socially enriching' alternatives to the current model.[297] This type of socioeconomic interaction anchored around greater localisation of production and consumption can enable sustainable and more community-based lifestyles, favouring improved cohesion and livelihoods.

IMPACTS ON EQUALITY AND SOCIAL JUSTICE

Handling materials and natural resources in a more socially responsible way can positively impact the distribution of opportunities and choices within society, particularly for new and future generations.[298] Considering not only the generational but also the international perspective is also important and relevant here. Internalising externalities into production costs (i.e. 'true pricing') can also have positive impacts on countries in the Global South that currently produce many of the products consumed in countries in the Global North, particularly for value chains such as food, renewable energy and textiles.[299] However, a transition to a circular economy does not automatically guarantee that the socioeconomic inequalities associated with the linear economy will be addressed. But, if designed and implemented well, opportunities can arise to narrow or diminish existing disparities and structural disadvantages in labour markets. This requires a fair and just distribution of benefits, costs and risks across society: the impacts of circular economy activities, and the socioeconomic transformations that these might entail, must also consider, identify and anticipate potential negative socioeconomic effects on vulnerable social groups, communities, sectors and/or regions and put in place targeted mechanisms to not only mitigate negative effects but challenge the status quo.[300] For example, to ensure new jobs created in high-value sectors are available to more women or people Black, Asian and Minority Ethnic (BAME) backgrounds, changes already being made to recruitment strategies and workforce development to address Scotland's ageing workforce could be complemented, in line with Scottish Government policy.

6 THE WAY FORWARD

Scotland's economy has transformative potential: it can nearly halve its resource use, while substantially cutting its carbon emissions, more than doubling its Circularity Metric and creating tens of thousands of new jobs. This report illustrates the amount and type of resources behind meeting Scotland's needs and wants. As a high-income nation with a material-intensive economy, at 21.7 tonnes per capita per year (in 2018), Scotland’s material footprint is very high—nearly double the global average and well above the suggested sustainable material footprint per capita of 8 tonnes.[301][302] However, this report also provides insight into how the country can almost halve its material and carbon footprints and grow its circularity from 1.3% to 11.8%. While this increase may seem slight, it has transformative power: embracing circular strategies can cut the material footprint by 44%, while lowering indirect carbon emissions by 43%—keeping Scotland well on-track to meet its net-zero goals. Our seven scenarios provide examples of how Scotland could structurally reshape its economy, swapping out materials- and emissions-intensive processes embedded in linearity for ones that make the most of materials' value, minimise waste and regenerate natural systems instead. 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 Scotland's people within planetary boundaries, while contributing to the creation of 59,000 new jobs.

The transition to a circular economy will not be easy—nor will it take place overnight. While the strategies presented in Chapters four and five have transformative potential, their implementation will be met by numerous challenges. For the first time, we've modelled the implications of shifting away from high-impact imports—finding that this could deliver a deep 10% cut in the material footprint—yet making this a reality will be complex and would require careful planning. Shifting to a 'material sufficiency' lifestyle characterised by minimalist homes and wardrobes would be similarly high-impact—massively cutting the material footprint by around 15%. Mobilising the Scottish population away from fast-fashion, excessive consumption and prevailing models of ownership, however, will require large-scale behavioural change. Effective policy-making via fiscal reform, as we explore in Chapter five, is a key lever to stimulate such changes. On the other side of the scale, interventions that have a smaller impact by comparison—such as those for mobility—must not be ignored: while disruptive change must usher in more-than-modest gains, benefits must be viewed holistically and not just in the context of reductions in the material footprint and indirect emissions, or gains for the Circularity Metric. All scenarios present their own unique co-benefits, from pollution mitigation to the protection of biodiversity to the creation of new circular jobs. There is no silver bullet for ecological breakdown or the climate emergency, and while significant work has been done since 2018—the baseline year for this report—progress remains to be made. Everyone will have a role to play: the Government, businesses and society as a whole.

All stakeholders have a role to play in making a Scottish circular economy a reality. As noted, our suggested changes won't take place overnight: system-wide changes will require mass mobilisation and joint efforts across all facets of Scottish society, from government and business to trade unions, civil society and academia. Through coordinated policy action, a whole-of-government approach, and proactive stakeholder engagement, the Scottish government must play a guiding and enabling role. Policymakers are responsible for setting the new 'rules of the game', adapting both taxation and regulation to incentivise businesses to make a change—while setting a level playing field for those already embracing circularity. Already, Scotland has launched a range of transformational measures, from bans on certain single-use plastics to a Deposit Return Scheme (to be launched in 2023) to a reformation of its extended producer responsibility scheme for packaging—all in addition to national reuse and consumption and waste reduction targets.[303] With the right enabling incentives in place, corporations can drive change by developing circular strategies and business models: start small by building a business case to move away from linear modes of production, and build new partnerships to allow for bigger investments into circularity at scale. Individuals will also have a role to play in demanding more circular and sustainable offerings from businesses, as well as regulatory action from government—while also rethinking their own consumption and shedding wasteful habits.

Targeted investments will be crucial in realising a circular future. The practical implementation of circular economy strategies will require concrete and targeted investment and spending, in order to provide enabling and competitive infrastructure. In addition to the suggested investment in household recycling infrastructure, Scotland could look into investments in industrial-scale infrastructure: steel recycling capacity, cross-laminated timber production, and material hubs for deconstruction, for example. In doing so, attention should be afforded to skills development and training policies—such as reskilling and upskilling programmes—that can prevent brain drain, attract talent and ensure access to highly-skilled labour. Action to address this is included in the *Scottish Government Climate Emergency Skills Action Plan*. Identifying and addressing gaps in infrastructure should be complemented by investing in upstream knowledge and innovation to anchor high-skill and high-value jobs in Scotland and local communities that maximise environmental and socioeconomic benefits. This could include, for example, infrastructure and industrial capacity closely linked to renewable energy development: from heat pump production and wind power supply chains to the development of appropriate port and onshore yard infrastructure. While the proposed €85 million (£70 million) investment in recycling infrastructure through the *Recycling Improvement Fund i*s an important initial step in the right direction,[304] there is still plenty of untapped potential for more ambitious investments. Another good example is the *Circular Economy Investment Fund*,[305] administered by Zero Waste Scotland, which since its inception in 2017 has made 65 investments in businesses and organisations across Scotland, contributing to job creation, delivering annual carbon emission savings and leveraging significant private sector investment. Similarly, regulatory reform will have a key role to play in embedding circularity in renewable energy development: this could involve tighter requirements for local supply chain involvement, or the incorporation of changes in renewable energy development bid documents, for example.

Action moving forward should centre on changes that fall within Scotland's devolved competences. As part of the UK, Scotland has devolved competences when it comes to certain policy areas.[306] Brexit has widened regulatory and governance gaps and highlighted the challenges and opportunities presented by the UK's devolution settlement, particularly regarding environmental policy.[307] Concern has arisen that this has weakened environmental governance.[308] To this end, it's important to consider that Scotland has limited influence over certain crucial issues relating to the circular economy: phasing out fossil fuel extraction, radically rethinking fiscal frameworks, changing trade and industrial policy, and regulation on areas such as food and environmental standards don't fall within Scotland's competence, for example. The country should instead seek structural changes that fall within its competences: in other words, focus on what it can do to decrease its material consumption, carbon footprint, and boost circularity.

Scottish cities will play a pivotal role in the transition—promoters, facilitators and enablers. For Scotland to fully develop a circular economy, its cities must embrace and accelerate the transition as hotspots of consumption and resource use that concentrate large portions of the population. Opportunities relating to food, the built environment and mobility will be particularly crucial. For example, effective urban planning on the city-wide level could fundamentally enable and catalyse systemic change, maximising occupancy, bolstering car-free mobility, and stimulating the uptake of nature-based solutions. Cities similarly boast ample opportunities to drive change in the food system: they can cut food waste by investing in the necessary infrastructure for food rescue, redistribution and cycling, and encourage dietary choices that support sustainable and local food production(such as vertical farming), as well as better biomass management. While the most impactful change will likely be driven by—and felt in—Scotland's most populous cities, Glasgow[309] and Edinburgh,[310] rural and island communities will still have an important role to play in the transition. Local communities should be considered as agents of change rather than the recipients of initiatives and programmes. All places have a unique opportunity to drive and facilitate change: building on established local networks and relationships, using their voices to influence and instigating action to meet local challenges and seize opportunities.

Change must come—yet current solutions are grossly inadequate for the challenges we face today. It is crucial to remember why we need broad, large-scale and quick systemic change across geographies: the Earth system's delicate balance, upon which life depends, is dangerously close to its breaking point. This trend is only set to continue if the global economy and population continue to grow. Observing human history—and our current linear system—shines a light on how affluence is tightly linked to material use—and consequently, to waste generation and emissions.[311 312] And in spite of this, the myth that we can protect the environment alongside unbridled economic growth prevails. The only way forward is to cut excess consumption, creating a resource-light and low-carbon economy that provides high-quality quality of life and operates within planetary boundaries. For Scotland, this means creating a socially just system that centres on the long-term sustainable use of natural ecosystems and resources—lowering consumption and extraction both at home and abroad—particularly considering Scotland's historical responsibility as part of the UK. If well-designed, a circular economy can increase sustainability, reduce vulnerability and diminish inequalities by cutting consumption, emissions and waste, enhancing food sovereignty, diversity and community, and finally tackling economic accumulation and marginalisation.[313] The changes to be made are holistic and cross-cutting—and while the circular economy isn't a silver bullet, it's a crucial first step, with shining potential.

A huge opportunity for Scotland—and the risk of missing out. While the country exhibits levels of consumption and extraction that far surpass the global average and well-exceed ecological limits, it's well-positioned to take on the challenge of going circular. With well-formed goals for decarbonisation and the circular economy widely accepted as means for achieving them, Scotland is already taking crucial first steps to leave linear behind. With some of the world's boldest climate goals, and systemic change beginning to permeate governments and businesses, Scotland has the opportunity to become a global leader for circularity: the future we need to shape is within reach. Scotland must embrace bold action on its journey forward: the risk of missing out on the opportunities a circular economy could bring is one too great to take.

FOUR STEPS TO BRIDGE THE CIRCULARITY GAP THROUGH LEADERSHIP AND ACTION

- **Ensure action is diverse and citizen-centric**. Citizens have an important role to play through embracing more sustainable lifestyles and demanding change through the choices they make. 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 for change, and creating fiscal and policy drivers.
- **Call on the government to enable circular economy action.** Building on the world-leading *Circular Economy Bill*, there is scope for the Scottish Government to further amplify its impact. A systemic approach needs to be taken to incorporate circular economy thinking across government and collect the right Scotland-specific data to measure progress and inform future policy. Transitioning to a more circular economy will build resilience and create jobs as well as benefit the environment.
- **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, natural materials to developing innovative business models and shortening supply chains, businesses are well-positioned to deliver impactful change.
- **Strengthen regional and global knowledge and pace toward circularity and consumption reduction.** Peer-to-peer learning and knowledge transfer will increase the pace towards global circularity. There are opportunities for international collaboration; establishing knowledge-sharing relationships to explore synergies and exchange key learnings and best practices.

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55. This refers to cycling in the technosphere, as opposed to cycling in the biosphere (ecological cycling).
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