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The World Wakes Up To ~~Waste~~

EDITORIAL

There are no sustainable materials

When plastics were first invented and developed in the 19th century, they were an answer to a looming environmental crisis. Now, 150 years later, they are the cause of one. So what shall we do? There are many calls to replace them with more sustainable materials, but history will repeat itself if we do and we will stagger from one environmental crisis to another. This is because there is a widespread misconception that sustainable materials exist. They don't – they are a mirage. Only sustainable *systems* exist, and we have very few of those.

The first commercial plastic, celluloid, was invented in response to a shortage of ivory and the recognition that the market for it was driving animals such as elephants to extinction. Celluloid became synthetic ivory before finding an even bigger market replacing glass as the flexible substrate for photography. Because of this flexibility, rolls of film became possible and using them to take a sequence of pictures created a new visual culture, the movies. More plastics followed, changing the way we lived in almost every way, from footwear to furniture, from telephones to packaging. But despite all the excitement and birth of modernity through these plastics, a system was never put in place to collect them after use. Nor was there a plan or the economic model to fund recycling and remanufacture. Without such a system, plastic pollution grew to become the disaster it is today.

There are no simple solutions to tackling the plastic waste crisis. Take food packaging as an example. Analysis shows that banning plastic will be counterproductive because it will increase food waste and so increase carbon dioxide emissions and global warming. Moving to biodegradable plastics just replaces one problem with another: they also require energy to manufacture and need a separate collection system so they can be industrially processed. These collection and processing systems largely don't exist, so most biodegradable plastics end up in landfill, where the conditions mean that they are likely to create methane, which is 28 times more potent as a greenhouse gas than carbon dioxide. If they end up in the sea, the evidence indicates that they will be there for years because the temperature is too low for them to biodegrade. Paper and glass are frequently mentioned as less environmentally damaging alternatives to plastic packaging, but although there are effective recycling systems for both, their impact in terms of energy and water usage is high.

Packaging is a fairly simple example. Now think of your trainers, or your bicycle tyres, or your clothes, all which end up in landfill. These examples illustrate a truth, which is that all materials have an environmental impact and unless there is a sustainable circular economy in place for manufacture, use, collection and remanufacture, that impact will be high and will scale with consumption. In other words, we need to be clear that there is no such thing as a sustainable material, there are only sustainable systems, and we need to start building these *fast*.

Mark Miodownik is Professor of Materials & Society at University College London, where he is Director of the Institute of Making and runs the Plastic Waste Innovation Hub.

Cover design: Phil Holmes and Adam Donnan Phil is a freelance museum consultant and Vice President of the IES. Adam Donnan is the IES CEO.

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The environmental SCIENTIST provides a platform to discuss key issues within the environmental sciences, hosting original articles written by professionals, academics and experts working across the sector.

INTRODUCTION

What's wrong with waste?

Julie Hill examines our changing relationship with waste.

Some 25 years ago, I had a conversation with a Treasury official to try to persuade him of the need for the UK to reduce waste, end its dependence on landfill and improve recycling. He was unenthused. 'What's wrong with waste anyway? Landfill is good business, isn't it?' My instinctive reaction was 'Well – it's just a waste!' but of course that is somewhat circular.

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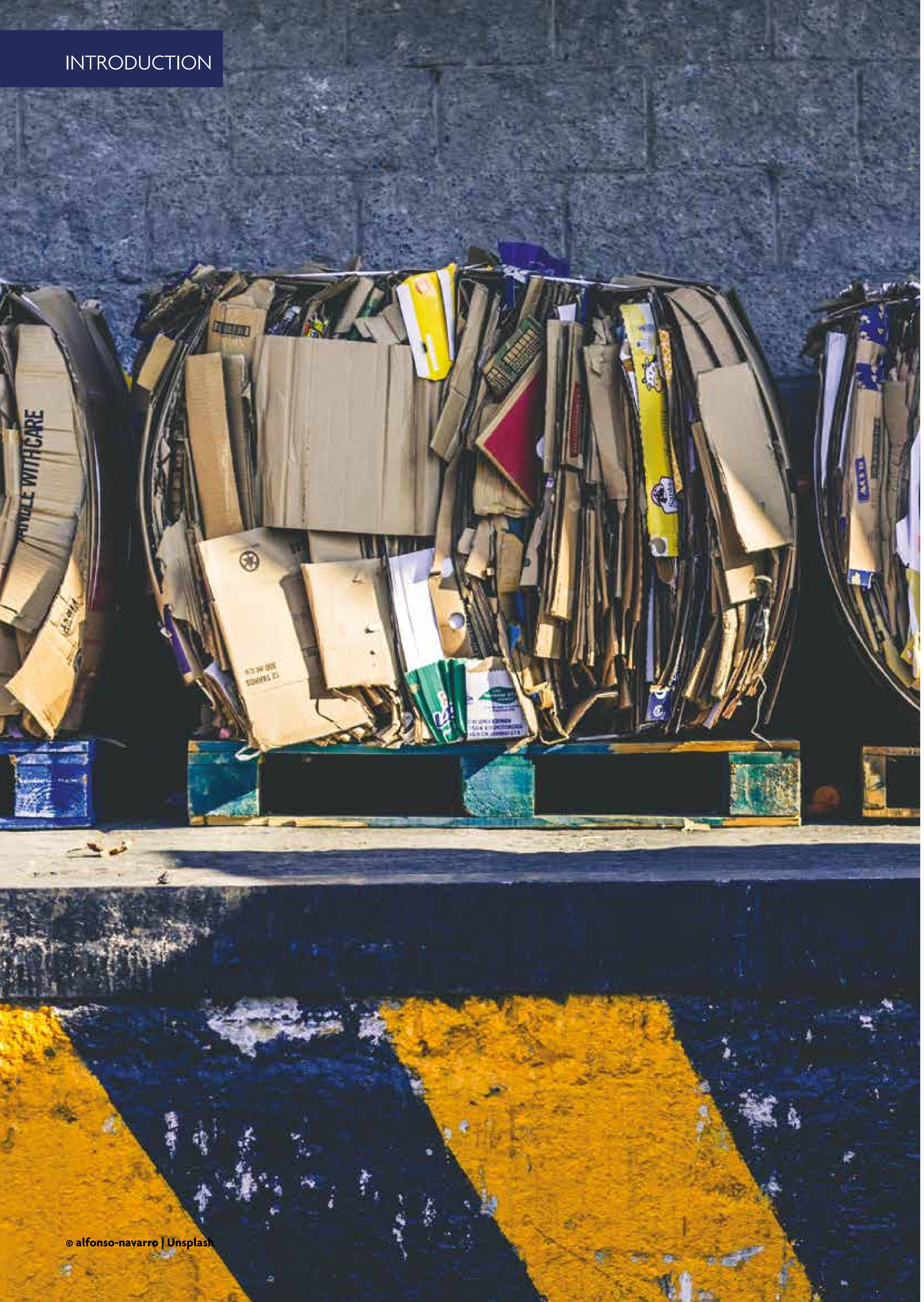

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INTRODUCTION

WHY DOES WASTE MATTER?

In the 1972 report *The Limits to Growth*,[1] the authors argued that if human populations continued to increase and consume at increasing rates, we would start to run out of material resources. Just as importantly, we would run out of the ecological capacity to absorb the pollution and waste that would accompany such growth. One of the reasons that this message took so long to hit home is that many of the projections about running out of materials turned out to be wrong, because any suggestion of scarcity tends to lead to rising prices, which makes it worthwhile to increase efforts to find new sources, thus averting shortages. Meanwhile, however, the second part of the message, about running out of carrying capacity for pollution, was coming terribly true with the reality of climate change. More recently, understanding that the world's oceans and coasts are awash with plastic pollution has underlined that point. We are now increasingly aware of limits of all kinds.

Several articles in this issue demonstrate the power of a visual image to make our predicament real. The article by myself and my colleagues at WRAP tells the story of the concept of the circular economy and the evidence of how more circular behaviour can contribute to cutting greenhouse gas emissions. Jamie Woodward's article on plastic pollution in rivers builds on the *Blue Planet* momentum to keep that issue to the fore. The story and images of the Shrewsbury Cup show us that a different way is possible. David Greenfield's article on urban recycling demonstrates just how complex, but also technically feasible, resource-efficient city living might be. Sophie Thomas makes the case for a design approach that solves problems and makes us happy at the same time, while Mike Webster shows us what we have to learn from the challenges facing lower-income countries.

Some articles sound important warnings. In our zest for recycling, we have to take account of a legacy of chemical use in relation to food containers, as Jonathan Ritson and Libby Peake point out. Blaise Kelly asks us not to dismiss the option of energy from waste since, properly specified, it has a role – at least until everything is designed in the way that Sophie Thomas is arguing for. And Dorothy MacKenzie makes it clear that change is in our hands as consumers as much as in those of governments and business – often one party cannot move far without the cooperation of the others. Mark Miodownik, materials expert and enthusiast, reminds us of an underlying truth – that there are no sustainable materials.

TRANSITION TO THE FUTURE

This issue of the environmental SCIENTIST comes just as the UK completes the first stage of leaving the EU and begins the long process of deciding the countries with which we want to align our future environmental standards. It is worth remembering that in terms of waste and the circular economy, the EU has taken us on a very important journey, and it is arguable whether we would have made that journey on our own. Although a recent book[2] tries to argue that the 'British way' of dealing with waste has always been progressive, with an instinct for thrift and recycling and perfectly sound landfill practices, I know few in the field who would agree with this rosy view of the past. The UK has come a long way, and we must hope that the global direction is onwards and upwards.

I hope that this special edition will enlighten, entertain and, most of all, energise the environmental science community. Despite growing awareness of the consequences of our use of resources and our wasteful habits, there are many problems still to be solved. Our community, with its inter-disciplinary emphasis and its multiple talents, is ideally placed to take on these challenges.

ES

Julie Hill has qualifications in English, philosophy, politics and ecology. She is an environmentalist and author, Vice-Chair of the Institution of Environmental Sciences, and Chair of the Waste and Resources Action Programme (WRAP), a UK-based global environmental charity focused on the sustainable use of resources. She is also the author of *The Secret Life of Stuff: A Manual for a New Material World*, published by Vintage Books.

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Embedding circular design

Sophie Thomas calls for collective bravery, creative audacity and left-field thinking to design a way out of the climate crisis.

FEATURE

Take a look around you. Wherever you are, there will be things that have been designed by people like me: beautiful things, functional things, frivolous and possibly questionable things. Probably too many things. I am one of the 1.7 million people working in the UK design sector, specifically in the business of influence and attraction – so in one way or another, designers like me are responsible for all those things and more. In simple terms, designers create stuff to make people want it, need it, be compelled to buy it. But I want that all to change. This may sound a bit extreme because we are all probably quite happy with our lives as they are. But I have spent over a decade researching the beginning and the end of the life of our stuff and I have seen the growing impact of it all. Things are spiralling out of control. Our love of stuff is intrinsically linked to our current environmental crises around the world.

> **'You can't have everything. Where would you put it?'**
>
> **Steven Wright[1]**

There is a growing consensus that we are now in a time of climate emergency. We have eco-anxiety, wondering what the future will hold for us, for our children, for all animal species, for the planet's ecosystems. It feels bleak and out of our control. The UN's Intergovernmental Panel on Climate Change says it is our last chance to act, that we have 12 years to turn it around, to restore our Earth back to a place where the next generation has a fighting chance of bringing back balance and prosperity.[2] We want to do something. But what? Stop flying? Get renewable energy? 'Yes' to both, and these in themselves will change the way we live. But they are not enough. It's time to address our global consumption habits.

THE LINEAR MODEL

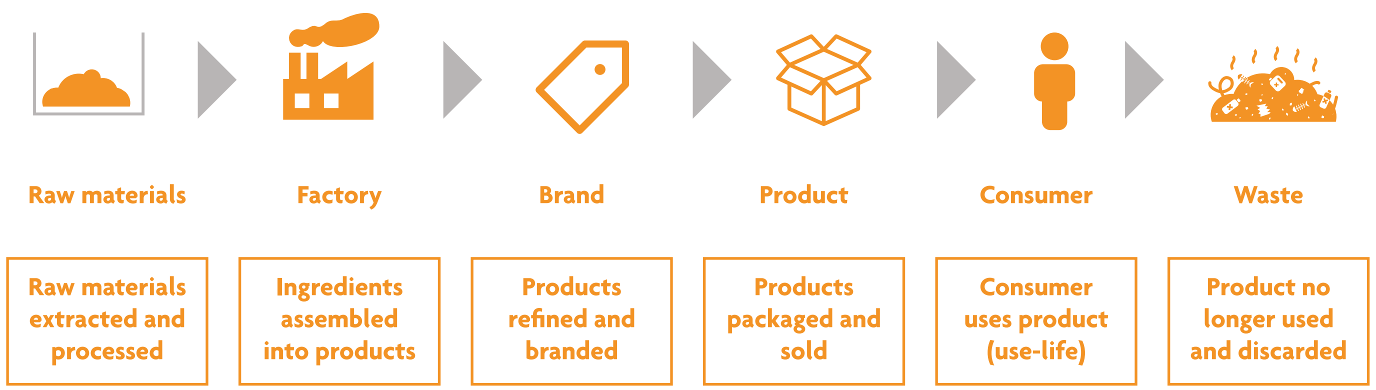
Having such full lives comes with major consequences that are becoming too hard to ignore. Comfortable developed world living standards require huge amounts of resources to maintain and these take a massive amount of energy to extract. In order to continue to consume at the current levels, we will need to increase the raw materials extracted from the Earth. According to the recent Circularity Gap Report 2020 launched by Circle Economy at Davos, the global economy is now consuming 100 billion tonnes of materials a year for the first time ever, but the [re]cycling rate of resources has gone into reverse.[3]

Our existing linear economic model of 'take stuff out of the ground, make and process it into products, consume then chuck them away after a very short period of time' has created big environmental impacts. Whether it's plastic pollution in our oceans, toxic heavy metals leaching into our soils or CO_2 belching into our atmosphere – everything has a consequence.

The Ellen MacArthur Foundation, in collaboration with Material Economics, set out the compelling climate-change reasons to shift from the 'take, make, waste' extractive economy that is so reliant on fossil fuels (see **Figure 1**) to one that is circular, restorative and resilient. To date, efforts have focused on the transition to renewable energy complemented by energy efficiency that will address 55 per cent of the global carbon emissions. The remaining 45 per cent comes from the production of all those things we consume every day, and these cannot be overlooked.[4]

BRING IN THE DESIGNERS

Around 80 per cent of the environmental impact is embedded into a product at its concept design stage,[5] so design is crucial to solving environmental challenges. Ultimately, the decisions we make around material specification



▲ **Figure 1. The linear 'take, make, waste' model of current economic models of production and consumption. (Source: The Great Recovery/Thomas.Matthews)**

BOX 1: TRANSPARENT SUPPLY CHAINS

A new laptop can cost you under £300, but if you track the flow of raw materials from the mines (often starting their life in war-torn Democratic Republic of the Congo) to the factories and distribution centres, the average computer travels the equivalent of three or four times around the world before it ends up in the hands of the customer.

Designers do have to work with the global market system, but understanding material flows and designing to circular economy principles would result in more local and less carbon-intensive production. Traceable supply chains designed around transparency can enhance resource security and support the corporate social responsibility objectives many large manufacturing businesses have adopted.

and manufacturing processes will be instrumental in determining the product's embedded energy and impact in its use and then disposal. Disappointingly, the design sector, like many others, is slow to acknowledge its relevance as impacts are often hidden deep in very opaque supply chains that we don't investigate (see **Box 1**). Why is the design sector engagement so low? Perhaps designers think of themselves as creative experts who have all the answers. Maybe we don't feel that we can ask questions of our suppliers, or it could be that it feels too hard to change our clients' minds. And then our selling models have to change too. Our desirability to upgrade for the next model fuelled by tantalising ads and seductive designs makes us upgrade even when we are probably quite happy with what we have. Marketing would have to refocus on leasing, repair, longevity and modularity.

END OF LIFE

We find it easy to forget about waste as it slips from our fingers into the dustbin and we moan about the effort of sorting out recycling for the kerbside collection. But waste is a design flaw and should be eradicated. We seriously need to start designing ways to redirect it, reuse it, remake it, upcycle it, eliminate it and, more importantly, reduce it. The designer's response to the brief stops at the point where the consumer picks it from the shelf and takes it to the cashier. We rarely consider what happens post use and when we do, our knowledge is out of date and often incorrect or swayed by myths. This will need to change with possible new legislation around extended producer responsibility.

▲ **Figure 2. The four circular design models. (Source: The Great Recovery/Thomas.Matthews)**

BOX 2: THE GREAT RECOVERY

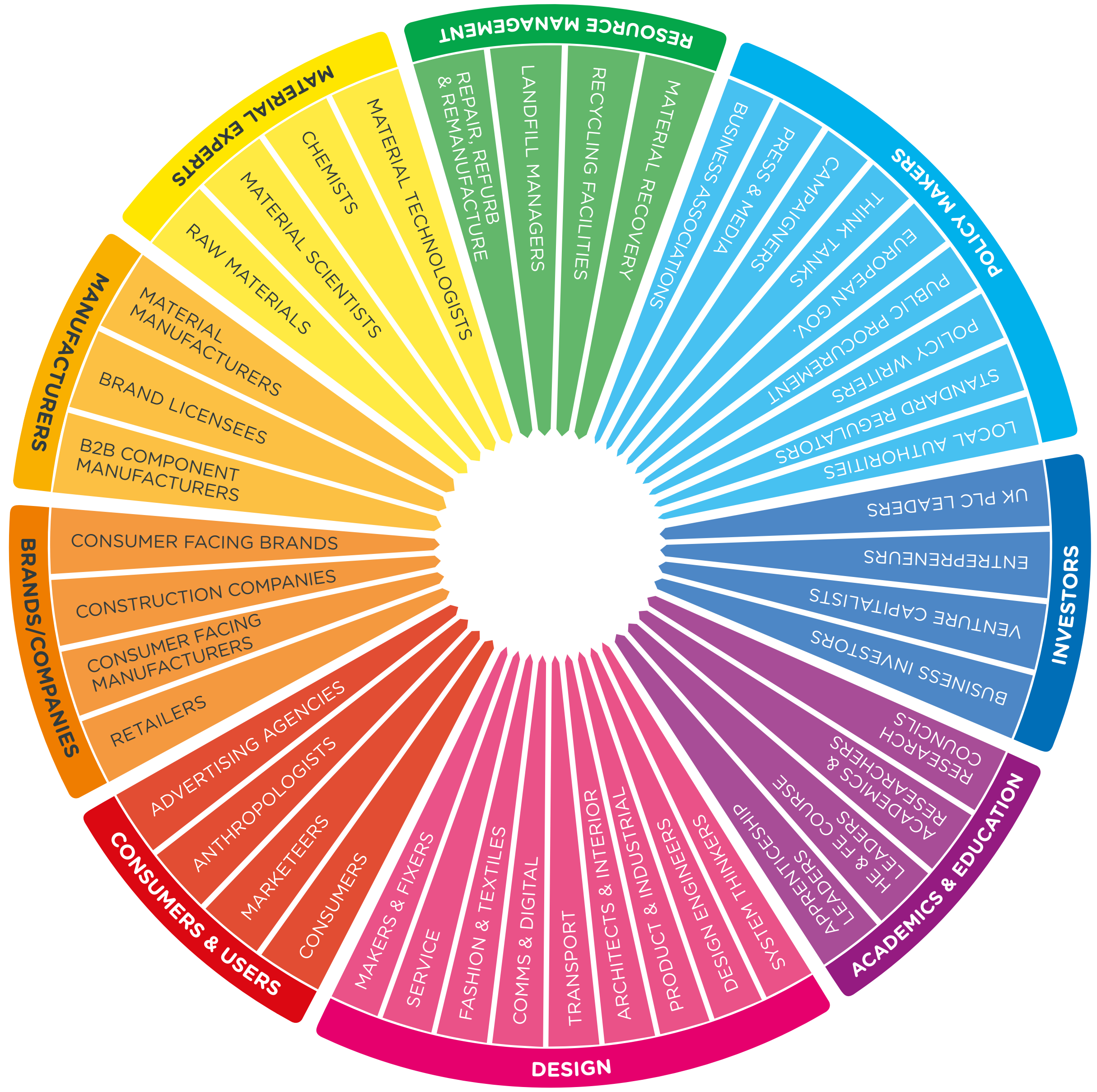
The Great Recovery[7] was a project run by the RSA and supported by Innovate UK (2012–2016). It investigated the role of design in the circular economy, building networks and using the creativity of the design industry to help understand why current design does not include closed-loop principles (where product ingredients can be recovered back into raw materials through reuse, industrial cooperation and recycling).

The programme of public workshops and networking events set in the industrial landscapes of recovery and recycling facilities, disused tin mines and materials research labs worked with people across all sectors mapped to the circular network model (see **Figure 3**). The work supported competition calls from Innovate UK that helped the development of a circular economy through investing in new designs and business models that facilitated more circular approaches.

Of the 600 million tonnes of products and material that enter the UK, WRAP estimate only 115 million tonnes find their way to a material recycling plant. Waste has terrible consequence on our environment. It is not only throwing away resources that, if we could extract them, could become products again, but it is also affecting the climate. Using circularity as a way to reduce our emissions from resource use will start the move towards slowing our runaway climate crisis.

DESIGNING RESOURCES BACK IN

Circular design requires holistic systematic thinking (see **Figure 2**) alongside conversation and collaboration with helpful chemists, waste managers and systems engineers (see **Figure 3**). The challenge starts right at the beginning. Pretty much everything has had a written brief given



▲ **Figure 3. The circular network. (Source: The Great Recovery/Thomas.Matthews)**

BOX 3: EXTENDED PRODUCER RESPONSIBILITY (EPR)

William Nicolle, *from the thinktank Policy Exchange, sounds a warning on EPR and tax approaches to furthering the circular economy.*

The concept of EPR was coined in the 1990s by a Swedish academic called Thomas Lindhqvist. He defined it as any strategy that makes the manufacturer more responsible for the full life cycle of their products, in order to reduce the environmental impacts of production and consumption.[1]

Leveraging the private sector to deal with the waste it generates should be a core principle of any government waste strategy – as Policy Exchange has previously advocated – to effectively price in the environmental damage.[2] This fulfils a core environmental principle of polluter pays, which the British government has sought to embed into its waste and resources strategy. Several schemes, derived from EU law, already exist and operate in the UK, most notably for packaging, end-of-life vehicles, batteries and accumulators, and waste electrical and electronic equipment.

EPR schemes are set to multiply in the UK, as reflected in the Department for Environment, Food & Rural Affairs (Defra) 2018 *Resources and waste strategy* – an ambition-signalling document that outlines government plans to create new EPR schemes for a range of waste categories in the UK. It details the goal of making producers bear the 'full net cost of managing their products at the end of their life', and promises to consult on introducing individual, bespoke EPR schemes for five new waste streams by the end of 2025: textiles; bulky waste; construction and demolition; vehicle tyres; and fishing gear.

However, according to the Organisation for Economic Co-operation and Development (OECD), an understudied area of EPR schemes is their international dimensions, particularly in trade. 3 For example, it can be difficult to monitor where waste goes and how it is disposed of when it travels internationally, as highlighted by the recent issues raised by the trade in plastic waste with East Asian countries, supposedly for recycling.

Another aspect of EPR and trade is to ensure that any new domestic taxes do not set up tariff barriers that could cause the UK to be challenged by the World Trade Organization (WTO). The 2018 budget, intending to stimulate demand for recycled plastic, proposed a tax on any plastic packaging with less than 30 per cent. However, it was only apply to imported plastic packaging, thus threatening to disrupt the level playing field that is such an important feature of WTO rules. The lesson for future EPR schemes is that they must not discriminate between producers, because this can distort trade and increase the risk of trade-related disputes, thus distracting from the intention of the EPR scheme, which is the reduction of waste.

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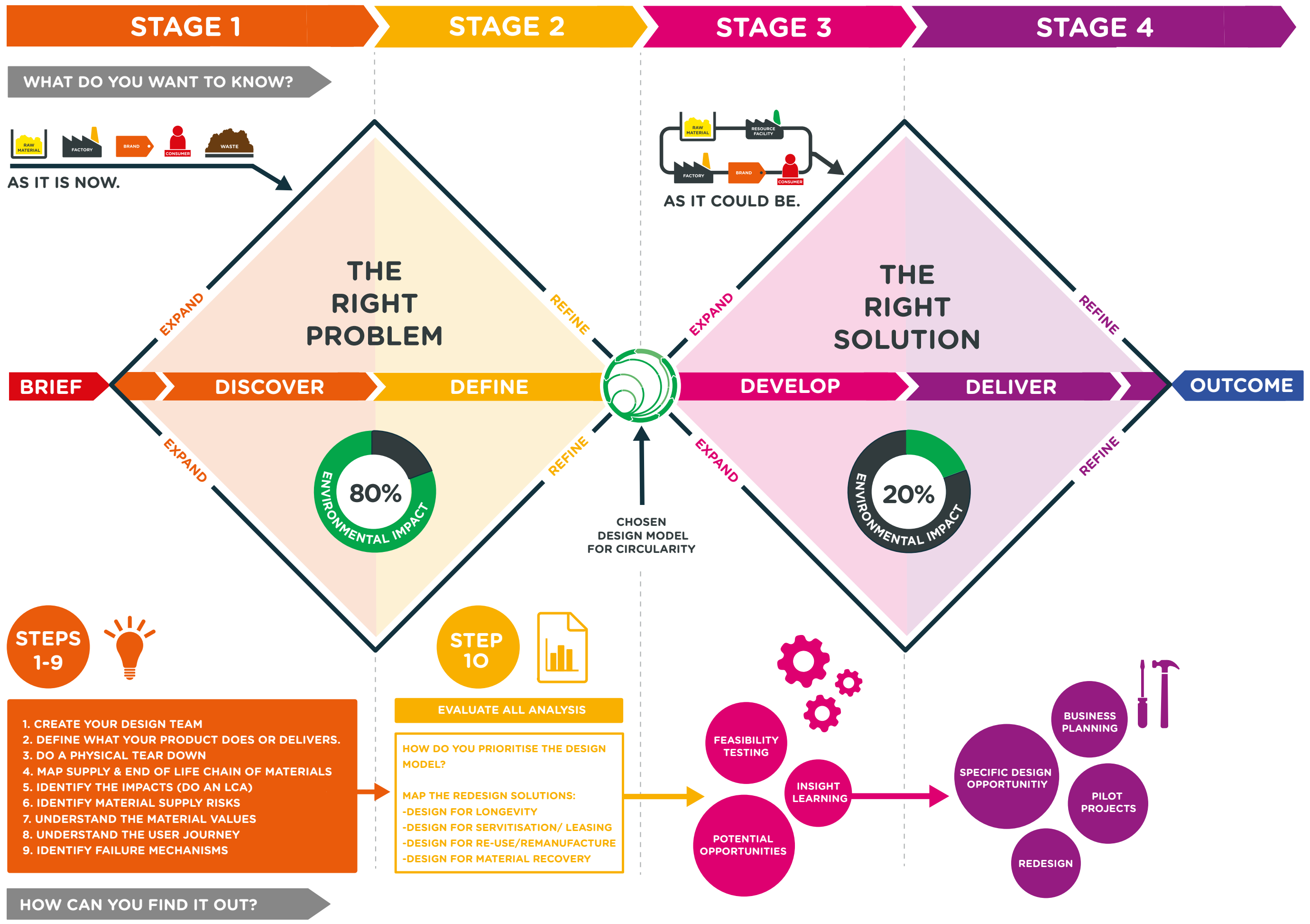
to the design team to tell them what they needed to consider. These design briefs can often include quite specific instructions, for example: 'We want a kettle that is weighted so it can be held comfortably by an elderly arthritic person; is able to boil two cups of water in less than 20 seconds; uses minimum metal in the moulding; and retails at £12.99'. Or, it might say something about the aesthetic outcome: 'We need a 50-page full colour brochure that makes our company look youthful and innovative'. However, you can absolutely guarantee that a brief will not include phrases such as: 'This product is required to be designed for a second, third or fourth life', 'must be able to have all its raw materials fully recoverable to their maximum value', or 'must not in any way be diverted to landfill in the first five years of its life'.

Imagine a brief that did. Consider how different our products would look, how differently we would use them (we wouldn't buy more things) and how much easier it would be to recapture the materials. The way our products are made would change radically. A lot more collaboration and knowledge transfer around the extended supply chain would be required, with those who see the problems at the end of product life (i.e. waste management or material recovery experts) telling those who potentially build in those problems at the beginning (i.e. designers) what they see on a day-to-day basis at the waste facilities. Another approach is to use the concept of Extended Producer Responsibility (see **Box 3**) Designers would not be so focused on the initial sell, but would extend their vision far into a product's potential second or third life and towards a circular system of maximising the resource value and keeping it flowing. Think clothes libraries and light (lux) leasing. To get to this point, the whole process of design, manufacture, recovery and ultimately remanufacture would need a complete rethink. This is successful design for a circular economy (see **Figure 4**).

From where I stand, as a citizen and designer, it doesn't look impossible, just challenging and complex. But I do see multiple solutions (there is no silver bullet), positivity and achievable actions. Change can and needs to happen, and design has a definite role to play in creating the solutions. As Victor Papanek said, 'only a small part of the designer's role lies in the area of aesthetics'.[6] ES

Sophie Thomas is a campaigner, practising designer and Chartered Waste Manager. She has been working in the fields of sustainable design, behaviour change and material process for over 20 years through her design agency, Thomas.Matthews Communication Design, and through a number of campaigning posts including Director of Design and Circular Economy at the RSA and trustee for WRAP.

FEATURE



▲ **Figure 4. The double diamond tool 2.0 for circular design. (Source: The Great Recovery/Thomas.Matthews)**

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The need to mitigate risks in moving to circular food contact materials

Jonathan Ritson and **Libby Peake** report on the contaminants in food packaging and what needs to be done to reduce them.

ANALYSIS

Food contact materials (FCMs) play a vital role in ensuring the safe delivery and preservation of food products. When designed and used correctly, they protect foods and extend their shelf life, which can result in less food waste and reduce the risk of illness through spoilage. However, there have been growing scientific, regulatory and consumer concerns about the fact that potentially endocrine-disrupting chemicals migrate from FCMs into food. This has changed some manufacturer behaviour, with many products now being advertised as phthalate- or bisphenol-free, but there has been no coordinated response and public exposure routes remain.

If these routes are not closed off and recycled content becomes more common, there is an increasing risk that compounds that should not be in contact with food are present in FCMs made from recycled material. These concerns also hold true for material that is destined for composting rather than recycling. The rise in compostable material used to replace single-use plastic opens new avenues for the potential for chemicals to re-enter the food chain and be released into the wider environment when compost is spread on soils. As the economy becomes more circular, the use of potentially harmful chemicals must be addressed.

Table 1: Classes of compounds present in common FCMs and suggested actions to limit their risk

Material	Contaminant	Likely origin	Comments	Recommendations
Plastics	• Additives such as antioxidants, UV absorbers, plasticisers and their degradation products	• Intentionally added, though products of degradation will also likely be present	• Hard to quantify risk due to lack of available information, but many known additives are endocrine disrupters	• Require producers to disclose the identity and concentrations of additives • Focus on removing compounds harmful to health so they do not enter recycling loops
	• Production process contaminants such as monomers, oligomers and catalysts	• Incomplete purification processes during production	• The catalyst antimony has been found in recycled and virgin PET, and other heavy metals have been detected	• Further research on migration and health risks • Better cleaning processes during recycling
	• Contaminants from non-food-grade materials, such as flame retardants	• Mixing of food-grade material with non-food-grade plastics, coupled with poor sorting	• Very high risk, as these compounds have been specifically banned from food-grade applications	• Ban use in products that may end in recycling • Clear labelling • More rigorous separation at the collection and sorting stages, potentially enabled through tracers
	• Food compounds	• Carryover of adsorbed food compounds during the recycling process	• Can interfere with recycling processes	• Improved cleaning processes • Limit the use of some plastics for applications that are likely to be contaminated by food
Paper and cardboard	• Mineral oils	• Inks, particularly from newspapers	• Potential carcinogens and liver toxicity	• Switch to vegetable inks • Enhance deinking processes in recycling
	• Bisphenols	• Thermal paper, inks and adhesives	• Endocrine disrupter	• Seek benign substitutions
	• Phthalates	• Inks and adhesives	• Endocrine disrupter	• Seek benign substitutions

ANALYSIS

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In **Table 1**, we summarise the potentially harmful compounds in common FCMs, based on previous published research,[3] and suggest potential steps to either remove these compounds or mitigate their risks.

UNCLEAR RISKS FROM PLASTIC MATERIALS

Alongside the main polymer, plastics contain a range of compounds that are included to add key extra properties to the material. As well as this, chemicals may be added unintentionally as impurities from their production or with contaminated recycled material. In many cases, toxicity information is not available for all the additives, meaning the impact on human health is currently unknown. Work by CHEM Trust has shown that the public is exposed to thousands of plastic additives, some of which may be dangerous, whereas others may be perfectly safe. However, it is not currently possible to be sure of their identity or concentration as the formulations of plastics are considered trade secrets.[1]

Risk-based standards for FCMs cannot be implemented without access to the chemical identity and concentration of different additives in plastic. Without this information it is impossible to assess the risk to human health in the use and reprocessing stages of the plastic. It is already clear, though, that many endocrine-disrupting compounds are turning up in FCMs, albeit at low concentrations.[2]

The current state of affairs risks a crisis in consumer confidence as the public becomes increasingly aware of the potential for exposure to chemicals of concern. Without detailed knowledge of what chemical additives are in FCMs, by accident or design, there is a risk of creating a culture of suspicion around materials that may in fact be perfectly safe.

Low concentrations of brominated flame retardants, including compounds that have been banned, have been found in around 50 per cent of household waste plastics, suggesting that circular material flows can be contaminated for extended periods if plastics for different uses cannot be accurately separated.[4] Removing additives that are potentially toxic should be a priority as the circular economy grows, to decrease the risk of keeping these compounds within the loop.

COATINGS AND DYES

Plastics have received a lot of public, media and policy attention. However, many other FCMs do not have any regulations to protect consumer health from chemicals in the material beyond a general requirement that they do not endanger health. These can include coatings and dyes on paper, cardboard and metals that make them water resistant or prevent chemical interactions. Bisphenol-A, for example, is still sometimes used in coatings in metal cans.

RECYCLED CARDBOARD

Over 250 compounds of potential health concern have been identified in recycled cardboard used in food contact material,[5] many of which have no related toxicological data, meaning understanding risks is impossible. Phthalates and bisphenols (used in adhesives, inks and thermal paper) have been detected in recycled cardboard used for food packaging[3] with demonstrated migration into food.[6]

MINERAL-OIL INKS

Mineral oils, frequently used in paper and cardboard packaging, can also migrate into food. This class of compounds can have varying effects, but some are known to concentrate in the liver and affect its function, while others are carcinogenic.[4] Although commonly adopted technical processes in the recycling of paper and board, such as deinking, can reduce contamination, these cannot protect consumers against all chemicals. So a precautionary approach should be adopted towards FCMs, with substitutions, such as vegetable-based inks instead of mineral-oil inks, adopted where possible.

ANALYSIS


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COMPOSTABLE CONTAINERS

Compostable materials are increasingly being adopted for FCMs as consumers and businesses seek alternatives to plastic. These materials, whether compostable plastic or paper-based options, are potentially useful in instances where food contamination is likely. Currently, though, they may also present a public health concern if they contain persistent organic pollutants (POPs) that can enter the food chain, contaminate soils or reach drinking water supplies when the compost is returned to the environment.

Recent evidence has shown that the presence of compostable food containers in waste treated at industrial composting facilities increases the levels of per- and poly-fluoroalkyl substances (PFAS) in the resulting compost.[7] This group of toxic chemicals is used to improve water resistance in paper and cardboard materials, but is linked to health problems such as high cholesterol, lowered fertility and testicular cancer. Its presence in compost is especially worrying as PFAS can migrate into food grown in contaminated soil and compost, resulting in accumulation in humans.[8] In the wider environment, PFAS has been found in Alaskan fish despite the great distances from major sources, indicating worrying dispersion and accumulation properties.[9] This issue is just one example that highlights the need to consider the identity, concentration and ultimate fate of all chemicals included in materials likely to enter material or organic matter recycling loops.

THE NEED FOR COHERENT REGULATION

The trade-offs between various environmental impacts of different FCMs represents a large flaw in current regulation, which has been led by the EU. On the one hand plastics are regulated but the regulations are outdated, and on the other, many alternatives to plastics – including paper, card and linings – are not covered by harmonised regulations to protect public health beyond a general requirement that they do not endanger health.

As consumers and manufacturers seek alternatives to plastics, the circular economy will grow. To make it successful – and also to understand and minimise potential risks to public health – FCM regulations must be urgently reviewed and strengthened. That process will need access to the identity and concentration of known additives in plastics and other materials, along with a focus on designing both materials and systems for circularity, so that harmful chemicals do no enter FCM recycling loops. ES

Jonathan Ritson is a policy analyst at Green Alliance. Prior to this he completed a PhD and post-doctoral research in environmental engineering at Imperial College London and the Grantham Institute – Climate Change and Environment.

Libby Peake is head of resource policy on resource stewardship at Green Alliance and manages the Circular Economy Task Force, a forum for policy, innovation and business thinking on efficient resource use in the UK. The task force is currently considering how to create a systemic solution to the plastic problem.

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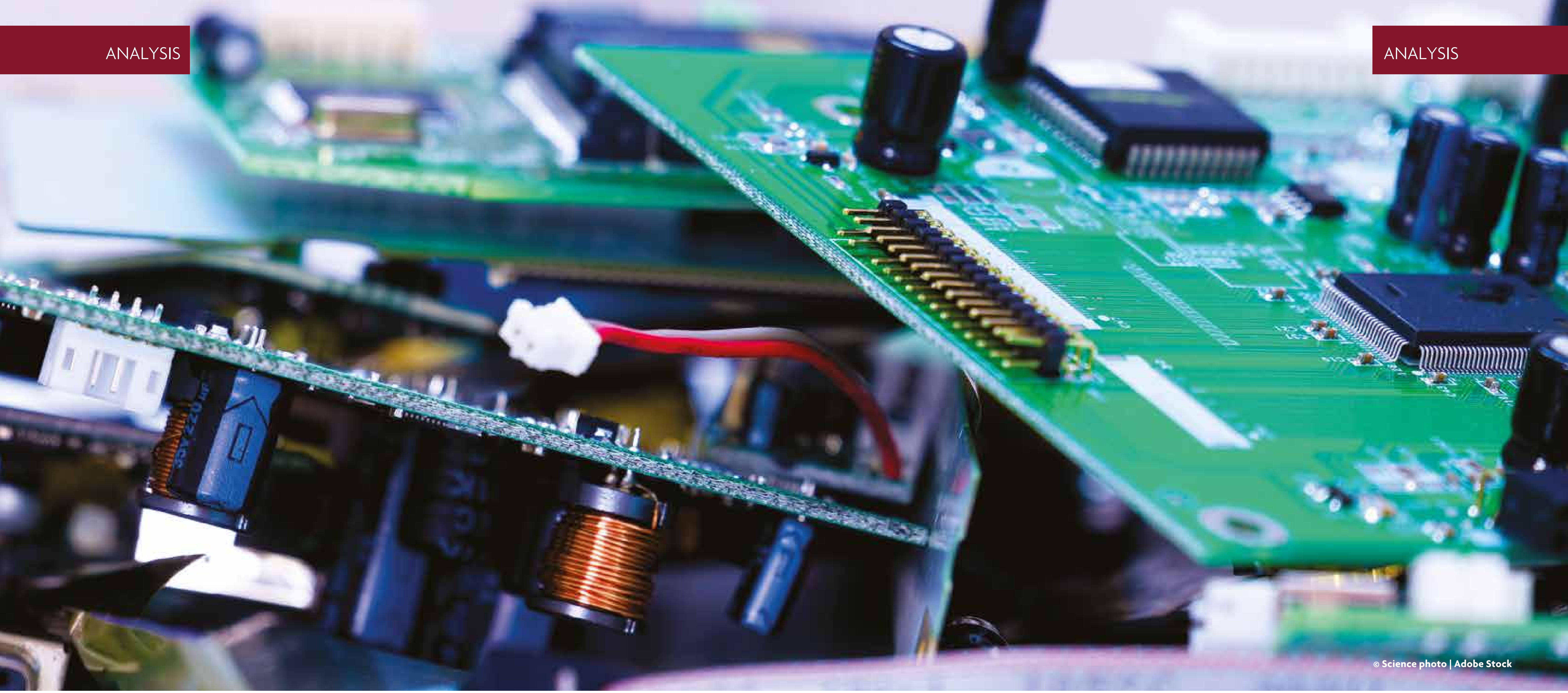

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How can a circular economy help us meet net zero?

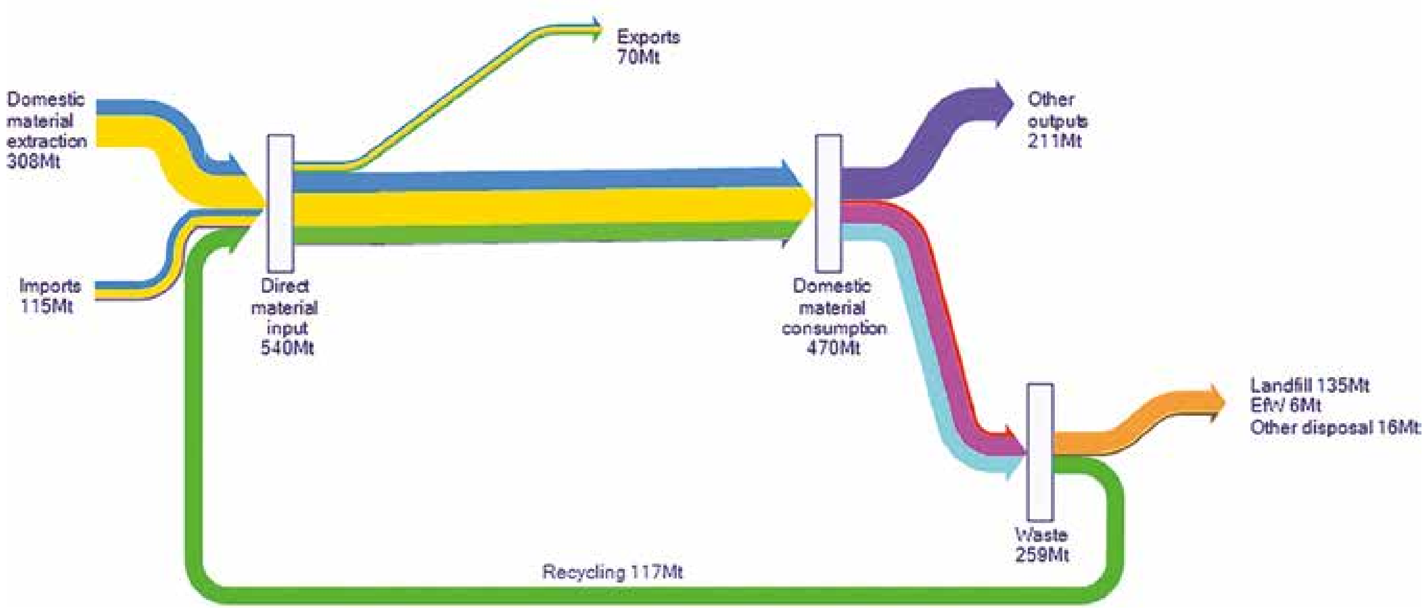
Julie Hill, Patrick Mahon and **Peter Maddox** chart the steps towards circularity that will reduce carbon emissions.

Since the 1990s, the world has become increasingly aware of the effects of greenhouse gases, including those resulting from producing food, fashion and other products, as well as those from our energy and transport. It seems obvious that our wasteful throughput of stuff – extract, make, use, discard – is a big contributor to climate change, but it has not always been clear how to calibrate this. Just how bad is our stuff, and the way we waste it? Where does it matter most, and which waste-prevention behaviours have the most potential to help us meet net zero?

TOWARDS A NEW UNDERSTANDING OF WASTE

To understand the knowledge journey we have been taking, we need to go back to more than 20 years ago, when the UK was still sending around 80 per cent of its waste to landfill. In response to targets in the 1999 EU Landfill Directive, the UK agreed to change, and policies such as the Landfill Tax and mandatory recycling targets for local authorities were introduced. In 2000, the Waste and Resources Action Programme (WRAP) was created by the government as an independent body to complement these policy initiatives and help increase recycling in the UK, which at that point was only 10 per cent for household waste and around 35 per cent for commercial and industrial waste.

Early WRAP programmes prioritised tackling packaging waste prevention and recycling, food, and construction. Campaigns such as 'Recycle Now' and 'Love Food Hate Waste' were launched, and big food retailers signed up to voluntary agreements to reduce their own food and packaging waste first, and then across their supply chains. Similarly, those in the construction sector pledged to halve their waste going to landfill.[1] All the while, WRAP was building the evidence base to show the extent and impacts of different types of waste.



▲ **Figure 1. A sankey diagram of material flows in the UK economy in 2010 - not very circular. (© WRAP)[4]**

In 2002 the No 10 Strategy Unit, under then Prime Minister Tony Blair, published *Waste Not, Want Not.* The Prime Minister's foreword to this strategy document (one of the few times a prime minister has made detailed statements about waste) emphasised the need to move away from landfill. This was because household waste was increasing faster than growth in gross domestic product (GDP), we were projected to run out of landfill space, and also because of the methane, a potent greenhouse gas, generated from biodegradable waste. The foreword also stated: 'the most important reason for changing direction is that the current position is, literally, wasteful. Half of the waste we generate could be reused and recycled, and transformed from a problem into an asset'.[2]

A BROADER WASTE STRATEGY

By the time of the publication of the Waste Strategy for England 2007[3] (waste being by then a devolved matter), this recognition of the value of the materials in waste, as well as the downsides of disposal, had expanded to embrace the ideal of sustainable consumption. In the foreword to the 2007 strategy, Waste Minister Ben Bradshaw stated:

It has become quite clear that we have to raise our sights on waste policy by making faster progress in landfill diversion and recycling so as to reach the levels achieved by many of our European neighbours, and by putting more emphasis on the linkages between waste and other policies and in engaging a wider range of players. That means taking account of waste in our broader carbon and resource policies, in our approach to sustainable consumption and production and to government procurement policies.[3]

That broader concept was crystallised in visual terms in 2009 through WRAP developing the world's first diagram of the circular economy.[4] Or rather, hardly circular. By representing the flows of materials into and out of the UK economy, with lines proportional to the flow volumes, it was clear that very little was kept in productive use (the green line in **Figure 1**). That picture of the whole economy helped to illustrate and popularise a growing narrative about the risks of consumption along with ideals of stemming that consumption by keeping resources in play. These ideas were articulated by, among others, Walter Stahel (who coined the term 'circular economy'), Michael Braungart and William McDonough (authors of *Cradle to Cradle*)[5] and Ellen MacArthur (around-the-world yachter and fierce champion of the concept of circularity).

ACTION ON CONSUMPTION, NOT PRODUCTION

At roughly the same time, and as the climate debate gathered pace, WRAP set about understanding in detail how preventing waste, reusing materials and recycling them could help meet the climate targets recently passed into law by the UK government. The resulting 2009 report, *Meeting the UK Climate Challenge: The Contribution of Resource Efficiency*,[6] was groundbreaking. The report investigated strategies for making the supply of, and demand for, materials and products in the UK more efficient. It was the first time that supply-chain emissions associated with all materials and products used by the UK economy had been accounted for in such a detailed and consistent framework. Its key messages reverberate today:

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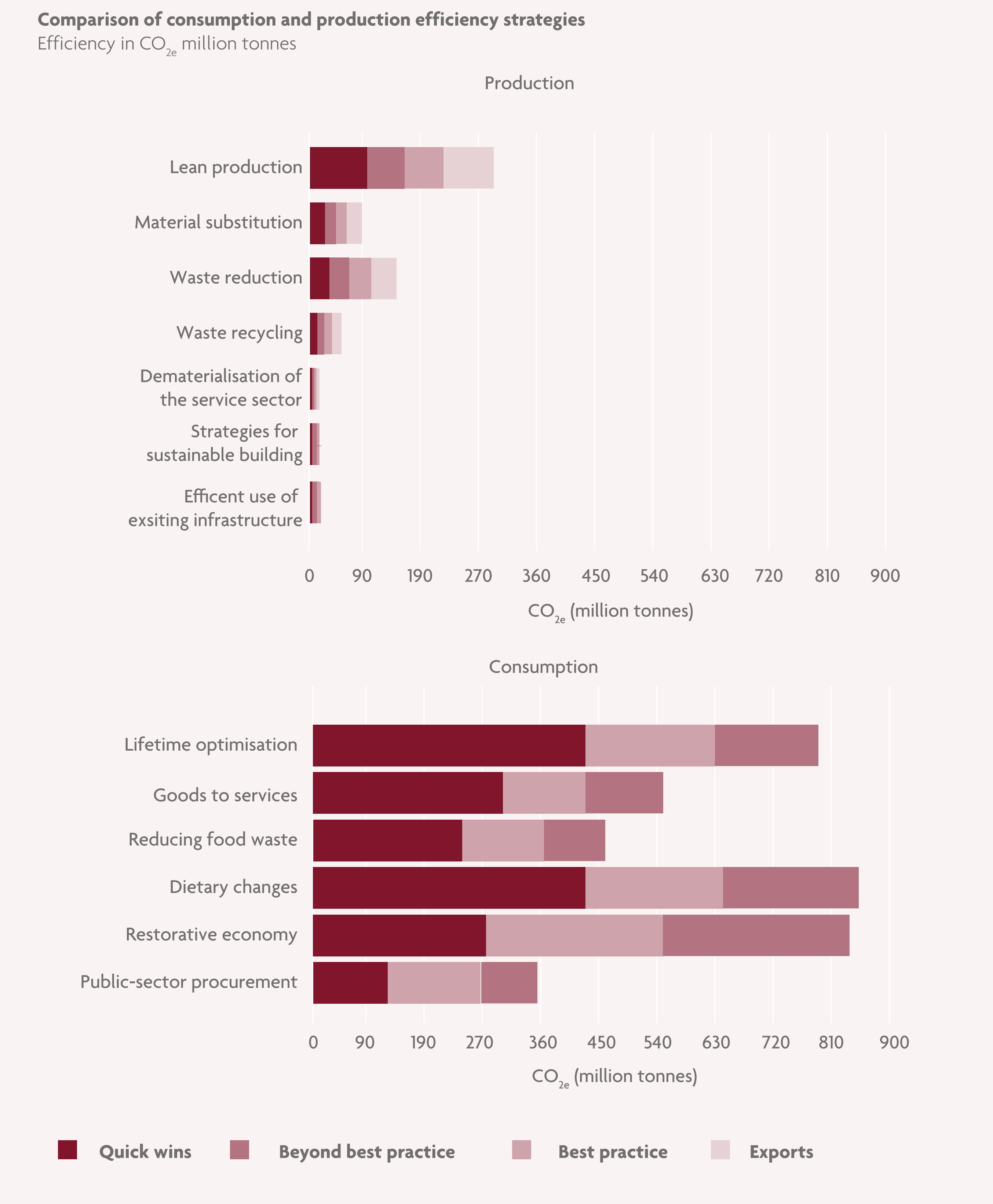


▲ **Figure 2. Consumption efficiency strategies can achieve more than production efficiency strategies. (© WRAP)**

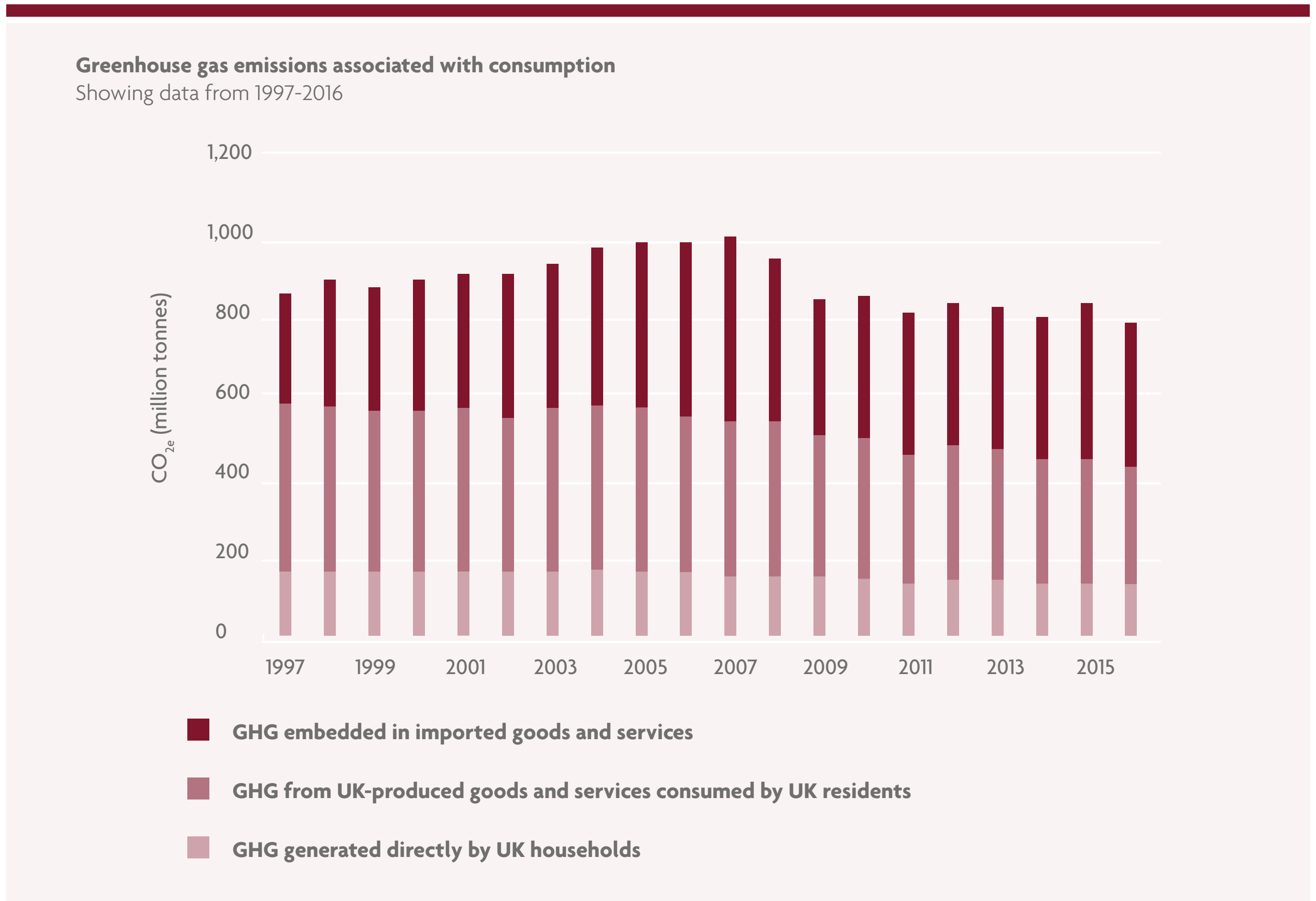
- The importance of service sectors was growing;
- Growth in the transport sector was one of the main drivers behind rising CO_2 emissions (which included the transport of our stuff as well as our own personal transport);
- Resource efficiency and sufficiency measures were not delivering the reductions required to reduce absolute emissions;
- The UK was increasingly relying on carbon-intensive manufacturing overseas to meet growing consumer demand; and
- Accounting for the impact of imports revealed that the UK's contribution to climate change was *increasing*.

The report investigated the greenhouse gas emission reductions that could be delivered by 13 activities – seven on the supply (production) side and six on the demand (consumption) side. The important conclusion was that the greatest cuts could be achieved by focusing on the consumption-related activities, with only one production-related activity (lean production) being comparable in scale (see **Figure 2**). Of the six consumption-focused actions, the three best performers were introducing dietary changes (e.g. reducing meat intake, as meat production is highly carbon intensive), moving to a restorative (circular) economy, and lifetime optimisation (i.e. continuing to use products until they break, rather than replacing them when the next model is released).

This data helped to set priorities for WRAP. It confirmed that reducing and recycling food waste should be a key priority because of the methane generated by food waste in landfill, which was its main destination at the time. Also, that influencing product design for durability and longevity is key. Our work on construction, which has high embedded emissions because of energy-intensive concrete and steel, had made a significant contribution by getting more circularity into building practice through reuse and recycling. The report also helped to validate the concept of the circular economy, and very likely influenced a growing public awareness that reuse and recycling are important personal contributions to reducing carbon footprint. But despite these clear messages, government climate policy has tended to concentrate largely on renewable energy, energy efficiency and electric vehicles, rather than a broader agenda for resource efficiency.

HOW TO ACCOUNT FOR CONSUMPTION EMISSIONS

In the UK, the government's independent Committee on Climate Change has highlighted the differences in progress in territorial emissions (mainly from energy produced and used here) compared to consumption emissions (the overall carbon footprint of all goods and services used in the UK). Territorial emissions have fallen thanks to a shift from coal to gas and renewables, and consumption emissions for UK on their own have fallen thanks to efficiencies. However, the UK's overall



▲ **Figure 3. Falls in emissions from UK-produced goods have not been matched by falls in GHG embedded in imported goods and services. (© Defra)**

footprint has fallen only slightly since 1997 because of the amount of stuff we import and the fact that we import it from countries that are less resource and energy efficient. The biggest contributor to this imported effect is the food supply chain.[7]

Defra's footprint figures (see **Figure 3**) show this consumption trend clearly, although the good news is that the footprint of imports appears to have peaked in around 2007.[8]

Consumption emissions are still, however, treated as 'experimental' measures by the UK government because of uncertainties in their calculation methods. It is in many ways disappointing that the best way to include consumption emissions in global climate targets is still being argued about. This is despite knowing in detail for a decade how far global reductions in waste and material consumption, plus moving to a more circular economy, could help meet climate goals.

The 2019 Conference of the Parties (COP) to the UN Framework Convention on Climate Change (UNFCCC) on reducing greenhouse gas emissions ended without significant new pledges from signatory nations to reduce their emissions. As we approach COP 26, taking place in Glasgow in November 2020, not only do we need greater political will to rapidly bring down emissions, we need a joint understanding of which areas of global economic activity hold the most potential to effect change, and the strategies we can use to do so. Alongside reducing meat consumption, it is now indisputable that tackling food waste has huge potential – if food waste was a country, it would be the third-largest emitter on the planet after the USA and China. Construction also has huge embedded emissions, specifically concrete and steel, making circular use imperative. Other consumption areas such as fast fashion are coming up the agenda as the rate of consumption of clothes increases but the number of times we wear each piece of clothing goes ever downwards.

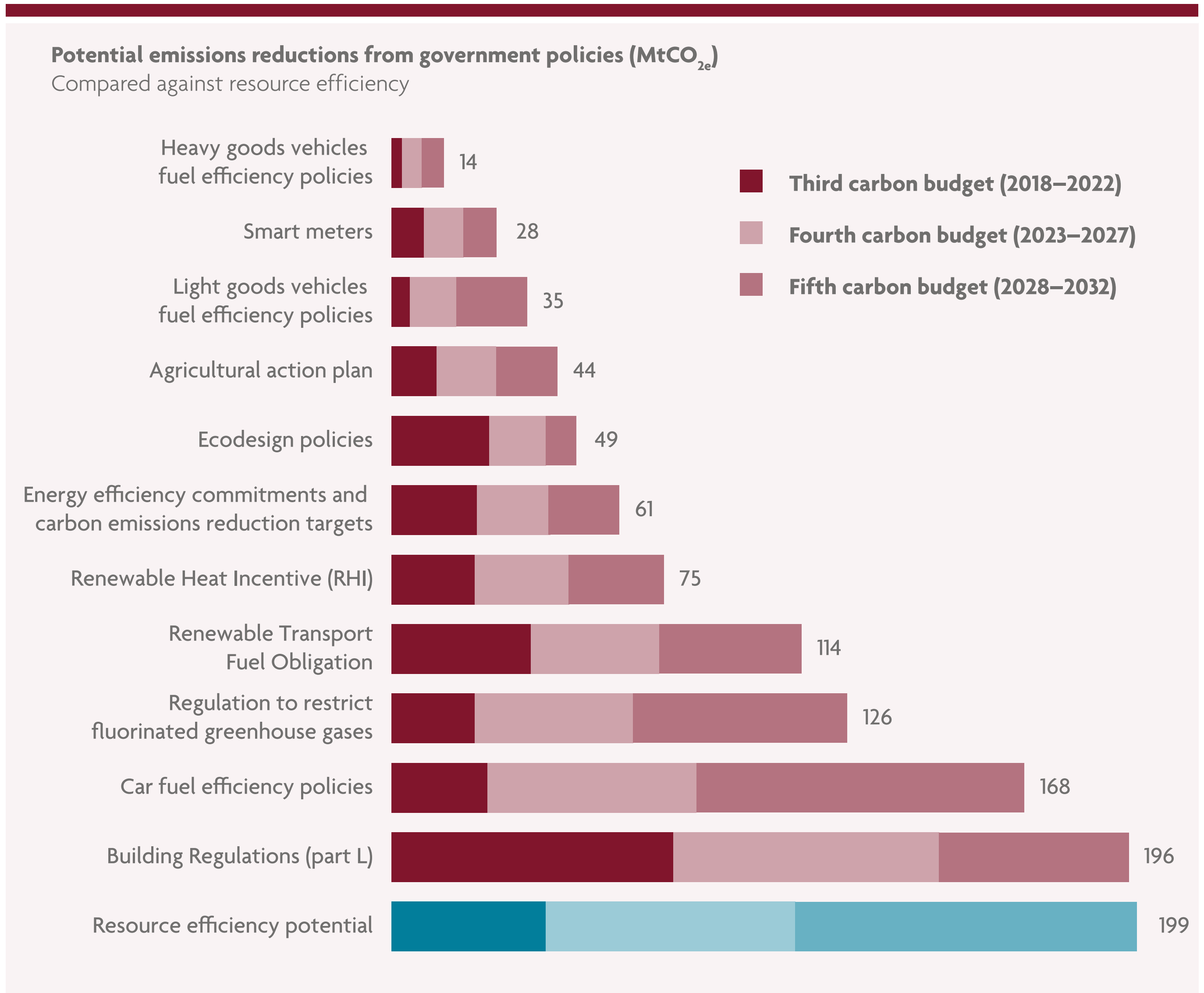
ANALYSIS

> **"If food waste was a country, it would be the third-largest emitter on the planet after the USA and China."**

UNDER-RECOGNISED POTENTIAL

In the meantime, WRAP's work has contributed to carbon reduction in key areas. Food waste was reduced by some 27 per cent between 2007 and 2018. Household recycling has nearly quadrupled, from around 11–12 per cent in 2000 to over 45 per cent today. The Sustainable Clothing Action Plan – a plan for players from across the fashion supply chain to sign up to with the aim of achieving reductions in carbon, water and waste – has seen carbon reductions amounting to more than 13 per cent per tonne of clothing. Between 2011 and 2020, WRAP's work in these three areas will have saved over 18 megatonnes of greenhouse gases (CO_{2e}) (4.7 megatonnes from food, 12 megatonnes from recycling and 1.5 megatonnes from textiles). On electronics, our work has now concluded, but in the past has pioneered take-back and reuse models, helping to meet the challenge of extending product lifetimes.

Leading policy non-governmental organisation Green Alliance and the Centre for Industrial Energy, Materials and Products (CIE-MAP) recently reinforced the resource efficiency and carbon message at the consumption end in a report that drew on WRAP data.[9] Some of the recommendations are very ambitious: 80 per cent reduction in avoidable food waste by 2032 – though achieving this would yield 25 megatonnes of carbon reduction. Substitution of high-carbon building materials with lower carbon alternatives (e.g. timber instead of steel), as well as better design and more reuse of materials, could save nearly 80 megatonnes of carbon. Other strategies that would have significant impacts are really not a huge ask – the quarter of electronic appliances thrown away before their time saved for reuse, or clothing worn for an extra year would add up to 12 megatonnes of carbon saved. All together, resource-efficiency measures in just five sectors of the economy could save as much carbon as radical changes to building efficiency (see **Figure 4**).



▲ **Figure 4. Resource efficiency has great potential to cut UK emissions (in million tonnes of CO_{2e}). (© Green Alliance)[9]**

Resource efficiency is of course not just about carbon: products preserved in the economy are holding on to their precious materials and avoiding unnecessary water use as well. WRAP's Sustainable Clothing Action Plan shows an 18 per cent reduction of water footprint per tonne of clothing.[10] The astonishing amount of water used to produce cotton is now widely known and the 2,700 litres per T-shirt figure widely quoted. Discovering that there is more gold in a tonne of waste electronics (it is a key component of circuitry) than in the mined ore gave impetus to the repair and reuse agenda promoted by WRAP.

At WRAP, we hope that the coming together of public, business and political concern over climate, with awareness of the polluting effects of our consumption (plastics being the current focus, with fashion not far behind) will turn into a well-informed debate about how to meet climate goals through lowered, more circular consumption. Whichever way we cut the data, slowing the wasteful throughput of stuff through global economies can only yield benefits – and free us from a pattern of disposability that an increasing number of people are finding dispiriting and unsatisfying as well as unsustainable. **ES**

Julie Hill has qualifications in English, philosophy, politics and ecology. She is an environmentalist and author, Vice-Chair of the Institution of Environmental Sciences and Chair of WRAP. She is also the author of The Secret Life of Stuff: A Manual for a New Material World, published by Vintage Books.

Patrick Mahon leads WRAP's policy and political engagement work. He is a Chartered Resource and Waste Manager, and has a Master's degree in environmental management from The Open University.

Dr Peter Maddox is a Director at WRAP. He has a DPhil in chemistry, and is responsible for WRAP's work on food, textiles, plastics and recycling in the UK.

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CASE STUDY

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The Shrewsbury Cup scheme

Alison Thomas and **Sophie Peach** describe how they are making it easy to switch from single use to reuse.

The use of single-use paper cups in the UK is spiralling out of control. The town of Shrewsbury in Shropshire is fighting back with an innovative way of encouraging reuse over single use. Shrewsbury Cup is a scheme that makes reusable take-away cups available at the point of sale in cafés so that customers can choose to reuse by renting a robust and durable cup for a £1 refundable deposit.

THE AGE OF CONVENIENCE

We live in an age of convenience and disposability. Over the last 50 years, great minds have conjured up hundreds of ways to improve the ease of day-to-day life, saving us time and effort. Online shopping, 24-hour delivery, take-away food, fast food, fast fashion…the list goes on.

As we have transitioned to this life of ease, we have paid little attention to one of the consequences – packaging and other items, which come with a huge environmental cost. Single-use coffee cup waste is a prime example: 7 million single-use cups with an average life of just 15 minutes are used in the UK every day, which equates to around 2.5 billion a year. Half a million of these cups are littered on a daily basis and only 1 per cent of these are recycled. On top of that, 3,000 trees have to be cut down to make enough cups for one day. Zero Waste Scotland revealed that the associated CO_2 released in the production of a single disposable cup is approximately 28g CO_2. So the production of 2.5 billion cups in a year generates 70,000 tonnes of CO_2.[1]

People are becoming aware of the damage being done, and there is an inspiring sense of momentum to do something about it. We have had the solutions to tackle waste for years: 'Reduce. Reuse. Recycle'. However, all too often 'reduce' and 'reuse' are ignored and it is assumed that we can rely on recycling. Unfortunately, this is one problem we cannot recycle our way out of.

WHY CAN'T SINGLE-USE CUPS JUST BE RECYCLED?

While in theory it is possible to recycle single-use cups, breaking that process down into its component stages reveals why recycling is not a feasible option.

When it comes to disposing of these cups, consumers are rarely presented with a cup-only bin and, as a result, most of the cups are placed in general waste bins and then sent to incineration or landfill. Providing designated cup bins would require a huge investment in 'binfrastructure', signage and labour to empty the bins, collect and process the waste. After the cups have been collected for recycling, they must be sorted to remove any non-cup contamination.

ATTEMPTS TO ENCOURAGE REUSE

The idea of imposing a 'latte levy' has been up for debate by ministers in the UK, with the argument that this would reduce the number of single-use cups consumed. A look back at the impact of Starbucks' work provides a clear illustration of why this is not an effective strategy. In 2008, Starbucks' reusable cup rate was less than 2 per cent.[2] In that year Starbucks partnered with Hubbub to explore the impact of a 5p levy on single-use cups; reuse rates more than doubled but still remained at only 5.8 per cent. So, while there was a slight change in the behaviour of Starbucks' customers, it was limited. A levy has been more successful in a campus situation: the 25p levy introduced by Winchester University in November 2016 saved 55,000 single-use cups by March 2018.

THE SHREWSBURY CUP SCHEME

Further measures are required to help the majority of customers choose to reuse. A reusable cup on a deposit–return basis, available at the point of sale, overcomes three obstacles to behaviour change:

- The need to buy a travel cup;
- The need to remember to bring the cup when you leave the house; and
- The consequence of having to carry the dirty cup around after using it.

Shrewsbury Cup is just that: a deposit–return scheme at the point of sale for reusable cups. The concept is simple: you pay a £1 deposit for a reusable cup when you buy your take-away drink, and when you have drunk it, you return the cup to any participating café and collect your £1 deposit. Cups are then washed for reuse.

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CASE STUDY

The £1 deposit is charged to incentivise the customer to return the cup rather than throw it away. Similarly, if the cups are accidentally littered, someone else can pick the cup up and hand it in to collect the £1. So, the scheme encourages reuse and reduces waste and litter.

Membership of Shrewsbury Cup Community Interest Company (CIC) gives participants:

- Access to a stock of cups that are paid for upfront at £1 per cup;
- Point-of-sale materials;
- Support with stock management;
- Regular promotion through social media; and
- Reduced costs through not having to purchase single-use cups.

ABOUT THE CUP ITSELF

The Shrewsbury Cup is made using pioneering EcoCore® technology developed and manufactured in the UK by Bockatech and Amaray respectively. It is made of polypropylene (PP; plastic number 5) and has skin-foam-skin walls. The foam core means that the thickness of the walls can be increased while using the same amount of material. The Shrewsbury Cup is therefore:

- Good at keeping its contents hot or cold for longer, and protecting hands from being burnt;
- Stronger in use; and
- Less likely to break if dropped.

So the Shrewsbury Cup is low cost, lightweight, insulated and very durable. The environmental impact of manufacturing the cups is also reduced to a minimum.

THE SUCCESS OF THE SCHEME

Shrewsbury Cup now has 24 participating organisations. They range from traditional independent cafés to sports clubs and the local Sixth Form College Group. The existence of the cups in the community has prompted schools' parent–teacher associations to sign up, keen to use the cups at fundraising events. Conversion rates from single-use to Shrewsbury Cups vary from 100 per cent in cafés, where all single-use cups have been withdrawn, down to around 20 per cent where perhaps either the customers or the staff are less aware of the scheme. There are just over 3,000 cups in circulation and it is estimated that the scheme is now saving around 500 cups per week.

Inspired by Shrewsbury Cup, communities in Newport and Oswestry in Shropshire and Whitstable in Kent have launched their own cup schemes. In addition, the founders of Shrewsbury Cup CIC have been asked to advise communities across the UK on how to set up their own cup scheme.

CASE STUDY


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ENVIRONMENTAL IMPACT OF THE CUP

When compared to single-use paper cups, a typical plastic reusable cup needs to be used around 20 times to begin to have a positive impact on carbon emissions.[3] However, the small amount of material and energy used to create EcoCore cups means their breakeven point is only three uses.[4]

Due to the PP skin-foam-skin walls, the cups are not only lightweight but also very durable. Tests carried out by a local supermarket in Shrewsbury showed they were still good to use after 1,000 washes in a commercial dishwasher.

Analysis of cups made with EcoCore carried out by The LCA Centre in the Netherlands showed them to be the most sustainable solution for hot and cold drinks overall.[5] The study compared EcoCore cups to both reusable alternatives (e.g. heavy plastic, glass and ceramic) and single-use alternatives (e.g. PET, PP, PLA [a biodegradable plastic], PE-lined paper and PLA-lined paper). The research showed a reduction in CO_{2eq} of 45 per cent compared to the average single-use cup, and a significant reduction against *all* reusables after just 17 uses. EcoCore cups also came out as the preferred solution in a broad-scope environmental ReCiPe study by the LCA Centre that took into account 18 environmental factors.[5]

Deposit–return means that only very few cups are lost from the system. Those that are damaged are returned so they can be recycled. The combination of deposit–return and closed-loop recycling considerably reduces the possibility of littering, and marine and freshwater environmental pollution.

If any cups do enter kerbside waste collection streams, the fact that they are made of widely recycled PP plastic enables them to be recovered for recycling as well.

THE RIPPLE EFFECT

The Shrewsbury Cup scheme has been successful thanks to the support it received from a local community keen to see something done to eradicate unnecessary waste. The concept is ideal for festivals, campuses, sports clubs and towns. They are all suppliers of the convenience of single-use that we have become accustomed to, but are also under the most pressure to find sustainable solutions that do not have a negative impact on their bottom line.

As a result of seeing the Shrewsbury Cup in action, Harper Adams University, under the guidance of Shrewsbury Cup CIC, ran a four-week, campus-wide trial in four cafés. It was a huge success and led to the removal of all single-use cups on campus at the start of the 2019 academic year. Nine weeks after the launch of the Harper Cup, 8,100 drinks had been sold in a reusable cup, thus saving the equivalent number of single-use cups. Staff and students were fully behind the scheme and not offering single-use cups had no detrimental effect on sales of hot drinks.

Shrewsbury Cup CIC worked with 14 events between May 2018 and November 2019 to replace single-use cups with the EcoCore cup on the deposit–return basis. At the 2018 Hay Festival, for example, there was a 92 per cent reduction in single-use cup waste.

NEXT STEPS FOR SHREWSBURY CUP

The Shrewsbury Cup scheme was launched in April 2019 with support from Shrewsbury Business Improvement District (BID). The close collaboration between the CIC and the café members means that the scheme is still evolving, allowing operational issues to be ironed out and ensuring the sustainability of the scheme.

The ultimate aim of the scheme is to make it the norm in Shrewsbury to choose to reuse and to eliminate the vast majority of single-use cups in the town. Estimates suggest that over 80 per cent of cups tend to remain within their own community, so the aim is now to encourage other sports centres, towns and campuses to employ this simple model to eliminate unnecessary waste. ES

Alison Thomas, Shrewsbury Cup Co-founder. Alison is an environmental scientist and worked in industrial waste before switching to behaviour change solutions for commercial, domestic and event waste.

Sophie Peach, Shrewsbury Cup Co-founder. Sophie has a business degree and is a public speaking trainer for secondary school pupils across the West Midlands and North Wales.

info@shrewsburycup.co.uk
@shrewsburycup

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New members and re-grades

Member is for those individuals who have substantial academic and work experience within environmental science.

David Brett – Senior Consultant
David Caddy – Water & Environmental Consultant
Ellen Carvill – Senior Geo-environmental Engineer
Jacqueline Clarke – Sustainability Consultant
James Cochrane – Senior Environmental Scientist
Olivia Collington – Associate Director
Richard Deeney – Senior Environmental Consultant
Felicia Douglas – Graduate
Natalie Foster – Lecturer in Systems
Stefano Gallo – Team Member
Francesca Gauntlett – Science Adviser
Emily Harris – Hydrogeologist
David Heuston – Environment Team Manager
Ross Holman – Principal Hydraulic Modeller
Freya Hoyle – Senior Air Quality Consultant
Kairen Keller – Senior Consultant, Environmental Permitting
Christopher Kernahan – Environmental Scientist
Gareth Leonard – Managing Director
Mark Lewis – Managing Director
Rosemary Lodge – Sustainability Consultant
Margaret McGowan – Senior Remediation Advisor
Megan Moore – Environmental Consultant
Samantha Mutters – Regulatory Professional
Stephanie Nichols – Principal Consultant
Christina Petrides – Independent Environmental Consultant
Laura Polazzi – Senior Environmental Consultant
Sarah Poulton – Principal Consultant
Malcolm Pounder – Senior Environmentalist
Troy Randall – Senior Geo-environmental Consultant
Emily Royan – Contaminated Land Consultant
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Gavin Scott – Associate Geo-Environmental Advisor
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Microplastics in rivers

Jamie Woodward, James Rothwell, Rachel Hurley, Jiawei Li and **Marianne Ridley** outline a new challenge for water quality and river habitat management.

Microplastics are commonly defined as plastic particles smaller than 5 mm in size, although many studies have recorded microplastic assemblages dominated by much finer particles. Microplastics have been found in all kinds of environments – in the deepest part of the ocean, in Arctic sea ice and in remote Alpine soils. There is particular concern about microplastics ingested by aquatic fauna and their transfer up the food chain, and microplastics have recently been recorded in human faeces.[1]

To date, most of the research on microplastic contamination has been focused on the marine environment.[2] Research on microplastics in rivers has lagged behind, but it has recently been established that: (1) river channels can be very heavily contaminated with microplastics and (2) fluvial transport is a major supplier of microplastics to the oceans. There are many reasons why we need to deepen our understanding of the processes that control microplastic transport and storage in river catchments, not least of which are the potential threats to aquatic organisms and ecosystem health.

How do you go about assessing the extent of microplastic contamination in your local river? What do you sample – water, sediment or biological material such as fish guts or freshwater mussels? How do you identify and quantify the microplastic burden? What units do you use? The study of microplastics in freshwaters is developing rapidly and researchers are currently grappling with these important questions. There are no standard protocols for sampling microplastics in rivers.

In 2015 a group of us in the Department of Geography at The University of Manchester began investigating microplastic contamination in the River Irwell (793 km^2) and the upper Mersey (734 km^2) and their tributaries – a catchment area of some 1,500 km^2. These rivers

▲ **Figure 1. A typical sub-urban reach in our study rivers. This is the River Tame – a tributary of the upper Mersey – a few kilometres downstream from the Denton hotspot. This river has registered the highest concentration of microplastics in the world.[3] It was the focus of more detailed study in 2019. (©Mike Wafer, Outpost Pictures)**

are small by global standards but they drain a range of land uses, from rural uplands to heavily urbanised centres of population. We quantified the geography of contamination in 10 rivers as well as, in specific reaches, the total microplastic load and the assemblage of microplastic types stored within the fine sediments of the river bed (see **Figure 1**). Globally, it is the largest study of microplastic contamination in freshwaters[3] (see **Figure 2**).

WHY SAMPLE THE RIVER CHANNEL BEDS?

River beds are generally well-oxygenated, providing an important habitat for macroinvertebrates such as stoneflies, caddisfly larvae and shrimps. The fine channel bed sediments contain important food sources for this ecosystem, including algae and decaying organic matter.

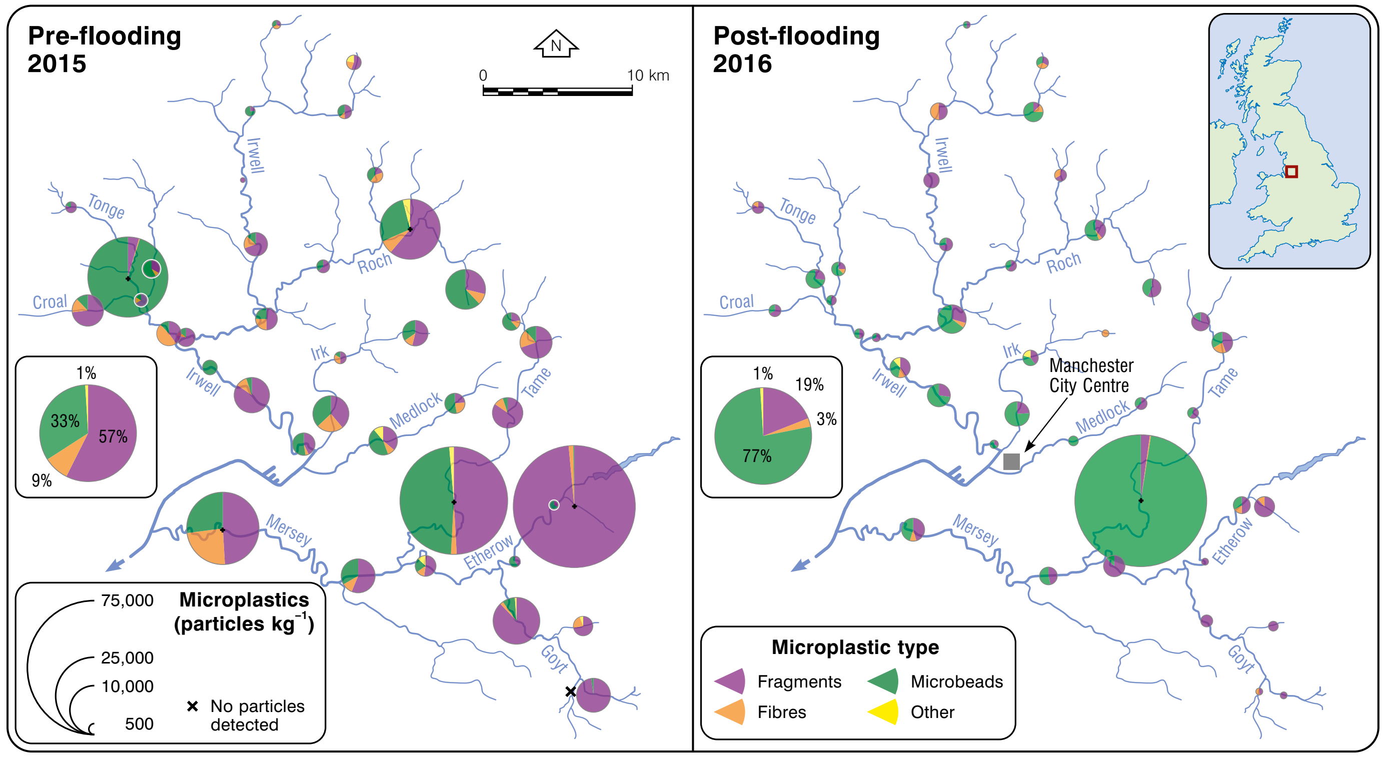
Many species of fish and waterfowl also feed in this zone. Where this channel bed habitat is contaminated with microplastics, the potential exists for microplastic ingestion and for microplastics to enter the food chain.[4] It can therefore be argued that the fine sediments on a river bed are the most ecologically relevant sampling environment and the most appropriate context to establish the extent of microplastic contamination and any potential threat to the aquatic ecosystem.

We sampled the fine channel bed sediments because they inform us about the *accumulation* of microplastics in a given reach and capture the recent history of microplastic contamination in that reach. For each sample, we used an aluminium cylinder to isolate a portion of the channel bed so that we could agitate the gravels, bring the fine sediments and microplastics into suspension, and capture a representative sample (see **Figure 3**). In the laboratory we isolated and quantified the microplastics.

In the 2015 survey we recorded microplastics at 39 out of 40 sample sites, but concentrations were highly variable (see **Figure 2**). We also found that most sites contained microplastic fragments, plastic microbeads and synthetic fibres in varying proportions. A key finding was the presence of distinctive urban contamination hotpots, where concentrations of channel bed microplastics could exceed 40,000 microplastic particles per kg of fine sediment. The most heavily contaminated reaches were located immediately downstream of wastewater treatment plants or combined sewer overflows. In the 2015 survey we identified five reaches where microplastic concentrations exceeded 15,000 microplastic particles per kg of fine-grained channel bed sediment, with one site on a tributary of the River Etherow exceeding 60,000 (see **Figure 2).**

The rivers we surveyed saw sustained flooding in the winter of 2015/16, including an exceptionally large flood in the River Irwell catchment on Boxing Day. In spring and early summer 2016 we resampled all 40 sites to assess the impact of the catchment-wide flooding. Microplastic concentrations had fallen at 28 sites, and 18 of these had decreased by at least an order of magnitude (see **Figure 2**). We discovered that flooding can efficiently flush gravelly river beds of microplastic contamination. So in this context, flooding represents a significant ecosystem service. The post-flooding dataset allowed us to estimate the microplastic load flushed from channel bed storage and transported downstream: about 70 per cent, i.e. some 43 ± 14 billion microplastic particles or 0.85 ± 0.27 tonnes of microplastics.[3] The proportion of the fluvial microplastic load that actually reaches the open ocean is not yet known because some of the microplastics will be stored in floodplain and estuarine environments.

One site stood out in the 2016 post-flooding dataset. At a reach in Denton on the River Tame, the microplastic concentration actually *increased* very considerably from 48,300 to 72,400 particles per kg of fine channel bed sediment. In this case, the post-flooding microplastic



▲ **Figure 2. Patterns of microplastic contamination and microplastic assemblages in 10 rivers around Manchester. Note the significant decrease in microplastic storage following the winter flooding of 2015/16. The charts in the boxes show mean data for all sites. In both surveys samples were collected in spring and early summer under low-flow conditions. One site in the headwaters of the River Goyt recorded microplastics in 2016 but not 2015, and the Denton hotspot in the middle reaches of the Tame is a prominent feature of the 2016 survey. (Drawn by Nick Scarle, The University of Manchester, modified[3])**

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assemblage was overwhelmingly dominated by microbeads (see **Figure 2**). The striking change in the Denton microplastic assemblage tells us that this site also saw significant downstream flushing of microplastics but this was followed by rapid *accumulation* of microplastics – in a matter of weeks – and from a local point source.

This multi-catchment study provided several important new insights: microplastic contamination is spatially highly variable across the drainage network, concentrations in a reach can increase or decrease quite rapidly over time, and concentrations are strongly influenced by fluvial processes, including antecedent flow conditions (especially length of time since the last significant flood) and proximity to point sources of wastewater. There appears to be a broadly seasonal pattern of microplastic accumulation on channel beds, with build-up taking place principally during low spring and summer flows. During periods of high runoff – which are often in the winter months – these microplastics are flushed from channel beds and dispersed downstream.

MICROPLASTICS IN SEDIMENTS AND WATER

In summer 2019 we carried out an intensive programme of sampling on the River Tame (see **Figure 1**) to look at microplastics in various contexts. What you sample, where you sample, when you sample – all of these factors are important when attempting to assess levels of microplastic contamination in a given river reach. At 14 sites we collected water samples, channel bed sediment samples and fresh sediments deposited on the floodplain surface following a summer 2019 flood. Each context yielded very different microplastic assemblages *and* concentrations. **Figure 4** provides a schematic illustration of our preliminary findings with mean values of microplastic concentrations found in three different parts of the river environment. Note that the channel bed sediments typically showed by

▲ **Figure 3. Sampling microplastics stored on the channel bed under low-flow conditions. Microplastics are present within the sandy and silty sediments between the loose gravels. The insets summarise, from left to right, the field sampling and laboratory recovery of microplastic particles. A known area of channel bed is isolated using the aluminium cylinder, the gravels are agitated to bring the fine sediment load into suspension, samples of turbid water are returned to the laboratory where the recovery, identification and quantification of microplastic particle types takes place. This sampling method also allows us to estimate the amount of fine sediment stored within and on the channel bed. (©Mike Wafer, Outpost Pictures, with graphics drawn by Nick Scarle, The University of Manchester)**

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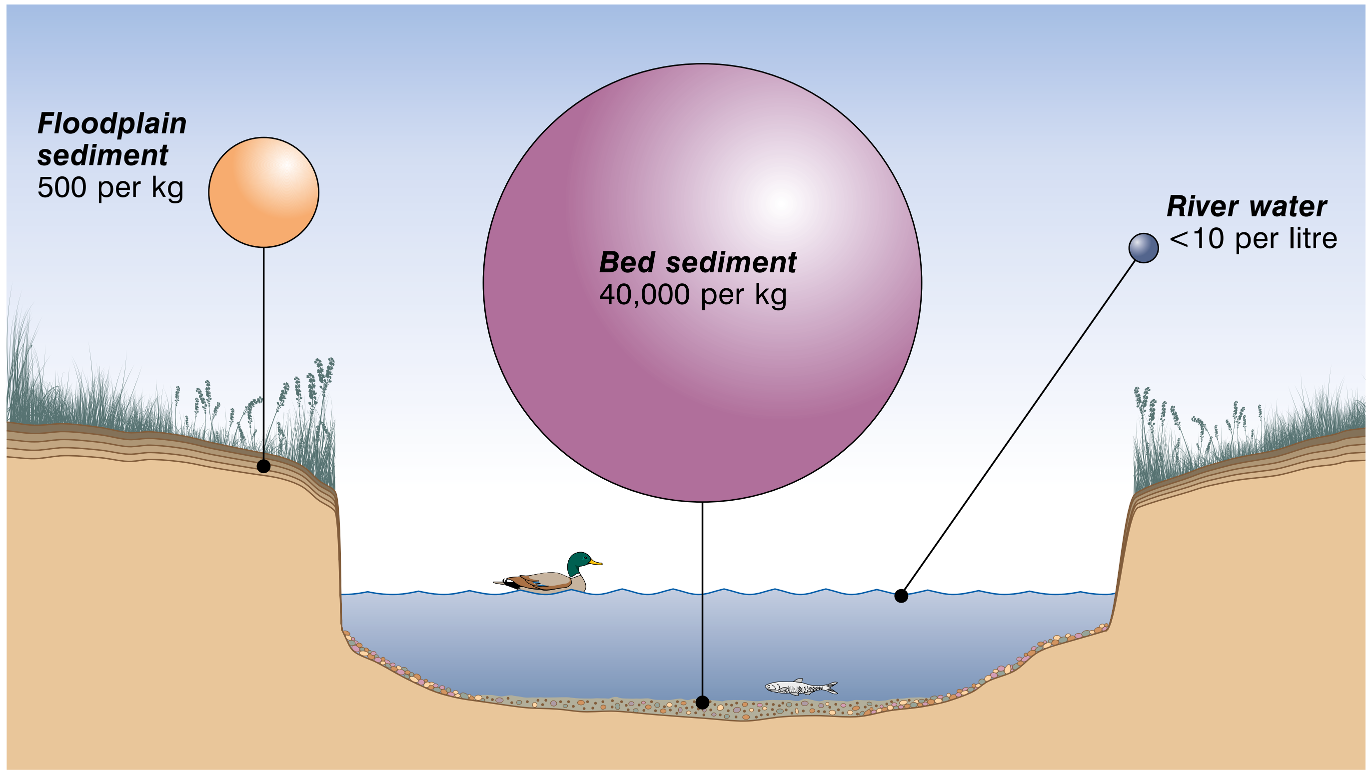


▲ **Figure 4. Schematic diagram with proportional circles summarising microplastic particle concentrations from the River Tame derived from water and fine sediment samples collected in summer and autumn 2019. In each context mean values of microplastic counts from 14 samples are given. The channel bed sediment–water interface is a zone of intense biological activity where many animals feed. (Drawn by Nick Scarle, The University of Manchester)**

far the highest concentrations of microplastics – these were orders of magnitude higher than the other two media. They also contained *all* components of the fluvial microplastic assemblage. By contrast, water samples collected under non-flood conditions were dominated by synthetic fibres. Overbank floodplain sediments were dominated by microbeads, with some microplastic fragments, but fibres were largely absent.

Our latest work on the Tame indicates that untreated discharges from wastewater treatment works and combined sewer overflows are the main source of microplastics. The highest levels of contamination are close to these major outfalls. Wastewater treatment works receive effluents from various sources, including industrial discharges and domestic wastewater.

MICROPLASTICS IN THE OCEANS

It is important to appreciate that it can be difficult to compare microplastic data collected using different methods. Most data on microplastics from the marine environment, for example, are collected from surface waters using Neuston nets towed behind boats. These nets trap floating microplastic particles down to a lower size limit of about 330 µm. These data are commonly expressed in microplastic particles per surface area of ocean or per volume of water. Most microplastic particles that we see on the river beds in our study areas are finer than 300 µm (see **Figures 5 and 6**), so these particles could pass through the Neuston mesh and go unrecorded. This is just one example of how we need to better coordinate research across river and marine environments. In addition, much of the marine microplastic load sinks to the ocean floor and is buried in sediment. Clearly, the microplastic load in the world's oceans has been significantly underestimated.[3,5]

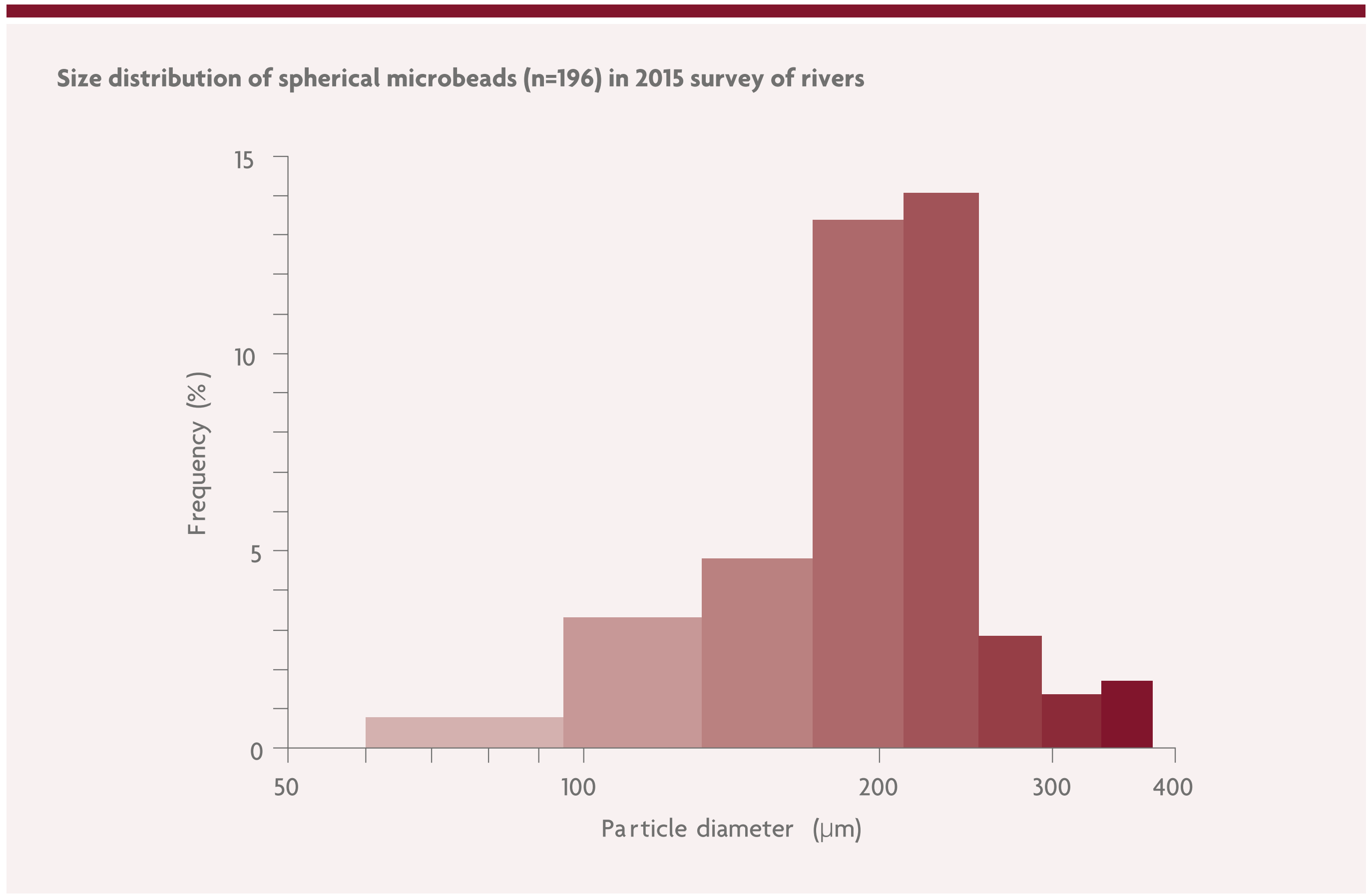
HOW WERE RIVERINE MICROPLASTICS MISSED?

The fluvial microplastic contamination problem we have identified has passed under the regulatory radar.[3] It has been described as a contaminant of emerging concern. This is not surprising in the UK context because microplastics are part of the sediment load of rivers, and the Environment Agency, the Scottish Environment Protection Agency (SEPA) and other regulatory bodies do not routinely analyse sediment properties as part of river water quality monitoring. While the total concentration of suspended solids in water is commonly recorded, these agencies (and their predecessors) have traditionally focused only on water samples and a fairly narrow range of water quality properties to assess river water quality.

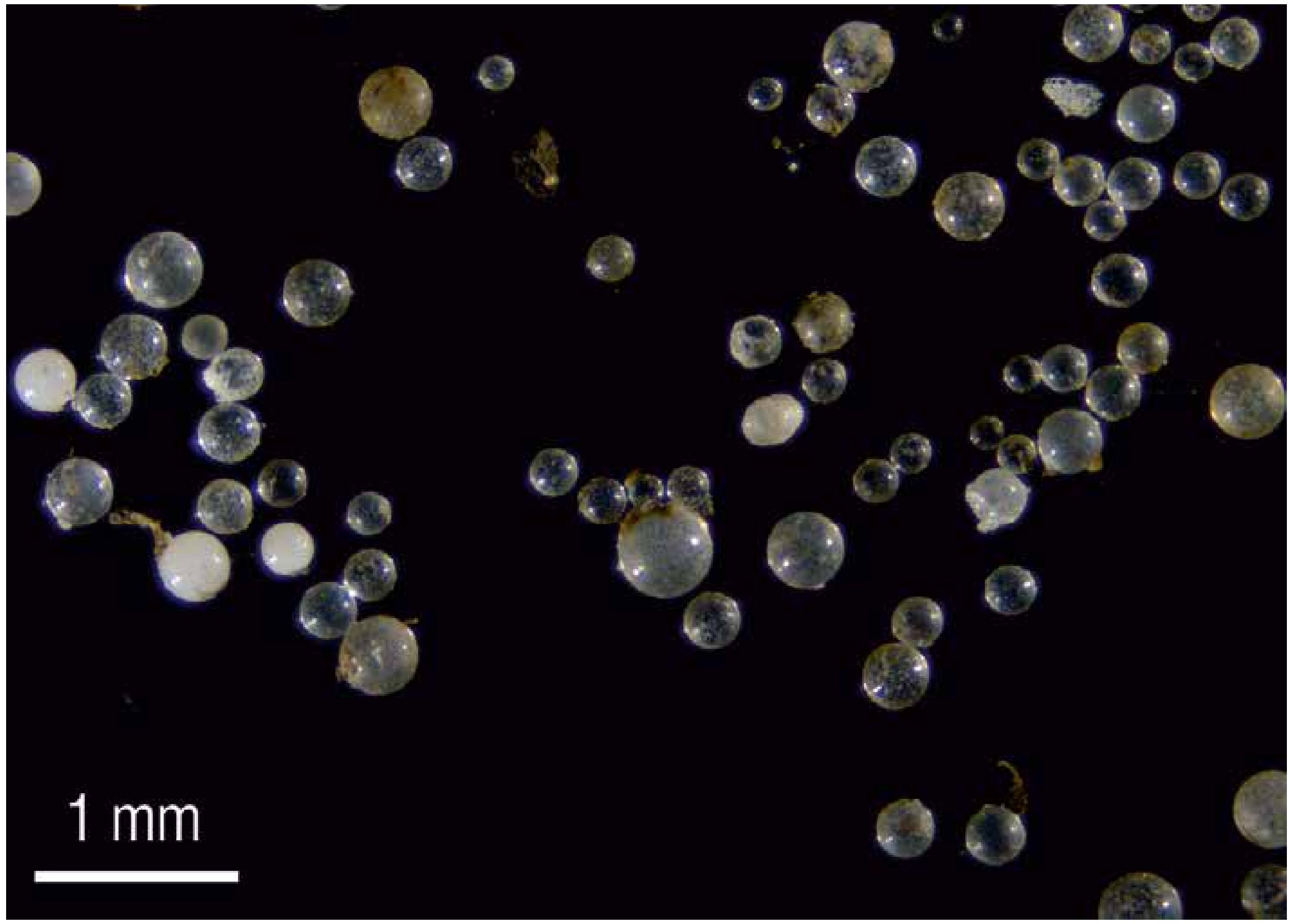
MICROPLASTICS AND RIVER HABITAT QUALITY

A key objective of national water quality strategies is to ensure that river environments have good biodiversity and provide a suitable habitat for fish and other aquatic fauna. A recent study of microplastics in fish in the non-tidal River Thames found at least one synthetic fibre within the gut contents of one third of the sampled fish.[6] Because of the ecological importance of the benthic zone, and the progressive build-up and storage of microplastic particles of all types on the channel bed (see **Figure 4**), it can be argued that the concentration of microplastics in the fine-grained channel bed sediment is the most useful indicator of riverine microplastic contamination. Macroinvertebrates are most commonly used to assess the environmental quality of rivers and streams. As we work towards environmental best practice in this area, we would argue that the concentration of microplastics in river bed sediments should form part of the assessment of river habitat quality.

Given the high levels of microplastic contamination identified in the rivers that we have surveyed, it is very likely that this type of river habitat degradation is common in many UK rivers – especially in those in large towns and cities. This poses important new challenges for river catchment management and how we deal with runoff and wastewater. Microplastics are widespread in the environment and we have to develop effective ways of reducing microplastic inputs to rivers. We need to identify an acceptable level of riverine microplastic contamination, define critical loads and set targets for compliance. Before we can do this there is a need for much more fundamental research to better understand the origin, movement and storage of microplastics in our rivers, as well as the potential impacts of microplastic ingestion on aquatic ecosystems and human health. ES



▲ **Figure 5. Note that most particles are finer than 300 μm. Very few of the fluvial microplastics we have recovered are larger than 0.5 mm (500 μm). (Drawn by Nick Scarle, The University of Manchester)**



▲ **Figure 6. Plastic microbeads recovered from the bed of the River Mersey. (Photo taken by Rachel Hurley, The University of Manchester)**

Jamie Woodward is Professor of Physical Geography at The University of Manchester, where he leads the microplastics group. He is a fluvial geomorphologist with a particular interest in catchment sediment sources, fluvial sediment properties, and the Anthropocene river.
✉ **jamie.woodward@manchester.ac.uk**

James Rothwell is a Professor of Physical Geography in the Department of Geography at Manchester. He has expertise in environmental pollution and urban green infrastructure.

Rachel Hurley did her PhD on microplastic contamination of rivers in the Department of Geography at Manchester. She is now based at the Norwegian Institute for Water Research in Oslo and works on microplastics in various environments.

Jiawei Li and **Marianne Ridley** are post-graduate research students at Manchester, with particular interests in microplastic dynamics in rivers.

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ANALYSIS

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The role of waste to energy in the circular economy

Blaise Kelly explains why waste is too valuable to be wasted.

I have confidence that one day, everything will be able to be recycled. Until then, there are many items that perform very useful functions but are not recyclable: greasy pizza boxes, aluminium foil with food on it, carpets, toothbrushes, sponges, laminated glass and Pyrex are some examples. Even the most considered eco-build project will require sealants, glues and paints, all of which have to be packaged between production and use. It is currently impossible to separate these substances from their plastic container for recycling, but those contaminated containers and residues burn exceptionally well. Similarly, in healthcare, single-use plastics now dominate where once metal instruments were cleaned and reused. If the energy from the medical incinerator is used to supply electricity and heat to the building, the result is arguably more sustainable than using metal components that require much more energy and resources to manufacture than plastic, and require energy for cleaning.

Through the controlled burning of materials that are difficult to recycle or refuse that has not been separated, waste-to-energy plants can enable this material to contribute to the circular economy by generating very significant amounts of electricity and heat that would otherwise be provided from virgin fossil fuels. Incinerator

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Annual energy (GJ/year) produced as electricity or heat (electricity multiplied by 2.6 and heat by 1.1) − **Energy input to the system from other fuels/0.97** X **Net calorific value of the waste** + **Energy input into the system from fuels that contribute to the production of steam**

▲ **Figure 1. Formula to calculate the energy efficiency score of a waste-to-energy plant.**

bottom ash can also be sorted very efficiently. Ferrous metals are removed using magnets and then the rest is sent past eddy current separators to pick out non-ferrous metals. Left over is a mix of carbon, glass and ceramic that is commonly used in construction materials, reducing the need to extract finite virgin material.

THE ADVANTAGES OF CENTRALISATION

In London, for example, domestic gas boilers are the second-largest individual source of NO_x emissions after transport.[1] While emissions from a well-maintained boiler are relatively low, the flues are much closer than vehicle exhausts to where people spend long periods of time – at home. In spite of this, the monitoring of emissions around gas flues is almost non-existent.

Rolling all these flues into one centralised power station with district heating would mean the emissions could be controlled and treated with a plethora of technologies. And since all homes generate waste, it makes sense to use that waste at source. In the future, when we can recycle all our waste, these plants can be converted to other energy technologies that simply plug into the heating grid that feeds people's homes.

Countries such as Austria, Holland and Sweden have had long-standing commitments to using as much energy as possible with the lowest emissions. Denmark and Sweden have been incinerating waste since 1903; the first plant was installed using British technology. They have been heating their homes with energy from waste since the mid-1920s. During the oil crisis of the 1970s, they worked to make the most of their energy resources, so district heating systems were pushed as sound energy-efficiency practice.[2] This historic investment in infrastructure has allowed them to use waste to energy in cities far more effectively than Britain.

THE SITUATION IN THE UK

The two focal points of waste to energy are the amount of useful energy from the waste and the emissions from the plant. The Confederation of European Waste-to-Energy Plants (CEWEP) considered that during 2017, only 37 per cent of the UK's municipal waste was converted to energy[3] in the 40 incinerators around the country. According to EU directive 2008/98/EC, the definition of waste to energy is a plant that is 'used principally as a fuel or other means to generate energy' and meets the R1 standards. An R1 plant has an energy efficiency equal to a score of more than 0.6 for operations permitted before January 2009 and 0.65 for operations permitted after that date.[4] The formula used to calculate this energy efficiency score is shown in **Figure 1**.

As of 2015 only three of the 40 incinerators operate to this standard, because of a lack of infrastructure to distribute the heat. This means most of the energy in the UK's incinerated waste is lost to the atmosphere.

The debate on waste to energy in the UK is frustratingly simplistic and short sighted,[5] with the assumption that burning waste adds to overall CO_2 emissions and almost no consideration of the impact of the alternatives. Many planning applications for incinerators in the UK are opposed on pollution grounds. The technologies used are poorly explained to the public and there is a deep-rooted opinion that emissions are harmful. While standards have improved over the years and emissions from UK incinerators are far less than other industrial facilities, the UK could do much better. Instead of debating the merits of substandard plants, we should be aspiring to use the best technology available.

THE REGULATIONS IN THE EU

European Union environmental standards for waste incineration plants are now finally being updated. Yet rather than tackling toxic pollution, in line with what is already being achieved by some of the best-performing plants, by and large standards have remained the same – and in some cases even weakened.

In 2018, a report from the European Environment Bureau (EEB), a member of the Sevilla Process, which is designed to agree on what constitutes the best available techniques (BAT) for pollution prevention and control, reviewed the draft of the revised BAT reference document for waste incineration and compared plants around the EU.[6] Sweden and Holland were praised for meeting the EU's BAT-recommended values and for pressing for more stringent regulation during this process. The UK was amongst the countries singled out for weakening the ambition of the revisions.

The lowest NO_x emitting 10 per cent of waste-to-energy plants in the EU are fitted with selective catalytic reduction (SCR). These generate on average less than 55 mg/NO_x/Nm^3 (milligrams of nitrogen oxides in a normal cubic metre, i.e. at 0 °C and atmospheric pressure). The regulation in the Netherlands is 70 mg/NO_x/Nm^3 and in France it is 80 mg/NO_x/Nm^3. There are no waste-to-energy plants in the UK that have SCR fitted, meaning emissions are significantly higher than these benchmarks.

Mercury emissions (denoted as total mercury [THg]) have been steadily declining. The best plant in the EU is Austria's Pfaffenau municipal waste incineration plant, with an average emission of 0.02 µg/THg/Nm^3. The current limit is a daily average of 5–20 µg/Hg/Nm^3.

It is also possible to reduce CO_2 emissions from plants by reacting the flue gas with sodium hydroxide to produce sodium bicarbonate. This has been demonstrated by the Twence waste-to-energy plant in the Netherlands.[7]

Clearly, increasingly onerous mitigation and monitoring has costs associated with it. To expect the private sector to altruistically invest in technology above and beyond the minimum requirements is perhaps unrealistic. Government support is essential to assist with plants achieving these standards in order to protect the public and reduce opposition to this necessary infrastructure.

Waste to energy is one of the best technologies to deal with our difficult-to-handle municipal waste. Countries that have well-developed waste-to-energy systems also have high recycling rates and more efficient heating systems. We must not confuse waste to energy with incineration as we do in the UK. Waste to energy should only be promoted when the energy it generates is used to offset fossil fuels with the very best available mitigation to minimise emissions. **ES**

Blaise Kelly MIEnvSc MIAQM is a Senior Air Quality Consultant at Hydrock Building Performance Engineering. He lived in Vienna for nearly five years while working on a number of European energy efficiency projects, in particular looking at external costs. He has an MSc in Renewable Energy and the Built Environment and a BEng in Materials Science and Engineering.
✉ **blaisekelly@hydrock.com**
@BlaiseKe11y

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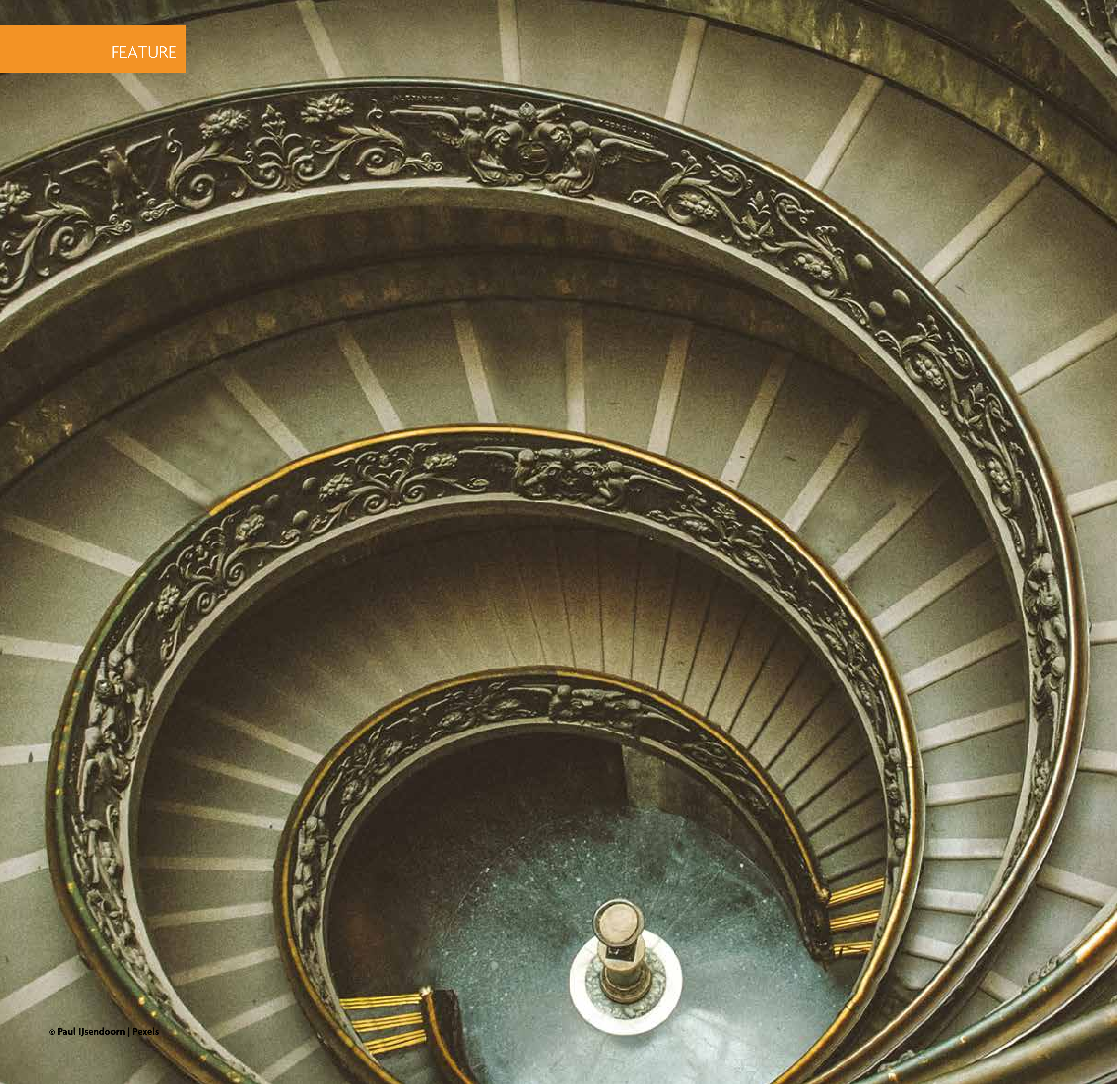

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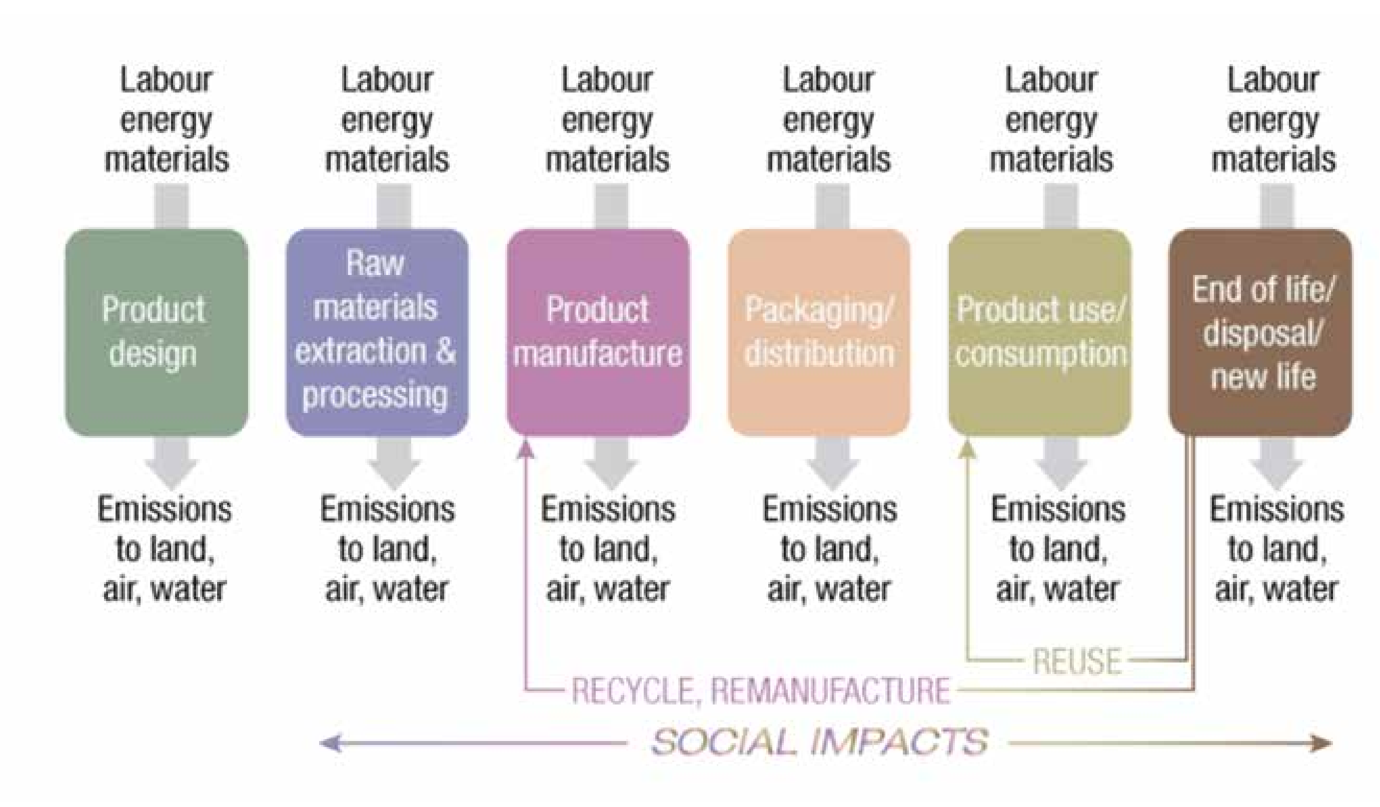
FEATURE

The circular economy in cities

David Greenfield makes the case for building circularity into urban housing at the design stages.

As 70 per cent of the world's population is projected to live in urban areas by 2050,[1] cities present sustainability challenges but also exciting opportunities for innovation. Resource recovery is one of these challenges. Collecting and processing waste (which could be a resource) in high-density environments such as cities is difficult and expensive. In the UK, the Mayor's London Plan[2] projects that by 2036 there will be an additional 1,000,000 households living within the greater London area. The vast majority of the new homes required will be medium- to high-density developments, i.e. flats. The Plan also includes a 50 per cent recycling target for London by 2020.

To achieve that goal, design, behaviour change and technological solutions that enable and encourage both households and businesses to adopt more resource-efficient and cost-effective behaviours are being developed and implemented. Proper consideration of waste management must form a fundamental part of the design and planning process for all new residential and office developments. It is essential that such consideration takes place early in the planning of new developments, as it is estimated that over 80 per cent of all product-related environmental impacts are determined during the design phase of a product[3] (see **Figure 1**).



▲ **Figure 1. Lifecycle stages[4] and the stages that are impacted by design. (© Life Cycle Initiative)**

CIRCULAR ECONOMIES START WITH COLLECTION

The circular economy concept proposes the minimisation of the amount of resource needed to provide humanity with a good standard of living, followed by high levels of recovery and redeployment of the resources we need to bring into the economy.[5] Recovery starts with collection, and the circular economy is only as effective as our means of getting resources back, whether they are building materials, plastic bottles, smartphones or organic wastes. For large waste streams, such as those from primary industries (such as mining) or large businesses (such as construction companies, manufacturers and retailers), approaches can be designed using industrial ecology and reverse logistics to secure a large level of recovery of what are often homogenous waste streams.

For households and smaller businesses, however, recovering mixed and often contaminated materials from a large number of individual properties will always pose challenges. These challenges are particularly acute in high-density dwellings and offices, for three main reasons:

- Providing enough space to store recyclable materials for the individual dwelling and then for the whole building while awaiting collection;
- Securing the buy-in of residents and office workers for the effort involved in ensuring that materials are allocated to the right containers and put out at the right times and;
- Balancing the need for regular pick-ups with the associated transport and disruption.

These questions have occupied many circular economy and recycling specialists around the world, and WRAP has been providing advice for local authorities on planning for waste in flats.[6] However, architect Nitesh Magdani, director of sustainability at BAM Construct UK.[7] says, 'I don't believe the UK construction industry has really entertained the circular economy as a serious proposition'.

UNDERSTANDING FLOWS

Key to the developer strategy is the understanding of the flow of materials during the building's operational lifetime. So, in kitchens, designing in enough containers and space for the material streams that need to be collected. New kitchens in the UK are on average the smallest in Europe.[8] If kitchen containers are needed for, say, dry recyclables, organics and residual, this pattern should be reflected throughout the building, so that residents can easily transfer what they have collected to

a bulking-up point, without having to make additional decisions or carry the waste long distances.

These flows also present on-site opportunities. For instance, if there are 1,000 units, waste generation is likely to be around 1 tonne per unit per year, based on a family of four. If 30 per cent is food waste/other organics, that is a 300 tonnes per year. If we can capture even 150 tonnes of that, there are good solutions already for what we can do *in situ* – small-scale anaerobic digestion plants can turn it into gas, and the gas turned into LPG. Food waste could have unique codes for access to a suction system, which would also weigh it, and we could reward householders for the inputs on that basis. Local collection authorities might say it is 'better' to take away, but that needs to be considered alongside the totemic effect of creating a 'circular economy' of a particular kind in just one building.

START WITH NEW DEVELOPMENTS

From my perspective, we need to start with new housing and office developments, as new infrastructure is a good place to embed new behaviours – indeed, Nicola Spurling, from the Sustainable Practices Research Group, suggests that 'material infrastructure can encourage more sustainable variants, such as homes with dedicated space for air drying laundry but not for tumble dryers. This approach, in some senses, can be seen as a more radical version of re-crafting practices'.[9] The concept can be applied to the management of recycling. New developments can act as demonstrators and provide a mindset in the partners in such developments that can then be applied to the more difficult task of retrofitting existing buildings.

The first step is to be clear about the goal. Innovative construction projects in the UK and elsewhere in Europe have variously aimed at being branded as 'circular economy', 'sustainable', 'zero carbon'. These concepts are all compatible, but the tendency is to focus on one and emphasise certain features over others. Any major construction project has many stakeholders and opinions, and many drivers (for instance 'green belt' or zoning policy, meeting local population growth, creating iconic buildings). So it is crucial to define goals at the outset, and to keep updating them.

Many buildings have been designed with an environmental focus, or to have iconic status, but they are not holistic. In the attempt to demonstrate eco-credentials it is possible to miss crucial elements. For example, there are buildings aiming to be carbon neutral

FEATURE

and showcase renewables with wind turbines built into the roof – without the architects anticipating the vibration transmitted to floors below and thus the effect on liveability. Some eco-buildings have no recycling system other than taking rubbish to the lower ground floor, with little guidance on separation for recycling and little promotion of the importance of doing so.

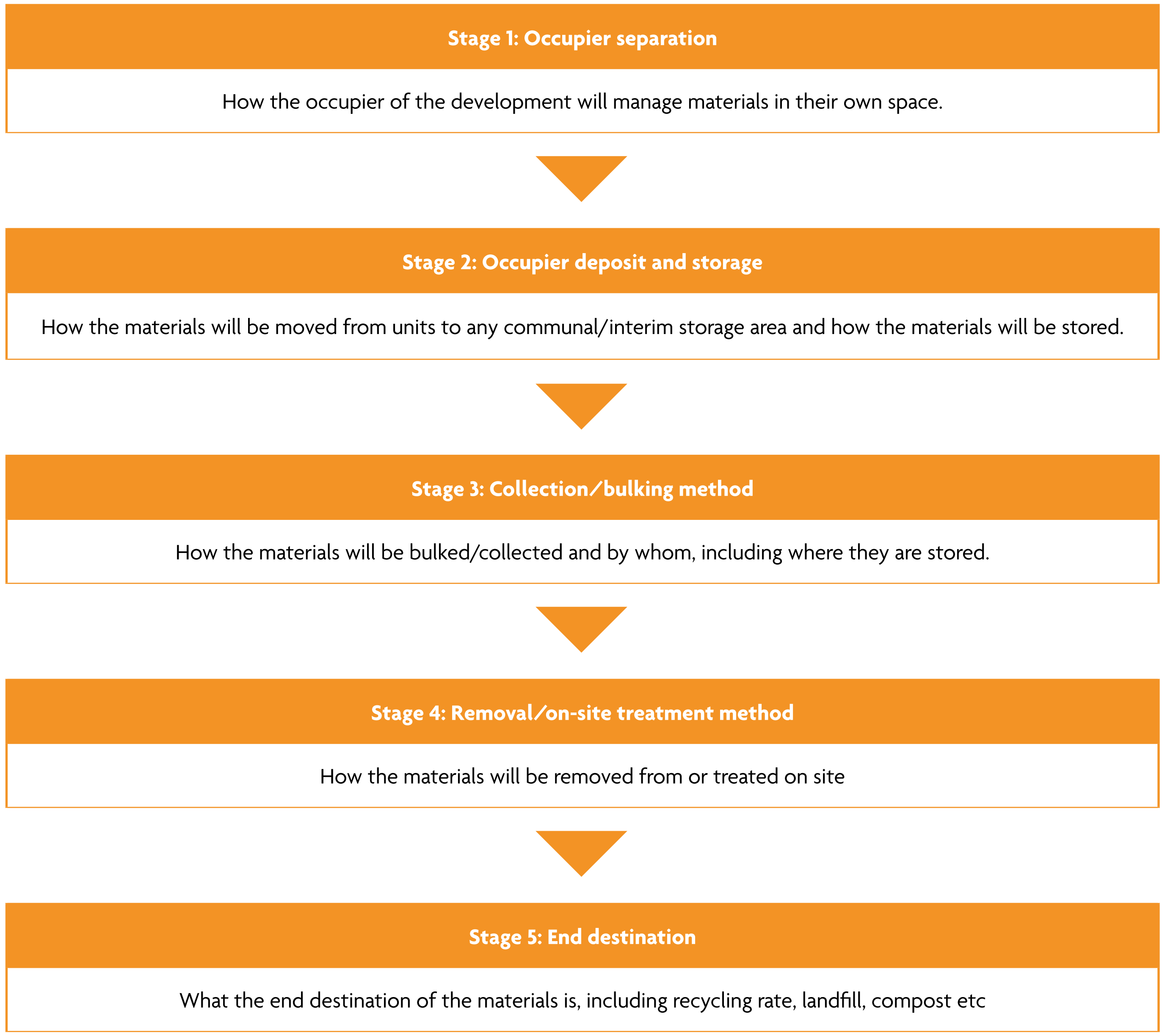
START WITH PLANNING POLICY

There are relatively simple solutions for encouraging recycling in high-density buildings, including dedicated small recycling rooms on each floor or vacuum systems in each dwelling that convey materials to a single point. The problem is that space is money, so developers will not naturally drive these ideas. Developers build to sell buildings, not to manage them, so their priorities are the price of construction, meeting regulations, and, crucially, the kudos needed for an effective sale. Sustainability is not yet a kudos factor in any very sophisticated sense, so perceptions of what is 'green' become confused and can amount to 'green bling'. Gus Alexander, in his analysis piece 'Green Bling' for Building.co.uk[10] suggests that 'everybody wants green. (Well, except for my hotelier clients. They don't seem to be very interested in green as they can't sell it. Although they can sell air conditioning.)'. This is one of the fundamental challenges: how do you make the circular economy in building design saleable?

In all new developments, waste management is by the British Standard, which is interpreted by many developers (not incorrectly) as specifying that residents must be no more than 30 m from a place to deposit waste. Against all logic, this tends to be interpreted horizontally and not vertically, so it is possible to be many floors and many metres above a place to deposit waste or recycling! In addition, as an example, all London local authorities provide planning advice for how developers should consider management of wastes.[11] There are, though, as many different interpretations of waste management guidance as there are London boroughs (33). Some are simply unclear or unspecific, some are very specific and some actively cut off particular options such as chutes and therefore new technologies such as vacuum collection systems.

In many cases, the problem is lack of discussion, between waste managers on the one side (the local authorities that shape policy and the companies that then provide the services) and developers on the other side, about how the new building will fit into the existing system. The liveability aspects are downplayed – such as the frequency of waste collection, how much storage capacity there is, and where it is. One new development was designed with only enough storage space for one day's waste, when the local system provided collection once a week.

In 2014, a consortium I formed was appointed by the London Waste and Recycling Board (LWARB) and the London Environment Directors' Network (LEDnet) to write a report, called 'Planning Recycling in Flatted Properties'.[12] By working with planning colleagues (BBP LLP) and a sustainable architect (BBM architects), we were able to produce a template for planning policy. The template ensures that the developer is asked for a waste recovery strategy at the master planning stage – any later, and these considerations cannot easily be accommodated. To complete the system, we then also developed a template called 'Waste Recovery Strategy for Developers' to help them to produce the strategy demanded by the planners' template. Developers often do not recognise that different boroughs collect different wastes for recycling using different collection methods (e.g. bins or bags, separated or mixed).



▲ **Figure 2. Planning for waste and recyclate management (David Greenfield, adapted from *Template Recycling & Waste Management Strategy for new-build flats in London*[13]).**

▲ **Figure 3. The pneumatic waste conveyance systems (PWCS) used in Singapore. (© Envac)**

KEY CONSIDERATIONS FOR PLANNERS

The Planning Template[11] lists the following points for recycling that builders and planners should take into account when designing a block of flats:

- Adequate storage (both for individual flats and the whole block);
- Separation of materials for recycling;
- Collection of materials (e.g. sacks, containers);
- Accessibility/convenience (to resident, on-site manager and collector);
- Amenity impacts, including management of odour, noise and visual impacts/design;
- Hygiene;
- Safety and security;
- Practicability of on-site treatment;
- Local authority waste-management targets (e.g. regarding recycling);
- Management of bulky waste.

Focusing on the planning process is crucial to delivering circular economy. If the right framework for planning can be established at the outset, all the opportunities for meeting recycling challenges remain open, and careful choices can be made.

One of the key outputs from this work was a Template Recycling Planning Policy for all London boroughs (where there is a great deal of new building). If followed, it means that every London borough will provide a consistent response to the building developers. There is no point in the developer presenting their waste strategy if the interpretation does not match the planning authority's. To complement the planning policy, a template strategy was also developed to guide developers through series of stages (see **Figure 2**):

If all planning authorities adopted the template policy, which essentially asks developers for a waste and recycling strategy at the master planning stage, then having a consistent strategy would reduce the admin burden and ensure local authority waste managers, planners and developers were all working from the same benchmark.

USING WASTE

Ultimately, we need to see waste as a utility, alongside gas, electricity and water, and consider how they are linked. Where a lower ground floor is being used for existing services, it could also be dedicated to materials recovery. Or it might be possible to use lift shafts for moving both energy and materials, freeing up floor space. Water could be stored on the top floors of buildings, using gravity to move it around, or stored it under buildings, using energy from waste (e.g. combined heat and power [CHP] plants burning unrecyclable wastes) to pump it around.

There is the option of using vacuum systems – which do work and are gradually recovering from their bad reputation from malfunctioning early versions (see **Figure 3**). They are not the only solution, but they should be considered as they do promote good materials management in the home as they are easy to use. For medium and large developments, the civil engineering costs of putting in a basement for bins is about the same as a vacuum system, according the International Solid Waste Association (ISWA). By contrast, the operational cost of transporting waste is higher.[14] The concept that technological systems can be as cheap, if not cheaper, needs to be considered at an earlier point.

GENUINE EMBEDDING

To truly embed the most productive behaviours, there are emotional considerations as well as technical, again to be considered at planning stage. People may be prepared to put nappies in designated containers, but would they feel the same about incontinence pads, if that fact were visible to neighbours? Which materials do people feel comfortable handling, and which not? We have to understand deeper attitudes to wastes and materials.

And if our premise is that people moving into new developments are more open to change, we need to understand whether the new behaviours last, or whether people revert to old habits.

The key to overall embedding is to condition planning policy from the very centre, i.e. the overall planning policy frameworks. These should be providing guidance on planning that consciously embeds circular economy approaches in buildings, and includes flow analysis and a joined-up materials storing and collection strategy. This a very different mindset to asking simply, 'How shall we get rid of waste?' ES

Dr David Greenfield FCIWM, CEnv, FRSA is Managing Director of Social, Economic & Environmental Solutions (SOENECS) Ltd, European External Affairs lead for the Circular Economy Club (CEC) and chair of the Institution of Civil Engineers (ICE) Expert Resource Management Panel.

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OPINION

If you’re bothered by plastic in the ocean, take a minute to consider why it’s there

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Julie Hill talks to **Mike Webster,** Chief Executive of WasteAid, a charity set up to share waste management and recycling skills in the world’s poorest places.

Why is WasteAid needed?

For a long time, the problems of solid waste management in low-income countries have been ignored. One of the triggers for WasteAid was the 2015 UNEP *Global Waste Management Outlook*.[1] It produced the terrible statistic that two billion people don’t have any form of waste collection, and another billion might get their waste collected, but its disposal is uncontrolled. We know that living surrounded by waste leads to chronic as well as acute health problems, so WasteAid was set up to raise awareness and mobilise help. It really took off after the ‘*Blue Planet* moment’ and the increased concern about plastic – because plastic in the ocean is primarily a symptom of poor waste management on land.

How does tackling waste in the countries you work in differ from the UK?

In the UK we are used to having our bins emptied on a regular basis and assuming that what follows is proper waste treatment. In a lower-income country, that doesn’t

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always happen – municipalities either can't or won't collect the waste. They may not have the money, because they are not collecting taxes, for instance. So we partner with local organisations and we go and talk to people about waste – why it matters that there is a burning pile of rubbish outside their house. The answer is that kids growing up in dirty environments have respiratory and cognitive problems, amongst other effects. Those kids won't thrive, so countries won't develop.

Reframing waste in this way gets the development sector to take notice and, crucially, to focus on locally appropriate solutions. In the 1970s, 80s and 90s a lot of money was spent bringing energy from waste plants to some countries, but these failed because they were wrong for the mix of waste (it is too organic, too wet). Also, the plants are expensive and there is insufficient regulation of pollution. So a different approach is needed.

So what's your model?

We started by getting good exemplar projects going, initially in Gambia, Kenya and Cameroon. We are beneficiary led. Local organisations contact us for help – they might be church groups, women's groups, a variety. We go to see them to understand what kind of waste they have, what kind of things people are buying that then become waste and who will be on board with improving the waste management. The aim is to build the capacity of local organisations to deal with the waste: we train them to be trainers, advocates and leaders – people who will then challenge unsafe disposal. If the local government is against it, it is hard to make progress, and it can take years to get funding, but it has been hugely successful. We always work with local partners, to be confident that the practices we help them to establish will endure.

In effect, you are establishing local circular economies?

What happens to the waste differs. In Kenya, for instance, near cities there are markets for paper, plastic and metal, so these materials are collected by our partner organisations, bulked up and sold on. Our central aim is financial sustainability – one project is 80 per cent towards that by clever upcycling, such as turning glass bottles into drinking glasses. And the benefits become clear very quickly – in one project we've seen a 60 per cent drop in gastroenteritis in the population.

Can this approach be scaled up?

Certainly. We have set up our projects as exemplars and hubs, and people travel a long way to see them and take ideas back to their communities. We also have an online toolkit, funded by the Chartered Institute of Waste Management. Our work has to be catalytic because we can't be everywhere at once.

▲ © WasteAid, Ecobricks from Siem Reap, Cambodia.

You must be very proud of your work. What does your job find you doing on different days?

Almost no one chooses waste as a career when they are a kid! But it is a hidden gem and a growing sector – once into it, you realise it touches every aspect of life. My work embraces everything from social marketing and behaviour change to technical expertise, chemistry and finance. And once you get interested in waste prevention, you realise it challenges some fundamental values of our society – do we really need all this stuff? But it is hard work. I spend one week in four travelling, so it takes commitment.

What could we learn from lower-income countries?

The benefits of more localised waste management. Our mixed recyclables are collected and go to a huge plant. In the process, a lot of value is destroyed and reuse is minimal. In lower-income countries it is sometimes easier to make a proposal to local government and have, for instance, a small anaerobic digester on the edge of every town or link up with informal waste collectors. In India there is an established system for informal waste collectors: they collect the waste and then call someone to pick it up to be taken for processing. Why can't we do that? Our ultimate vision is total community solid waste management – collection and segregation followed by reuse, recycling or composting locally, as appropriate. Then, for final disposal, a community landfill site – in a site where it can be properly controlled.

If you could solve one big issue, what would it be?

Waste changes as countries develop, and plastic becomes more prevalent. The deposit–return systems that used to ensure that glass was recaptured and refilled are disappearing. So plastic should carry a deposit, preferably also to be refilled, as food-grade recycling is expensive and hard to access in lower-income countries. I would like to see the big drinks companies establishing return systems.

Any thoughts about how members of the IES can help?

Get involved – think about waste as a career. We also need help with the evidence base for waste – in particular, evidence to link poor solid waste management to poor health outcomes. We have had a huge focus on the effects of plastics in the oceans, but in my view, the human impacts should concern us the most. ES

Mike Webster is co-founder and CEO of WasteAid. He holds a BSc in Environmental Science from the University of East Anglia, and a Master's degree in Environmental Economics from the University of York. In 2017 he was voted the top waste and resource influencer in the UK by his peers.

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FEATURE

The role of retail

Dorothy MacKenzie outlines the evolution of the relationships between producers, retailers and users.

Transitioning to a circular economy will require change in many areas – product design, manufacturing, service relationships, distribution infrastructure and logistics, as well as our everyday behaviour. Changes will be radical and far-reaching, well beyond the small ripples that are the result of the current focus on recycling and waste management. One aspect of these changes will be new roles and responsibilities for producers, retailers and citizens working with new business models and new relationships. Brands will play a big role too, using their reach and influence to create a new, *circular* normal and provide the information, engagement and incentives that individuals will require.

CONSUMERS AT THE CENTRE

Circular economy systems require changes in our consumption behaviour and will be more achievable if we are engaged and motivated to participate. Customers have considerable power through the expansion of available choice and access to information – power that could transform markets.

There is now a strong body of attitudinal research showing people's concern and their belief that their personal actions can make a difference.[1] They expect companies to take a lead in facilitating this.[2] However, despite very high levels of concern about issues such as climate change and waste, a high proportion of people fail to take even limited steps to reduce their impact.[3] Research exploring consumer attitudes and behaviour towards circular systems designed to reduce waste and carbon

FEATURE

impact shows low actual participation, but significant willingness to engage if the offer is right. A study for the EU's Consumers, Health, Agriculture and Food Executive Agency (Chafea) in October 2018[4] showed that up to 25 per cent of people across Europe are willing to engage in circular economy practices such as leasing or renting in markets for items such as phones, durables and clothing if they see personal benefits, including lower prices, greater convenience or superior performance.

OPPORTUNITIES FOR INNOVATION

The obvious discrepancy between people's beliefs and intentions and their actual behaviour requires that consumers are placed at the centre of thinking about circular offers and models. Technical solutions and new business models will succeed only if they reflect deep insights into people's needs, problems and perspectives. The starting point for creating new circular systems should be the consumer – focusing on the end benefits that people want and need, rather than on the products and business models that currently deliver these. For example, people's desire to feel fashionable could be better addressed by renting clothes than by purchasing them; people's need for convenient urban mobility might be addressed more practically through occasional access to a shared vehicle than by car ownership. Renting furniture from IKEA, with the ability to change items when office or household needs change, could deliver the functions of furniture more efficiently and desirably. Younger people are leading the way in sharing products and accessing them in different ways, attracted by economic and convenience benefits, and by increased opportunities for social interaction.[5]

There are many products that are truly consumed: food, toiletries, medicines, for example, where we will continue to frame people's primary role as 'consumer'. But for many other products, 'user' will be a more useful and more accurate description, bringing with it a new set of opportunities, benefits and responsibilities. Products may have different owners at different stages of their life within a circular system, with the potential for extended product life and the realisation of greater value from the same resource, benefiting consecutive 'temporary owners'. This could lead to a greater sense of user responsibility for maintaining value through repair and restoration.

Users will become product re-sellers, either to other users or back to the original producer. Across a wide range of sectors, from packaging material to clothing, users will become suppliers of essential resources to producers that will no longer be able to rely on unlimited supplies of virgin materials. This gives users new potential power, and requires producers to consider carefully how they incentivise product or packaging return. However, in some sectors, leasing or renting models may be preferred to sales, with maintenance services outsourced and products upgraded to enhance performance as technology develops, and users becoming service users rather than product owners.

COMPREHENSIVE INNOVATION

Many producers have been adopting circular economy principles for some time, realising the benefits these can deliver in terms of cutting resource use and costs, and increasing revenue from drawing more use from existing resources. The next stage will see big changes to products, new impetus behind the product to service transition and a shift towards greater collaboration within and across industry sectors.

The most important emerging roles for producers in the circular transition will be as innovators and designers, creating the new materials, new technologies, new business models and new behaviours that will be needed for system change. This will require not only technical creativity but also a commitment to design thinking, placing user insight at the heart of building new offers and models to design a total experience that covers user behaviour as well as product design. Designing for product longevity, reparability or upgradeability will require engineering expertise, but also an understanding of user attitudes, skills and expectations.

Servitisation (where manufacturers focus on delivering benefits and outcomes to customers rather than on selling products) has been an aspiration for producers

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in many business-to-business categories for years. This approach offers the potential for differentiation and added value through service delivery and tailoring offers to customer needs, helping to counter the threat of commoditisation, where indistinguishable products are sold on price. The move towards circular systems will accelerate this, and expand servitisation further into consumer markets. Circular systems based on service provision will lead to higher levels of interaction and engagement between producers and users leading to opportunities for closer, longer-term relationships as well as richer insights that will help to identify opportunities for innovative offers.

COLLABORATIVE WORKING IS ESSENTIAL

An essential aspect of a circular economy is that it keeps the value of all materials at their highest by applying the principles of regenerative and restorative design, with waste viewed as a valuable resource. This requires high levels of cooperation within supply chains, but also between different sectors and even between competitors. Many of the current circular economy initiatives, such as the Ellen MacArthur New Plastics Economy and Make Fashion Circular, involve collaboration around issues such as the restriction of material choice to improve recyclability or the acceleration of technological development to enhance traceability.

All participants in circular systems also have an interest in encouraging others – such as customers – to adopt a circular mindset, and therefore there will be shared interests in working together to encourage appropriate infrastructure development or align around common standards. Working collaboratively may of course restrict the scope of competition, but could focus competition on areas that are useful and productive in terms of both customers and the environment. For example, rather than considering a differentiated plastic resin with minor cosmetic benefits in packaging to be a worthwhile focus for innovation, a personal products producer might instead focus on innovations in product sourcing transparency.

REINTERPRETING RETAIL

Bricks-and-mortar retailers in particular face huge challenges due to high levels of competition and customer volatility. The circular economy offers them an expanded role and many new opportunities for revenue generation with the potential for improved customer loyalty and retention.

The primary role of retailers within the linear economy is to distribute and sell new products. Within the circular economy, retailers have a much broader role to play, and pioneers are already exploring this. There are opportunities to increase the frequency of customer interaction by providing services such as refills or repairs. H&M is piloting a clothes repair service in store, providing added value to customers as well as additional revenue and increased footfall in store for themselves. BestBuy offer take-back and trade-in services for used electronic equipment, encouraging customers to come into the store rather than buy online. The equipment is either refurbished and resold or recycled. Many other retailers are facilitating the reselling of used products, offering customers the opportunity to reclaim economic value from their unwanted product as well as broadening access to new customers who have the opportunity to buy products at lower prices. The clothing retailer Patagonia sell their Worn Wear range of used products in store at prices that make their range more affordable.

PA Consulting's report *Keeping Customer Connections*,[6] based on research conducted with Cranfield University and Arizona State University, suggests that retailers that help customers sell, donate or recycle items can generate increases in customer loyalty. Two-thirds of people said they would resell clothing or electronic goods if their retailer facilitated this. Deeper, more continuous relationships with customers will also offer retailers richer understanding of their needs and problems, providing insights into new opportunities for service provision and revenue generation.

Retailers with physical locations have recently struggled to demonstrate their relevance, in an era where online shopping provides high convenience and flexibility. As active facilitators of the circular economy, retailers can find new ways to show how they can make people's lives easier and better. This is happening already in a limited way, where retailers have provided solutions for parcel collection, charity donations or easy recycling of products that are otherwise problematic, such as batteries or clothing. There is the potential for this role to expand, with some retailers becoming community hubs that offer repair services, equipment sharing, communal purchasing or even food sharing.

A further role for retailers within a circular economy is in user education, where there is an opportunity for retailers to help people make informed choices about what they use and how they use it. Some retailers may find opportunities in providing warranty services around the re-sale of used products, acting as trusted intermediaries to facilitate product repair, re-use and remanufacture.

BRANDS CAN USE THEIR INFLUENCE

Big brands have an important role to play in making circular behaviours aspirational and normal by leading the way. The Loop reusable packaging system offered by TerraCycle is a good example: major brands such as Häagen-Dazs, Crest and Tropicana are offered in durable, refillable containers delivered to people's doors. Whether or not this system is adopted more generally, the participation of mainstream brands is important in signalling that circular is a major trend rather than an exclusive niche.

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Brands understand the importance of effective communication through stories that connect on an emotional as well as a rational level. Within the small community of circular economy 'specialists' there has been a tendency for the circular economy to be framed in highly rational, technical and economic terms. However, to engage well with a broader audience it is important to make circular accessible and relevant, drawing on more human-centred stories around sourcing, usage, remanufacturing, reinvention – emphasising the benefits to the user of the circular offer rather than focusing only on environmental benefits. Finding the right language to describe different circular models will also be important in winning acceptance. In their report,[6] PA Consulting suggest that, for example, the term 'leasing' is less appealing than the idea of being part of 'club', while 'refurbished' is preferred to 'second-hand'.

The circular economy offers a powerful stimulus to re-think how we produce and consume, creating many challenges but also real opportunities for producers, retailers and consumers to find new roles and new sources of value, in the process building new relationships with each other for mutual benefit. ES

Dorothy MacKenzie is the Founder and Chair of the London operations for global brand consultancy Dragon Rouge, one of the Knowledge Partners to the Ellen MacArthur Foundation. Dorothy has written and spoken widely on sustainability and the circular economy. In 1997 she updated her 1991 book *Green Design: Design for the Environment*, a guide to design best practice. Recently she contributed to *Longer Lasting Products: Alternatives To The Throwaway Society* and *The Handbook of Design for Sustainability.*

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Guest editor Julie Hill

Editor Adam Donnan

Subeditor Caroline Beattie
carolinebeattie.editorial@outlook.com

Designer Kate Saker
katesaker.com

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Tel +44 (0)20 3862 7484
Email info@the-ies.org
Web www.the-ies.org
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