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Zero Waste

Robin Murray

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Foreword

Stephen Tindale, Greenpeace Executive Director

The issue of waste has become a political hot potato. Central government wants 'sustainable waste management' but passes the buck to local authorities. Local authorities decry the lack of funds from central government to enable anything but the cheapest option and reproach householders for failing to participate in reduction and recycling schemes. And the public opposes waste disposal facilities – both incinerators and landfill – with a vehemence they normally reserve for nuclear waste dumps.

A new awareness that our society faces a waste crisis has moved waste management from a marginal issue to one at the centre of political debate. Some are stricken with panic at the prospect of overhauling the waste system, but at the same time a new, more positive attitude is emerging. There is now a far greater willingness to see waste as an opportunity and to see the solutions as part of a wider agenda stretching from climate change through resource management to urban regeneration.

As Robin Murray eloquently explains in this book, 'from the perspective of pollution, the problem is a question of what waste is. From the perspective of resource productivity, it is a question of what waste could be. As a pollutant, waste demands controls. As an embodiment of accumulated energy and materials it invites an alternative. The one is a constraint to an old way of doing things. The other opens up a path to the new.'

What is emerging is a polarisation of approaches to waste. One clings desperately to the old way of doing things, the other embraces the new and drives further change. This book details the failings of the old, business-as-usual option, that has been dressed up in the new clothes of 'integrated waste management'. It then outlines a new approach, a Zero Waste policy, that promises to transform attitudes to waste, the organisational forms used to manage it and, crucially, the systems that produce it. Perhaps most importantly it outlines practical policy measures necessary to achieve this.

The integrated waste management option

The race is now on to draw up 'sustainable' waste strategies. But the failure of central government, and most waste disposal authorities, to make any serious progress with the 'reduce, reuse, recycle' paradigm during the last decade, has led to the emergence of a national policy in the UK that encourages strategies that are anything but sustainable.

This policy, and the local strategies based on it, are referred to as 'integrated waste management'. Based on a simple forecasting model that predicts a maximum recycling level of around 40% and a continued increase in municipal waste generation, the 'integrated option' relies on incinerators, or other forms of thermal treatment, to deal with the large predicted residual waste stream.

Integrated waste management policies nominally give primacy to waste minimisation, recycling and composting, but inevitably solve the 'disposal problem' through incinerator-reliant packages. The incinerator element commits us to a future in which increasing levels of pollutants such as dioxin, a known carcinogen, will be generated and dispersed to air and land. Meanwhile, much recyclable material will be lost to disposal along with most of the energy contained within it, and opportunities for jobs and community participation will likewise be bypassed.

Incinerators lock us into an eternal present of waste generation and disposal. The capital investment they embody and their relentless hunger for feedstock places a very real cap on minimisation, reuse and recycling of waste for at least a generation. They provide an easy option for waste that stifles innovation, imagination and incentives. They effectively kill off the possibility of transforming waste management from its current obsession with cheap disposal to the genuinely worthwhile goal of high added-value resource utilisation.

Thus integrated waste management precludes the radical new approach to waste that is urgently needed. Fortunately there is a way out of this cul-de-sac.

Zero Waste

The first and most obvious question from the casual observer confronted by the concept of 'Zero Waste' is, 'Can it be achieved?'.

The term Zero Waste has its origins in the highly successful Japanese industrial concept of total quality management (TQM). It is influenced by ideas such as 'zero defects', the extraordinarily successful approach whereby producers like Toshiba have achieved results as low as one defect per million. Transferred to the arena of municipal waste, Zero Waste forces attention onto the whole lifecycle of products.

Zero Waste encompasses producer responsibility, ecodesign, waste reduction, reuse and recycling, all within a single framework. It breaks away from the inflexibility of incinerator-centred systems and offers a new policy framework capable of transforming current linear production and disposal processes into 'smart' systems that utilise the resources in municipal waste and generate jobs and wealth for local economies.

The right question to ask, then, is not (yet) whether Zero Waste can be achieved, but how can it be used as a policy driver, to free us from the disposal cul-de-sac and break through the currently perceived limits to minimisation and recycling?

Robin Murray is one of the world's leading thinkers on waste issues. In this book he describes a system of waste management that addresses all the environmental problems associated with conventional waste disposal and outlines the political, financial and organisational changes necessary to implement this system.

The Zero Waste policy Murray describes could move Britain to the forefront of modern ‘smart’ waste management. As such, it provides a beacon for politicians wishing to move the UK from the dark ages of waste disposal to a new era of Zero Waste.

I Waste and the Environment

Waste policy has become one of the most keenly contested areas of environmental politics. At a local level in the UK and abroad, the siting of landfills and incinerators has provoked degrees of civil opposition matched only by proposals for new roads and nuclear power plants. Nationally and internationally, there has been hand-to-hand fighting in the institutions of governance over clauses, targets and definitions of the strategies and regulative regimes that are shaping a new era for waste management.

For those professionally involved in the waste industry in Britain, it is as though a searchlight has suddenly been shone on an activity that for a hundred years was conducted in obscurity. Throughout the twentieth century, waste was the terminus of industrial production. Like night cleaners, the waste industry had the task of removing the debris from the main stage of daily activity. Some of the debris had value and was recycled. Most was deposited in former mines, gravel pits and quarries or, via incinerators, was 'landfilled in the air'. The principle was to keep it out of sight. Whereas consumer industries seek publicity, this post-consumer industry prided itself on its invisibility.

In the past twenty years, this situation has changed dramatically. Waste has moved from the margins to the political mainstream. The prime mover has been a new awareness of the pollution caused by the disposal of waste. This has been, and still is, the entry point for communities and governments becoming involved in what has hitherto been an untouchable issue. But there is now also a recognition of the significance of waste for two other major environmental issues – climate change and resource depletion. For policy makers the question of what to do about the targets reached at the Kyoto summit on climate change is also a question of what to do about waste. Similarly, issues of the world's forest cover, of mining degradation and soil loss cast a new perspective on old newspapers and discarded tin cans.

From the perspective of pollution, the problem is a question of what waste is. From the perspective of resource productivity, it is a question of what waste could become. As a pollutant, waste demands controls. As an embodiment of accumulated energy and materials it invites an alternative. The one is a constraint to an old way of doing things. The other opens up a path to the new. Any discussion of waste policy, of local waste plans and of their economic consequences must start from these three issues: pollution, climate change and resource depletion.

Pollution control

The acknowledgement of the significance of waste for the environment is comparatively recent. It was only in the 1970s that the poisoning of watercourses by the leachate from landfills became generally recognised, together with the risk of explosion and the toxic effects of air particles on those living in the neighbourhood of landfills. A recent European survey, based on Swedish evidence, has suggested that landfills are a significant source of the highly toxic carcinogen, dioxins, principally through air dispersion and the impact of landfill fires. A range of epidemiological studies found elevated rates of cancer, birth defects, low birth weights and small size of children in households living close to landfills.[1]

In the UK, the dangers associated with landfills were reinforced by the publication, in August 2001, of a study on the health effects of living near landfills. Focussing on 9,565 landfills in the UK, the study found that the risk of birth defects increased by 1% for those living within 2km of a landfill (and by 7% for those near special waste sites). For neural tube defects like spina bifida, the increase was 5%, for genital defects it was 7% and for abdominal defects 8%. Since 80% of the UK population lives within 2km of a landfill site, this study has posted a general health warning on Britain's predominant means of disposal.[2]

In addition, landfill was early identified as a major source of methane, one of the principal greenhouse gases, that contributes 20% of global warming. In the UK, landfills account for more than a quarter of all methane produced. For the EU as a whole, the figure in 1999 was 32%.[3] The methane given off in the process of decomposition of organic waste in landfills carries with it the local dangers of contamination and explosion in addition to its contribution to climate change. As these effects have become known, there has been increased resistance to the opening of new landfills throughout the developed world. Planners have often referred to this as self-interested 'nimbyism'[4], but the resistance has developed into a much wider critique of waste and the hazards associated with it.[5]

It was also discovered that incinerators, the main traditional disposal alternative to landfills, and widely adopted in countries where landfilling was difficult (such as Japan, Switzerland, Holland and Scandinavia) have been a major source of pollution. In their case, the problem has not been with organic waste but with materials which give off toxic emissions when burnt. Early tracking of the source of dioxins and furans identified incinerators as the prime source and even in the mid-1990s, when other sources were uncovered, municipal incinerators still accounted for over a third of all estimated emissions. They were also important sources of the release of volatile metals such as mercury, cadmium and lead.[6]

The health impacts of incinerator pollution on air, water, and land (through the landfilling or spreading of toxic ash) have been the subject of an intense and expanding scientific debate.[7] Few now dispute the extreme toxicity of many of the substances produced by incinerators. In spite of repeated plant upgrades and the introduction of new flue gas treatment technologies, municipal incinerators and other forms of 'thermal waste treatment' such as pyrolysis and gasification remain at core dirty technologies for four reasons:

(i) if flue gas emissions are reduced through improved scrubbing and cleaning, this does not destroy the toxic residues but transfers them to the ash, and creates the problem of the safe disposal of toxic ash and of polluted wastewater;[8]

(ii) municipal incinerators and thermal treatment plants are not dealing with streams of a single material with a standard calorific value. There are constant changes in the composition of the waste, in its calorific values and its moisture content. This means that there are difficulties in operating these plants at the consistent combustion conditions necessary to minimise the toxicity of emissions;

(iii) the inclusion of volatile substances and fluctuating highly combustible materials is one of the reasons for the regular fires, process upsets (and even explosions) that characterise incineration, and which in turn lead to large increases in toxic emissions;[9]

(iv) it is difficult to control the illicit introduction of toxic waste into incinerators, or of materials such as PVC, which can be major sources of dioxin when burnt.

For all these reasons there has been a continuing gap between the government's view of the effectiveness of incinerator pollution control via regulation and local experience of the impact of incinerators. It is a gap between ideal and 'actually existing' incineration. One measure of the gap is the data on regulatory 'exceedances' by incinerators.[10] Another is the epidemiological and contamination evidence of those who live near them. A third is the evidence on the hazardous conditions faced by those working in incineration plants. The gap defines an increasingly intense space of environmental politics, one that centres on information, and is engaged principally at the level of local and regional policy, planning inquiries and elections.[11]

Landfills and incinerators have highlighted the problems of the toxicity of waste and how it has traditionally been managed. In part the new awareness can be seen as an aspect of the knowledge revolution, a result of improved measurement technology which has brought to light many longstanding problems which previously went unmeasured. But in part it is a response to the growing toxicity of modern materials themselves.

In landfills the decomposition of waste leads to emissions from many of the 100,000 chemicals now in use in modern production, while the acidifying process of biological degradation leaches out dangerous substances. With incineration, a core problem has been with those materials known to be particularly toxic when burnt (such as chlorine-based products, batteries and brominated flame-retardants). In each case the dangers associated with particular hazardous materials are compounded when their disposal is part of a general waste stream.

As these effects have been recognised, the response has been increased regulations and improved technology. Modern landfills are required to be lined, and to treat the leachate and burn the gases emitted from the sites. Incinerators in Europe have had to be upgraded with new flue gas treatment technologies, which have cut toxic emissions to air. In this, the policies to control pollution from waste are part (if a later part) of the wider regulatory history of pollution abatement which characterised environmental policy in the last quarter of the twentieth century.

Yet in the case of waste, more stringent regulations have far from solved the problems. A large number of current (and past) landfill sites lack leachate and gas treatment. Those that have installed them have not been able to eliminate toxic emissions to air and water.[12] The improved flue gas cleaning at incinerators has reduced air emissions but not stopped them. There are still regular exceedances, and as we have seen there are still problems with the handling and disposal of the toxic ash. Incinerators remain generators of pollution which is dispersed widely (by design) via stack emissions, ash spreading, ash burial and water discharges.

There are no reliable, risk-free technologies for waste disposal. The issue of toxicity is a shadow over the present management of waste that will not go away.

Climate change

If waste is a threat, it is now also seen as an opportunity – nowhere more so than in relation to climate change. At one level, it is a question of cutting emissions – of methane in the case of landfill or of carbon dioxide ($C0_2$)and oxides of nitrogen (NOx) in the case of incineration. Equally significant is the potential contribution of waste management in displacing other global warming activities and in acting as a carbon sink. In the words of the US Environmental Protection Agency (EPA) in 1998:

"Among the efforts to slow the potential for climate change are measures to reduce emissions of carbon dioxide from energy use, reduce methane emissions and change forestry practices to promote long-term storage of carbon in trees. Different management options for Municipal Solid Waste provide many opportunities to affect these same processes, directly or indirectly." [13]

Of these, the most significant is the opportunity to retain the energy embodied in waste products by reuse and recycling. One quarter of greenhouse gas (GHG) emissions stem from the life cycle of materials. Any substitution of the demand for primary materials by the reuse and recycling of secondary materials and discarded products stands to contribute significant savings in energy and the resulting emissions.[14]

One estimate of the savings has been made for the USA in an exhaustive study by the USEPA. In the USA, nearly half the municipal waste is accounted for by five materials – paper, steel, aluminium, glass and plastic. The virgin production of these materials consumes one third of all manufacturing industry's energy consumption. According to the USEPA study, recycling these materials rather than disposing of them by landfill or incineration would result in savings of 0.8 metric tonnes of carbon equivalent (MTCE) for every tonne of waste diverted, or 17 million MTCE for each 10% of municipal waste diverted from disposal.[15]

For the UK, the intensive diversion of waste from disposal has a similarly striking impact. One model that used the USEPA data on relative CO2 effects found that the reuse and recycling of 70% of the UK's municipal waste would lead to a saving of 14.8 million MTCE, which would have a similar impact to taking 5.4 million cars off the road.[16] If this was repeated for commercial and industrial waste, the total savings would amount to nearly a third of the reductions (over and above existing measures) that would be necessary for the UK to meet its target of 20% cuts in CO2 by 2010. This is one measure of the significance of waste diversion within the context of the Kyoto protocol.[17]

There are two other ways in which the form of waste management can reduce net CO2 emissions. The first is the impact of using composted biodegradable waste on land as a soil amendment and, in doing so, 'sequestering' carbon from its everyday cycle. Applying compost acts as a counterweight to the release of stored-up carbon in soils resulting from depletion induced by intensive agriculture. This is an area of increasing scientific interest in the context of agricultural and climatic sustainability. One estimate is that 20 billion tonnes a year of carbon are captured in the soil's organic matter, compared with 80 billion tonnes of anthropogenic carbon emitted to the atmosphere.[18] In Italy, Favoino cites evidence to suggest that an increase of 0.15% of organic carbon would lock the same amount of carbon into soil biomass as is released annually into the atmosphere by the use of fossil fuels in Italy.[19] The significance of composting for carbon sequestration in soils was recognised by the recent Bonn Conference on Climate Change and is becoming an increasing influence in EU policy.

The other potential impact of waste management on CO2 reduction is more controversial, based as it is on the production of power (and in some cases heat) from incinerators. The energy value of waste materials is 5% of primary energy consumption, using Western European data.[20] Until the publication of the USEPA results, it was commonly argued that burning the combustible elements of waste – particularly paper, plastic and wood – was environmentally more beneficial than recycling them, and there have even been attempts to suggest that the same holds for burning organic waste rather than composting it. From this perspective it is argued that waste should be reconceptualised as a renewable energy source, a form of bio-energy similar to coppice wood, with incineration a significant contributor to the shift from fossil fuel to renewable energy production.

There have been three main objections to this argument:

- plastics are derived from fossil fuel, and their combustion may well produce more CO2 than the electricity sources they displace;
- the energy value of organic waste is low, at 4 megajoules (MJ) per kg.
- the increased demand for paper, even with 39% recycled input worldwide, is leading both to the destruction of original natural forests, particularly in the South and the former Soviet bloc, and to the growth of plantation forests. Leaving aside the implications of these trends for biodiversity, acidification, erosion and water quality, recycling paper rather than prematurely burning it would allow old growth forests currently due for felling, as in Finland, to remain standing (and thus to continue to act as a carbon sink) or would allow fully grown wood destined for pulp manufacture to be used directly as a biomass fuel, thus preserving the energy already embodied in waste paper.[21]

Since the USEPA results and parallel studies in the EU, there has been a shift in the argument – away from the environmental benefits of incineration over recycling, to the recovery of energy from residual waste that has no value as a recyclate. In parallel the research debate has moved from life cycle analyses of incineration and recycling to models showing the maximum practicable level of recycling, thus defining a boundary beyond which incineration no longer competes with recycling but produces net savings in CO2. The issue of maximum recycling levels will be discussed more fully later. Here it is enough to note that there is agreement on the potential for recycling and composting to reduce fossil fuel energy production and emissions of CO2.

Ecosystems and resource productivity

In the past five years a third argument for waste recycling has come to the fore – namely the impact that it can have on reducing the pressure of industrial growth on primary resources. An early version of the argument was framed in terms of the 'limits to growth' and the impossibility of generalising the current model of material intensive production to the developing world. The limits were described primarily in resource terms. Economists replied that the price mechanism plus new technology would deal with scarcities, citing evidence that material supplies have continually run ahead of demand and that primary product prices – far from rising – are now approaching a thirty-year low.

The modern version of the argument is wider and is posed in terms of ecological systems rather than particular resources as such. The stock of the 'natural capital' is being run down, depleting the life supporting services provided by natural systems. In the words of three articulate exponents of the case:

"It is not the supplies of oil or copper that are beginning to limit our development but life itself. Today our continuing progress is restricted not by the number of fishing boats but by the decreasing numbers of fish; not by the power of pumps but the depletion of aquifers; not by the number of chainsaws but by the disappearance of primary forests … Humankind has inherited a 3.8 billion-year store of natural capital. At present rates of use and degradation, there will be little left by the end of the [21st] century."[22]

The destruction of natural systems such as fresh water and marine ecosystems, forest cover and soil nutrients is not adequately reflected in the price system, since they are either free (like access to common land), or subject to 'founders rent' – an access price to a free natural resource which permits the depreciation of a resource without requirements of restoration.

The argument is both immediate and long-term. In the short run, over-fishing, the pressure of intensive agriculture on soil quality, and of industrial demand on natural forests are all depleting key resources in ways that the economists' formula of 'price system + new technology' has commonly hastened rather than reversed. To take only one example, the European Environment Agency estimates that five tonnes of soil per capita are being lost annually as the result of erosion.[23] Soil content in Italy has been halved in the past twenty years. Globally the world is estimated to have lost a quarter of its topsoil over the past fifty years. Desertification in China has come within forty miles of Beijing and is advancing at the rate of two miles a year. In this context, the use of composted organic wastes for agriculture is not just a question of carbon sequestration but of returning biomass to the soil and restoring the nutrient cycle.

The case is not confined to these immediate issues. As those in the Limits to Growth tradition point out, even if new technology extends the stock of recoverable mineral resources, or switches to new ones, the continued expansion of the current mode of industrial production and its extension to less developed countries, threatens many longstanding ecosystems without offering an adequate alternative.[24] As Schumpeter pointed out, capitalism has always advanced through creative destruction. In many of the central issues of the environment, destruction is running ahead of creation. From this perspective, the issue of climate change is only one example of a more general ecosystem phenomenon.

The policy question is how to reduce the intensity of resource use faster than the countervailing pressure of the growth of demand. Part of the answer lies in the way primary production is carried out (through the reduction of artificial fertilisers and pesticides in agriculture, for example, or clear cut logging); part in the dematerialisation of production and in changes in consumption. But there is also the question of the reduction and reuse of waste. At any one time, waste accounts for the majority of material flows. Until recently it was treated as a leftover from useful production. But it is clear that any strategy to reduce resource pressures has to address the volume of waste and what is done with it.

The size of these flows is only now being calculated. The World Resources Institute led an international team that traced the flows of 55 materials in 500 use streams (covering 95% of the weight of materials in the economy) for four leading OECD economies (the USA, Japan, the Netherlands and Germany). They found that the total materials requirement in these countries was 45 to 85 metric tonnes per person and that of this between 55% and 75% takes the form of waste materials that are discarded in the course of production (such as mining overburden, agricultural waste or material removed for infrastructural works).[25] They termed these 'hidden resources' since they do not enter the market economy save as a cost of disposal or restoration. They can be reduced by lowering the demand for the marketed resources to which they are attached, or by lowering the ratio of waste to primary marketed resources, or by reclaiming value from what would otherwise be waste. The same applies to waste from secondary production and to post-consumption waste: it has to be either reduced or 'revalorised' through recycling.

Waste – both in its process of generation and its treatment –

thus takes a central place in strategies to reduce the material footprint of industrialised economies. Every aluminium can recycled not only means that the need for new aluminium is reduced, but that the waste (and energy) associated with bauxite mining, as well as alumina and aluminium production, is also avoided. These are referred to as the upstream benefits of recycling. They represent avoided materials production, avoided wastes and avoided energy.

Resource productivity is becoming a major theme of environmental policy. The UK Cabinet Office has published a study on the subject.[26] The European Environment Agency has just produced the first collection of data on European primary resource productivity. Environmental engineers and scientists have been discovering ways in which resource efficiency can be discontinuously increased. Amory Lovins, one of the principal proponents of the new 'materials revolution', sees the scope for using resources ten to a hundred times more productively, and increasing profitable opportunities in the process.[27] He and other members of the Factor Four and Factor Ten clubs suggest that if the first industrial revolution was centred around increases in labour productivity, the next frontier will be materials productivity.

A number of national and international bodies (including the OECD Council at Ministerial level) have proposed a goal of increasing materials productivity by a factor of ten within a generation, and the Austrian Government has adopted this in its National Environmental Plan. (The equivalent Dutch plan has a more modest target of a four-fold increase in materials productivity, and the German one has a 2.5-fold improvement.)[28]

Improving materials productivity through recycling conserves materials as well as the energy embodied in them. The Dutch Government forecasts that half of the energy efficiency gains it will make up to 2010 will be the result of improved materials productivity. The MARKAL researchers estimate that materials reduction in Western Europe – following increases in penalties for carbon use – would contribute emission reductions of 800 million tonnes of CO_2 equivalent (compared to the current European emission level of 5.1 billion tonnes).[29] Materials savings and energy savings thus go hand in hand.

A turning point in the waste industry

Over the past ten years these environmental imperatives have provoked a response which was at first pragmatic and particular, aimed principally at identified problems of pollution. But in recent years its scope has widened, to the causes of pollution on the one hand and to the gathering global concerns of climate change, ecosystem depletion and resource productivity on the other.

Waste has suddenly become an issue too important to be left to the waste industry. It is seen no longer as simply a sectoral matter – though the waste industry itself has been put under pressure to change. Rather, waste like energy and water is now recognised as pervasive, connecting as it does to every sector of the economy. It raises questions about the toxicity of modern materials and the profligacy with which mass production uses up non-renewable resources.

As the questions have widened, so has the response. There has been a shift from the concentration on pollution control to a broader policy of 'Zero Waste'. 'Zero Waste' as a concept has only recently been applied to waste management. But it has already built up a momentum which promises to transform not just the waste industry but material production itself. In a way that could not have been predicted in the 1980s, the redefinition of waste promises to be, along with the information and knowledge revolution, one of the defining features of the post-industrial era.

II Zero Waste

Fair and foul

At one level the term 'Zero Waste' appears to be a contradiction in terms. Just as there can be no light without shadow, so useful matter, to have meaning, requires its opposite – useless waste. Or, to put it another way, if waste is defined as matter in the wrong place, then eliminating waste would take with it the possibility of matter being in the right place. If waste didn't exist we would have to invent it.

And that of course has been part of the problem. Waste has been seen as the dark side, as that against which we define the good. It has been the untouchable in the caste system of commodities. The idea that waste could be useful, that it should come in from the cold and takes its place at the table of the living, is one that goes far beyond the technical question of what possible use could be made of this or that. It challenges the whole way we think of things and their uses, about how we define ourselves and our status through commodities, by what we cast out as much as by what we keep in.[30]

There have been two currents that have sought to give waste a new identity. The first is longstanding. It combines the puritan and the utilitarian. It takes the view that nothing useful should be wasted. Overriding the personal usefulness of things, it seeks other uses as a way of preserving their inherent value – particularly the value that comes from the labour that made them. The work ethic finds its reflection in the commitment to recycling, one reason why recycling has always been strongest in northern Protestant Europe.

The other current is more recent. It is the environmental. Here waste is redefined in terms of its role in natural cycles. On this basis it turns the tables on conventional distinctions. Instead of the value of commodities and waste being defined in terms of personal utility, it looks at them both in terms of recyclability. Good waste is that which can be recycled. The test of commodities is whether they can become good waste. The problem of waste disposal is replaced by the problem of phasing out those materials which are hazardous and which cannot be recycled. The issue is not to get rid of them when they are finished but to avoid producing them in the first place. Environmentalists have recast the opposition of good things and bad waste into a question of good waste and bad things.

For both these currents Zero Waste has been an aspiration. The environmental imperatives discussed earlier are now creating a pressure for Zero Waste to be made real. The decisive forces to link aspiration and practice together have come from two quarters: the environmental movement itself which has inspired a new generation of practical experimentation and design, and the world of industry and its rethinking of production.

The term 'Zero Waste' originates from the latter. In the past twenty years it has been increasingly adopted as a goal for commercial waste minimisation. It is an extension of the Japanese-based ideas of total quality management (TQM) into the environmental field.

One of the early TQM concepts was 'zero defects'. This involves the establishment of practices that allow a firm to eliminate all defects. It is incremental in approach, with intermediate 'stretch targets', directed at the pursuit of optima rather than restricting progress to choices between alternative known solutions. It has been extraordinarily successful, with producers like Toshiba achieving results as low as one defect per million.

The same approach has been applied within a TQM framework to zero emissions and Zero Waste. As the Japanese planning ministry recently put it: 'Waste is an un-Japanese concept.' Japanese firms have been in the lead in adopting Zero Waste policies, with Honda (Canada) reducing its waste by 98% within a decade, and Toyota aiming for the zero target by 2003. The puritan aspiration is becoming an industrial reality.

Over the past five years, the idea of Zero Waste has been transferred to the municipal field. In 1996 Canberra became the first city to adopt a Zero Waste target (for 2010). Its example has inspired a municipal Zero Waste movement in New Zealand. Some Californian authorities, having achieved their initial targets of 50% waste reduction, are now moving to the next phase of Zero Waste. The approach adopted is to set demanding targets in terms of what has to be done, which then become challenges at every level of the organisation. As with TQM more generally, Zero Waste is at the same time a long-term goal and a particular methodology about how to get there.

As an approach to municipal waste it has three distinguishing characteristics:

- its starting point is not the waste sector as such but the systems of production and consumption of which waste forms a part. It is an industrial systems view rather than a view from one (the final) part of the economic chain;

- it approaches the issue of waste and its redefined role from the perspective of the new industrial paradigm – looking at it in terms of the knowledge economy and complex multiple product systems;

- it proposes a different model of environmental policy and of the process of industrial change.

Intensive recycling and composting remain at the centre of Zero Waste as a strategy. Yet its impact goes beyond these approaches, to the contribution of the waste sector to the wider project of industrial redesign.

The three prime goals of Zero Waste are a direct response to the environmental imperatives currently pressing on the waste industry:

(i) zero discharge

First it is a policy to reduce to zero the toxicity of waste. Such a policy, applied to water and termed zero discharge, was first actively pursued by the US and Canadian governments in the Great Lakes Water Quality Agreement of 1978. The International Joint Commission that oversees the progress of the Agreement defined it as follows:

"Zero Discharge means just that: halting all inputs from all human sources and pathways to prevent any opportunity for persistent toxic substances to enter the environment as a result of human activity. To prevent such releases completely their manufacture, use, transport and disposal must stop; they simply must not be available. Thus zero discharge does not mean less than detectable. It also does not mean the use of controls based on best available technology, best management practices or similar means of treatment that continue to allow the release of some residual chemicals."[31]

The idea of zero discharge was adopted (without the term) by the fifteen-country Oslo and Paris (OSPAR) Commission on the North East Atlantic in 1992 and by the Barcelona Convention on the Mediterranean in October 1993. This is how the OSPAR agreement put it:

"Discharges and emissions of substances which are toxic, persistent and bio-accumulative, in particular organohalogen substances, and which could enter the marine environment, should, regardless of their anthropogenic source, be reduced by the year 2000 to levels that are not harmful to man or nature with the aim of their elimination."

What is being said here is that substances that are toxic, which resist the natural processes of material breakdown and recycling, but rather accumulate to ever higher levels in the environment, should be eliminated. Reducing their discharge means only slowing their rate of accumulation. The goal must therefore be zero discharge through phasing out the production of the substances in question. In the words of the Agreement, 'They simply must not be available.'

The three Agreements all relate to the pollution of water. The pollution can come about in the process of production, use or disposal. It can pass directly to water (through water emissions in production for example) or indirectly via the air, or through run-offs and leaching to water from land. Solid wastes are one form that can transfer or increase the pollution.

Zero Waste as applied to solid waste carries with it the idea of reducing with the aim of eliminating the presence in wastes of substances 'harmful to man or nature'. It means reducing all forms of toxic waste entering the waste stream, and methods of treatment of waste materials which result in 'persistent toxic substances' entering the environment.

Zero Waste goes beyond the existing practices of separating out hazardous materials and subjecting them to more stringent disposal requirements, and of basing required levels of control (at hazardous and non-hazardous sites) on assimilative capacities and acceptable discharges. It does not stop with end-of-pipe controls. Such controls have faced repeated problems of regulatory infringement, of the switching of pollution from one means of discharge to another (as with incinerator air emission controls, where toxicity is switched from air to ash and to the water used for plant cleaning), and of the lack of controls on emissions whose long-term health effects are not yet known (such as micro-particulates). Rather the aim of Zero Waste, like zero discharge, is to track to the source the cause of toxicity and control it by substituting non-toxic alternatives.

As such, Zero Waste invokes the principle of Clean Production. Clean Production aims to phase out the generation and use of toxic chemicals and materials by redesigning products and manufacturing methods to eliminate the inputs of toxic substances.[32] It targets toxic substances such as long-lived radioactive materials and heavy metals, which have been persistent sources of waste pollution. Its current priority is the phasing out of organohalogens, the substances specifically targeted in the OSPAR and Barcelona Agreements. Of the three principal organohalogens – organochlorines, organobromines and organoiodines – it is organochlorines that are the focus of immediate attention (the twelve priority pollutants of the current Stockholm Convention all being organochlorines). Waste products containing organochlorines (such as PVC, solvents, and PCBs) are the source of dioxins produced by incineration, and of many of the toxic effects of landfills.

(ii) zero atmospheric damage

The second principle of Zero Waste is the reduction to zero of atmospheric damage resulting from waste. With respect to climate change the first issue is the reduction of methane emissions from landfills. This would largely be ended by prohibiting the landfilling of untreated biological waste. Article 6 of the EU's Landfill Directive contains such a provision which should be interpreted – from the environmental rather than the bureaucratic perspective – as requiring forms of treatment of residual waste which reduce the fermentability of the organic fraction to no more than 10% of its initial level. Zero Waste here means zero untreated waste to landfill.[33]

A wider question is how the management of waste can help restore the carbon balance. Zero Waste in this context does not (and could not) mean eliminating CO2 emissions but rather:

- the minimisation of the loss of energy embodied in existing materials and products and of the use of fossil fuel energy for the process of recycling;
- Zero Waste of carbon that could be sequestered through the return of composted organic materials to the soil.

As far as CO2 is concerned, the central operational concept of relevance is environmental opportunity cost. This means estimating environmental costs in terms of the net environmental benefits forgone by choosing one method of production or disposal over another. The net environmental benefits of incineration, for example, cannot be estimated solely by comparing the energy recovered from burning waste with the environmental cost of the incineration process, but must take account of the net environmental benefits foregone were that waste to be recycled.

Estimating these environmental costs and benefits is the subject of life cycle analysis (LCA), which normally compares alternative methods of disposal (landfill and incineration) with recycling. It aims to show where, in what respects and for what materials it is preferable to use one method of waste treatment rather than another. It has become a new form of environmental accountancy.

But there are problems in the way in which LCA has been used. It has been static, considering solely an existing pattern of alternative resource use. It does not take account of potential patterns that may emerge in the future. For instance, it takes time for new markets to develop for recycled materials, and as a result early recyclers often have to ship their materials long distances to find existing processors. Over time processors move closer to the recycled materials and the environmental (and financial) costs of transport fall. A dynamic approach looks at the results of life cycle analysis to see how the environmental costs of recycling can be reduced in order to maximise the net benefits from conserving resources.

Nor do LCAs look beyond the product to the systems of which they are a part, and how those systems can be transformed in order to reduce negative environmental impacts. LCAs tend to be narrow and incremental. Instead of being used as a means for judging between alternative methods of waste treatment, they should rather be seen as a tool in the design process of recycling and the production systems of which recycling forms a part.[34]

Zero Waste adopts a dynamic systems perspective to the conservation of embodied energy. It aims to maximise the net energy saving from recycling, by finding ways of cutting down energy use in the recovery and reprocessing of materials, and of substituting renewable for fossil fuel energy to produce the energy required.

Leading recycling jurisdictions have developed reprocessing close to the point of recycling (reviving urban manufacturing in the process). They have promoted renewables to produce energy for reprocessing, and in the UK and Italy, used low energy electric vehicles for recycling and organics collection. The goal is to use zero non-renewable energy in the process of recycling in order to achieve Zero Waste of the ‘grey energy’ contained in the recyclables.

(iii) zero material waste

Third, Zero Waste aims to eliminate material waste itself. Most tangibly, this means an end to all waste for disposal. No material would be discarded as worthless, instead a use would be found for it. Thus builders’ rubble which was not recoverable for construction could as a last resort be used for land restoration (like much quarry waste).

This pragmatic goal highlights the potential value of waste, and the importance of phasing out the treatment of mixed waste streams. Its limitation is that it cannot distinguish the relative environmental (or financial) value of alternative uses of the materials. Thus metals recovered magnetically after incineration are of low quality, but their reuse used to be classed as recycling alongside high quality metals recovered through source separation. The definition of Zero Waste in this context then turns on the definition of use, which can be made so wide that it undercuts the goal of conserving resources.

To the pragmatic definition should then be added a concept of Zero Waste that entails the maximisation of material conservation. This perspective is embodied in the concept of material cycles developed by two of the most innovative Zero Waste thinkers, Michael Braungart and William McDonough. They distinguish two main cycles:

- the biological cycle for products that are composed of biodegradable materials called biological nutrients that can be safely returned to the environment at the end of a product's useful life and contribute to the rebuilding of depleted soils;

- the technical cycle composed of 100% reusable materials called technical nutrients designed in such a way that they can remain in closed loop systems throughout their life cycle.

The residual 'unmarketable products… those that cannot be used or consumed in an environmentally sound way and for which no safe recycling technology exists,' should in the long run no longer be produced.[35]

The biological cycle is renewable, whereas the technical cycle comprises non-renewable resources. One strategy they suggest is to develop new biological materials that substitute for non-renewable ones. The replacement of oil-based plastics by vegetable-based ones is an example (as in the case of plastic bags) or of bio-plastics for steel (Volkswagen is now making car doors out of plant-derived plastics). In cases where the resource and financial cost of recycling is high (e.g. plastic bags) the product can be returned as a nutrient to the soil.

A second strategy – which is inherent in this concept of cycles – is that of sustaining quality. In the biological cycle, it is critical that the 'bio waste' is returned to the soil in a way that enhances rather than degrades it. Contamination and mineral balance are central to issues of soil quality. Compost that is suitable only for landfill cover represents a degradation in terms of the reproducibility of the cycle.

The same applies to technical nutrients. There are technical cycles that continuously degrade the materials, such as the use of recycled PET bottles for garden furniture. Braungart and McDonough refer to this as 'downcycling' and see it as characteristic of most current waste diversion practices. 'Reduction, reuse and recycling are actually only slightly less destructive (than landfills and incinerators) because they slow down the rates of contamination and depletion rather than stopping these processes.' The environmental goal should be recycling and up-cycling: 'the return to industrial systems of materials with improved, rather than degraded, quality'.[36]

The idea of up-cycling suggests that we should talk of material spirals rather than cycles. Zero Waste becomes a question of not merely conserving the resources that went into the production of particular materials, but adding to the value embodied in them by the application of knowledge in the course of their recirculation. An example given by Michael Braungart is the use of rice husks. Originally they posed a waste disposal problem in Asia because they were incombustible. Braungart developed new uses for them, first as a substitute for polystyrene as a packaging material for electronic goods and then, after that use, as a fire-resistant building material. In this case, previously unacknowledged natural properties of a material were identified that allowed them to be revalued as they were applied to a succession of uses.

Projects to realise the value of secondary materials have generated a new technology of alternative uses as these materials are studied for their properties and then substituted for existing primary-material-based processes. One of many examples is the use of rubber crumb made from old motor tyres to make basketball courts in the USA. The extra spring in the court has reduced the knee stress on professional basketball players, extending their careers.

Cyclical Production, the proposition of reconceptualising (and redesigning) the economic process in terms of two cycles – of biological and technical nutrients – is one of the central ideas of Zero Waste. Its focus is on the material life cycle and the conditions for materials to flow through a succession of uses ('from cradle to cradle' rather than 'from cradle to grave').

A second key concept is Sufficient Production. This addresses the amount of materials and energy consumed (and potential waste produced) in a single cycle. It deals with the material intensity of production, the reduction of extractive and manufacturing waste, the lifetime of products, the effectiveness of their uses, and the way in which they can achieve their desired outcome in consumption with less material input. It shifts the strategic emphasis from efficiency to sufficiency, and to how the productive systems and the products they contain can be reconfigured to cut the material flows required.

If Cyclical Production focuses on the qualitative features of materials from the perspective of recycling, Sufficient Production highlights ways in which the quantities of materials and potential waste can be reduced. Both apply to energy as well as to material 'sufficiency'. Together with Clean Production they form the three central industrial pillars of Zero Waste.

Zero Waste is a consequence as much as a cause of these shifts in production. The pollution problems of waste management may have triggered innovation, as is the case with the movement for Clean Production. Waste management also has a role to play in re-establishing the material cycles. Yet now the drivers for change are shifting back up the pipe. Manufacturers and industrial designers are moving to the centre of the stage both to ensure technical and economic recyclability of materials, and to reduce the need for production and the use of materials in the first place.

This is an important point, since too often the quantity and toxicity of waste has been held to be the responsibility of waste managers, and within their capacity to control. Yet waste managers are for the most part the passive recipients of problems which have been produced elsewhere.

Responsibility has been passed down the line and ended up with them because there was nowhere else for it to go. Their job has been to get rid of these problems as safely and cheaply as possible and now, when the limitations of this old system have become apparent, they are being asked to devise an alternative system for reducing and neutralising the environmental damage done by waste.

The task is an impossible one. The keepers of the terminus cannot be expected to redesign the system. They are strangers to the industrial world. They are structurally and culturally far removed from design. Once waste is connected back to the wider industrial system – through reuse and recycling – the axis of responsibility for waste shifts from the waste industry back to those who produced it. They in turn are in the best position to do something about it. If waste is re-conceptualised as a resource, then it is the specialists in resources – who produce them, apply them and discard them – who should take responsibility for transforming the way they are used.

A new way of seeing

Zero Waste has multiple perspectives – of clean production, of atmospheric protection and resource conservation. Taken together these provide a new way of analysing waste – a new way of seeing. Although it is a contributor to environmental degradation, waste cannot be treated in isolation. Waste is only the final stage of a much wider chain of production and consumption in which the problems associated with it are rooted. In this sense waste is a symptom as much as a cause, a sign of failure in the design and operation of the material economy. It provides an insight into deeper structures, as well as an opportunity for changing them.

For these reasons, while Zero Waste provides the basis for reformulating policies for waste management, it is not just about cutting waste going for disposal, whether landfill or incineration. Its aim is the restoration of pre-industrial circuits – the biological circuit of organic materials and the technical circuit of inorganic ones – using post-industrial means. It offers a way in which the negative detritus of an earlier era is transformed – through ecodesign – into a positive nutrient for clean production. Zero Waste is a manifesto for the redesign of the material economy, and at the same time, it is a set of tactics for realising its principles in practice.

It is also a description of what is already happening. Over the past decade a change has taken place in the industrial landscape that has been too little noticed. The change is occurring in two fields – in the way waste is managed on the one hand, and the way it is produced on the other. The first is creating a new waste industry, the second a new industrial approach to materials. Both are part of a wider green industrial revolution.

III The growth of recycling

First the waste industry. It has since its inception been primarily concerned with mixed waste rather than recycling. Although there has always been some measure of recycling, it has been a residual function, commonly carried out by processing industries, or, where wages are low, by totters, scavengers and nightsoil collectors. In industries where there were relatively homogeneous waste flows and materials with a good resale value (like metals and paper) the waste was either recycled within the plant or transferred through merchants to mills that could handle it. The problem came with low value waste, and with mixed waste streams from which it was difficult to recover usable materials.

Municipal waste was particularly intractable. Local authorities would put out recycling bring banks and even run a newspaper collection, but municipal recycling rarely averaged more than 10%. The remainder, like most industrial and commercial waste, was bulked up and disposed of in the cheapest way possible. Waste and those who managed it were marginal to the economy.

Now the demand is for the opposite. It is recycling which is being moved to the centre of the stage, with residual waste banished to the wings. The turnaround has been most rapidly achieved in the commercial sector. In Copenhagen, for example the proportion of construction and demolition waste that is recycled has gone from 10% to 90% in less than a decade, and over half (51%) of industrial and commercial waste is now recycled. In Canada offices were diverting 70-80% of their waste within six months after simple recycling systems were introduced. Large events, like the Olympic Games in Atlanta, found that they could recycle 85% of waste produced. Schools, prisons, shops and hospitals have achieved similar levels.

The greatest challenge has been the municipal sector: mixed waste from thousands, even millions of people.

But here, too, the advance has been of a kind that few would have predicted ten years ago. A few communities have reached the levels common for commercial waste – 70-80%. Elsewhere, '50%' jurisdictions are now becoming commonplace. Cities, regions and even countries have passed through the 50% recycling barrier, the point at which residual waste becomes a minority share.

In North America:

- California, with a recycling rate of 10% in 1989, passed legislation requiring all its municipalities to reach 50% diversion from disposal by 2000. They reached 42% by the target date and expect to have hit 50% by the end of 2001. A majority of the 304 cities and counties in the state now have recycling rates of 50% or more;

- the USA as a whole raised its recycling rate from 8% in 1990 to 32% in 2000, with six states reaching 40% or above;

- Canada made 50% diversion by 2000 a national goal. Nova Scotia was the first province to hit the target by 2000, with its capital, Halifax, registering a level of 60%. Leading municipalities have now reached levels of 70% diversion.

In Australasia:

- Canberra has reached a level of 59% of municipal diversion and is shortly to introduce an organics collection scheme which will take it a further large step forward;

- in New Zealand, 8 of the 78 municipalities have already reached the 50% target.

In Europe:

- a growing number of states and regions have passed the 50% mark, including: German länder like Baden Wurttemberg, Lower Saxony and Saarland; Flanders (now at 54%); and Italy's Milan province, where 88 out of 180 municipalities have reached the target, with 32 of them now over 60% and five over 70%;

- whole countries are now approaching or surpassing the benchmark. Germany raised its municipal recycling rate from 12.5% in 1990 to 46% in 1996. It's level of waste as a whole fell by a third. The Netherlands, in spite of its stock of incinerators, has managed to switch the balance of its waste from landfill to recycling, achieving a municipal recycling rate of 46% by 1998 (and 70% for all waste). The highest national level has been reached in Switzerland, which now has a rate of 53%.

These changes, when achieved at a national level within so short a time, are remarkable given the complexity of the new collection and sorting systems required and the quite different modes of operation for intensive recycling and mixed waste disposal. What they have established is that for any locality or region 50% diversion from disposal is readily achievable, usually within six to eight years, even without a new waste regulatory regime being fully in place.

The 1990s saw a head of steam arising at the municipal level for intensive recycling and composting, and the amassing of a body of experience in how to deliver it. The decade showed the economic significance of the new systems in practice, as they generated substantial numbers of new collection and sorting jobs[37] and also prompted the expansion of a wide range of processing industries. Institutions for finance developed, as well as advisory support for collectors, material sales and market development. In short, the 1990s saw the birth of a new industry and a new profession.

The industry is still in its early stages. It still bears the imprint of the refuse industry – with capital intensive sorting plant, large vehicles, and wheeled bins with automatic lifts. Some places have responded to the recycling challenge by collecting mixed waste as usual and trying to recover materials through centralised sorting (in so-called dirty Materials Reclamations Facilities - MRFs), using screening and magnetic extraction, or through mixed waste composting (a method in which non-organic materials are partially separated out from the organics, leaving a low quality compost residue).

A step forward from this has been to collect waste in two streams – a wet and a dry – composting the former and sorting the latter either by hand or through the application of increasingly complex sorting technology. More commonly, separate dry recycling collections are run in parallel with the main weekly collection, handling a limited number of materials separated at source. Germany has gone one step further with separate collections of packaging, organics, paper and residuals, each using similar set-out and collection technologies, and processed in centralised facilities.

All these are examples of recycling using the old methods. This is not unusual at points of industrial transition, as when the first cars located their drivers high up at the back, where a coachman used to sit to control the horses. But the old methods are often ill suited to their new tasks. Mixed waste systems have low recovery rates and yield poor material quality and the conditions for those working in the central sorting facilities are unsustainably hazardous.

The German systems have much better recovery rates but they are high cost, they entail expensive sorting technology, and are transport intensive. In the end these systems are self-limiting, either because of the quantity of recyclable material they can recover or the level of their costs. In either case they risk putting a technical or economic cap on the recycling rates that can be achieved.[38]

Yet in many places the barriers presented by the old ways of the waste business have been broken open. There is now a wave of innovation in the technical, organisational and economic structures of the industry that is both lowering costs and increasing recovery rates. The outlines of a new recycling economy are emerging which provide the conditions for the further advance towards Zero Waste.

This economy has three distinguishing characteristics:

- *flexible production systems.* It is replacing the single flow management of mass waste with flexible systems for handling multiple streams of good quality materials;

- *the core role of the social economy.* It recognises householders as key producers within the wider economic circuit of recycling, and is developing the incentives, knowledge and institutions appropriate to voluntary labour;

- *reconnecting to markets.* It is reorienting an industry that has hitherto been entirely dependent on public funding, to one that supplies materials to commercial processors and recycling services for a wide spectrum of waste producers.

Flexible recycling systems

The change in the system of collection and logistics required by recycling – from a single flow of materials to multiple flows – is similar to that which has been taking place in other manufacturing and service industries over the past 20 years. It lies at the heart of the new flexible manufacturing systems first introduced in Japanese manufacturing which have since spread throughout the world and to many service sectors.

Waste in this context is a latecomer, and the pioneers of intensive recycling reflect many of the features of this new industrial paradigm. They often come from areas whose economies have already made the transition: from the west coast and sections of the east coast of the USA and Canada; from the European regions celebrated for their dynamic manufacturing networks in the 'third Italy', Germany and the industrial districts in Spain; and from Australasia.

Flexible manufacturing entails a shift from the dedicated machinery of mass production to general-purpose machines. It has turned the principles of FW Taylor and Scientific Management on their head, decentralising operational control to frontline workers, and re-skilling them. It has also involved the development of complex management information systems to keep track of the multiple flows, and to provide the data necessary for statistical production control by both the operatives and the technical support staff. Table 1 below summarises a number of key differences between the old paradigm of mass production and the new paradigm of flexible specialisation.[39]

Many of the features of mass production can be recognised in the traditional system of waste management and its methods of recycling. Most local authority waste departments and waste firms have extended vertical hierarchies of control. The role of the dustman or the recycling collector/sorter remains an epitome of unskilled labour (in some cases the sorting function being designed for the mentally impaired). Planning is separated from execution (in one UK case by no less than nine layers of authority). Investment is directed towards hardware not software. Systems are set up to feed large pieces of capital equipment (large MRFs with high capacity sorting of both plastics and paper, using electronic recognition technology). Scale still dominates over scope.

The 'smart' recycling systems, by contrast, combine the characteristics of the knowledge economy (design, multi-skilling, branding, advanced management information systems) with the technologies and organisational forms of flexible manufacturing.

Table 1

Mass Production (Fordism)	Flexible Specialisation (Post-Fordism)
Single product flow	Multi-product flow
Dedicated machinery	General purpose machinery
Push through	Pull through
High stocks	Just-in-Time production
Lengthy design and pre-production testing	Multiple products tested on the market
High reworks	Zero defects
Unskilled, single task labour	Multi skilled, multi-task labour
Division of planning, control and execution	Greater front line autonomy and continuous improvement
Pyramidal structures with vertical lines of command and reporting	Flat structures with horizontal as well as vertical linkages
Closed organisations	Open structures with multiple external networks
Price determined sub-contracting	Innovation-based subcontracting
Fixed capital-intensive	Knowledge-intensive

They have the following characteristics:

- *multiple services*. Collection moves from a standardised weekly model to multiple services geared to the time requirements of the particular waste stream. There is a new waste calendar (combining simplicity with the seasons) with weekly collections of dry recyclables, alternating fortnightly collections of food waste and residuals, monthly week-end collections of green waste, and quarterly collections of seasonal, durable or hazardous items (Christmas trees, clothing, spring cleaning clear-outs).

- *customised collection systems*. Services, vehicles and containers are designed to suit particular types of housing: in suburban areas and small towns multi-compartment vehicles have been effectively used; in dense inner city areas small pedestrian controlled vehicles (PCVs) with builders bags as compartments can be used (an innovation from the UK), or micro pick-ups for food waste and dry recyclables (an Italian scheme); in rural areas co-collection, as adopted by North American recyclers, allows commingled dry recyclables to be picked up with residual waste one week, and organics the next.

- *general-purpose equipment*. Vehicles are designed for multiple functions, adapting the principle of the container and pallet to the needs of recycling (flat-backed trucks with multiple mini-containers provide the flexibility that many multi-compartment vehicles lack). One of the features of modern flexible systems is the central importance of low cost switching, in this case the ease of transfer between types of vehicle (from a feeder vehicle to a compactor, for example, without the need for a transfer station).

- *decentralisation*. Sorting and logistics is redesigned away from a centralised hub and spoke model, to decentralised nodes and a 'latticed web' pattern of material movements. For example, the shift to small vehicles means that they can be stored in local garages and a measure of sorting can be conducted locally or at the kerbside, with materials stored at sub-depots in small containers for eventual transportation. Each collection round develops a greater operational and logistical autonomy.

- *de-scaling and modularising material processing*. Many processing industries have found economic ways of descaling production – notably the expansion of mini-mills in paper production and steel, and of micro-chemical plants. Commonly processes requiring scale are separated off, so that other processes can be decentralised, through sub-assemblies, and specialised preparation plants. For recycling, small, widely distributed processing centres reduce transport and encourage local 'loops' or cycles. Closed vessel micro-composters serve the same purpose, being able to economically process waste from a tower block or village. They are modular and can be located at civic amenity (CA) sites, parks, in the grounds of a hospital or beside a fishing port (see inset 1).

- *multi-skilling*. Collectors take centre stage in Zero Waste recycling: they are the frontline interface with householders (or firms); they provide a channel of advice and information; they analyse the data from their rounds and are responsible for improvements (houses passed, participation rates, levels of contamination). In addition to sorting they may also be responsible for some local processing, such as in-vessel composting. The pioneers here have been environmentalists who have set up recycling and composting schemes and who represent a new kind of 'green-collar worker'.

- *central service support*. 'Head office' services are geared to support the frontline staff (from standardised management information systems to the provision and maintenance of equipment, social marketing materials, and the administration of secondary material markets).

- *redefining management*. In the most advanced schemes senior management has changed its functions from day-to-day control to strategy, market development, system design, problem solving assistance, finance and recruitment and training.

- *stock management and gearing supply to demand*. Just-in-Time principles can only partially be applied in recycling since programmes are constrained by their function of recovering materials which would otherwise be discarded as waste. Yet recycling does play a role in managing the cyclical flow between discards and reuse. It influences the supply of materials in response to market demand: through campaigns to expand the supply of particular materials (effectively reducing the stock of the

Inset 1

Vertical compost unit

A vertical closed vessel compost unit in Waitakere, New Zealand. Waitakere is town of 80,000 households within the Aukland region. The unit has a capacity of 14,000 tonnes a year, using ten chambers, which allows different qualities of feedstock to be processed separately.

The technology was developed by microbiologists in New Zealand. Temperatures reach at least 80 degrees, which encourages the development of pyrophilic bacteria that act as a bio-filter for the exhaust gases from the compost. As a result, there is no odour, so that the plants can be sited in dense urban areas, within 50m metres of housing.

Since the equipment is modular, it can be geared to the size of the area served. A single unit with a capacity of some 1,250-1,400 tonnes, would service the organic waste from a town or urban estate of 5,000 – 10,000 households, and require an hour a day to maintain its operation.

The Waitakere plant processes source separated organics and garden waste from households, and catering scraps from a scheme run by the council for local shops and restaurants. It sells the compost to a local landscaping firm, which mixes it with topsoil for use in new housing developments.

Plants of this kind have recently been established in the UK in Sheffield, North Lincolnshire and Bromley.

material held by the householder); and/or by stockholding or redirecting materials to alternative uses in the case of oversupply. Reuse centres cut their stocks, by the use of a database with internet access and the allocation of repair labour according to demand.

- *cybernetic planning*. Instead of the old system of waste planning, with long-term plans containing multiple uncertainties and linked to large scale capital investments that provide the ‘skeleton’ of the waste system, the new paradigm works on iterative short-, medium-and long-term plans, regularly revised in the light of experience, with flexible collection (and disposal) systems that can be rapidly reprogrammed to take account of unforeseen events.

The key words found in the ‘post-industrial’ recycling systems are flexibility, micro-processes, distributed knowledge, operational decentralisation, nested organisations and ‘the present as laboratory’.

In sum, intensive recycling is transforming the waste industry in line with the wider industrial changes of the current era – applying the approaches and modes of operation of the knowledge economy and flexible manufacturing systems to waste. It has been found that the methods, skills, technologies and organisational forms necessary to achieve high levels of recycling performance have much in common with the new post-industrial economy, and at the same time the post-industrial economy is now taking on the issue of its own waste minimisation as part of the environmental reorientation of industrial production. The operational ‘ecologies’ of the two are remarkably similar.

Recycling as social economy

Successful recycling depends critically on the voluntary labour of the household. Whereas in the past householders had merely to put out their bin once a week, now they are asked to separate their waste and supply recyclables. They come to play a central role in production.

Furthermore they are unpaid. This presents an economic conundrum. Householders with a convenient, simple service (the dustbin or paladin) are being invited to engage in a more time-consuming service which, far from being paid for, commonly costs them more. Seen through the utilitarian lens, it is surprising that there is any voluntary participation at all in recycling schemes.

The answer of course is that recycling provides an opportunity to contribute to a wider social goal. It is an example of 'productive democracy', for which payment would be no more expected than it would for voting. This explains the remarkable popularity of recycling and the high participation rates of 80% or more that well run systems have achieved.

It also underlines the point that this is a 'value-led' service, that people engage in it because of its meaning. One of the characteristics of high diversion programmes is that many of them grew out of opposition to landfills and incinerators. It was the direct experience of 'old pollution' that drew in communities to the recycling alternative. It established recycling's environmental meaning. Successful programmes have always treated this 'meaning' as central and have organised their processes to reflect it.

Recyclers in North America look at the issue in terms of social marketing. From this perspective recycling is a brand. It is a word that carries with it an environmental and ethical meaning. Like any brand it has been attacked by those with whom it competes (the traditional waste industry) and it has been subject to 'brand degradation' where its practices fail to match up to its principles. Nothing does more to damage recycling than the discovery that recycled materials are finishing up in landfills or that sorting mixed waste in dirty MRFs causes as great a hazard for the workers involved as conventional dumping.

Market research analysts regard the rise of green and ethical consumption as part of a wider 'post-industrial' trend in which commodities are valued for the ethic they represent as well as the services they deliver. Large corporations recognise this and seek to associate themselves with ethical organisations and causes. Recycling is a paradigm case of an activity centred round 'meaning'. People are urged to buy recycled goods not because they are better (they are usually indistinguishable) but because they are less environmentally damaging. They are asked to set out their recycling box not because there is anything in it for them as individuals, but because it contributes to a social solution. It is 'other directed' rather than 'self directed', which is why recycling was so successful during the Second World War.

It also explains why so much social enterprise has grown up around recycling. Community collectors achieve the highest participation rates, followed by local authorities and private waste companies (in that order).[40] In Britain and France, social enterprise has pioneered the recycling of white goods, of furniture and more recently of electronics. There is a strong community composting network in the UK. In North America, grass roots recyclers have developed remarkably successful reuse centres which deal not just with waste but with goods (like textiles) which people do not want to waste. In New Zealand community enterprises have been at the centre of the expansion of recycling. As diversion expands, these functions may be taken over by private commercial enterprises, but their success has in part proved dependent on their being able to sustain goodwill.

The new recycling is in its essence a social as much as a technical economy. The leading programmes internationally have invested as much if not more in social marketing and education as they have in recycling vehicles. They have provided teams of compost advisers. They have invested in training so that the frontline collectors also act as advocates and sources of information. They have involved local communities in the planning of recycling-led waste systems, and in their monitoring. The social and environmental meaning of recycling has been a core criterion for decisions as diverse as collection technologies and the acceptance of sponsorship.

Recycling as market economy

If the social economy is one element of the new recycling, the market economy is another. From the late nineteenth century, household waste disposal has been defined as a public function to be provided free and paid for through taxation. The state took responsibility – on public health grounds – for its collection and disposal. High level recycling has changed this in two ways.

First, responsibility for waste – including household waste – is being transferred from the state to producers and consumers. The polluter is being made to pay. This has led both to the introduction of fees for household waste disposal (a reflection of increased consumer responsibility) and the establishment of recycling schemes by or on behalf of manufacturers or others held responsible for the waste (producer responsibility).

In some cases producers recycle their own products and materials through take-back schemes or, like some recycled paper mills, run their own collection schemes. In others, they have subcontracted the task of return and recycling to particular collectors. In the UK the 'obligated parties' under the packaging directive use intermediary brokering institutions to perform this function – the so-called packaging schemes. As the packaging targets increase, some of these schemes are looking for ways of securing sources of supply of recyclates through sub-contracting, as well as long-term contracts for demand.

In each instance the waste operators, whether public or private, find themselves no longer funded solely through the public purse, but through householder contributions and producer payments. The market for waste services, in short, is being fragmented and diversified.

Second, recyclers have become materials merchants facing commodity markets. As recycling increases so the value of recovered materials assumes ever greater importance in the economics of waste. This is straightforward, even if a challenge for a sector previously insulated from the market.

But one of the principal features of the high recycling programmes is that as material intermediaries, they have come to play a distinct function in the re-establishment of material cycles.

On the one hand they transmit the demands of the users of materials back down the chain, identifying problems originating in the initial production of the recycled materials (such as pathogens and heavy metals in food which are carried over into compost) and putting pressure on the producers to resolve them at source.

On the other they have acted as innovators in the use of materials, identifying multiple uses of recycled materials and developing new markets accordingly. Some of the most advanced recycling programmes (such as that in Washington State in the USA) have established market development units, staffed with engineers and material specialists to identify and market new uses for recovered materials.

What is emerging from these arrangements is the direct organisation of the material cycle, involving the producers and retailers of products, the recyclers and the reprocessors. This allows the technological and quality requirements of the reprocessors to be fed directly back down the line, and like the Japanese vertical production chains, for issues concerning the development of the chain as a whole to be discussed by all involved.

It is therefore not just a question of the marketisation of waste as a resource, but the introduction of a particular type of market. At first recyclers were secondary material merchants operating in national and international commodity markets. But as recycling has expanded, recyclers become key intermediaries, assuming the role of specialist suppliers of collection, separation and logistics within directly organised material cycles.

Towards Zero Waste

The above describes the key features of the emerging intensive recycling economy. I have referred to it as 'smart' recycling since it applies the principles of the knowledge economy and flexible manufacturing systems to the recovery and recirculation of materials. In its most challenging sector – municipal waste – it combines in a remarkably innovative way all three spheres of the economy – the household, the state and the market.

When the system is introduced in this way – quite apart from its reduced environmental impact – it is commonly a cheaper way of managing waste than the old disposal system. Although it is necessarily more expensive to run multiple collections rather than one, leading programmes have found ways of restricting the cost increases for separated collections of dustbin waste to as little as 20% above the single mixed waste system. The critical variables are the savings that can be made on residual collections once high recycling is established, the use of low cost/high productivity vehicles and bins for the separated waste, and the capture rate of materials. Against the increase in collection costs are set the savings from disposal on the one hand and the sale of materials on the other. The higher the disposal costs and the higher the sales income, the sooner will intensive recycling systems lead to budget savings.

These can be considerable. Seattle cut its waste budget by 8% in six years. In Quinte, Ontario, the savings reached 38% in eight years. In a recent survey of high recycling programmes in the USA, nine of the fourteen for which comparable cost data were available reduced their waste budgets through intensive recycling, and a further four would have done so if the rise in landfill costs had not offset the collection savings. The economics of Zero Waste should be seen as an opportunity, not a constraint.

For those at the bottom of the Zero Waste mountain it is hard to believe it can be climbed. There is incredulity that towns and cities, and even countries, are even halfway there, and have saved money in the process. The next section describes the routes they have taken. There is no single model, no one set way. But a broad pattern is emerging which makes it easier for those still looking up from below.