Plastics are now the most widely used materials group in the world. Global production of plastics has increased twentyfold since the 1960s, reaching around 360 million mt\(^1\) in 2018 (Garside 2019). By 2050, these figures are expected to quadruple (Qualman 2017). The extent to which plastics materials are used, combined with many of the products being intended for single use, has given plastics a bad name but the fault lies with us rather than with the material itself. This chapter explores the scale of production, its environmental consequences, the human role in the creation of the plastics waste mountain, the value widely attached to the plastic things that form it, and ways of addressing the problem.

Plastics are contradictory materials, variously considered as useful and adaptable, but also often considered to be cheap and throwaway. This perception grew more prevalent in the 1950s with the rising use of plastics in various applications, including toys, consumer goods and the increasing proliferation of packaging. Another less common viewpoint is that modern plastics may be expensive and highly engineered materials designed to perform in challenging environments and to demanding standards, whether in high-tech applications such as aerospace, high-end sporting
equipment, electronics, or highly specific medical uses such as bioengineering. During the 2020 Coronavirus pandemic, plastics have become of vital importance for use in certain items, including personal protective equipment for medical and care staff and in ventilator components. Some commonplace perceptions of plastics actively misrepresent their value and discourage their sustainable use, reuse, recycling and disposal. Provoking a transformation in customary attitudes towards plastics and their perceived value may well help to cultivate a sense of social responsibility towards them.

Only in the last twenty years, have Britain and Western Europe become more attuned to the idea of social responsibility related to the manufacture, use and disposal of plastics. From the 1950s onwards, the main emphasis was on the modernity, convenience, practicality and cheapness of plastics compared with more traditional materials. Elsewhere attitudes have varied and sometimes ‘elsewhere’, notably the oceans, has increasingly become garbage dumps for those plastics that ‘we’ choose to throw away (Fig. 15.1).

Plastics’ pollution in oceans has evoked widespread outrage in the media and public attitudes towards this blight on our natural environment.

Fig. 15.1 Classic example of a catcher beach along the shores of Hawaii. (Photo: NOAA)
are hardening. Plastics waste is rising annually, mainly due to increasing consumption of ‘single-use’ plastics, including packaging and other mass-produced consumer items discarded after one use, and rarely recycled. The most vilified items have been plastic water bottles, packaging, and bags: recent research found 122 million plastic bags along 5000 km of European coastline (Environment and Energy Committee 2019, 20; SAPEA 2019).

**Reflecting Back**

Plastics are often considered to be a twentieth-century phenomenon, beginning with the first phenol formaldehyde-based synthetic plastic, Bakelite. However, plastics have their semi-synthetic roots in the mid-nineteenth century with vulcanised rubber and cellulose nitrate-based materials such as Parkesine. Even earlier are the natural plastics, materials that could be formed under heat and moulded into various forms, notably horn and tortoiseshell.

Throughout the development of plastics, their makers and users have varied in their approach to social responsibility. From 1877 onwards, the British Xylonite Company marketed their products as an alternative to the increasingly rare and expensive elephant ivory and tortoiseshell, revealed by their company logo showing an elephant and a tortoise. However, as early as the 1909 patenting of Bakelite by Leo Baekeland, likened to a Grand Duke and wizard (Kaufmann 1968), there seemed to be little thought given to the sustainability of this thermosetting material which is made from hazardous chemicals and has to be ground down to be recycled. By the 1920s, The Bakelite Corporation was promoting Bakelite as a magical material. The extravagant language continued. *The Bakelite story* (Mumford 1924) was so fulsome in its praise that even Baekeland thought that there was ‘Something not quite right about it’, distancing himself from the account (LHB 1924). In 1924, The Bakelite Corporation issued *A Romance of Industry*, a booklet aimed at female consumers, using imagery such as the genie lamp, again emphasising the magical theme. In 1937, The Bakelite Corporation’s self-aggrandising film, *The Fourth Kingdom*, placed Bakelite on the same level as the animal, vegetable and mineral kingdoms, celebrating Bakelite’s ‘magical’ qualities and as ‘a material of a 1000 uses’.

Perhaps this highly optimistic approach to the new world of plastics informed the later thoughts of French philosopher Roland Barthes, who, in 1957, referred to plastics as a ‘magical substance’ capable of ‘infinite
transformation’ (Barthes 1972). This contradicts the viewpoint of those modern environmentalists who have demonised plastics, recording plastics garbage littering land and sea with increasing frequency and passion. With up to 8 million mt of plastics waste being dumped in the oceans each year adding to the estimated 150 million mt already present, the modern perspective deserves very serious consideration as does the urgent need for steps to be taken to diminish these figures for ocean plastics waste (Ocean Conservancy 2020).

**ACTION AGAINST PLASTICS WASTE**

In 2018, UK Prime Minister Theresa May tweeted: ‘In 2015 we introduced the 5p charge on plastic carrier bags, we now see 9 bn fewer bags being used. It’s making a real difference. We want to do the same with single use plastics. Nobody who watched #BluePlanet2 will doubt the need for us to do something—and we will’ (May 2018). Although there is debate as to how effective plastics bans really are. The UN estimates that at least one trillion plastic bags are made globally, so bag production is still a large use of a precious feedstock resource, namely oil (Parker 2019a).

In 2018, the UK’s London *Evening Standard* newspaper campaigned to reduce or remove the use of disposable plastics straws (Prynn and Edwards 2018), and in 2019 the UK government confirmed a forthcoming ban on them (DEFRA 2019). Pressure is increasing to reduce the amount of single-use plastic bottles. Notably, the 2019 Glastonbury festival organisers encouraged visitors to bring their own refillable water containers and banned the sale of single-use plastic bottles (Herbert 2019; Marsh 2019). Some local UK councils are increasing the availability of drinking water fountains as are public venues such as airports.

Quantities of plastic-stemmed cotton-buds in plastics waste resulted in the cotton bud project and related legislation to ban plastics stems. Cotton buds were banned in Scotland in 2019 with EU plans to ban them in 2021.

Single-use PPE such as masks and gloves, which have become so essential during the 2020 Coronavirus pandemic, are now proving problematic when disposed of carelessly (Allison et al. 2020).

The use of microplastics has provoked debate. These plastic particles, smaller than 5 mm, are used in body scrubs, toothpastes and other cosmetic applications. Microplastics have been found to accumulate in the sea, where they are ingested by marine life. The UK banned the use of microplastics in 2018 (Carrington 2018).
There are also concerns about microfibres entering the environment and the animal kingdom through water routes: ‘Tiny plastic particles washed off products such as synthetic clothes and car tyres could contribute up to 30% of the “plastic soup” polluting the world’s oceans and … are a bigger source of marine plastic pollution than plastic waste’ (IUCN 2017; Boucher and Friot 2017; Cole et al. 2011).

In the USA, Perfluoroalkyl and polyfluoroalkyl substances (PFAS) have been banned in food packaging as they have been found to be harmful, commencing with a ban in California on 1 January 2020, with other bans to follow (Vorst 2020; Safer States 2020; Ross 2019).

China noted the value of waste plastics and took steps to acquire and repurpose the plastics that Europe and North America threw away. By 2016 China was importing 45% of the world’s plastics waste (c.10225 mt) (Brooks et al. 2018). Until the end of 2017, Britain shipped up to two-thirds of its waste plastics to China for recycling: about 500,000 tonnes a year (Taylor 2018a). However, Chinese processing facilities became overrun with vast quantities of contaminated materials, creating an environmental problem (Katz 2019). Thus, from 1 January 2018, China banned imported plastics waste (Hataway 2018). This ban is challenging for the EU and the USA and has greatly impacted on the UK’s recycling industry (Bodkin 2018). In reaction, the UK and some other developed countries have begun to send their plastics waste to other Southeast Asian countries, such as Thailand and Malaysia. Consequently, some Chinese recyclers have seized the opportunity to open new processing plants in nearby countries (UNEP 2018). Longer-term, local solutions to deal with local waste would be preferable.

Future sustainability depends on increasing the awareness of individuals, organisations and government departments of what happens to their waste plastics. This will enhance social responsibility at all levels. Efforts made at every scale can help manifest a transformation in the way we look at our ‘waste’ material and see it from a different perspective. The future archaeologist (or garbologist) may excavate landfill piles of waste plastics, regarding their finds as treasure. Alternatively, plastics mountains may become a source of fuel or material to be recycled and turned into new plastics.

To help meet these challenges, the 2015 strategy document entitled ‘A Vision for Europe’s New Plastics Economy’ promulgated: ‘A smart, innovative and sustainable plastics industry, where design and production fully respects the needs of reuse, repair, and recycling, brings growth and jobs
to Europe and helps cut EU’s greenhouse gas emissions and dependence on imported fossil fuels’ (EC 2018a, 2019b, 5). Certain individuals and companies have led the way with a more sustainable approach, whether in manufacturing clothing made from recycled PET bottles or furniture made from waste plastics packaging. MIT has converted discarded plastic soda bottles into solar bottle bulbs to help light thousands of homes of the poor in the Philippines. The ‘bulb’ is made from a one-litre soda bottle filled with purified water and bleach, inserted tightly into a house roof. The clear water disperses the sunlight and functions like an electric light bulb, costing only 2 or 3 dollars (Oshima 2011; Chen et al. 2014).

The integration of designers into initial product design at earlier stages of projects has contributed a more coherent approach to plastics manufacturing. Credit in the UK for supporting this methodology goes to the government-funded Knowledge Transfer Network. Since 2005, it has facilitated introducing designers to industrial and materials’ manufacturers to grow mutual understanding, increase comprehension and collaboration, and develop this interdisciplinary community (KTN 2020). The KTN are partners with the Materials and Design Exchange, which publishes the Journal MaDE® (Materials and Design Exchange 2020).

Plastics Waste and the Great Pacific Garbage Patch

Nonetheless, the plastics waste mountain is forever growing. About 8.3 billion mt of plastics have been produced worldwide since the 1950s, reflecting the enormous increase in their use for packaging. Annual global plastics production reached almost 360 million mt in 2018 (PlasticsEurope 2019, 14) with until 2017, only 9 percent of these plastics being recycled (Sönnichsen 2020).

In 2018, the EU produced almost 62 million mt of plastics. Almost 39.9% of the 51.2 mt of plastics converted in Europe’s manufacturing plants went into packaging; 19.8% went into building and construction, the second-largest application of plastics (PlasticsEurope 2019, 20). The recycling and recovery rate of packaging waste doubled from 2006 to 2018, with over half the EU countries recycling above 40% of their plastics packaging, although annually plastics waste is still increasing (PlasticsEurope 2019, 31). In 2018, Europe collected 29.1 million mt of total plastics waste, of which 32.5% was recycled, 42.6% went to energy recovery and 24.9% to landfill (PlasticsEurope 2019, 29).

Packaging waste comprised 17.8 mt of this total: 7.5 (42%) mt were recycled, 7 (39.5%) mt went into
energy recovery and 3.3 (18.5%) mt into landfill. In 2019, the EU reused less than 12% of its recycled materials so it is encouraging that ‘Work is ongoing to review the essential requirements for packaging, which will aim at improving design for reuse and high-quality recycling of packaging materials’ (EC 2019a, 1, 2).

Legislation has raised plastics packaging recycling levels. The EU has issued a series of packaging laws, key being the 1994 Directive 94/62/EC on packaging and packaging waste legislation. It focused on minimising the creation of packaging waste, promoting the reuse, recycling and recovery of energy from packaging and avoiding single use packaging. Subsequently EU Directive 2018/852 amended Directive 94/62/EC setting the minimum recycling target for plastics in packaging waste at 50% by 31 December 2025, rising to 55% by weight by 31 December 2030 (Packaging Waste Directive 2018).

Why is this legislation so important? The world’s annual consumption of plastics materials increased from around 5 million tonnes in the 1950s to nearly 360 million mt in 2019 (Garside 2019). In Europe, in 2018, 24.9% of the plastics waste ended up in landfill, and contained 3.3% packaging. This is an improvement on EU 2006 figures when 7.2% of plastics packaging waste went to landfill, but globally the picture is not so optimistic. Worldwide, 40% of plastics waste goes to landfill with a plastics consumption of 45 kg per head (Wang 2020). It is estimated that, buried in landfill, a plastic bottle or bag will take up to 1000 years to decompose. Also degrading plastics may leak pollutants into the surrounding soil and water. Alternatively, carelessness may lead to plastics waste ending in the oceans which already contain an estimated 150 million mt of floating plastics debris, with quantities entering marine and bird life, proving hazardous to their health and sometimes even fatal. The icon of the British media, Sir David Attenborough, brought wider recognition to this issue in the 2017 Blue Planet II television series (Blue Planet II 2018). In response, on 22 November 2017, the British government undertook to penalise single-use plastics via tax measures. Former Chancellor of the Exchequer Philip Hammond stated: ‘I want us to become a world leader in tackling the scourge of plastic’ (Gabbatis 2017). The British Plastics Federation commented: ‘plastic needs to be used responsibly and where it provides value—and ultimately recycled in all cases where possible … .We can all make a difference’ (BPF 2020).

The UK annually generates nearly 5 million mt plastics, of which 2.4 million mt is packaging (WRAP 2019, 2; House of Commons 2020).
In 2019, authorities collected approximately 550 kT$^2$ of packaging waste, 10% more than 2013–2014. Only two types of plastics are consistently recycled: polyethylene terephthalate (PET) and high-density polyethylene (HDPE). The UK Plastics Pact, launched in April 2018, aims to create a circular economy for plastics packaging with 2025 goals for plastics packaging to be 100% reusable, recyclable or compostable and the elimination of ‘problematic or unnecessary single use packaging … through redesign, innovation or alternative (reuse) methods’ (WRAP 2018).

Some European countries still use landfill extensively for waste plastics. In 2011, the European plastics industry launched the initiative ‘zero plastics to landfill’, to reduce the amount of post-consumer plastics waste sent to landfills to zero by 2020. This target has not been met. Seven EU member states have introduced landfill bans on plastics waste although, following their bans, incineration rates increased in the Netherlands, Germany and Denmark (Zero Waste Europe 2015). By 2016, the EU plus Norway and Switzerland had collected 25.1 million mt of post-consumer plastics waste, a recovery rate of 72.7%. The highest recycling and recovery rates were for plastics packaging; and, in a first, more plastics waste was recycled than landfilled. In 2018, the EU sent 7.2 (24.9% of total) million mt of plastics waste to landfill (PlasticsEurope 2019, 28). The target date of 2020 ‘zero plastics to landfill’ was modified to 2025 as was the mandatory separate collection of all packaging from residual waste, both by the year 2025 (Bioplastics 2016).

However, there is an ongoing problem. In 2011, 61.5% of UK beach litter was plastics and, in 2015, the Marine Conservation Society recorded 160 plastic bottles per mile of UK coastline they had cleaned (Marine Conservation Society 2013, 8; Daniels 2016, 7). In 2018, a million volunteer-strong initiative to clean up beaches, involving 120 countries, found plastics food packaging was the most common form of rubbish (Parker 2019b).

Globally, much of the plastics found in the oceans travels there from ten rivers, running largely through areas with no rubbish collection facilities nor programmes to turn waste to advantage, including the Yangtze, Mekong and Indus rivers (MoDiP 2020). Captain Charles Moore observed in 2003, while sailing back to Long Beach, California: ‘… we decided to take a shortcut through the gyre, which few seafarers ever cross. … Yet as I gazed … at the surface of what ought to have been a pristine ocean, I was confronted, as far as the eye could see, with the sight of plastic’ (Moore 2003).
About 54% of the Great Pacific Garbage Patch (GPGP) debris originates from land-based activities in North America and Asia. The rubbish takes about six years to reach the GPGP from the coast of North America and a year from Japan and other Asian countries (National Geographic 2020). Most of the remaining garbage is fishing gear such as ropes and nets dumped by sea vessels (National Geographic 2019). In 2018, the GPGP was estimated to contain nearly 80,000 tonnes of plastics in 1.6 million square kilometres (Gabbatis 2018). By 30 April 2020, it had reached almost 2 million square kilometres, growing at a rate of almost 350 square kilometres daily (The World Counts 2020). It is the largest of five such subtropical garbage patches (gyres) found worldwide (The 5 Gyres Institute 2020). Due to their growing use in increasing numbers of goods, plastics make up the largest proportion of ocean waste. That many plastics products do not biodegrade in sea water but instead break down into smaller pieces is also problematic.

**NEW APPROACHES, FUTURE STRATEGIES AND TECHNOLOGIES**

An alternative to recycling or burying plastics is converting them into crude oil or other types of liquid fuel through pyrolysis, using high temperature techniques. American company Agilyx produces processing units that can be placed where the plastics waste is collected, for example, in municipal waste facilities. This system transforms ground, unsorted plastics into synthetic crude oil which can then be refined into ultra-low sulphur diesel, gasoline, or jet fuel and into synthetic lubricants and greases. Some of these products can then be turned back into plastics. In 2018, Agilyx adapted their pyrolysis technology to produce a naphtha base-stock which may enable the production of olefins from recycled materials. One potential product might be feedstock for polypropylene, the plastic most in demand worldwide (ICIS 2018).

Waste plastics can also be burned in waste-to-energy (WTE) plants which recover energy and reduce the quantity of plastics in landfills. Inorganic carbon in plastics does not decompose through anaerobic digestion processes, so there are no emissions if it is landfilled (Lee et al. 2017, 340). WTE processes using non-recycled plastics, release carbon into the atmosphere during fuel production and combustion processes as in other WTE technologies. Such a WTE plant is situated in Baltimore, USA.
(Wheelbrator Technologies 2020). These plants produce electricity and heat in boilers, which are designed for complete combustion and are reported to produce electricity ‘with less environmental impact than almost any other source of electricity’ (Sustainable waste solutions 2020). However, they are often perceived locally as blights on the landscape and accused incorrectly of giving off noxious fumes. Better design would improve the first and the ‘noxious fumes’ misperception could be eradicated by better public education.

A 2009 report on converting plastics waste into a resource described the production of gaseous fuels by using high temperatures to decompose plastics waste, obtaining solid fuel, from a mixture of waste plastics, wood and paper (UNEP 2009). The forecast is that energy recovery will become the second-largest plastics waste destination in the future. The main impetus for this in Europe is the Waste Framework Directive revisions stipulating a limit of 10% waste going to landfill by 2030 (EC 2019b). In 2018, Europe sent 42.6% of its plastic waste to energy recovery.

It is also important to develop new ways of making plastics not dependent on fossil fuels. Innovative research is ongoing into plastics based on natural materials including cellulose, algae and bacteria, a field known as bioplastics or biopolymers. Bioplastics are made from renewable feedstock, some being biodegradable or compostable. An early example is ICI’s Biopol, first commercialised in 1990, made from polyhydroxybutyrate (PHB), obtained from the bacterium Alcaligenes eutrophus, and degrading to form carbon dioxide and water (ICIS 1991; New Scientist 1990). Some other bioplastics are based on foodstuffs such as sugar, starch and corn, including polyhydroxyalkanoates (PHA), polylactic acids (PLA), thermoplastic starches (TPS) and feedstocks from vegetable oils. However, less than 40% of these bioplastics are designed to be biodegradable (Vorst 2020; Barrett 2019) and often need optimum conditions to degrade completely. When they are combined with other plastics components to reduce cost and/or improve properties, the degradation may only be partial; PLA bioplastics do not degrade in sea water (Barrett 2019). Again, with global population increasing, using food stocks to make plastics needs very careful consideration to ensure that human food requirements are not sacrificed in return for yet more consumer goods.

A further active field is reconsideration of semi-synthetic plastics based on cellulose but using more sustainable production processes, such as less toxic solvents. Tencel® is a noteworthy case, developed to be a more
environmentally friendly form of viscose rayon by Courtaulds in the late 1970s (Blanc 2016, 217).

Developers of ever more complex plastics and designers of future plastics products will increasingly have to consider the entire life cycle of their material and product design, adopting a cradle-to-cradle approach, rather than cradle to landfill or ocean grave. It is vital that industrial designers work collaboratively with other disciplines including polymer scientists, environmental and sustainability engineers and specialists, to ensure that their new designs integrate the principles of sustainability and social responsibility. A MoDiP exhibition Encore displayed examples of the many ways in which plastics can be recycled, reworked and repurposed (MoDiP 2009).

New ways of making and treating plastics waste are in development, a vital aspect being new methods of making packaging. When possible, it is desirable to change from using complex multi-layered plastics that, when recycled, produce a very low quality and low cash value recyclate to packaging made of one or two closely related plastics that can be turned into a good quality reusable material. Research is ongoing to blend recycled polyethylene/polypropylene with other waste fillers to produce a higher quality recyclate (Vorst 2020). Others are piloting upcycling technologies to transform waste polyethylene into high quality monomers for onward use in high quality products (Biocellection 2020). Developments continue on improving compostable packaging, for example, cellulose-based food packaging, applications including coffee bags and capsules (Natureflex 2020).

Although efforts need to be made to reduce plastics packaging use, this is not as simple as it sounds as the downside of returning to a plastics-free packaging world is that more food would go to waste. The Netherlands’ initiative is the ‘no plastics’ shopping aisle but this is misleading as goods are wrapped with compostable bioplastics (Taylor 2018b). The shopper who unpacks their purchases at the counter and returns the waste packaging to the retailer can also contribute personally to a shift in attitudes.

Reduction of the GPGP requires major global initiatives. ‘Hoovering’ the sea is a possible route, although this might endanger marine life. It is clear from the evidence that using alternatives to damaging and toxic plastics additives, such as bisphenols that are poorly soluble in water and toxic to marine life, should be sought. Teams are seeking different ways to break down plastics packaging waste. In 2016, a study showed how specialised bacteria might be used to biodegrade PET bottles (Yoshida et al. 2016).
The Ocean Cleanup team aim to remove 90% of ocean plastics by 2040 using a floater system that captures plastics, using natural forces, and is slowed down by a sea anchor. Once full, the system will be emptied by a sea-going vessel (The Ocean Cleanup 2020).

However, most importantly, what is essential is a change of mindset. Mass consumption of single-use goods that grew rapidly from the 1950s onwards, to which the cheapness, easy availability, malleability and practicability of plastics contributed, must be largely abandoned. Perhaps a return to an older perception of plastics as being valuable and sometimes even precious materials that should be used with discrimination and care would provoke a major transformation. The early cellulose-nitrate dressing table sets made by companies such as Xylonite (British Xylonite 1927) and the iconic vintage EKCO Bakelite radios are cases in point (EKCO 1939).

**Artists’ Responses to Plastics Sustainability**

Artists are using plastics to comment on sustainability and suggest their value. Two British examples are Michelle Brand and Richard Sowa. Brand turns plastic bottles into decorative items (Brand 2020) and Sowa made an island from 150,000 recycled plastic bottles (Carroll and Roberts 2014). The Ghanaian artist Serge Attukwei Clottey explores his country’s culture of reuse, turning plastic jugs, locally known as Kufuor gallons, into works of art (Jansen 2016).

Joshua Sofaer’s *The Rubbish Collection* exhibition held at London’s Science Museum in summer 2014 continued a series of thought-provoking displays and events related to the museum’s 2010 *Atmosphere* gallery and associated five-year *Climate Changing* programme. Playing with the recognisable role of the museum in collecting, sorting and displaying precious objects, and using them to tell stories, he explored that which the museum throws away institutionally and additionally as individual staff and visitors. Firstly, project staff, volunteers and museum visitors sorted and documented the Museum’s rubbish for 30 days. Secondly, the equivalent amounts of transformed materials produced from the rubbish were brought back into the museum and displayed beside items retained from the original rubbish. The preparatory stages stimulated conversations within the museum and the subsequent self-reflection influenced decisions the institution made concerning future sustainability and climate change. The installation itself clearly presented that which the museum itself produced in the form of waste and exposed the value of these overlooked
materials, in aesthetic and monetary terms. The concept was surprising and had the potential to shock as Sofaer brought his audience and the museum’s visitors face to face with their daily consumption and waste of resources.

The team had predicted that around 28 tonnes of rubbish would be thrown out. Over 18 tonnes of materials were brought back to the gallery for the exhibition’s second phase, including 7.4 tonnes of paper and card reels, 2.4 tonnes of bottom ash aggregate, 2.3 tonnes of glass sand, 1.4 tonnes of wood, one tonne of fertiliser, 698 kilograms of steel, 650 litres of dehydrated sewage sludge, 291 breezeblocks made from air pollution control residue and nearly one tonne of various recycled plastics. Items retained included an astonishing quantity of plastics cutlery.

When the display closed, the materials, including the plastic disposable pellets, were returned to the companies that had lent them and were then turned into new products. Electrical goods were sent to specialist recycling companies to separate any reusable parts and recycle what could be salvaged. Most of the items retained from the rubbish bags would have originally gone to incineration if they had not been selected. These items were recycled wherever possible although some were incinerated.

At the recycling facility, the rubbish was separated into different recycling streams. Magnets separated the ferrous from the non-ferrous metals. Infra-red technology identified and sorted the remaining rubbish into paper, card, glass and several types of plastics. Rubbish that could not be recycled, or pieces that were too small to be captured, were taken elsewhere for incineration. Nothing went to landfill. The materials were then baled as raw materials for resale to companies who took on the next stage of processing.

The recycling and recovery processes were different for each material. There is always a loss of some material, which cannot be recovered or usefully re-used. With plastics and glass, the loss came from paper labels and glues that were soaked off in the washing process, forming a sticky substance which was sent for incineration. A future is envisaged where these materials will either be captured for future use, or the waste will be designed out altogether. By using plastics labels instead of paper, the material could be more easily collected and recycled to make new products such as plastic bags.

The recycling of this rubbish produced some useful and valuable products. One discovery was that much recyclable material was incinerated. Those materials retain much more value when they are recycled so by
continuing to improve and refine institutional recycling systems, and through new initiatives like separating food waste, general waste could be decreased further in the future.

Joshua Sofaer concluded: ‘the very thing that this project has relied on, that people throw stuff away, is also the thing we want to reduce. Let’s work towards a time when a project like this is unnecessary or even impossible. Disposal is the last resort’ (Sofaer 2014).

Other more recent, linked, museum initiatives include the British Museum’s exhibition *Disposable? Rubbish and Us* and the Swedish Röhsska Museet’s exhibition *Ocean Plastics*, both in 2019. The first explored how humans have interacted with rubbish over the millennia including producing single-use items over time and commented on the modern ‘unprecedented levels of waste’ (British Museum 2019). The second presented a selection of conceptual design projects underpinned by an interdisciplinary approach and a belief in design’s ability to contribute to the solution rather than the problem. Themes included cleaning the oceans, plastics recycling and bioplastics (Röhsska 2020).

**Conclusion**

Bans of plastic bags and single-use plastics seize headlines but are only the start of what needs to be done to deal with the much bigger issue. Karl-H. Foerster, the former executive director of PlasticsEurope, stated that: ‘To protect our environment effectively, we need to educate citizens so they understand that plastics are too valuable to be thrown away’ (Foerster 2014). This perception that educating the public is key to a more balanced and responsible view of plastics is something that may become more evident as plastics waste increasingly becomes a rich resource for future reuse. The increasing plastics waste in the oceans provokes extreme concern. Behaviours must change, on personal, commercial, industrial and governmental levels, so that the casual littering of seashores and disposal of rubbish into the sea is reduced and ultimately prevented. International collaboration will be essential to support research into ways of designing disposal mechanisms for plastics waste that create value rather than devastation for the environment and to make recycling and energy recovery more effective. One country’s waste should not become another’s burden.

Modifying people’s behaviour can be achieved through legislation, education, or by example. However, legislating can be a clumsy, expensive,
and lengthy process and may cause resentment. Making disposing of plastics waste in a responsible way both easy and affordable, and irresponsible practices expensive and a matter for public shame, would be helpful. Education in schools and influencing behaviours from a young age is perhaps the most effective route. However, experience from developing-related exhibitions at the Science Museum in London, and elsewhere, has shown that it is much more effective to engage positively with the public rather than to preach to them.

**Notes**

1. mt is abbreviation for metric tons.
2. Kt is abbreviation of kiloton (1000 tons).

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