



Contents	3	Waste as a driver of change Part 2: Approaches to the problem of waste <i>Rachel Birch</i>	34	Sustainable transport infrastructure investment: A case study for South Africa <i>Andrew Marsay</i>
	15	Damped outriggers for tall buildings <i>Rob Smith Michael Willford</i>	44	Y2E2: The Jerry Yang and Akiko Yamazaki Environment and Energy Building, Stanford University, California <i>Kurt Graffy Janette Lidstone Cole Roberts Brandon G Sprague Jake Wayne Armin Wolski</i>
	22	The Royal Ontario Museum, Toronto <i>Florence Lam David Lewis Julian Sutherland</i>		

1. Although it is the least favoured option, much global waste still finds its way into landfill.

Waste as a driver of change

Part 2: Approaches to the problem of waste

Rachel Birch

“Our enormously productive economy... demands that we make consumption a way of life... We need things consumed, burned up, worn out, replaced and discarded at an ever-increasing rate.”¹



2. Only some 10% of computers are reused and refurbished; the remainder are disposed of.

Introduction

This article is the second of two on the issues of waste. The first² looked at why waste is generated and the problems this causes. The present article explores current waste management practices, and the transition required to move towards a more sustainable economy whereby waste becomes a valued resource. It continues the “drivers of change” research theme in *The Arup Journal*, which has so far included water, climate change, energy, demographics and urbanisation³⁻⁷.

Every year more than half a trillion tonnes of materials are dug up, processed, and thrown away. Less than 1% of the materials embodied in the products we consume are still in our possession six months after purchase⁸. All the rest have become waste, be it from construction, commerce, manufacturing or households.

This rapidly increasing volume of waste, generated by economic growth, urbanisation, materialism, and industrialisation, has severe impacts on the global and local environments, natural resources, public health, local economies and living conditions, and is threatening attainment of the UN’s Millennium Development Goals⁹. There is much evidence to suggest that today’s growing society is using more resources and generating more wastes than the planet can sustain, and that our consumption habits have led us to an environmental crisis point, with depleting resources, the spread of dangerous pollutants, the undermining of ecosystems, and the threat of unhinging the planet’s climatic balance.

Radical change is needed to move humanity from the prevailing economic system of manufactured goods and over-consumption to one where people significantly reduce their use of resources. However, the deep divides that exist within humanity make this a hugely complicated task.

An ever-growing body of evidence suggests that the current global consumer class of 1.7bn people needs to significantly reduce its consumption, but an equally large number of people in an emerging global middle class are striving to emulate the perceived “good life” - in stark contrast to the 3bn people who live on less than US\$2 a day¹⁰.

Clearly, the solution should not be one that allows the entire global population to consume at the rate current in Western society, nor can it involve moving to a place where Western consumption is accepted whilst the poor are denied a decent standard of living. Instead, the rich need to curb their over-consumptive lifestyles, and industry needs to reduce the resources embedded in products.

Calculations suggest that to achieve the twin objectives of environmental protection and social equity, the developed world may need to cut its use of materials by about 90%¹¹. Yet at present it appears that we are moving in the wrong direction. Modern economies produce, at ever-decreasing prices, commodities that consumers regard as little more than goods to be discarded relatively quickly rather than items embodying valuable energy and materials that should be repaired, maintained, and designed to last over a long lifespan.

The good news is that meeting human needs while becoming more resource-efficient can be more profitable and can deliver a higher standard of living than maintaining current practices. A new model of prosperity for an environmentally degraded and poverty-stricken planet may be found in efforts to lower consumption, in practices that increase resource efficiency, and systems that circulate materials through recovery and reuse.

Waste management options

Historically, the amount of waste generated used to be so small that dilution in the environment was seen as a suitable management option. Industrialisation and urbanisation, however, have made this no longer viable, and organised waste management is now a necessity for assisting in environmental protection, in resource management, and in combating global climate change.

Until recently, waste management focused on “end-of-pipe” solutions with landfill as the predominant means of disposal. But in today’s society, sustainable waste management relies on managing resources so that wastes can begin to be avoided altogether. The root of this transition requires moving from a mindset of “waste” as unwanted material requiring disposal to one where it is regarded as a raw material to be fed back into the production process as part of a closed loop system.

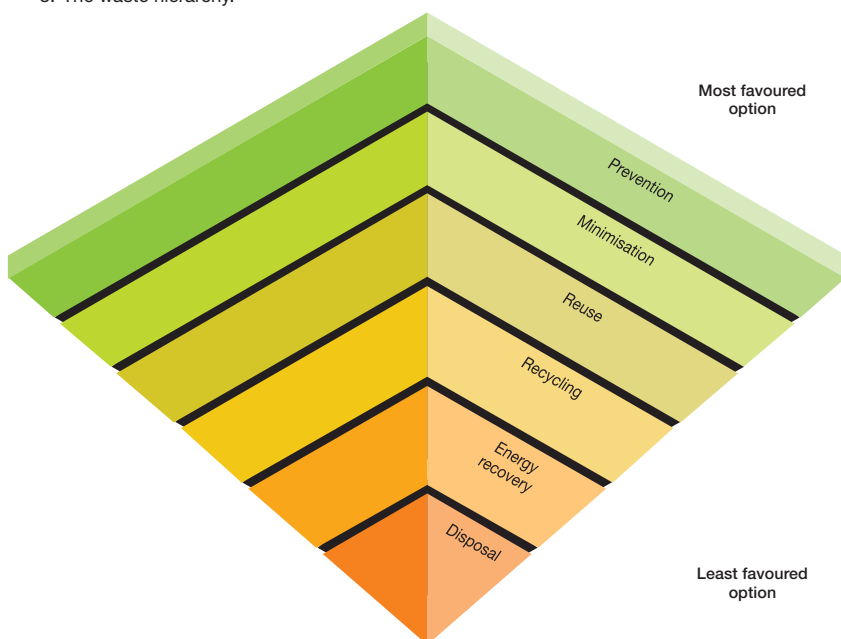
Energy and carbon are also becoming key issues in waste management, with a drive towards systems that maintain the embodied energy or carbon held within the materials.

To effectively manage wastes, therefore, we need to address the issues of sustainable production and consumption using a life cycle-oriented approach. The waste management agenda has recently begun to make this transition, and the focus is shifting from waste towards the sustainable use of natural resources. This is clearly evident in the increasing number of resource management strategies being written to replace waste management strategies. These strategies not only consider physical materials but also seek to reduce the energy required to treat and manage waste and generate an overall reduction in carbon emission. This new focus is encouraging engagement along the entire process chain for products - design, production, and consumption - before finally addressing waste management.

The waste hierarchy

The waste hierarchy¹² (Fig 3) is a useful framework that has, rightly or not, become the cornerstone of modern-day waste management. It sets out the order in which options for waste management should be considered, based on their environmental impact. Although this hierarchy has taken many forms, the basic aim remains the same: to extract the maximum benefits from consumer items and generate the minimum amount of waste.

3. The waste hierarchy.



4. “Light weighting” has resulted in less metal being used in drinks cans.

The hierarchy has been criticised both for being unscientific and not applicable to all countries. It should therefore only be used as a guide. It does not mean that under all circumstances, at all times, a higher option will be better than a lower one. In most cases a combination of options for managing the different waste streams will be needed.

Nevertheless the hierarchy provides a simple rule-of-thumb guide to the relative environmental benefits of different options.

Globally the waste hierarchy has been applied almost exclusively to managing wastes once they have entered the waste stream, but it actually conveys a much broader concept - that end-of-pipe solutions need to be coupled with strategies that look at the essence of the problem, such as how product design and consumption patterns can prevent or reduce waste production. Yet these upper elements of the hierarchy tend to be driven from a waste management perspective without detailed analysis of the overall production cycle of goods and products, and consumer aspirations. Fundamentally this is because waste is still predominantly managed by people employed in the waste management industry who rarely have any control over the waste avoidance techniques placed high in the hierarchy.

Prevention and minimisation

Reduction of waste through prevention and minimisation sit at the top of the hierarchy as they are the most effective ways of both avoiding waste and preventing the associated raw material and energy consumption, as well as any other environmental impacts from the production and consumption activities associated with a product. “Waste reduction” refers to actions taken before waste is generated to either reduce or completely prevent its production, and can be achieved through several mechanisms. In industry a product can be designed thinner and lighter, a process called “light weighting”: if a product contains less material, inevitably less waste will be generated at the end of its life. For example, a steel drinks can produced in 1998 was 30% lighter than one manufactured in 1993, and aluminium cans have decreased in weight from almost 100g in 1935 to only 15g¹³.

Industries can also reduce waste during manufacturing and through the way a product is transported or a service provided. Some companies, in the UK at least, are getting quite good at waste prevention due to the increasing cost of managing the wastes they generate, ie the recently elevated landfill gate fee of £32/tonne of waste in the UK – to rise to at least £48/tonne by 2010/11¹⁴. At the consumer level, waste reduction depends on changing our consumption patterns to make us less wasteful and requires significant efforts in public engagement such as education and promotional activities. Changing consumption patterns is notoriously hard to achieve, as it requires modern consumer society to be addressed. To minimise waste, individuals can choose to consume less or choose products with less packaging, for example. They can also choose to buy products designed to last, rather than rely on disposable commodities.

Waste prevention also includes reducing the toxicity of commodities. Removing a heavy metal like cadmium or lead from a piece of electronic equipment lowers the environmental impact of the waste by preventing it from being dispersed into the environment when the equipment itself becomes an item of waste.

Although minimisation should be the top priority in every waste strategy worldwide, most countries have failed to achieve it. In OECD (Organisation for Economic Co-operation and Development) countries, municipal waste has increased approximately 40% since 1980 in absolute terms and 22% on a per capita basis, and projections estimate that waste generation is continuing to grow and increase by a further 43% between 2000 - 2020¹⁵.

Reuse

“Waste reuse” means using an object or material again, either for its original purpose or similar, without significantly altering the object or material’s physical form. Recycling, by contrast, does alter the physical form. Reuse is generally preferable to recycling because it often requires less energy and resources.

5. Battery reuse is increasingly common.



6. Composting is a familiar way of managing domestic organic waste.

The major exception is that of electronic appliances where, given a choice between repair and replacement, it may be environmentally preferable to replace appliances such as boilers with new models because of the substantial reduction in energy and/or water requirements.

Reuse has the added advantage of stopping objects and materials becoming waste under its legal definition and can therefore be considered as a form of waste prevention¹⁶. Charity shops are an example of a reuse service as they take items that are still good for use and resell them to the public.

Composting and recycling

No matter how much effort is put into reduction and reuse, some elements of waste will always be generated from human activities. Composting and recycling are the preferable options for dealing with such wastes.

Composting is the controlled biological aerobic (with oxygen) fermentation and decomposition of organic waste (food, garden waste, and paper) by microorganisms into a soil restorer. Composting has huge benefits, primarily in that it keeps organic matter from landfills where it decomposes anaerobically (in the absence of oxygen) producing CO₂ and methane, a greenhouse gas (GHG) with a global warming potential 25 times that of CO₂¹⁷.

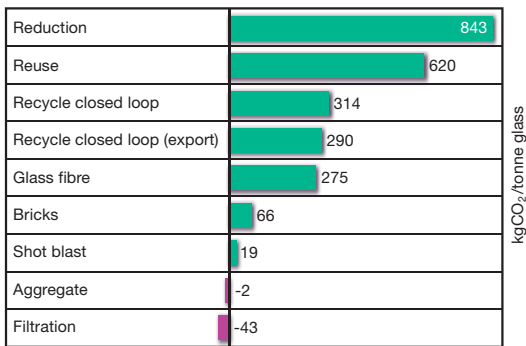
Composting organic waste prevents the release of methane and is therefore beneficial in terms of climate change. Composting can be done at many different scales and is particularly effective at the individual household level, eliminating the need for waste transport and further reducing environmental impact.

A second option for managing organic waste treats it in such a way as to encourage the production of GHGs. Biowaste plants use a process called “anaerobic digestion”, in which all organic waste (except for liquids) is broken down anaerobically into compost and biogas. The compost is used as a soil improver and the biogas combusted to produce heat and electricity. Such plants are becoming commonplace in many countries.

Recycling uses waste material to manufacture new products, and in doing so alters the physical form of objects and materials. It has the benefit of saving resources as well as preventing impacts from the extraction and transformation of raw materials into products, but appears lower in the waste management hierarchy as additional energy and resources are required to reduce waste levels. Recycling involves collecting, transporting, cleaning, sorting, and then processing of materials so that they may form a new product. Indeed, recycling is not considered to be part of waste prevention because only waste can be recycled.



7. Colour-coding for waste receptacles is now commonplace.



8. Environmental impacts of recycling routes for glass¹⁹.

9. Municipal waste processing plant Spittelau, Austria²⁰.



The ease and rate at which different materials are recycled vary. Some, such as steel, have been recycled for centuries. Now other metals, paper, glass, some types of plastic, and construction/demolition waste are more or less systematically recycled. Some materials, like aluminium, can be recycled almost indefinitely, but others become increasingly difficult to free from contaminants or – as in the case of paper – may require an addition of virgin material for successful recycling. The economics of recycling vary a lot; metal scrap has been at a very high price for several years, driven by demand from China in particular. Even in the absence of environmental legislation, these materials are recycled where possible.

Recent years have seen a dramatic rise in the export of recyclable materials to markets where it is economically viable to process the waste and where there is a high demand for raw materials. For example, China is the world's biggest waste importer receiving 4bn tonnes of plastic waste, 12bn tonnes of waste paper and 10bn tonnes of scrap iron and steel in 2004. Within Europe, Germany is the biggest waste importer, receiving approximately 4.15M tonnes of waste in 2003, 98% of which originated in Western Europe.

Although recycling usually consumes less energy and resources than making products from raw materials, it is important to note that some strategies, although well intentioned, can use more energy or themselves produce new wastes or types of pollution. It is therefore important not to assume that recycling is always the best option. Instead a holistic overview, such as a lifecycle assessment (LCA), should be taken to ensure that associated impacts are fully understood. For example, air emissions from aluminium recycling can contain particulate matter in the form of metallic chloride and oxide as well as acid gases and chlorine gas. However, recycling 1kg of aluminium saves 5-8kg of bauxite, 4kg of chemicals, and 14kW of electricity¹⁸. Because most bauxite is mined in the tropics, recycling aluminium also helps to save tropical rainforests.

Recycling requires the input of energy. LCA enables the comparison of different energy inputs and the associated carbon emissions of recycling methods. One study¹⁹ has demonstrated that some recycling routes offer negligible or even negative benefits in terms of CO₂. For example, recycling glass into aggregate generates more not less CO₂ than using aggregate from other sources. Such information demonstrates the importance of taking a holistic approach and considering the full environmental impacts of waste-related policy rather than just striving for high recycling targets at the consequence of other environmental impacts (Fig 8).

Energy from waste

The term “waste to energy” refers to the process whereby the “energy” content (calorific value) is recovered from waste material. Energy can be extracted from both hazardous and non-hazardous waste streams in several ways. Opinions vary widely on where waste to energy should sit in the waste hierarchy. Some view it as a valid source of renewable energy, substituting for the need to burn fossil fuels as well as diverting waste from landfill. Others, however, regard burning waste as an unacceptable loss of raw materials that may hamper recycling programmes.

Incinerators are the most common mechanism for extracting energy from waste. Incinerators with energy recovery burn waste to produce energy in the form of heat, electricity, or steam to supply other facilities or dwellings. Historically, many badly managed incinerators in Europe have led to a series of scandals and negative public opinion. Today, nearly all such incinerators in the EU have closed, and new ones must comply with strict standards.

Nonetheless, it has been demonstrated that incineration with energy recovery can be very efficient in environmental terms, particularly in Nordic countries where, as well as the electricity produced, incinerators produce heat for local district heating. Currently there are over 600 incinerator plants recovering energy from waste spread over 35 countries²¹. These plants treat nearly 170M tonnes of waste per year and generate energy equivalent to approximately 220M barrels of oil.



10. Waste scavenging is an important but hazardous source of livelihood for the world's poor.

Pyrolysis and gasification are newly developing technologies that use high temperatures to break down waste containing carbon, such as paper, plastics, and organics. Pyrolysis degrades waste to produce synthetic gas ("syngas"), comprising mainly carbon monoxide and hydrogen, with smaller amounts of CO₂ and methane. Other outputs of pyrolysis are pyrolysis oil and char (ash). By using controlled amounts of oxygen, gasification can then break down the remaining hydrocarbons in the pyrolysis oil into syngas. The resulting syngas can be used as a fuel to generate electricity or as a basic chemical in the petrochemical and refining industries.

Landfill

The final waste management option is disposal to landfill. Much global waste is still managed in this way, although it is the least favoured option. Indeed, it is likely that with the current patterns of production and consumption and the mix of toxic chemicals entering the waste stream, landfill in some shape or form will be required for many years to come.

Landfills in the EU must be designed to take one of three categories of waste (hazardous, inert, or other), must be separated from the water table, and must have equipment to collect the methane and CO₂ from fermentation of the biodegradable portion. This biogas can then be used to generate electricity.

Informal waste management

In developing countries, waste management is often reduced to what a community can afford. Waste is mostly a big city problem; complications start with waste collection and continue with open dumps and open burning in the middle of towns. In impoverished cities, "waste scavengers" make a living by sorting through landfill sites and collecting recyclable materials.

Such informal systems actually have some environmental and economic advantages. For example they reduce the need for landfill and save natural resources, while providing an important source of livelihood for some of the world's poorest people who are unable to obtain formal employment. In Buenos Aires, informal waste "scavengers" recover 9-17% of municipal waste, representing an estimated saving for the municipality of US\$30 000-\$70 000 every day, and scavenger households earn about US\$58.4 per week¹⁸. In Asia, whole communities have developed out of the



11. Waste scavengers often endure poor living conditions.

waste industry. Over 60 000 people work on waste dumps in the Philippines. In Brazil 100 000 people earn their living collecting aluminium drinks cans, enabling Brazil to achieve the highest global aluminium recycling rate of 89% in 2003¹³.

Despite these environmental and economic benefits, scavenging also comes at a huge social cost. The workers are often exploited by waste buyers, have poor health and living conditions, and work day and night without any protective clothing. In Mexico, waste scavengers have a life expectancy of 35 years as opposed to 67 years for the general population²², a near-50% reduction. It is estimated that children account for roughly half the waste scavengers working in Argentinean cities, with 90% of these minors working more than once a week and for a minimum of three hours per day¹⁹.



12. The plastic bag is omnipresent in our landscape of waste.

Waste as a resource:

Can we move beyond waste?

Waste management experts are beginning to think that the present system of waste management may have fundamental flaws, and that a thoroughly effective system may need an entirely new way of looking at waste. As a result, talk about “resource management” rather than “waste management” is becoming increasingly common, as people begin to embrace the “zero waste” philosophy.

The aim of zero waste is to stop thinking of waste as a “waste” and to instead see it as a valuable resource for society. In this sense waste will cease to exist. Put simply, “zero waste” extends current concepts of recycling into a circular system whereby as much material as possible is reused²³.

In this it replicates natural ecosystems that have evolved over millennia so that the waste products of one organism naturally become the resources or feedstock for another, and the major nutrients of carbon, nitrogen, hydrogen, and oxygen are cycled and recycled between animals and plants the planet over.

To move towards such a system will involve breaking away from the current “linear” economy whereby resources are extracted, converted into products, consumed and discarded, and instead embrace a “circular” economy that imitates nature’s highly efficient “cradle-to-cradle” system which allows nothing to be wasted.

This will involve fundamentally changing the end-of-pipe way materials are currently managed and instead address wastes and resources along the entire supply/demand chain, starting with product design so that material efficiency and zero waste are in the mind of the designer when pen first hits paper.

It will need an integrated systems approach across all sectors to improve efficiency, avoid all unnecessary waste, and maximise reuse, recycling, and recovery at all stages in the process chain over the lifecycle of goods and services - from sourcing of materials, product design, and production method right through to addressing consumer habits and consumption patterns.

The global consumer class will obviously be key in reshaping the relationship between consumption and sustainability, not only because it is responsible for most material consumption and waste generation, but also because its actions are echoed around the world. Yet solutions will also need to take into account how developing countries are tied into the global economy and their desire to emulate the materials-intensive consumption model that is widely perceived as embodying the “good life”.

It is therefore critical to achieve a reduction in the environmental impact associated with consumption, particularly so that increased consumption in developing countries is entirely compatible with global sustainability objectives.

How can we achieve this?

The encouraging truth is that there is no problem without a solution. To move towards a resource-efficient cradle-to-cradle system whereby all the planet’s inhabitants live sustainable lives will require the correct balance of economic, social, political, and technological measures. The following list is by no means exhaustive, but sets out some of the ways more sustainable resource management practices can be achieved.

Economic measures

Subsidies and eco-taxation: A key means to achieving more sustainable resource and waste management practices is to send effective pricing signals that encourage more sustainable practices. Numerous subsidies currently make products such as fuels, timbers, and minerals far cheaper than they would otherwise be, encouraging their increased consumption. Although it is difficult to derive an exact value, it is estimated that global subsidies amount to over US\$1 trillion per year, with OECD members accounting for three-quarters of the total²⁴. Phasing out destructive subsidies and shifting a proportion of the funds to resource efficiency initiatives would help address unsustainable resource consumption practices.

Ecological tax reform is the process whereby market prices are adjusted to reflect the full environmental costs of economic activities. Examples include levies on the use of virgin materials, landfill fees, and other waste and pollution charges that incentivise manufacturers to reduce their generation of wastes and emissions.

In California, a recycling target of 50% diversion from landfill by 2000 was set in 1990, and the state threatened all municipalities with a US\$10 000 fine per day for non-compliance. Although it took longer than anticipated to arrive at this goal, by 2005 California reached a recycling rate of 52% with some communities diverting over 60% of their waste²⁵.

Costing externalities: Through incorporating the cost of a wasteful process into the price of a commodity, the total amount of waste generated can be limited. Though plastic bags are still provided free in almost all countries, Ireland has levied a 15c (10p) charge on plastic bags since 2002, a policy that reduced usage by 95%²⁶. Similar success was experienced in South Africa where bags were made more durable and expensive to discourage disposal, generating a 90% reduction in usage²⁶.

Some countries are now beginning to charge for bags in supermarkets, including Austria, Denmark, Germany, Sweden, Finland, Belgium, and the Netherlands. In Mumbai, India, and Bangladesh, governments have gone a step further and banned plastic bags altogether, with fines and prison sentences for people found distributing them.

Another example of incorporating the cost of environmental impact into commodity prices lies in beverage containers. Sweden has achieved an 86% recovery rate for these, driven primarily through an industry-imposed bottle deposit of 10c²⁷. Similar success has also been achieved in Michigan, USA, where a 10c bottle deposit has generated a 95% recovery rate²⁸.

Pay as you throw (PAYT): Charging households for the amount of non-recyclable waste they generate has been a successful way to both increase recycling and reduce the absolute volume of waste generated by a population. The first community to implement PAYT was Richmond, California, in 1916, and since then, over 6000 communities in the US alone have implemented PAYT schemes²⁹.

PAYT charges residents for collection of waste based on the amount they produce, providing a direct economic incentive to generate less waste and increase composting and recycling. Such schemes have demonstrated huge success in these areas, and additionally decreasing waste collection costs.

Kansas City, Missouri, implemented PAYT in March 2004. Each week residents can dispose of two bags of waste – each additional bag costs \$1. To help people maintain this limit, the city actively encourages recycling, and provides residents with free collection of such material. This system is estimated to save the city \$2M per year and generates a 30% reduction in waste sent to landfill - 25% of it due to increased recycling and 5% to residents' efforts at source reduction³⁰.

13. A market stall in Mumbai, where the government has banned plastic bags altogether.



14. Many communities now charge residents for the amount of non-recyclable waste they generate.

Similar success has been seen elsewhere, eg Torrelles de Llobregat, a province of Barcelona, where PAYT has increased recycling from 45% to 83%. In Korea a similar system delivered a 22% reduction in per capita waste volume between 1994 and 2002. The volume sent to landfill fell 43% in the same period and recyclable items rose by 146%³¹.

Green procurement: Through the products and services they buy, governmental institutions have great influence. Public purchasing in industrialised countries accounts for up to 25% of GDP. In the EU, government procurement totalled more than \$1 trillion in 2001 while in North America it reached \$2 trillion¹⁰. Institutions can therefore have a powerful influence over their suppliers. Through the placement of environmental demands, institutions can shift markets and influence design, efficiency, and durability. This is "green procurement".

In 1998 the US government set a standard demanding the recycled content of all federal paper to be 30%. This generated a shift in recycled content of paper from 10% in 1994 to 30% in 2000 and also increased federal recycled paper consumption from 12% to 90%¹⁰. The increased government demand also boosted the overall market standard for recycled content in the country. Buying recycled products is the important final stage in the recycling process as it effectively "closes the loop". Many countries are taking this on board: Denmark is a world leader in green procurement with a law in place since 1994 requiring all national and local authorities to use recycled or recyclable products.



15. The average DIY tool is used for just 10 minutes.

Social measures

Influencing consumption: The global consumer class is key in reshaping patterns of resource consumption, simply because it consumes the bulk of the world's resources. Cleaner technologies and more efficient products and production systems will help reduce the impacts of consumption but essentially, consuming better does not alleviate the need to consider moderation in overall consumption levels. In the words of Herman Daly: "To do more efficiently that which should not be done in the first place is no cause for rejoicing"³².

Influencing consumers is a major challenge. As already noted, a well-designed eco-tax can play a useful role, but the capitalist system leaves decision-making in product purchase almost entirely up to the consumer. More controls on purchasing would be undesirable, but some aspects of individual household consumption can be influenced.

For example, current consumption patterns lead to the production and purchase of many goods that are used infrequently by the consumer. It is estimated that the average do-it-yourself tool is used for just 10 minutes, the rest of life it sits gathering dust³³. This leads to far greater material consumption than is actually necessary.

Governments and communities can take action to help redress the balance between private and public forms of consumption. Car sharing is rapidly becoming popular in many European cities, and governments can facilitate such initiatives through tax incentives and grant schemes. Similarly, local communities can set up tool and appliance sharing arrangements so that not everyone has to own a separate item.

The "work-spend" lifestyle into which so many are locked drives growth in disposable income, which naturally translates into greater consumer purchases. As the saying goes, "we spend money we don't have, to buy things we don't need, to impress people

we don't like". It is clear that consumption goes way beyond satisfying individual's physiological and physical needs. Material consumption is used by many people to create and maintain a sense of identity and to show allegiance with certain social groups. Communication and education will therefore have to play a major role in achieving sustainable consumption. People will change behaviour if they understand the reasons for doing so and it is made easy for them. They need to be informed of the environmental and resource-related consequences of their purchasing and lifestyle decisions. Education is also needed to encourage the use of products made from recycled or recovered materials as well as to inform individuals about the importance of source separation of their household waste.

Developing a recycling culture: Most countries achieving a high level of recycling post-consumer waste have done so by creating a culture of doing so. In Germany, schoolchildren are taught about the importance of properly separating their waste, and separate bins are provided and weighed. The less mixed waste you have, the less you pay. In Vienna airport, for example, all public bins have four different-sized compartments: paper, glass, metal and "other".

The town of Kamikatsu, Japan, has adopted a goal of zero waste to landfill or incineration by 2020, due to the closing of both local incinerators. Although there was initial resistance from the local community, the town now achieves recycling rates of 80% for household waste in the absence of either legislative measures or financial instruments. Local residents take their waste to the local waste centre and separate it into 34 categories. "Recycle Kamikatsu" is a voluntary group set up to help transport waste from senior citizens without cars and also to help people separate their waste at the recycling centre. Anything in good enough condition for reuse ends up at the Kuru Kuru recycling shop where residents can drop off or pick up anything they like, free of charge³⁴. Although the success achieved in Kamikatsu may not be transferable to all towns and cities, it clearly demonstrates the success that can be achieved through developing a culture of waste separation and recycling.

Product service systems: A whole new way of thinking about products, the way an economy functions, and what it is supposed to accomplish, has recently emerged. Instead of just selling goods, manufacturers are moving towards the provision of services driven by a transformation of consumer habits. In this, customers do not demand products *per se*, but rather seek the utility that products and services provide. By using a service that meets need rather than a physical object, more needs can be met with lower material and energy requirements. Under such a system the emphasis is on quality retail, advising customers on the best leasing option available, on the quality and upkeep of the products, and on how to extend usefulness while using the least energy and materials.

16. Japan is one of the world's most active countries in initiating the recycling of domestic waste. This example is at Yamaguchi City.



Several companies have already begun to expand on this concept. Xerox already leases over 75% of its equipment, and Dow Chemical and Safety-Kleen have begun to lease organic solvents to their industrial and commercial customers. They advise on the proper use of the chemicals which they recover themselves instead of making their customers responsible for disposal.

Corporate social responsibility (CSR): Many companies are beginning to address environmental issues due to the positive association such moves will have with their brand. Wal-Mart has been pioneering in its approach to addressing sustainability through several initiatives, including one that concerns packaging. In 2006 Wal-Mart set a target to reduce all supply chain packaging by 5% by 2013. Additionally, Wal-Mart has set a target for all transport packaging to be reused and or recycled by 2011 through improved pallets and reusable plastic containers. The sustainable packaging programme is committed to using materials of the highest recycled content without compromising quality. This includes using components the choice of which is based on recyclability post-use.

To achieve these targets Wal-Mart has developed a scorecard system that allows manufacturers to rank their current use of packaging. Scores relate to metrics, including GHG emissions per tonne of packaging, raw material use, packaging size, recycled content, material recovery value, renewable energy use, transportation impacts, and innovation. 60 000 Wal-Mart suppliers use the packaging scorecard, and purchasing decisions are made based on the results.

Through reducing packaging in the Kid Connection toy line, Wal-Mart has reportedly reduced the number of containers required to transport the toys by 427, leading to \$2.4m saved annually in shipping costs⁸.

Political measures

Governments will play a critical role in moving towards implementing new sustainable waste and resource management processes. Specifically, regulation will allow industry to gain confidence in investing in new technology development, as investing in facilities that are not required to meet regulatory standards under legislation is risky.

Product regulation and labelling: Governments have the potential to influence product development through regulatory mechanisms. National minimum standards for product performance can be set. Minimum standards are complemented by eco-labelling programmes to give purchasers information and encourage manufacturers to design and market more eco-friendly products.

Integrated product policy: At the EU level there is support for integrated product policy (IPP)³⁵. This aims to influence the environmental impact of products by looking at all phases of their lifecycles - not just the consequences of disposal but also the impacts of production and factors such as energy use in consumption - and taking action where it is most effective. With so many different products no one simple policy measure can be applied to all. Instead a whole variety of tools - both voluntary and mandatory - can be used to achieve the IPP objective, including economic instruments, substance bans, voluntary agreements, environmental labelling, and product design guidelines.

Extended producer responsibility (EPR): Waste can be avoided if manufacturers factor in environmental considerations at the product design phase. EPR laws encourage this by imposing accountability with manufacturers over the entire product/packaging lifecycle and requiring companies to take back products at the end of their useful life.

EPR typically bans the landfilling and incineration of most products, establishes minimum reuse and recycling requirements, and specifies whether producers are to be individually or collectively responsible for returned products. This mechanism shifts the responsibility for waste from government to private industry and encourages the internalisation of waste management costs into product prices. EPR encourages producers to consider waste management and the full lifecycle of the product in the initial product design as it is of advantage for them to do so. They will then ideally eliminate unnecessary parts, reduce unneeded packaging, and generate products with parts that can easily be disassembled, recycled, remanufactured, or reused.

In Europe this concept has been embraced and legislation exists to control waste from electronic and electrical equipment, cars, tires, batteries, office equipment, furniture, construction materials, and packaging. Germany has been the EPR pioneer in tackling packaging, and passed a law in 1991 requiring producers to take packaging back for reuse or recycling.

Over three years, recycling waste paper rose to 54% from 45% where it had stagnated for 20 years¹⁰. Austria instituted a similar system in 1993 and has achieved 73% recovery and 64% recycling³⁶. In both countries the "Green dot" logo (Fig 17) is used by companies to signify the transferral of their obligation to collect, sort, and recover packaging waste to a third party.

17. The "Green dot" logo.



Tradeable permits: Governments can use permits to regulate and reduce resource consumption, waste generation, and environmental pollution over time. The concept behind tradable permits is that all polluters are sold a defined amount of permits allowing them to discharge waste or pollution. If an organisation can reduce their discharge, they can sell their remaining permits. For example, landfill allowance trading schemes (LATS) allocate tradable landfill allowances to each waste disposal authority in England, allowing the disposal of a certain amount of biodegradable waste per year. These authorities can then use their allocations in the most effective way such as trading with other disposal authorities or saving them for future years.

Technological measures

None of today's industrialised economies is truly sustainable and all could be leaner without suffering significant setbacks. Annual material throughputs in America and Europe are estimated as 80 and 51 tonnes/person respectively, but for an average Japanese it is just 21 tonnes. Given the broadly similar living standards of Americans, Europeans, and Japanese, clearly there is considerable room for improvement in both the US and Europe.

Hidden material flows: Much of the material flow in industrialised economies never passes through consumer hands, but these "hidden material flows" account for around 60% of the total in Europe and around 70% in the US. Dealing with these hidden flows requires some of the most destructive practices, ie logging, mining, and smelting in particular, be downsized.

This can be accomplished through numerous technical solutions that improve energy and material efficiency, boost recycling and reuse, and lengthen the lifetime of products, so that the need to extract virgin raw materials is much reduced.

Rethinking product design: 80-90% of products' lifecycle economic and ecological costs are already inevitable once they have been designed, and before manufacture. We must therefore address how we make things, from their design to how they are put together and how they are used.

Products should be designed to last, so that they become "waste" less quickly, and to be easily remanufactured, deconstructed, or recycled when they do become waste. Complementing this, manufacturers should move wherever possible towards using recycled materials.

A major problem, though, is that almost no product on the market is actually designed with recycling in mind. When a car is recycled, the high quality steel is mixed up and contaminated with copper cables, plastics and paints that decrease the quality of the steel and limit further options for its use. Recycled steel sometimes requires high quality virgin steel to be added to make it usable again, and still it will not be of a grade sufficient to produce a new car.

Product design coupled with new technological advancements can help to address this issue. "Active disassembly" makes use of smart materials, such as shape memory polymers, that will change their shape at a "trigger temperature"³⁷. This allows for product components to be easily disassembled and separated so that the different materials can be collected and reused, remanufactured, or recycled.

For example, mobile phones designed for active disassembly could be dropped into a special tumble dryer and heated to a trigger temperature. Within seconds the phones would be dismantled, allowing plastics to be recycled and toxic components dealt with appropriately.

Dematerialisation: This process is aimed at reducing the amount of raw materials needed to create a product. Advocates have pushed for a "factor 10" reduction - policies that aim at providing a given volume of goods and services with 1/10th of the material input¹¹. Indeed there was some success in this area with resource productivity in the EU improving by 30% between 1980 and 1997.

However, this improved efficiency has not translated into an overall reduction in resource consumption which instead has remained essentially constant as consumer wants and needs continue to increase. Although dematerialisation is an important step towards achieving more sustainable economic activity, alone it may be insufficient to contend with humanity's increased desire for consumption and thus must be coupled with strategies addressing consumption.

Clean production: Toxic materials are another matter for concern, yet there are plenty of opportunities to reduce and even eliminate reliance on them in manufacturing to prevent air and water pollution and avoid hazardous waste generation. An innovative example of achieving cleaner production was in a pulp and paper mill in Maine, USA. In the early 1990s it was a major polluter but a shift in management led to active co-operation with local stakeholders. Initial focus on end-of-pipe pollution control was replaced by the implementation of pollution-preventing measures. There was a rapid reduction in the release of organic pollutants and mercury, dioxin and chloroform emissions were eliminated, and particulate emissions reduced by 50%. Hazardous waste generation decreased 95% by 1998 and solid waste to landfill decreased 91%¹⁰.

Industrial ecology: This is the "cradle-to-cradle" system of integrated, closed-loop material flows whereby the byproducts of one organisation become the feedstock of another. The community of Kalundborg in Denmark is widely regarded as the best example of industrial ecology. Here, an increasingly dense web of symbiotic relationships among local companies has slowly evolved over the past three decades yielding both economic and environmental benefits. For example, natural gas from the refinery becomes feedstock in a plasterboard factory, fly ash from the coal-fired power station is used by a cement manufacturer, and sludge containing nitrogen goes to nearby farms for fertiliser. Interestingly, rather than planning for sustainable manufacturing, the business relationships in Kalundborg evolved spontaneously due to their economic benefits.

18. Agriculture is the beneficiary of organic sludge supplied as nitrogen-rich fertiliser.





19. Some new carpets are being made from perpetually recyclable fibre.

Cradle-to-cradle design: The current destructive qualities of our cradle-to-gate system can be seen as a fundamental design flaw rather than the inevitable output of modern-day economies. Good design, based on natural systems and a cradle-to-cradle philosophy, can transform the making and consumption of things into a positive system. Indeed, the traditional approach to sustainability focuses on improving the efficiency of material use and energy consumption and while this is a useful strategy it tends to reduce harmful impacts rather than prevent the harmful activity in the first instance. As Michael Braungart, one of the cofounders²³ of the cradle-to-cradle concept, put it: “By destroying a little less, we are not protecting anything. So it is not about being less bad, but about doing the right thing”³⁸.

A well-known example of cradle-to-cradle systems is Honeywell’s high quality carpet, *Zeftron Savant*, made from a perpetually recyclable nylon 6 fibre³⁹. The polymer has been specially designed to be reclaimed and turned back into new carpet without the requirement for extra material or degradation in carpet quality. Additionally, Honeywell can collect carpets made from old conventional nylon 6 and transform it into *Zeftron Savant* - in effect “upcycling” rather than “downcycling”, with the material “rematerialised” rather than “dematerialised”.

Modular products: Most consumer products are made in ways that render them near impossible to repair and have damaged or broken parts replaced. Even when something can be repaired the cost is often so great that it encourages people to throw the old model out and buy new.

Durability, repairability, and upgradability are essential to lessen the environmental impact of consumption. A modular approach permits access to individual parts and components so that they can be easily replaced. Companies like Xerox have

adopted this philosophy and extended the useful life of their products, leading to increased opportunities for maintenance, repair, upgrading, recycling, reuse, and remanufacturing, and thus greater business and employment potential throughout product life.

Xerox, a pioneer of remanufacturing, kick-started its Asset Recycle Management initiative in 1990, which led the company to design products from the outset with remanufacturing in mind and every part reusable or recyclable. As a result, 70-90% of equipment returned to Xerox at the end of its life can be rebuilt¹⁰.

Conclusion: beyond waste

Waste is a crisis of human doing and it is becoming increasingly difficult simply to ignore. It is a result of the ever-increasing population combined with our growing consumerist culture.

Adding to the difficulty in many parts of the world is the endemic corruption – the corner-cutting, local officials’ “hands in the till” – that tends to undermine central government efforts to bring in and, more importantly, effectively enforce environmental and waste management legislation. China, for example, has some of the most extensive environmental legislation in the world but currently lacks enforcement. Nonetheless it may be indicative that its State Environmental Protection Department (SEPA) was recently upgraded to the status of Ministry. This now opens the door for more funding, greater power, and more staff to radically strengthen enforcement.

Long-term, viable solutions will require action at every level - personal, corporate, and government, but the solution must start with rethinking the very concept of waste and our relationship with the world around us. Although it is hard for people to make the link between the waste they generate and the global patterns of resource depletion and environmental degradation, this is fundamental for achieving change. Sometimes it is said that thinking such change can be achieved is unrealistic and idealistic, but the true unreality lies in assuming that the global population can continue consuming at its current rate *ad infinitum*.

A movement is beginning that seeks to embrace sustainable consumption through the philosophy behind zero waste. This begins with the design of products that seek to eliminate the concept of waste - through cradle-to-cradle design, industrial ecology, clean production, dematerialisation, modular design, etc.

Changes at this level need to be reinforced with political, financial, and social drivers to encourage people the world over to consume more sustainably and, as a consequence, take better care of our global resources and produce less wastes. If this doesn’t happen, we will be limited to solutions that merely slow down our impact on the world around us, rather than dealing with the fundamentals of the problem at hand.

As Einstein is reputed to have said: “The world will not evolve past its current state of crisis by using the same thinking that created the situation.”

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Credits

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20. Young girl walking through her backyard at a waste dump in Mexico City.

