Government
Office for Science

From waste to resource productivity

Report of the Government Chief Scientific Adviser

Report of the **Government Chief Scientific Adviser:**

From waste to resource productivity

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Editor: Mark Peplow

This report is intended for: Policy makers, regulators, local authorities and a wide range of business people, professionals, researchers and other individuals with an interest in exploiting the potential to unlock productivity by moving from creating waste to valuing resources.

This report is presented in two parts: The first is the summary report of the Government Chief Scientific Adviser. This was developed as a result of seminars and the advice of the experts who provided the source of the evidence. The second part, the evidence, has been gathered from and written by a distinguished group of experts. The evidence takes two forms: chapters that consider a major aspect of the waste and resource productivity landscape; and individual case studies that illuminate points of detail and principle. The evidence section provides the views of the experts themselves, who met on several occasions during the preparation of the report and had the opportunity to help to develop the narrative and to comment on each other's contributions. This summary report to government by the Government Chief Scientific Adviser, is not a statement of government policy, and aspects of third-party commentary contained within it are not consistent with existing, or planned changes to policy. Sir Mark Walport and Professor Ian Boyd are responsible and accountable for the summary report, and the experts for their individual contributions to the evidence papers and case studies. Neither should be blamed for the sins and omissions of the other!

This report should be cited as: Report of the Government Chief Scientific Adviser 2016, From Waste to Resource Productivity, The Government Office for Science, London.

The Government Office for Science would like to thank the authors who contributed chapters, case studies and their time towards this report and gave it freely. A full list of authors can be found in the companion document: From Waste to Resource Productivity. Evidence and Case Studies.

The report project team was Colin Armstrong, Sam Bradley, Andrew Cole, Mike Edbury, Felix Grey, Pascoe Harvey, Fay Kenworthy, Patrice Mongelard, Laurel Morris, Liz Surkovic and Mark Turner.

Working with artists: MA Art and Science students and recent graduates from Central Saint Martins (Course Director: Nathan Cohen) collaborated with the Government Office for Science throughout the scoping and preparation of this report in visualising, debating and communicating the key themes and emerging issues. This was complemented by an exhibition *Tracing Wastelands* at the Depot, London, including artwork by Beckie Leach, Hannah Scott, Jennifer Crouch, Julius Colwyn, Silvia Krupinska, and Stephanie Wong (artsciencecsm.com/tracing-wastelands-exhibition/).

We are grateful to Hannah Scott who has given us permission to use photographs taken by her as part of the collaboration to illustrate this report.


We need to change from
a mindset of managing
waste to one of increasing
resource productivity

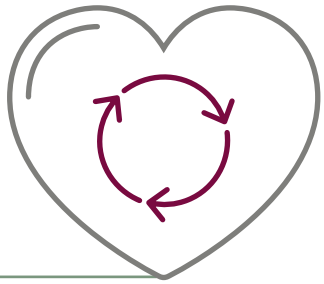
From waste to resource productivity: overview

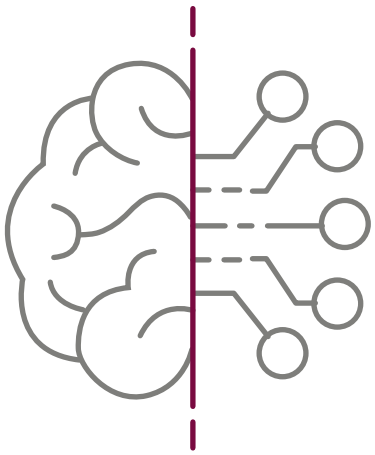
Waste nationally and globally is increasingly problematic and challenging to policymakers. It is a problem that is increasing in scale and scope. It matters to all of us for a series of reasons:

- There is simply so much waste. In a country with a small land area and a large population, the sheer bulk of waste is in and of itself a problem.
- As humans congregate in cities around the world, the production of waste has become highly concentrated and that creates particular challenges for its collection and disposal.
- Much waste is harmful. The scale of that harm has become global. It harms both humans and the other species with which we share the planet. That harm comes in many forms.
- Most importantly, there are big opportunities for the UK to become a more prosperous and secure society by generating value from: material that is prevented from entering waste pathways in the first place; and material that is extracted from waste pathways.

We need to change from a mindset of managing waste to one of increasing resource productivity. Based on the ideas in this report, we set out 13 specific Areas to Explore. These are designed to provide strategic direction; enhance our understanding of the issues, risks and opportunities; and encourage action on the ground to make the UK a more resource productive society.

Good waste policies cannot be designed without placing the consumer at the **heart** of the analysis





Areas to explore

The Government could bring leadership, direction and coordination in the following areas:

1. A Waste and Resource Strategy to increase the economic performance of the UK. This could harness the joint opportunities of the Industrial Strategy and the 25 Year Environment Plan and include i) pricing and market-based approaches; ii) regulatory approaches; and iii) strategic approaches.

2. To drive market behaviour, a "Data with a Purpose Initiative" to map data needs and prepare a roadmap of administrative and legislative action necessary to put in place a comprehensive and modern waste and resource data regime in the UK. Defra could lead this and involve representatives from Office for National Statistics, industry, the waste sector and academia.

3. A review of innovative circular economy practice throughout the economy to develop a sophisticated understanding of best practice, identify opportunities to share learning across sectors and explore specific opportunities to boost competitiveness through increasing allocative efficiency and reducing waste. BEIS have agreed to convene a working group to explore this issue and will engage CBI, The Royal Society of the Arts, AHRC, The Ellen MacArthur Foundation and the design profession.

4. Examining the scope for making fairer and more economically efficient the existing arrangements for sharing financial and behavioural responsibility for waste between householders, local authorities (including unitary and two tier authorities), private sector waste companies and reprocessors and business waste producers. This could be undertaken jointly by Defra, DCLG and Treasury.

The following activities could improve performance in specific sectors or areas:

5. **Business:** Measurement of the use of water, energy and materials needed to manufacture, use and recover products by businesses could lead to more resource-productive business models by showing the true costs of products. Defra and BEIS could examine the merits of introducing a scheme encouraging businesses to periodically audit resource usage within their supply chains.

6. **Environmental risks:** Providing consolidated evidence reviews. The Research Councils could work with Defra and its agencies to identify significant gaps in understanding of the accumulated evidence on environmental risks from waste, especially those arising from or identified by new technologies, and means by which these might by addressed.

7. **Building and construction:** Lean approaches, Design for Manufacture and Assembly, data, smart technologies, internet of things and Building Information Modelling techniques have an important role to play in increasing resource efficiency, delivering improved sector productivity and reducing operational waste over the lifecycle of a constructed asset to provide an important foundation for improved service and business delivery. The Infrastructure Project Authority and the Digital Built Britain Programme have jointly agreed to convene an initial roundtable to identify how these techniques might be further developed as an integrated process, who might progress this and to consider the merits of establishing a national centre of excellence for these modern approaches.

8. **Primary extraction:** To understand the research already underway on the environmental sustainability of the primary extractive sector, the research gaps and how these might be addressed, the Research Councils could convene an expert group.

9. **Agriculture and food:** The report, "Food waste: a response to the policy challenge" published by Government Office for Science in September 2017 sets out how food waste on the farm, within the household and in the supply chain could be better dealt with. Defra could examine and take forward the actions identified in that report.

Greater resource productivity could be achieved at the local, city and individual level by:

10. **Citizens:** WRAP (Waste and Resources Action Plan) should continue to help citizens to lead lifestyles which get the most out of the resources they acquire. This will involve citizens consuming more sustainably and businesses and local authorities supplying the products and services which enable them to do that.

11. **Cities:** Major city authorities could establish pilot models to examine the potential benefits for a partnership and systems approach (including through the use of smart technologies) to waste and resource productivity within cities.

12. **Local authorities:** WRAP (Waste and Resources Action Plan) working with partners has developed, "A Framework for greater consistency in household recycling in England" (published September 2016). DCLG and Defra could encourage local authorities to work with WRAP to understand the opportunities offered by the flexibilities of the framework to improve recycling performance within their specific local contexts.

Stronger leadership on resource productivity could be achieved at the international level:

13. The UK has demonstrated international leadership in global issues such as climate change and antimicrobial resistance, working through forums such as World Bank, G7 and OECD. The UK could take a similar approach on resource productivity – addressing both global opportunities and issues arising from the current management of waste, such as environmental degradation and exploitation of labour.

From waste to resource productivity

Sir Mark Walport, Government Chief Scientific Adviser, and Professor Ian Boyd, Chief Scientific Adviser at Department for Environment, Food and Rural Affairs

Introduction

Waste is a pervasive accompaniment to human history. Long after our ancestors died, their waste remains: in middens, littered with the bones of the animals they slaughtered and ate, along with broken cooking utensils, the remnants of shoes and clothing, and a host of other artefacts.

Apart from teaching us important things about our past, this archaeological record demonstrates the resilience and permanence of our waste. Yet populations could be counted in millions for most of human history – now they are measured in billions. Waste that once had a local impact now has a global impact, with important consequences for us and all the other species on the planet.

This report looks at waste through the lens of science. The natural sciences are critical to understanding waste, its material contents, its quantity and its environmental consequences. So too are the social sciences, from anthropology to economics. In preparing this report we have sought external advice and expertise from the worlds of academia, business, and the public sector.

Crucially, this report also surveys the potential value of greater resource productivity, and the various routes to achieving it. Resource productivity is a broad concept that involves using fewer resources in the first place; finding innovative ways of reusing the resources that we do use; and ensuring that we use resources for as long as possible before they become wastes. The UK government now has an opportunity to lead on this issue, and significantly contribute to a shift in focus from managing waste to increasing resource productivity.

Nationally and globally, waste is a problem that is increasing in scale and scope, posing a growing challenge for policymakers. The sheer volume of waste that we produce, and its persistence in the environment, also makes it a highly political issue.

We chose waste as the topic for this report for several reasons. The first and most important reason is that waste is actually an enormous opportunity. Much of it is a potential resource that can be recovered and reused in a huge number of different ways. We can generate great value from material that is extracted from waste pathways, and from material that has been prevented from entering those pathways in the first place. By doing so, we can reduce the amount of material that finally ends its life as residual waste. That is why this report focuses on how we can move from waste to resource productivity.

The second reason is simply that in a country with a small land area and a large population, the sheer quantity of waste we produce is a significant and growing problem. This is particularly true in cities, where the production of waste has become highly concentrated, thus creating particular challenges for its collection and disposal.

A third reason is that some waste is harmful, and the scale of that harm has become global. Indeed, the first phase of public intervention in waste management was largely driven by the need to deal with the miasma that contaminated our industrialised and overcrowded cities. It led to a pioneering infrastructure that separated sewage from clean water, which still continues to serve us. But today, the harms posed by waste come in many more forms, affecting humans and other species that we depend on or that are affected by our actions. Some of these harmful wastes are invisible: greenhouse gases, excess nitrogen and phosphorus fertilisers, and biogenic ammonia from agriculture, for example. And new, disruptive materials and technologies are emerging all the time, posing fresh hazards.

Our fourth motivation for unpicking the

problem of waste is that it presents an especially complex social and political challenge. Waste is a classic example of an externality: it has economic and other consequences for people who did not generate the waste in the first place, and over which they have no control. Thus a landfill site generates and releases methane into the atmosphere, adding to the greenhouse effect that ultimately causes anthropogenic climate change. Such carbon emissions are an example of an externality where nations around the world have decided to act individually and collectively, as illustrated by the agreements reached at the 21st Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC) in Paris at the end of 2015. And landfill sites themselves show how an externality can be managed through policy measures – specifically the Landfill Tax, a charge levied on those who deposit materials there. But this is a relatively uncommon exception. In general, the manufacturers and consumers of goods that end up as waste do not pay for their externalities.

In developing this report, we decided to consider waste from two different points of view. We looked first through the lenses of the different economic sectors that are responsible for generating waste: households; commercial and industrial; agriculture and food; mining and resource extraction; and construction and demolition. Then we looked through the lenses of different parts of society: first through the eyes of every one of us, as citizens; then from the perspective of businesses; of cities; of local government; and of national government. Finally we looked abroad, to see what we could learn from how other countries behave. Each of our authors developed a small number of key recommendations for policymakers, which we present here as suggestions. However, we should make it clear that we are science advisers, not policymakers, and we acknowledge that policymakers make decisions after looking through several lenses of their own: What do I know about the topic? Is a particular policy deliverable in practice? How does this sit with my political and personal values? And how will it play with the electorate?

This report should help to answer the first of these questions by providing evidence, and stimulating further questions about the evidence. For example, many of the policies within the legal framework for waste have been delegated to the devolved administrations, and this creates an important opportunity to evaluate and learn from experiences in different regions of the UK.

We really hope that this report will encourage thinking in government about the policy framework and management of waste at a pivotal time. The vast majority of the regulation and legislation that underpins the waste policies of the UK was developed during our membership of the European Union. The UK's exit from the EU provides an opportunity for the UK to examine the totality of its waste policies, and consider them within the context of the government's Industrial Strategy. This report offers evidence that will help to frame the post-EU regulations and legislation underpinning the future management of waste in the UK.

Our focus on resource productivity

Each generation should be able to enjoy the benefits of economic growth, higher incomes and the natural environment they live in. Seeking to extract the value from what we throw away, which would otherwise be burned or buried as waste, is crucial if we are going to make this a reality.

Consequently, a major theme of this report is that we need to stop thinking in terms of waste and focus instead on how we make the most of our resources. The evidence in this report shows how much we stand to gain from doing so, and outlines how it can be achieved. There are big opportunities for the UK to become a more prosperous and secure society by increasing our resource productivity. That will also mean breaking our reliance on imported products and jettisoning an approach to waste that focuses on its disposal or export.

Resource productivity is a means for making better use of the inputs needed for economic growth without undue degradation of the natural environment. That environmental protection is not only necessary for our wellbeing, it also safeguards the inputs that the environment provides to the economy directly (eg water, metals, timber) and indirectly (eg flood resilience, nutrient cycling, carbon storage).

Resource productivity also saves households and businesses money. Every year, UK households waste £12.5 billion on 7 million tonnes of food

and drink that is bought and subsequently discarded. UK firms can improve resource productivity by making better use of inputs to and processes for production, reducing energy bills and improving their management of water. Investing in resource-efficient technologies can help businesses to gain a competitive edge. Adopting resource-efficient practices will support business resilience to economic shocks and commodity price volatility. Beyond these savings, there is a great opportunity for UK businesses to develop innovations and new technologies to support and enhance resource efficiency, becoming market leaders and exporters of expertise to the world.

In the following sections of this summary report we will consider the key issues and areas for policy consideration that have arisen from the evidence chapters, and from seminars and individual meetings with experts. We are responsible and accountable for the contents of this summary report, while the individual authors are responsible for the content of their chapters. None of this report is government policy, but we hope that it will influence the development of policy.

Waste as a resource

No matter what we do, we will generate waste. This is, in essence, a consequence of the second law of thermodynamics: the energy used to manufacture raw materials into products increases their value, but as we use these products their value dissipates, sometimes very rapidly. Once that value falls below a certain level, we treat the product as waste. Even those materials that can be given a new life by reuse or reprocessing will eventually reach a point of such little value that they need to be disposed of, typically by incineration or in landfill.

But if waste is inevitable, then the volume and nature of it is not. Indeed, much of what we talk about as 'waste' still retains a great deal of value, and should more accurately be described as 'resources'. These include materials such as plastic bottles, drinks cans and paper that can be recycled; or food and garden waste that can produce compost. Although generally captured in the 'waste system', these materials are not waste: they are resources, because their value has not yet been exhausted.

Catherine Alexander and Nicky Gregson explore these issues about the nature of waste in Chapter 1 of the evidence report, and show that tackling waste is part and parcel of managing resources. One part of this challenge is to minimise the amount of residual waste that has no remaining value. This offers a clear way to reduce the processing costs and environmental impacts of residual waste, but it also requires the waste management sector to separate resources that retain some value – metal, plastic, and so on – from that waste.

Key messages

1. There will always be residual waste, so we need to have the appropriate disposal options.
2. We can do much more in the UK to reduce waste:
   - We can intensify our recycling efforts by asking manufacturers what kind and quality of recycled resources they want, when they want them, and by making the most of technologies such as smart bins.
   - We can embed sustainable design as an integral part of our education system, research and innovation approach, and manufacturing processes. These design principles include 'product passports' that identify and quantify the materials in manufactured goods, which enable those goods to be more readily reused, recycled or remanufactured.
   - We can promote the reuse of products, for instance through more involvement of the voluntary and non-profit sector (the 'third sector') to redress the inequality between recycling and reuse.
3. Following the UK's exit from the EU, we need to engage stakeholders in a wide-ranging dialogue to re-evaluate waste policy in the UK and devolved administrations in relation to waste policy in the EU, including its Circular Economy programme.

A second part of this challenge is to minimise the amount of waste generated in the first place, either through more efficient use of resources so that less is thrown away, or by 'designing out' waste. Firms can ensure that the products they market, for example, use packaging that is recyclable or, where it is not, that the quantity of what will be wasted is minimised.

When does waste pose a risk?

Public and environmental health remains one of the key drivers for policy about waste. When considering this, it is essential not to conflate hazard with risk. Risk to humans and other species is the product of hazard, exposure and vulnerability. However hazardous a substance may be, it poses no risk if there is no exposure. Indeed, a major purpose of waste management is to reduce risk by minimising exposure. This topic was considered in detail as part of the first of the Government Chief Scientific Adviser's annual reports, 'Innovation: Managing Risk, Not Avoiding It'.

When unseen waste escapes into the environment it is usually called pollution, a form of 'waste out of place'. The aim of analytical science and public health is to analyse the exposure and vulnerability of humans and other species to hazards that might carry a plausible risk, and to measure any harms associated with them. Physical and chemical hazards are becoming easier to detect because of increasingly sensitive analytical methods but there is considerable uncertainty about whether these hazards present a plausible risk. For example, there is accumulating evidence around the presence of plastic micro-particles in the ocean and there is now a very large range of synthetic chemicals in the environment. In these cases evidence of widespread harm is equivocal but for policy makers it is a judgement about whether the potential for harm is sufficient to suggest regulation is needed. Detecting the effects against background can be very challenging as illustrated by the problems of distinguishing between the effects of small exposures of ionising radiation from natural and human-made radioactive sources.

The precautionary principle was developed to respond to some of the uncertainties associated with hazard exposures. But the danger of the precautionary principle, if applied in an indiscriminate fashion, is that it can prevent innovation and increases costs. Not doing something can be as harmful as doing something: for example, continuing to accumulate radioactive waste in facilities above ground could carry as much risk as placing it in a geologically-stable underground store. The precautionary principle demands a very careful risk assessment, and it is not a mandate to avoid all hazards.

Science advances through the accumulation and consolidation of knowledge. The difficulty is that the dominant focus of scientific funders and scientists is on accumulation, with insufficient focus on consolidation. What is needed, both for the scientific endeavour and for policymakers, are state-of-the-art evidence reviews that are openly available to everyone for scrutiny. To make this happen requires two things: funding for the creation of such reviews, and a recognition by universities and the academic community that preparing these reviews is an activity that carries intellectual status.

Key messages

1. Waste policies must take into account not only the nature of the hazard, but also the significance of potential exposures and vulnerabilities of humans and other species.
2. Scientists and engineers (and those that fund them) must ensure that policymakers have the best scientific advice on the risks and hazards of waste and pollution.
3. Policymakers need state-of-the-art evidence reviews about these risks and hazards. These require funding, and a greater appreciation that preparing these reviews is a valuable intellectual activity.

Measurement and monitoring of waste

Waste that cannot be measured is difficult to manage. During the 1990s, efficient production and waste prevention increasingly became a business priority. In order for businesses to become more efficient, they recognised that they needed to know the nature and quantity of waste they produced, and to optimise their input of resources. The introduction of permits for the disposal of certain types of waste ensured that data could be collected on these waste streams. But there is more to do. If we are to make the most of the resources within waste, and discourage its production in the first place, we need to know: which products the waste has come from; the composition of the waste; the quality of the materials contained within it; where it ends up; and in what form. This information, alongside data on the carbon and economic impacts of waste, needs to be available and presented in an intelligible form to all of the stakeholders in the system – in essence, it needs to be open data.

Nigel Naisbitt considers the topic of data about waste in Chapter 2 of the evidence papers. He makes the point that there is not enough information about waste streams from the construction and demolition sector, the highest producer of waste in the UK, nor about commercial and industrial waste streams that have the highest economic potential. We should also carefully consider how we measure waste. For example, there may be other yardsticks, such as carbon content or pollutants, that are as important as simple tonnage.

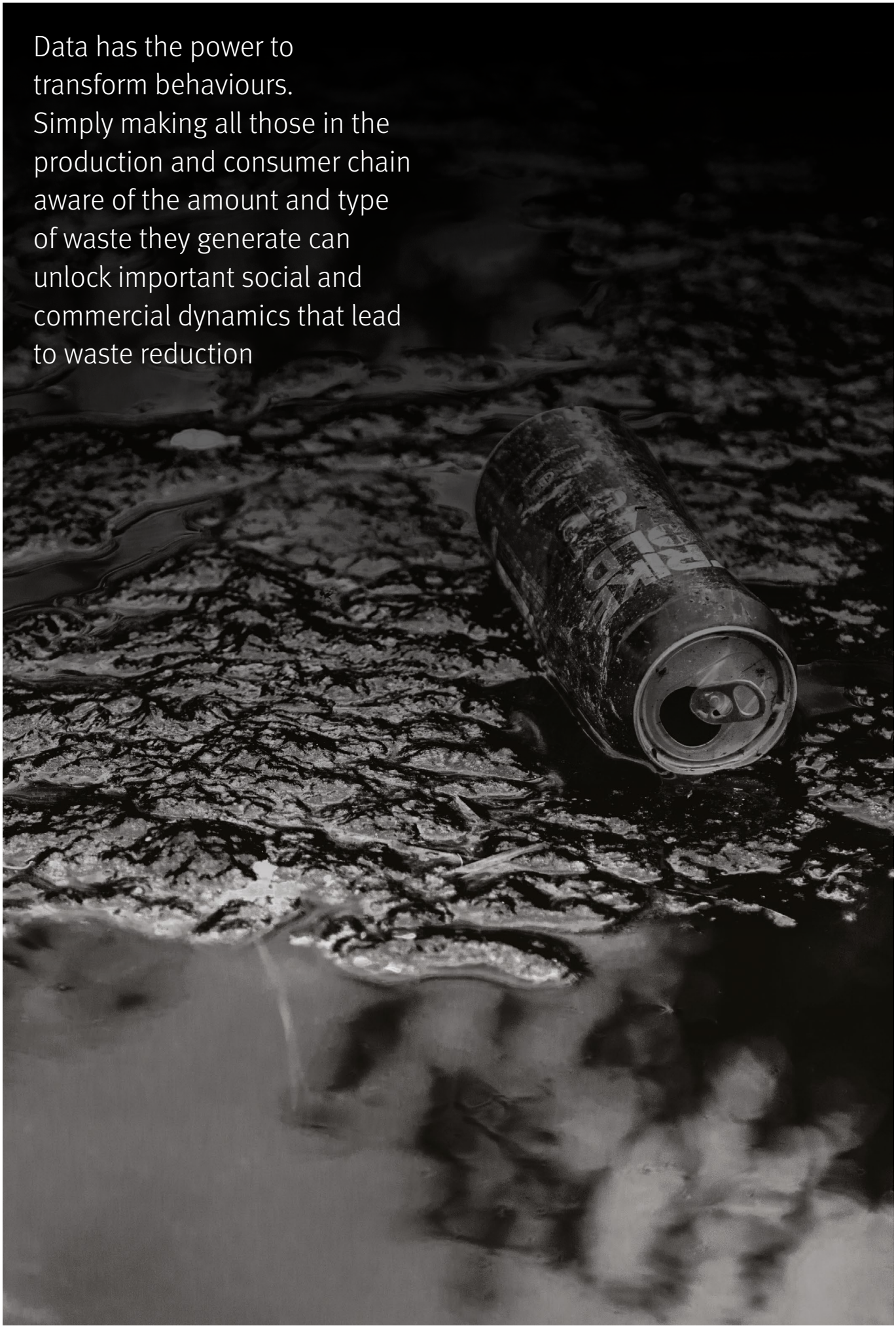
This leads to one of our strongest recommendations to policymakers: that we need to put in place the fundamental building blocks of data gathering and analysis to ensure we know the types, amounts and quality of waste, and where it is generated and ends up – and to make this information publicly available. Without a strong and open understanding of our waste data, we will have no firm basis to unlock the resource productivity potential of waste. That knowledge should be openly available, so that everyone with an interest in waste and its prevention and management has access to the same data sets. As part of this data collection, operators of waste management activities exempt from permitting should be required to report on the types and quantities of waste they handle. To enhance resource productivity, inputs to the open data store edoc (Electronic Duty of Care), especially in the commercial and industrial sectors, should be required. A sufficient level and quality of data will allow individual businesses to perform more strongly in their resource management, and enable better-informed policy choices. Within a framework of a presumption of open data, it is also critical to take into account circumstances, such as issues of business commerciality, where data release might need to be controlled.

Data has the power to transform behaviours. Simply making all those in the production and consumer chain aware of the amount and type of waste they generate can unlock important social and commercial dynamics that lead to waste reduction.

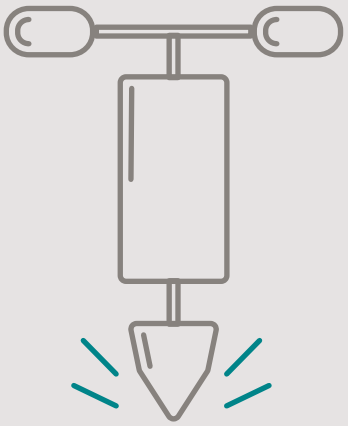
Key messages

1. To have the greatest impact on resource productivity, we need to know the amount, type and quality of waste, and where it is generated.
2. To ensure more complete capture of waste data, waste management operators that are exempt from permitting should be required to report on the types and quantities of waste they handle.
3. Enhancing or incentivising inputs to the open data store edoc, particularly in the commercial and industrial sectors, will enable reliable estimates of recycling rates and an improved understanding of resource productivity.

Data has the power to transform behaviours. Simply making all those in the production and consumer chain aware of the amount and type of waste they generate can unlock important social and commercial dynamics that lead to waste reduction

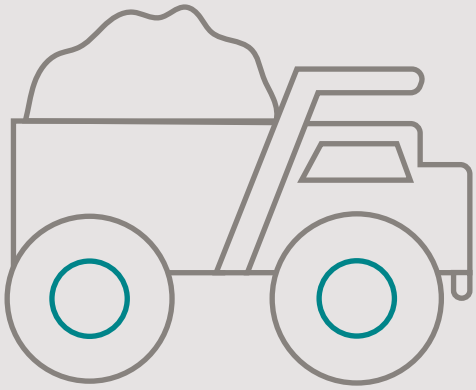


Excavation, construction and demolition



International

Agri-food

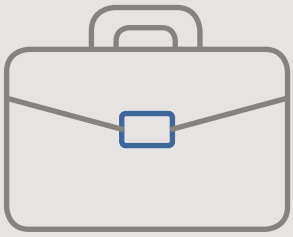


Mining and resource recovery

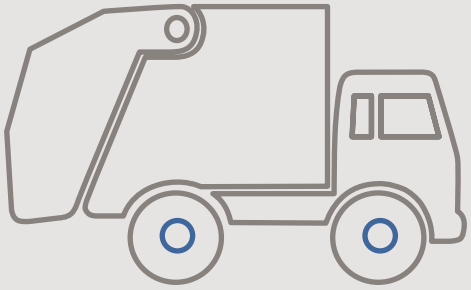
General industrial, manufacturing and commercial

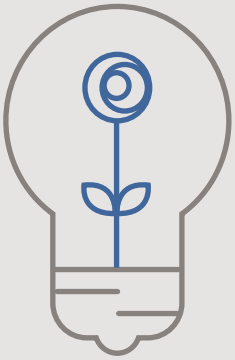
Household

Business



Local Government





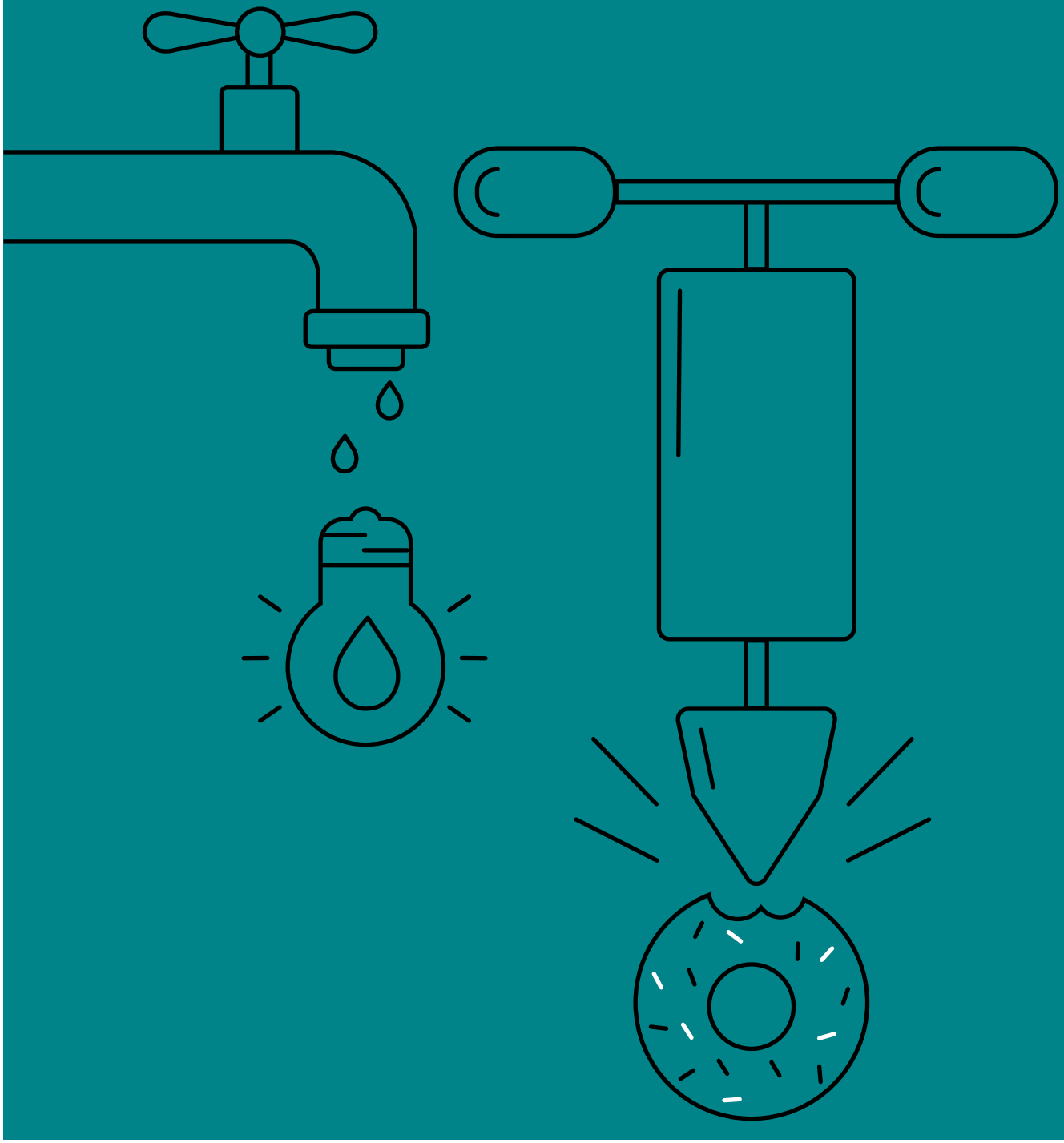
Citizens

Cities

National Government

Section 1:

Sectors



Excavation, construction and demolition

Excavation, construction and demolition is the highest waste producing sector, amounting to about 100 million tonnes of waste in the UK each year between 2004 and 2012. It is also a sector that has made considerable progress in the search for increased resource productivity. Construction and demolition waste comprises a large array of materials, including concrete, bricks, wood, glass, metals, plastic, solvents, asbestos and excavated soil. Most of the non-hazardous materials from this sector can be recycled, and in 2012 the recovery rate from construction and demolition waste was over 80%. But the challenge remains to extract the maximum value from this recycled material.

It is in the direct economic interests of industry to minimise waste in excavation and construction, and to recover the most value from the products of demolition. So this is a sector where dissemination of good practice, innovation and its uptake are important. It is also a sector that is subject to extensive guidance, regulation and legislation.

In Chapter 8, David Greenfield describes various approaches to achieving waste reduction. In the case of excavated soil, the 'waste hierarchy' provides the key principles for management. Waste can be prevented by first optimising site usage to minimise the need for excavation in the first place; then, wherever possible, excavated material can be reused on site; if this can not be achieved, then it can be recycled to other sites; and only if all other options are excluded should it be moved to landfill or other disposal.

When excavated material is being removed to create a large void for a tunnel or an underground section of building, it may require removal to another site. Here, planners and the construction industry can collaborate to achieve the most effective outcome. An excellent example is the Crossrail project in London, which has generated over 7 million tonnes of excavated material from stations, tunnels, portals and shafts. Over 98% of this has been reused, helping to create a landmark nature conservation project at Wallasea Island in collaboration with The Royal Society for the Protection of Birds (RSPB).

Design for Manufacture and Assembly (DFMA) techniques including off-site construction technology has the potential to revolutionise building and engineering projects. For example, over 85% (by value) of the Leadenhall Building in the City of London was constructed using components manufactured off-site. A factory approach to building construction can achieve substantial waste reduction by carefully managed scheduling, bulk deliveries, reuse in the manufacturing process and high volume throughputs. Legal and General is taking a similar approach to the construction of domestic housing.

A closely related theme is the use of Building Information Modelling (BIM), which creates 3D models of infrastructure, including all of its

Over 85%

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Key messages

1. The construction sector should continue to support and use integrated process models of lean thinking, DFMA, Government Soft Landings and Building Information Modelling, to enable building designers to plan for waste reduction at every stage of construction, lifetime operation and dismantling.
2. The government should work alongside the construction sector to promote better social, economic and environmental outcomes for all new developments in their construction, operation and end-use phases.
3. Greater focus should be placed on the lifetime of developments, and how recycling and waste management will be achieved during their operation.
4. Government and industry working together should consider how the data revolution and technological advances in modelling, artificial intelligence, sensor technology and robotics may be harnessed to assist the industry sector, construction clients and asset users to optimise resource efficiency.

services and surroundings. This is an example of how a systems engineering and modelling approach can be used throughout the entire lifecycle of an infrastructure project. Modelling the waste flow throughout a building's lifespan is particularly important for the complex ecosystems of modern high-rise buildings. The UK government has incentivised the use of BIM by means of the "Digital Built Britain" Programme, which acts as a procurement mechanism that encourages government departments to act as expert customers for BIM for new buildings for government. The government should continue to work alongside the construction sector to make the reduction of waste central to all new developments, placing more emphasis on how recycling and waste management will be achieved throughout the whole lifetime of the infrastructure.

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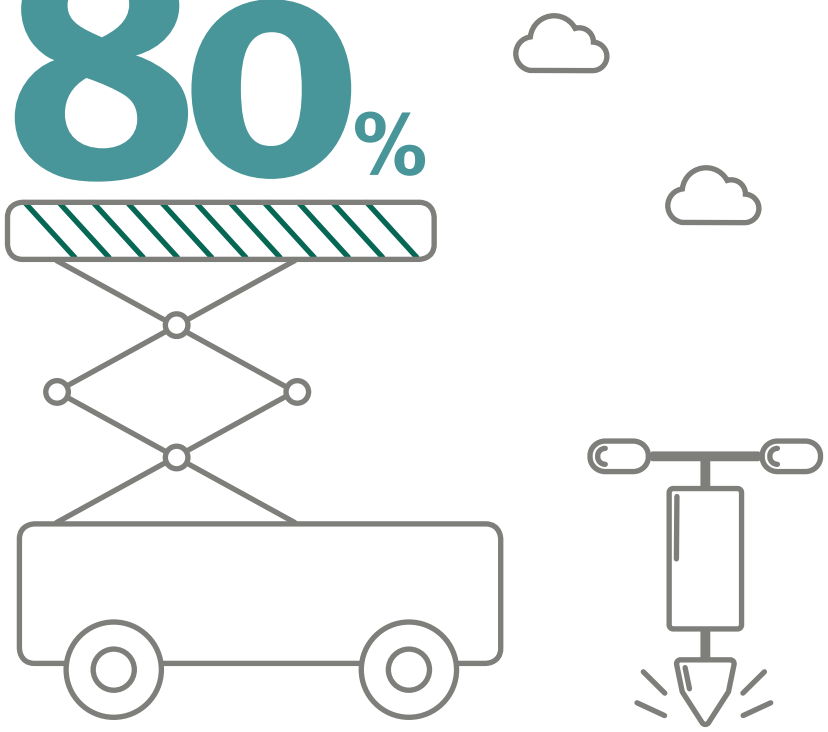
80%



Mining and resource recovery

The extraction and processing of metals and minerals from the Earth's crust for use by industry and construction is a major human activity. The global mining industry is very large and expected to grow, primarily in response to high rates of industrialisation and urbanisation in emerging economies. In 2010, the industry was valued at about $644 billion, constituting about 1% of global GDP.

In Chapter 7 of the evidence papers, Andrew Bloodworth and colleagues remind us that "if you cannot grow it, you have to mine it". Mineral material flows are global, due to the uneven distribution of minerals around the world and the sheer scale of the operations needed to extract them. Most primary minerals and metals have a low 'place value', meaning that their price is high relative to the cost of transporting them. These materials are generally traded on a continental or global scale and the UK, together with most developed economies, is highly reliant on this international supply chain for most metals and minerals.

This contrasts with bulk construction materials, such as crushed rock aggregate, sand and gravel. These are very widely distributed around the world and have a high place value, meaning that their price is low relative to the cost of transporting them. Trade in these materials is therefore much more localised and, as a consequence, the UK is almost entirely self-sufficient in domestically-produced aggregates. This has a profound influence on the use of secondary aggregate resources and the range of policy levers that can affect this use.

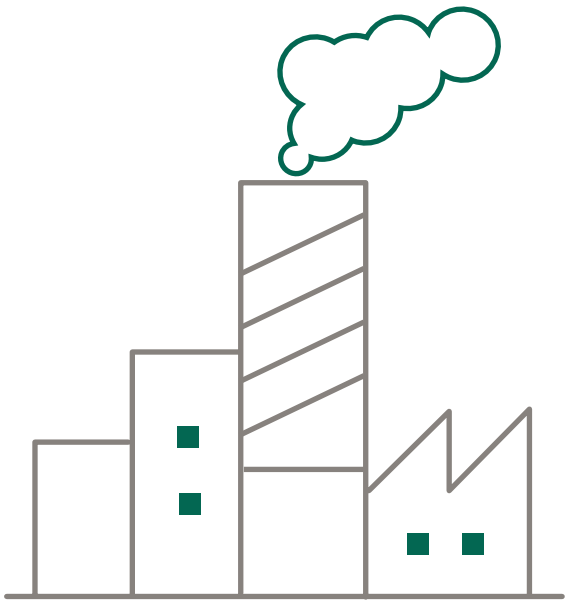
It is unlikely that we will exhaust the Earth's supply of minerals: the economic viability of lower-grade deposits increases as their price goes up, and as the technology for their extraction and purification improves. However, this comes at an energy and environmental cost, and reductions in our environmental capacity to cope with the energy and water usage may outpace the depletion of minerals. Between 3% and 5% of total energy demand is used solely to crush rock for mineral extraction. This leads to a risk that certain mineral resources may become inaccessible unless technological innovation enables their extraction with significantly greater energy efficiency.

Recycling provides an important complement to the supply of primary raw materials, and has a number of other important benefits, particularly in reducing the environmental impacts of primary extraction. For example, the total energy used in the production of copper from metal ores is nearly 4 times greater than that from high-grade scrap. This differential is even greater for the secondary production of aluminium, which requires only 5% to 10% of the energy used in primary production.

In many cases, however, recycling of metals and minerals occurs at a smaller scale and is less cost-effective than the extraction of primary material. This is in part due to the way that products are designed without consideration for easy separation of the different materials at the end of the products' lives, which makes it extremely hard to recover individual metals for reuse. Nevertheless, secondary recovery of higher-value metals like gold and platinum is increasingly common.

The trilemma associated with the production of power – the need for security, sustainability and affordability of supply – applies equally to the supply of key minerals and metals. Indeed, there is a high degree of overlap between the two sectors. One of the major economic challenges for both sectors is that their primary resources, be they oil or steel, are traded globally, and therefore their prices fluctuate dramatically according to macroeconomic and geopolitical factors. This has an important effect on the markets for renewable or unconventional sources of either energy or metals and minerals.

Because externalities are not priced into primary resources, their prices do not reflect their true economic costs. Many of these economic costs will have to be paid when the externalities 'come home to roost', in the form of climatic



In 2010, the industry was valued at about **$644 billion**, constituting about 1% of global GDP

and other forms of environmental damage. These costs are accruing to future generations that have not directly benefited from the extraction and use of these resources. The effect today, though, is to make it very hard for alternative energy, mineral or metal sources to compete in the market place, especially in the context of widely fluctuating primary commodity prices, even though they have the advantage that they do not bring in their wake a similar scale of externalities. One solution must be to encourage research and development aimed at driving up the effectiveness and efficiency of resource extraction, use and reuse.

A second approach is to persist in attempts at a global level to persuade present generations to take more responsibility for the impacts of current activities on future generations. We know that taxation of primary resource extraction can encourage a switch to secondary production. The tax on the extraction of primary aggregates in the UK is a good example, but this form of taxation only works at a national level on materials with a high place value. If we are to price in the externalities of metals and minerals with a low place value that are traded globally, we need an intergovernmental process analogous to the UN Intergovernmental Panel on Climate Change, that would consider and agree an approach to the extractive industries for minerals and metals. Indeed, carbon pricing would be one form of taxation that would deal with some, though not all, of the externalities of the extractive industries.

What does all of this mean for the UK? It is a timely topic for policymakers who are considering the future of the UK steel industry. Here, and elsewhere in Europe, decreasing steel spreads due to global overcapacity have caused significant challenges for the sector. In the UK, this coupled with high electricity costs, increasing imports and ageing infrastructure have caused difficulties for existing incumbents, most of whom use blast furnaces to produce steel from basic raw materials including iron ore and coal. Advanced economies tend to have relatively high stocks of steel in existing infrastructure and products, compared to their demand for new steel, which makes it possible to rely more heavily on recycled steel. With electric arc furnace production, a further consideration is the purity of the steel produced. If the scrap metal is contaminated with other metals such as copper, it tends to be 'downcycled' into lower-value products such as reinforcing bar for construction as opposed to high value sectors such as aerospace and automotive. Methods of separating scrap metals are becoming increasingly sophisticated, thus reducing the contamination problem, but in some key downstream sectors (such as automotive) there is still a preference for steel produced via a blast furnace.

This example shows that we need better data on the stocks of materials derived from the extractive industries in the UK, and more information about how they move from mining to processing to manufacturing, and then use, recycling and disposal. This will highlight future resource availability, potential supply bottlenecks and opportunities to improve resource efficiency. The manufacturing industries that use these materials must also play a role, and this is considered in the section on manufacturing.

Improving the recovery of metals from end-of-life products depends on achieving economies of

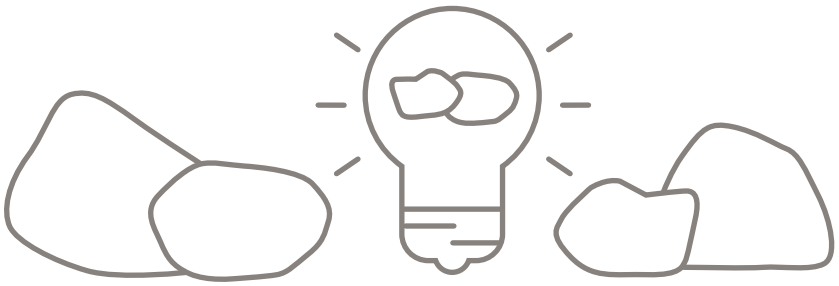
scale. The volume and variety of metal stocks in circulation in the UK economy, together with their price, will determine whether recovery is carried out on a national, European or global scale. But a critical issue for the balance between primary and secondary production remains: the absence of adequate pricing of the externalities of primary production. This is a global issue where the UK could show leadership, but it is not one that can be tackled by countries working in isolation.

A consequence of global population growth coupled with rapid urbanisation is that primary materials will continue as a major source of supply for the foreseeable future. As a result, research and development are urgently needed to improve substantially the environmental sustainability of the primary extractive sector, especially with regard to greenhouse gas emissions and water usage.

Between

3% and 5%

of total **energy demand** is used solely to crush rock for **mineral** extraction



Key messages

1. We need better data on the stocks of materials already in use in the UK, and how they move from mining and processing to manufacturing, use, recycling and disposal. This will highlight future resource availability, potential supply bottlenecks and opportunities to improve resource efficiency.
2. Improved recovery of metals from end-of-life products depends on achieving economies of scale. The volume and variety of metal stocks in circulation in the UK economy, together with their price, will dictate whether recovery is carried out on a national, European or global scale. The pricing of primary minerals should also better reflect external environmental costs of production.
3. A consequence of global population growth and urbanisation is that primary materials will continue as a major source of supply for the foreseeable future. As a result, research is urgently required to substantially improve the environmental sustainability of the primary extractive sector, especially with regard to greenhouse gas emissions and water usage.

Agri-food wastes that are homogenous are ideal raw materials for biological processes that create new products or existing products by new processes. These waste streams can provide sustainable feedstocks for the UK's growing bioeconomy, currently estimated at £36 billion per annum, enabling a more resilient food system by closing nutrient loops and reducing our reliance on finite resources

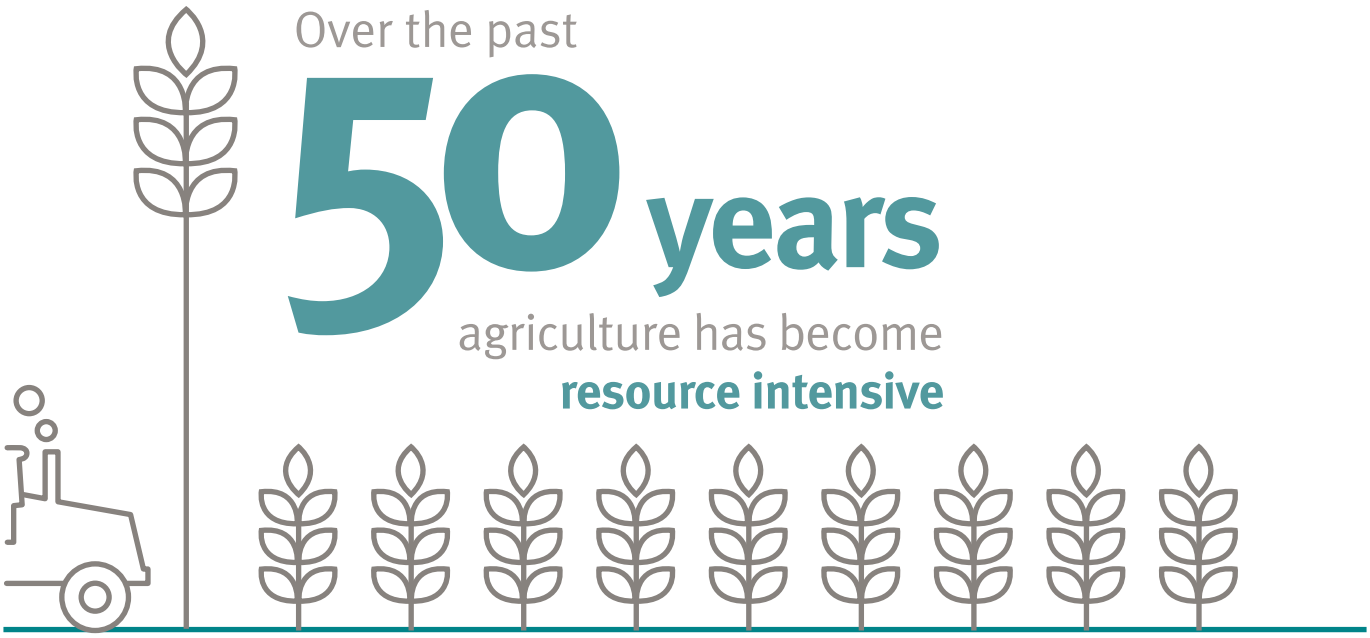
Agri-food

Over the past 50 years, agriculture has become resource intensive. It relies heavily on inputs that consume fossil fuels, including synthetic nitrogen-based fertilisers and petroleum-based agrochemicals. Agriculture currently uses 10 calories of fossil fuel energy to produce one calorie of food. This inefficiency – which uses up non-renewable resources – is not reflected in the price of food.

In Chapter 6, Shane Ward and colleagues explore the extent of agricultural waste, and the benefits and costs of agricultural waste reduction. The UK throws away at least 10 million tonnes of food every year, of which 6 million tonnes is avoidable and has a retail value of £17 billion. Globally, food production is responsible for 30% of total greenhouse gas (GHG) emissions, half of which comes from land conversion to agriculture, and the rest from production itself. Though there is uncertainty about the precise figures, around one-third of all food is wasted. The UN Food and Agriculture Organisation reports that if global food waste was a country, it would be the third largest GHG-emitting country in the world.

Key areas in which agri-food waste needs to be addressed are on the farm, in the supply chain, in the household, and by making better use of agri-food waste. We need to improve data collection and apply the right lifecycle and other assessment tools to better understand the issue. This enables us to distinguish agri-food waste that is avoidable (such as food discarded because it has gone beyond its 'best before' date) from that which is not (such as manures, crop residues, leaves and peels). This and other factors are highlighted in the Food Waste Recycling Action Plan produced by the Waste and Resources Action Programme (WRAP) in 2016.

As an example of what can be achieved, one means of reducing agricultural waste on the farm and in the supply chain would be through the use of whole crop purchase (WCP) contracts between farmers and food retailers. For some crops, up to 25% is wasted because it does not meet appearance standards set by retailers. WCP could ensure that produce not reaching



Key messages

1. Agri-food waste is a barrier to the growth of the UK economy, representing lost money, excess fossil fuel consumption and missed opportunities.
2. Distinguishing between avoidable and unavoidable agri-food wastes is essential to achieve optimal policy outcomes, with the primary focus being to cut out avoidable waste.
3. Unavoidable agri-food wastes should be exploited to the maximum as sustainable feedstocks for the UK's growing bioeconomy. The government can support this with a clear industrial strategy for the UK bioeconomy.

these standards is used in other parts of retailers' supply chains, for example in the manufacture of soup or diced goods. This could reduce farmers' incentive to over-produce. WCP has allowed the supermarket chain Morrisons to sell 100% British produce in season, make use of 20% more of a potato crop, and control its supply chain more effectively.

There are also major opportunities for exploiting many agri-food wastes that are homogenous, and are therefore ideal raw materials for biological processes that create new products or existing products by new processes. These waste streams can provide sustainable feedstocks for the UK's growing bioeconomy, currently estimated at £36 billion per annum, enabling a more resilient food system by closing nutrient loops and reducing our reliance on finite resources.

WCP has allowed supermarket chain Morrisons to sell

100%

British produce in season

General industrial, manufacturing and commercial

Central to the debate on waste reduction are the twin concepts of the circular economy and resource productivity. In a circular economy, wastes are used as resources for other processes – remanufacturing, reuse and recycling ensure that materials and products continue to circulate in the economy. Through resource productivity, industry works to minimise the waste it generates, then progresses to improving the value returned from that waste.

Both the circular economy and increasing resource productivity lead to greater dependencies between actors in the economy. As the circular economy becomes more multifaceted, the chance of complex failure increases. For instance, a decision by one company to change its business model or technology in order to produce less of a particular waste product may have consequences for companies elsewhere in the economy, even in seemingly unrelated fields, which use that waste as a feedstock. This could trigger a chain of unforeseen effects across the economy as a whole.

Chapters 3 and 5 analyse a variety of industries that already strive to understand how their waste is generated, how to manage it better, and whether they could introduce waste from other sectors as their feedstocks rather than utilising virgin natural resources.

In the bioeconomy, businesses are increasingly adopting an industrial symbiosis approach, where the outputs of one manufacturing process become the input of another manufacturing process. This requires all actors to recognise their role as a potential waste-user, and to understand how their own outputs could be used by others.

In terms of technologies, 3D printing is increasingly being recognised as an alternative to mass manufacturing. In some circumstances, 3D printing could offer reduced energy and raw materials use, emissions savings, and shorter supply chains. Equally, the pharmaceutical industry is developing novel approaches to manufacturing healthcare products. For instance, processes that rely on glucose as a feedstock to make medicines, including certain antibiotics, could source this raw material from food and organic wastes, replacing virgin materials such as sugar cane. Design can also play a vital role in minimising waste. Products designed to respect their social context and be more physically durable are used for longer, and clever design can determine when and how products become waste. There is more that can be done to embed resource productive design principles in business, including making closer connection between design and business courses in further and higher education.

50%

of European **truck tyres** are rented, and they are **remanufactured** many times before finally being discarded

Key messages

1. The commercial and industrial sector is not homogenous. To maximise resource productivity, we should tackle the specific challenges and exploit the unique opportunities in each sector, and then apply learning across sectors.
2. Optimising the value of materials depends on assigning ownership of a product throughout its life. The way products are designed must improve, and the education of designers must rise to that challenge.
3. We need to encourage business models that properly value inputs and outputs across global supply chains, including water waste and energy.
4. Manufacturers often create by-products as a consequence of optimising their production processes. We must use the outputs of each industry in a strategic way to generate higher productivity from the same resources across industry as a whole.

The individual citizen now has **more power** over how they use, **manage** and **profit** from their own assets

Just as fundamental to the future of waste is the innovation that is taking place in business models. We increasingly buy services instead of owning goods, for example, which incentivises the supplier of the goods to find ways to keep them generating revenue, rather than being discarded. For example, 50% of European truck tyres are rented, and they are remanufactured many times before finally being discarded. More generally, remanufacturing replaces broken components and restores the product to its original state, with a warranty to cover the next stage of its life.

With the emergence of the sharing economy, the individual citizen now has more power over how they use, manage and profit from their own assets. The sharing economy involves consumers getting products or services from each other, or via platforms hosted online. It allows individuals to make money from assets they own, helps consumers to get products or services locally, and can avoid the generation of waste. In the transport sector, for instance, the sharing economy is expanding rapidly: rather than owning your own car, in some cities it is now possible to use a platform such as Zipcar to rent one when and where you want.

These new business models also have important implications for managing waste. When a product comes to the end of its life, ownership is a crucial way to determine who is responsible for ensuring that the value of that material is not lost. We must track both the volume and value of materials used in a product, as well as who owns (and is responsible) for these materials, at all stages of the product's life.

Household

Household waste is the most socially complex, physically cross-contaminated and highly variable of the sectoral waste streams considered in this report. In total it only amounts to about 14% (about 27 million tonnes per annum) of total UK waste. However, this relatively small amount belies its importance to policymakers. This is because every one of us directly contributes to this waste stream. The history of public health is to a significant extent the history of waste management by householders and municipal authorities.

Because of this public prominence, the prevention and management of household waste has been the main focus of policymaking around waste. EU regulations have been central in shaping policy approaches to matters such as recycling targets and extended producer responsibility (under which producers are given financial and/or physical responsibility for the treatment or disposal of post-consumer goods).

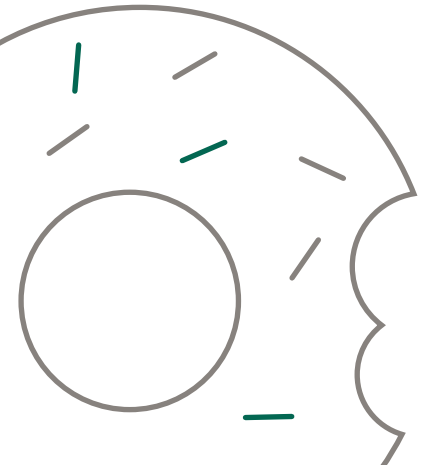
In Chapter 4, Steve Lee and Pat Jennings explore the wider context of household waste. EU legislation has set a clear framework for waste regulation, and the devolved administrations and regions of the UK have responded to this with various degrees of aspiration. The governments of Scotland and Wales have developed ambitious waste and resource strategies, aligned with wider climate change and economic strategies, which in some cases go beyond EU targets and legislative requirements. They have continued to invest directly in recycling, and given a stronger policy steer to their local authorities in comparison with a less prescriptive approach in England.

There are a number of challenges for the household waste sector at the moment. The financial environment for local authorities is constrained. Low primary commodity prices challenge the market for their recycled counterparts. And the nature of the materials entering domestic waste streams is changing as quickly as our consumer habits and the products we buy.

So how do we extract the most value from household waste? In fact, we win back the greatest value by not creating waste in the first place, for instance by not purchasing excessive perishable goods. Food waste is an important example. Of the 41 million tonnes of food that leaves the farm gate, mostly destined for households, we waste about 10 million tonnes per annum in the UK, some 7 million tonnes of which is thrown away by households. By weight, food waste amounts to about 25% of our domestic waste, and contamination by food reduces the value of the rest of our domestic waste. Food waste accounts for up to 20% of our greenhouse gas emissions, measured in CO_2 equivalents. It is in our obvious economic interest to produce less food waste in the first place.

The key question for policymakers at a national and local level is how to incentivise consumers and producers to minimise and manage their domestic waste more effectively. Their policy interventions can be categorised as behavioural, financial and regulatory.

For example, leadership and education can make a huge difference. Strong leadership has been provided in the UK by WRAP, demonstrating the value of a non-governmental organisation working in partnership with government, industry and consumers. WRAP uses



£12.5bn

is wasted every year by UK **households** on 7 million tonnes of food and drink that is bought and **subsequently discarded**

Key messages

1. A shift from merely managing household waste to maximising resource productivity requires a change in behaviour and infrastructure that involves almost every aspect of our social and business structures and attitudes. It requires a re-evaluation of the relationship and distribution of financial and behavioural responsibility for waste between householders, local authorities, private sector waste companies and reprocessors, and waste producers.
2. Recycling and reusability must be a central aspect of the design stage for new products. Clear responsibility for ownership of a product throughout its life is a key part of this.
3. We should apply the intensity, rigour and scrutiny that we have brought to bear in reducing municipal waste to other sectors.

'nudge' approaches such as education, campaigns like Love Food, Hate Waste, and Love Your Clothes. It has also brought together organisations across the food system to create the Courtauld Commitment, which aims for a 20% reduction in food and drink waste, greenhouse gas intensity, and a reduced impact associated with water use, between 2015 and 2025.

Policymakers can augment such voluntary schemes. The introduction of extended producer responsibility, which requires producers to internalise some of the externalities of their products, can make it much easier for the consumer to separate and recycle products such as used batteries and lightbulbs. If it's easy to recycle such products, consumers are much more likely to comply.

Financial policies can also reduce demand: the 5p charge on single-use plastic bags has led to an extremely rapid reduction (by around 85%) in their usage since its introduction in October 2015. Introducing financial incentives can also reduce waste and encourage recycling. The Government in England has stressed the need for comprehensive and frequent rubbish and recycling collections, and repealed previous legislation which would have introduced new taxes for the collection of household waste. The Government does not support direct charging or taxes for the collection or disposal of household waste, given the potential harm to public health and the environment from increased fly-tipping and backyard burning. The Department for Communities and Local Government has funded incentive schemes (such as Recyclebank and Green Points) which give rewards to those who recycle.

Different parts of the UK have different degrees of separation of household waste streams at the point of collection. All of these policies involve trade-offs. For example, pre-separating waste streams before collection is the most effective way to deliver high-quality supplies of recyclable materials, but this is less practical in a dense, high-rise urban environment than in a suburban or rural environment.

The key message to policymakers is that a suite of policy interventions is needed to handle domestic waste. A number of policy initiatives that charge directly for the externalities of domestic waste have been shown to be effective. Policymakers could consider whether there is more to be done on this front to improve domestic waste management.

Household waste is the most socially complex, physically cross-contaminated and highly variable of the sectoral waste streams considered in this report. In total it only amounts to about 14% (about 27 million tonnes per annum) of total UK waste

Section 2:

Perspectives

Citizens

Waste collection is primarily funded by the taxpayer, and as such is a universal public service. Citizens, therefore, have a strong vested interest in ensuring the management of waste is as effective as it can be. The best policies for waste minimisation and management can only be developed in the context of a good understanding of the needs and motivations of citizens. Social scientists have much to offer in helping to develop this understanding, particularly about what motivates the choices that affect our consumption of goods and services, and consequently our production and disposal of waste. Some of the key evidence is considered in Chapter 9 of the evidence papers for this report.

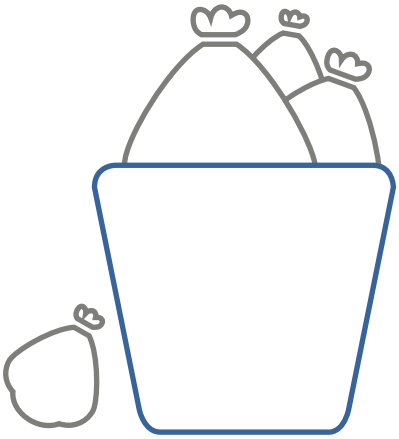
Communities with higher levels of deprivation, and urban populations (in comparison to rural), are associated with lower recycling rates. This suggests that some of the most important factors determining recycling rates are those controlled by national and local governments and mediated through provision of services. When consumers make decisions about how to manage their domestic waste, the most important factor is simplicity in decision and action.

Ultimately, there will be a trade-off between what local authorities should offer and what citizens themselves can do. Many of the factors that lead citizens to produce waste are outside their personal control: for example, we have little influence over the length of life of the products that we purchase. But societal factors such as fashion, the desire to possess the 'latest model', and peer-group pressure also drive demand and consumption. And although many consumers have a strong preference for buying and owning new products, WRAP has found that there is also a strong appetite for repair and rental services, trade-in and purchasing second-hand when delivered by trusted, major retailers.

The Scottish government's ISM (Individual, Societal, Material) model, which categorises the different factors that influence behaviour, could be applied to help to analyse and select policy options to encourage citizens to reduce waste. This involves focusing simultaneously on the 3 key elements that influence our choices. The first of these elements operates at the level of the individual: what are the economic incentives for me, and what information do I have? This is influenced by the medium used to disseminate the information (whether it is part of a campaign, for example). The second element is the social context in which we live: what are the norms and cultural conventions of society, how do our social networks behave, and how do the institutions that we respect behave? The third element is the material: what are the technologies, objects and infrastructure that shape, constrain and influence different behaviours? None of these factors can be considered in isolation. So, even in the face of strong individual and societal incentives to deal with waste in a particular way, if the infrastructure to achieve this is unavailable, then those incentives will fail to change behaviours.

The ownership and value of a resource are both critical and interrelated factors in engaging citizens with improving resource productivity. If I am the owner of a material resource (including waste), it is in my interest to extract value from that resource. I might be able to sell it; or, if the resource currently has little value, I could store it until it accrues more value (hence much of the junk in our dwellings). Or I might transfer

When consumers make decisions about how to **manage their domestic waste**, the most important factor is **simplicity in decision and action**



A key part of managing waste is reducing consumption

Key messages

1. Citizens do not actively choose to create waste; it is a consequence of a range of pressures. Some are in the control of the citizen, but others are external influences, such as product design, the availability of services and the simplicity of the product or service offer.
2. To help citizens respond to these pressures, we need action on multiple levels that accounts for the context of their behaviour, and which makes any changes as simple as possible.
3. When considering recycling, citizens would like to have a clear and consistent approach to service no matter where they live. Provision of better services, communications and promotion help people to adopt behaviours that increase recycling.

ownership of the resource to someone who is better able to benefit from its value, such as a charity shop. Or I can pay someone else to take ownership of the material. I could even gain some value from waste simply by separating it into different bins, if that meant that I avoided paying a cost for the removal of unsorted waste. But if waste is not my problem – perhaps because it is something that my local authority takes complete responsibility for – then I have little incentive to worry about it.

New models of ownership and value extraction are also developing, including platforms for selling or disposing of second-hand articles, sharing ownership of goods and recycling unwanted products. But it is unclear whether these platforms are generating a more circular economy, or whether they are acting to increase overall consumption. The answer is likely to be a mixture of both.

And this illustrates the overall challenge: a key part of managing waste is reducing consumption. There are limits to the extent that changing individuals' behaviours can reduce consumption of resources. Increasing resource efficiency, by using less material to produce the same output, does not necessarily lead to an equivalent reduction in resource use. Efficiency gains can depress the price of products, raising demand and consumption. Alternatively, reducing the cost of one resource gives the consumer more money to spend on other resource-intensive goods and services. This phenomenon is commonly referred to as the rebound effect, or the Jevons paradox.

The conclusion is that good waste policies cannot be designed without placing the consumer at the heart of the analysis. Policies that align the incentives of citizens with the need to reduce resource intake, thus reducing waste production and managing it more effectively, are the most likely to succeed. And the bottom line is that these policies must be easy for citizens to comply with. While this may seem blindingly obvious to experienced policymakers, it is not so easy to achieve in practice.

Business

As in the construction industry, wasteful use of resources is a cost to business that provides its own incentives for avoidance. Businesses compete to minimise their waste of expensive resources, and so one might think that there is little for policymakers to do on this front. But waste avoidance in business is much more complicated than this, as Andy Whyle and Richard Kirkman explain in Chapter 10.

The capital costs of replacing existing business infrastructure may provide an incentive to use outdated and resource-inefficient equipment. Many of the material resources used by business do not include the cost of their externalities, such as carbon emissions. Once businesses have sold their products, ownership passes to their customers; the businesses have no responsibility for the externalities of those products once they reach the end of their usefulness. Furthermore, when it comes to overall resource productivity, it is often in the interest of the business to sell a new product rather than to extend the life of an existing product.

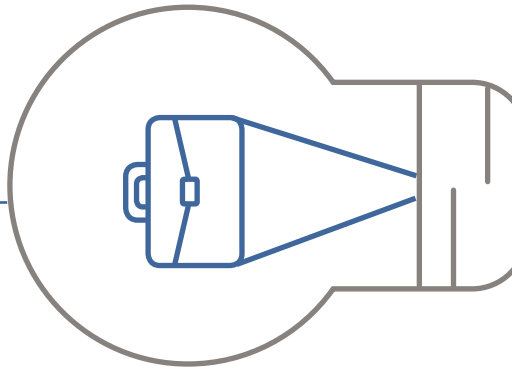
Science and innovation can provide technologies and inspire ideas that underpin the move from waste to resource productivity. It is, however, only when those solutions are adopted by business – and embraced by their customers – that their benefits become a reality. That process has to happen in 3 ways. Businesses need to make use of the new technologies in their production processes; they must transform their business models; and society itself must evolve to embrace these changes.

There are, however, a number of barriers to using technological and behavioural developments that reduce waste. Trust is particularly important when manufacturers are faced with a choice between primary raw materials (and the well-established global supply chains that guarantee their quality and purity), and materials recovered from wastes via new or unproven markets.

A specific example illustrates the challenge, and the opportunity. Many drugs are manufactured by microbial fermentation, and glucose is an important part of the microbes' food. Expensive, food-grade glucose is currently used, but a potentially cheaper source could come from the digestion of food waste. This approach would probably be cost-effective and allow drugs to be produced using fewer resources, but it is unlikely to be taken up by pharmaceutical manufacturers because the hurdle for changing their approach to manufacturing is high and heavily regulated.

What could be done to make it easier for manufacturers of goods to use secondary rather than primary raw materials? Firstly, manufacturers need to know more about the composition of the secondary material. This can be achieved by 'product passport' systems that identify the materials content of complex wastes, such as ships and buildings scheduled for demolition. These passports could be extended to 'point-of-manufacture passports' or 'assembly passports' (and 'repair updates') for manufactured goods.

Just as fundamental to the future of waste is the **innovation** that is taking place in **business models**



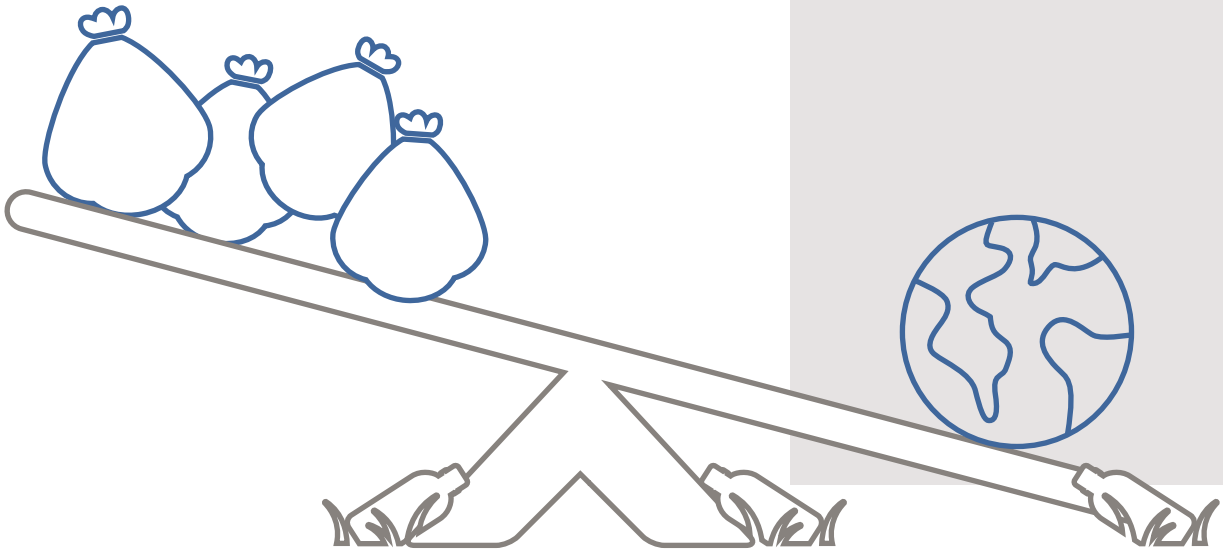
These would give confidence to both the recycling industry and potential purchasers of recovered materials. Secondly, standards can be developed for the materials used in manufacturing that are either independent of the source of the material, or that explicitly recognise materials from secondary sources. Thirdly, for regulated products, regulation needs to consider and enable the use of secondary materials.

New business models that sell services rather than products, or that rely on remanufacturing and recycling products, can be profitable as well as resource productive. But standards bodies and regulators could make it easier for manufacturers to use secondary rather than primary raw materials in their manufacturing processes. A clear, simple policy lever – such as the introduction of an all-encompassing carbon incentive – should be put in place to promote the benefits of more resource-productive business models.

Key messages

1. The UK needs a simple policy lever that costs-in the externalities of waste, analogous to the Landfill Tax mechanism, in order to stimulate businesses to adopt more systematic approaches to valuing resources throughout their lifetime.
2. Businesses can themselves maximise return on material costs by moving to integrated supply chain models incorporating circular economy principles. This would prompt them to review and analyse waste streams; build in lifecycles for materials; and establish agreements with suppliers and consumers to secure reuse of product waste and packaging.
3. Programmes similar to the Energy Saving Opportunities Scheme (ESOS) should be replicated for water and waste. These would require businesses in the UK to measure the use of water, energy, and materials needed to manufacture, use and recover a product. This would show the true costs of products and lead to more resource-productive business models.

Nationally and **globally**, waste is a problem that is increasing in scale and scope



Cities

The Government Office for Science's Foresight project, 'Future of Cities', considered the opportunities and challenges facing UK cities over the next 50 years. In the UK, 80% of the population lives in cities. They are the places where most of the UK's future growth, of both population and economy, is forecast to occur. New technologies and services – including innovative mechanisms for transport, high-density buildings and the use of 'big data' – will be introduced in cities. These provide some of the opportunities and means for cities to become better, cleaner and more prosperous places to live, work and play.

In Chapter 11, Chris Rogers sets out the size and immediacy of the issues. Cities are places of creativity, construction, business, manufacturing and commerce. These processes consume and create waste on a gigantic scale. The total amount of waste produced by the world's cities is projected to rise from 1.3 billion tonnes in 2012 to 2.2 billion tonnes in 2025. The mechanisms to deal with this waste must therefore be made more resilient and capable of dealing with this increase.

Knowledge enables action. So in order to understand the many opportunities for beneficial economic, social and environmental change, we need to accurately define the waste systems in cities. This includes identifying and understanding the interdependencies between waste management and other parts of the city's infrastructure, such as transport, energy, water and communications. Changes in any one of these systems will influence all of the others. The waste system is also one of the few city systems that is influenced by every citizen, directly and indirectly, through individual behaviours and attitudes, so the design of waste systems must respect these behaviours and attitudes.

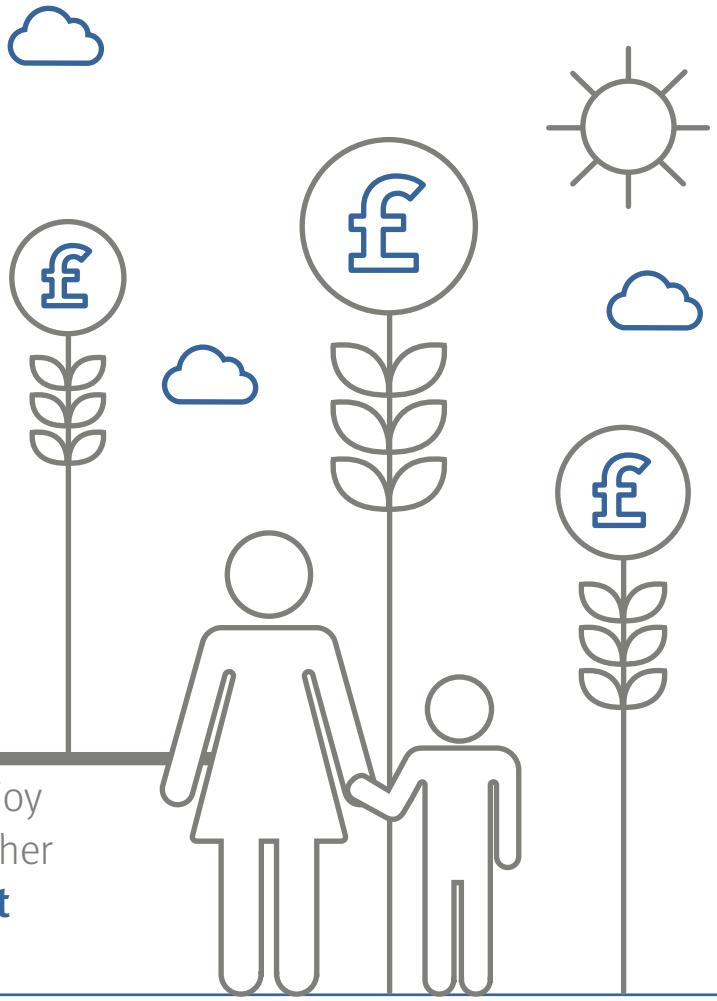
The new technologies of the 'smart city', including sophisticated modelling, mapping and monitoring systems, can manage and optimise the flows of waste. Because all cities are unique, this creates important opportunities for experimentation and innovation at a city level. Comprehensive systems maps, adjusted for the individual city context, are essential for understanding waste generation and flows. Due to their scale and coherence, individual cities can

Key messages

1. All cities are unique. Comprehensive systems maps, adjusted for the particular city context, are essential for understanding waste generation and flows in cities.
2. There are multiple dependencies and interdependencies between waste systems and other city systems. Recognising the consequences of these (inter)dependencies is necessary to meet the visions and goals for a successful waste system, and for the success of other city systems.
3. Cities are where citizens interact most intensively and intimately with waste systems, and where policies become practices. They are places where impacts are generated and, being bounded and governed as an entity, they are places of opportunity for beneficial change.
4. Managing waste in cities requires an understanding of ownership and responsibility for waste, and how this applies to the attitudes and behaviours of citizens.

create innovative spaces, such as test beds where experimental strategies to enhance resource productivity can be deployed. Managing waste in cities also requires an understanding of ownership and responsibility for waste, and how this applies to the attitudes and behaviours of citizens.

For the UK, the city is an extremely important lens through which to view waste. Cities themselves must grasp the opportunity to shift from waste to resource productivity. This will require city-scale partnerships between city authorities, their civic universities and their business and creative industries. Together, they should map their cities and ensure that waste is considered as a key part of the interconnecting infrastructures that underpin the lives of the city's inhabitants. Cities must also learn from each other, and work as a collaborative system of cities at a regional, national and global scale.



Each generation should be able to enjoy the benefits of **economic growth**, higher incomes and the natural **environment they live in**

Local government

One of the biggest blockages to dealing with waste is the economics of waste collection. For some abundant materials, like plastics, it usually takes less energy to manufacture them from primary sources than to remake them from waste. For other materials, like some metals, the case for recovery from waste is more straightforward. In general, those materials that take a lot of energy to produce in the first place are more economical to recover than those that cost less energy.

Arguably, waste collection is the service that councils are most routinely associated with and judged by. It is therefore inextricably linked to the local political situation. This raises questions about the timeframe for decision-making about waste services, the motivations that underpin these decisions, and the extent to which the framework should be set by central government. It is also influenced by structural differences between local authorities (such as those with single as opposed to two-tier structures).

In Chapter 12, Lee Marshall outlines how the emphasis of local waste collection has changed, beginning in the 19th century when it had a public health focus. Even in the early days, however, there was an active market in organics and valuable materials which councils sought to exploit economically, and which attracted the involvement of private contractors. The concept of waste as a commodity is not, therefore, new – there have long been markets for waste. However, there are limits to the effectiveness and maturity of markets for waste today, a result of a number of factors including the volume of inputs, the complexity of the system and the costs of waste collection.

Across the UK, where waste policy is a devolved matter, different nations are moving at different paces towards higher recycling levels. Councils in England are aiming for a 50% recycling level by 2020, but with no statutory duty to meet it; whereas Scotland and Wales have set statutory recycling targets of 70% by 2025. Each nation faces a subtly different set of challenges and circumstances. For example, all councils in Scotland and Wales are unitary, meaning that they control collection and disposal operations, whereas two-tier working is widespread in England. The Government's policy in England is to encourage comprehensive and frequent rubbish and recycling collection by local authorities.

Today, local authorities are driven by the need to maintain service levels and work within tight budgets. This challenging environment has led to councils finding ways of working in partnership, whether by sharing officer resource, full-scale realignment of complete waste services, or collective marketing of recyclable materials.

Materials that take a **lot of energy to produce** in the first place are **more economical to recover** than those that cost less energy

Key messages

1. The separate nations within the UK are increasing their recycling rates at different speeds. We should evaluate the different approaches they have taken, what has motivated them, how realistic the underlying analyses and projections are, and their respective economic costs and benefits in terms of resource productivity.
2. It is essential to explore mechanisms to ensure the costs of waste are borne by those who produce it, rather than local authorities.
3. Innovative partnerships between councils that share resources and waste services, and market recyclable materials as a collective, create economies of scale and lead to waste reduction.

There remain deeper questions about how realistic waste recycling ambitions are, and whether progress towards them requires more radical solutions. As a measure of the scale of the task ahead, achieving a 70% recycling rate would require councils to ensure that almost every household recycled virtually all their packaging at the kerbside, captured their food waste separately, and used mechanisms such as special collections to place bulky items into recycling streams.

If further decreasing waste incurs greater costs, this inevitably raises the question of how costs should be partitioned between the actors in the pathways from materials to waste.

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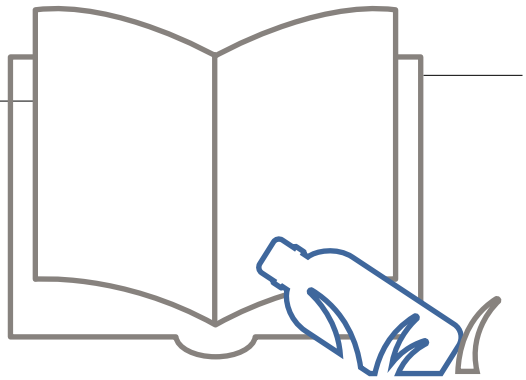
National government



Improving productivity is a major issue for the UK. Higher resource productivity, as with higher labour productivity, contributes to wealth creation. Specifically, it increases the amount of wealth that can be generated from any given amount of resource. As Paul Ekins and Nick Hughes note in Chapter 13, resource efficiency policies that reduce both waste and the dependence on natural resources could boost GDP within G7 countries by an estimated 3% by 2050, compared with business as usual.

The combination of reducing waste and increasing resource efficiency could help to improve productivity, and would also bring other economic and social benefits. Since the 1990s, manufacturing has contributed a declining share of the UK's GDP, while services have increased their share. Growing the resource productivity of the economy could lead to new skilled jobs in the industrial and manufacturing sectors.

As discussed earlier, enhanced resource productivity can also increase resilience to resource price volatility and mitigate the risks of possible future resource scarcity, with some projections indicating that overall material demand will more than double by 2050. Equally, it can bring considerable environmental benefits, including cost-effective reduction of greenhouse gas emissions (for aluminium, recycling can reduce energy demands by as much as 90% compared to metal produced from primary ores). Co-benefits include reducing the use and contamination of water and soil, avoiding the destruction or degradation of productive land or natural habitats, and reducing airborne pollutants.

From the perspective of national government, policies for waste and resource productivity can be considered under 3 broad headings: market-based and pricing mechanisms, regulatory, and strategic. In the first of these categories, the relative costs of different materials (or the cost of using less material) will strongly influence market behaviour. Similar comparisons will apply in the case of waste creation and disposal. Government can influence markets by means of pricing and market-based approaches, and internationally there are a number of precedents for this including the Landfill Tax, the Aggregates Levy, various consumer incentives, and compulsory pricing of plastic bags.

Regulatory approaches, such as waste product standards and warranties, and extended producer responsibility requirements, can also be developed. Regulations influence businesses and consumers by encouraging positive behaviours and discouraging unwelcome habits, but they can also have negative impacts if inappropriately deployed. For example, regulations concerning the design, sale and disposal of products that prohibit certain waste materials from re-entering product supply chains may act as a barrier against disassembly and remanufacturing of products in some circumstances.

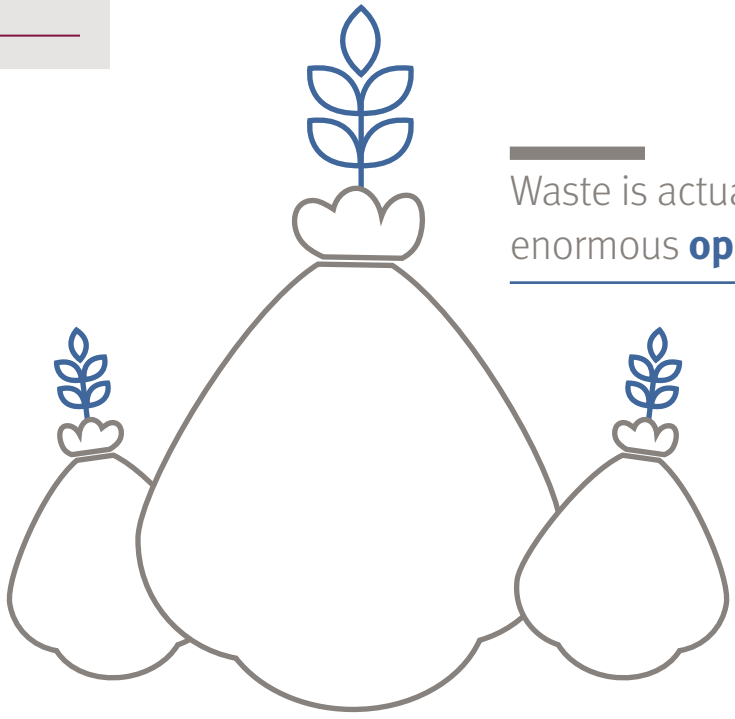
Finally, strategic approaches are also needed. To move beyond merely incremental improvements in resource productivity requires substantial reorganisation of the way that materials move through the economy. Government can provide long-term vision and leadership, influence supply chains through sustainable procurement practices, support skills training and fund research and development.

> What is needed, both for the scientific endeavour and for policymakers, are state-of-the-art evidence reviews that are **openly available to everyone for scrutiny**

Key messages

1. Prioritising resource productivity has many potential benefits, including wealth creation, new skilled jobs in the industrial and manufacturing sectors, reduced greenhouse gas emissions and a better environment.
2. Public policy (through levers such as economic incentives) can change the relative costs of materials, waste disposal and labour, to ensure that increased resource productivity is better aligned with economic efficiency and business profitability.
3. Regulations should be examined to ensure they encourage, and do not obstruct, resource productivity.
4. To increase resource productivity in the UK, the necessary reorganisation of infrastructure and coordination between public and private actors should be at the heart of a forward looking industrial strategy.

Efforts to improve resource productivity have many potential benefits beyond waste reduction. They can boost wealth generation, create new jobs, reduce greenhouse gas emissions and improve our environment. Policymakers can help resource productivity strategies to promote business profitability by fine-tuning the balance of costs of materials, waste disposal and labour, and examining regulations to ensure that they encourage rather than obstruct these efforts. Optimising all of these policies will require close engagement between the public and private sectors. They are also important considerations for the industrial strategy of the UK.



Waste is actually an enormous **opportunity**

What can we learn from other countries?

Waste production is a global issue requiring global governance and leadership, and resource productivity often involves multinational companies and markets for highly tradable goods. In Chapter 14, Jeff Cooper stresses the sheer scale and growth of the global trade in waste: it handles 700 million to 800 million tonnes of material per year – a quantity that has doubled since 2000 – which is worth about $200 billion. The UK itself exports around 15 million tonnes of waste for recycling each year.

Different countries have taken a range of approaches (strategic, behavioural, sectoral and technological) to reduce waste, and the UK can learn from international best practice. The Netherlands, for example, has moved from producing a waste strategy to adopting a 'resource strategy'.

Denmark and Sweden apply strict planning controls to the demolition of buildings, in order to maximise safe resource re-utilisation of the components and materials that are recovered. Other countries are utilising technological solutions. Norway promotes recycling through reverse vending machines for bottles and containers that scan a bar code on the bottle and give the depositor the correct payment. Sophisticated processes deployed in Switzerland optimise the recovering of metals, such as zinc, from incineration. These examples illustrate that the role of government in achieving greater resource productivity is limited to mechanisms such as those that extend producer responsibility, or increase the cost of disposal of goods. It is for business, innovators and the public to respond to the levers that government deploys.

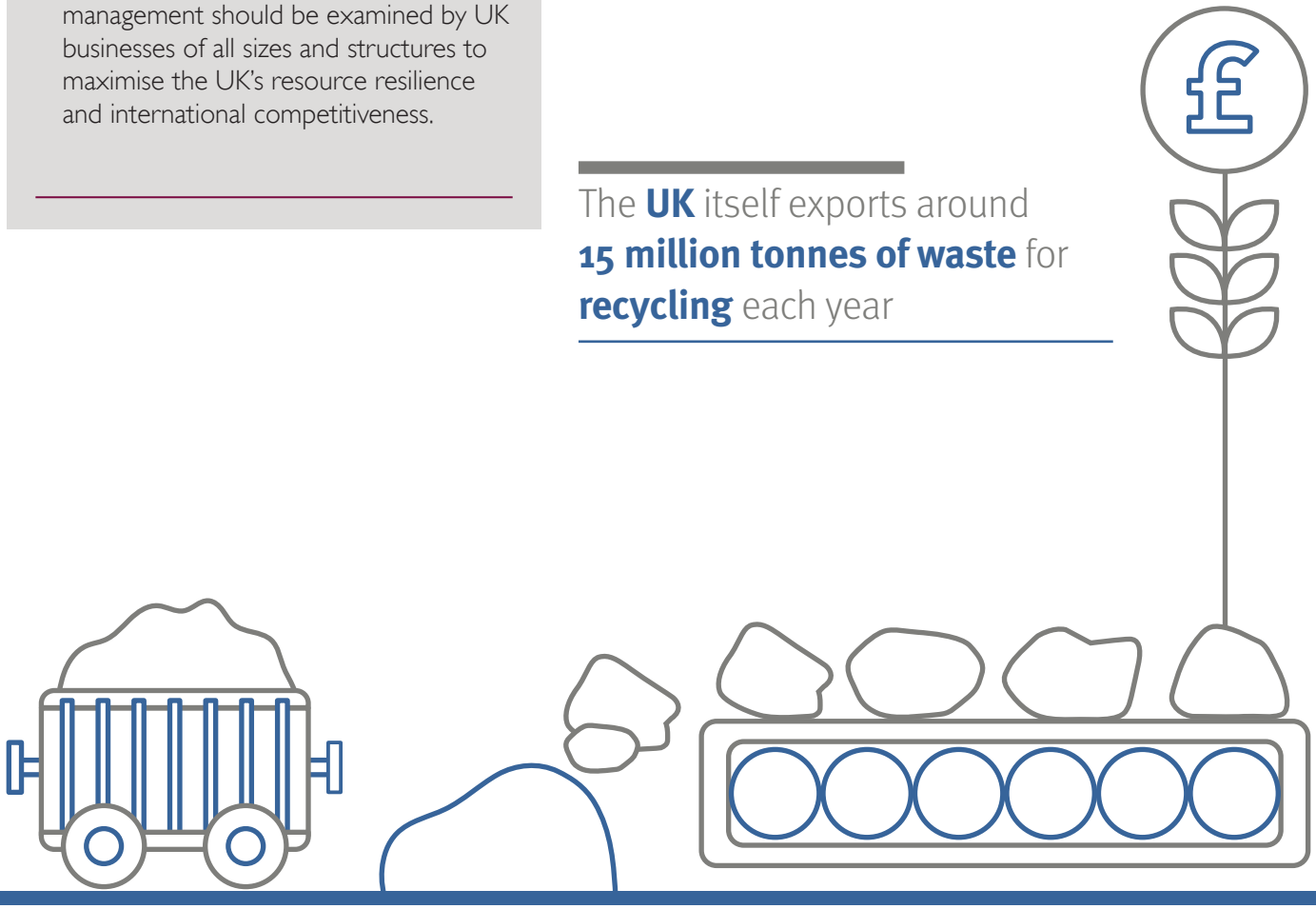
The UK should **compare** its performance to that of other countries and use this to **build ambition**

Key messages

1. Moving from waste to resource productivity is an international issue that requires a global response. As part of that response, the UK should focus on changes in society, the built environment, technology and how these influence resource use and waste management through processing to final treatment options.
2. In moving towards a closed-loop economy, the UK can learn from international best practice on waste, provided it is clear about where improvement is needed and the economic, political and social context from which it seeks to draw.
3. Every aspect of resource use and waste management should be examined by UK businesses of all sizes and structures to maximise the UK's resource resilience and international competitiveness.

The UK should compare its performance to that of other countries and use this to build ambition. But it should also be clear about where improvement is needed, and be aware of the economic, political and social context of those countries. Meanwhile, UK businesses of all sizes and structures should examine every aspect of resource use and waste management to maximise the UK's resource resilience and international competitiveness.

The **UK** itself exports around **15 million tonnes of waste** for **recycling** each year



Conclusions

With more than 7 billion people on the planet, and more than 65 million living in the UK, we are producing ever-greater quantities of waste that are damaging the environment. The planet itself will survive, but that may not be the case for our descendants, nor for the other species with which we share the planet. Indeed, the waste products of humanity are now so abundant and indelible that they have caused a debate within the geophysical community about whether it defines a new geological epoch, the Anthropocene.

Here in the UK, we can and should do much more to reduce our waste and manage it more effectively. That requires all of us to act in new ways. This will be for our economic good, as sparer and more effective use of resources will reduce costs and increase productivity. Furthermore, it is a business opportunity for the UK to create the resource-efficient goods and services that will be needed around the world.

The time is ripe for a comprehensive look at our waste policies as the UK exits the European Union. A key role for government is to provide leadership. But we are all in this together, and unless a majority of us care about waste then not much will happen. Throughout this report, we have provided case studies of policies and practices that, if scaled up, could have important impacts.

Unless we find ways, behaviourally or financially, to internalise the externalities of waste, we will not be able to develop the most effective incentives for the minimisation and management of waste. Ultimately, we can only manage waste effectively if we make it easy and cost effective. The world is going through another industrial revolution, enabled and driven by new technologies that share a common digital denominator. We should take advantage of the flood of data that these technologies generate to manage new resources and our existing assets much more effectively.

But cultural change is at least as important as technological change. There is evidence that younger generations are more environmentally aware and less materialistic than older generations. These values are going to be extremely important if we are to move to a society that conserves its resources more effectively.

Our single most important message to policymakers is that reducing waste and increasing resource efficiency matters. It would be the ultimate tragedy of the commons if individual interests were allowed to trump the collective interests of humans and other species, poisoning what is, in all probability, one of the very few planets in the universe to have allowed the evolution of life as we know it.

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