PET(4)WAI 15
Petitions Committee

Consultation on petition P-04-341 Waste and Incineration
Response from Greenpeace

Hello Rhodri,

I'm not sure if this is what you're looking for, but we produced some documents about incineration and the better alternatives a few years which may be helpful –

General report on incineration -
http://www.greenpeace.org.uk/media/reports/money-to-burn
There are some contact details for anti-incineration groups here –
http://www.greenpeace.org.uk/incineration/anti-incineration-links
info on health impacts –
http://www.greenpeace.org.uk/media/reports/incineration-and-human-health

Three large documents on alternatives -
http://www.greenpeace.org.uk/incineration/the-complete-guide-to-sustainable-waste-management
These last three are particularly useful, and should be sent to your all the relevant council officers (waste, planning etc)

Regards,

Graham Thompson
Press Office
Greenpeace UK

Money to Burn

Pollution and health impacts of incinerating resources

The current UK Government, some local authorities and incinerator operators have recently embarked on a campaign to hoodwink the public into believing that waste incineration is somehow a green option for waste management.

Words such as "renewable", "recycling" and "sustainable", are being used by the authorities and the industry to describe the burning of mixed streams of municipal waste. Incinerators have been renamed and transformed into benign sounding "Energy from Waste" plants, the toxic ash they produce is "recycled" into road aggregate and burning discarded products and packaging is no longer a method of waste disposal but, according to the Government, a renewable energy source.

This attempt to spin-doctor away the fundamental problems of incineration threatens not only human health and the environment by ignoring the serious pollution generated by incinerators, but also undermines targets and goals for reducing waste and increasing re-use and recycling of resources. By a cynical sleight of hand the UK Government's waste strategy allows local authorities to meet recycling targets by increasing incineration and disposing of the contaminated ash in reckless schemes which spread it far and wide over the country - using it to build roads and cycle tracks.

New Incinerators - Old Technology

No matter what the Government elects to call them, incinerators are nothing more than huge, indoor fires in which mixed rubbish is burned. Filters are added to capture some of the pollutants in the smoke and transform them into filter ash. The heat is used to make steam and generate electricity, but essentially the process is no different from the medieval practice of building a bonfire from rubbish and setting it alight. This process, whether it is called incineration or "energy recovery", is not possible without releasing hazardous substances to the air, water and soil.

Incineration – what goes in must come out

It is a common misconception that things disappear when they are burned. But the laws of physics dictate that nothing can disappear – matter cannot be destroyed, it can only be transformed into new forms. Roughly two and a half million tons of waste are incinerated in the UK every year.[1] But where does it go, and what does it become?

[1] ENDS report 293 June 1999 p 24

Where does waste go when it is incinerated?

The answer to this question is simple but unpleasant: a third of it comes out as ashes and slag, and the rest goes up into the air. The ashes will sooner or later be dispersed to water, air and soil from the landfills where they are deposited. The part that goes up into air, in the form of flue gases, will remain in the air or be deposited in water and soil, much of it in close proximity to the incinerator, the rest far away.

If waste does not disappear when it is incinerated, what does it become?

The answer to this question is even more discomforting: no one has full knowledge of what products burnt in an incinerator are transformed into. However we do know that some of the substances produced are extremely hazardous.

During incineration of household waste the intense heat causes chemical reactions in which new, and often extremely toxic, compounds are formed. For example chlorine in the waste, (from products made from PVC or materials that contain chloride salts), combines with organic molecules to form dioxins and other highly toxic and cancer causing compounds. There are many more we know nothing about. The number of organic substances in the releases from waste incinerators may be counted in thousands. Scientists have so far identified a few hundred such substances that are hazardous. These include some of the most toxic substances in the environment today, many of which have been listed for priority action by governments and international bodies. Hazardous chemicals routinely released to the environment by municipal waste incinerators include, dioxins, furans, lead, cadmium and other metals, particulate matter (dust) including PM10's, benzene, phenols and polyaromatic hydrocarbons.[2].

Filter systems, controlled temperatures of the burn and in the flue gas scrubbers and the addition of ammonia and lime can help to take out some of the harmful substances from the gases emitted to the air. But significant amounts remain. Exhaust gases come out of the incinerators chimney at the rate of around 80 cubic metres every second. (This is called the flow rate. In simple terms it means that, for a large incinerator, about 300 wheelie bins of exhaust gases, contaminated with many types of pollutants, flow from the chimney of a large incinerator every second.)[3]

---

[2] European Environment Agency Technical report no 38, Feb. 2000. Dangerous substances in waste p 18

[3] Figures based on the SELCHP incinerator in SE London. See Environment Agency report "Measurements of gaseous and particulate releases to atmosphere from Onyx SELCHP Ltd". Report No, 8467/990804, 7 March 2000 (average flow rate 40m^3/s for each of 2 burners)

Emissions from incinerators

To air

Incineration, far from making waste disappear, just transforms it into ash and small particles which are dispersed into the environment. Each tonne of waste burnt releases around 5000 cubic metres of contaminated exhaust gases into the air.[4]

Even though the gases coming from the stack may appear clean, (it may often look as though nothing is coming out) they contain very fine particles of dust including PM10's and PM2.5's. The heat in an incinerator turns metals into gases. These gases condense and attach themselves to the dust particles. Some are caught in filters and become fly ash. Others are washed out in the gas cleaning unit. The rest are emitted to air through the chimney stacks. For example the European Environment Agency note that "because of the high vapour pressure of elemental mercury, there is almost no binding of mercury in slag or filter dust. Almost 100% of elemental mercury present in the waste is therefore emitted (to air)"[5]

Incinerators operate within strict regulations don't they?

SELCHP the so called "combined heat and power" incinerator in South East London, is a flagship among the dozen municipal waste incinerators currently operating in the UK. Environment Agency figures, from measurements of gases coming from its stack in November 1999, show that by and large it operates within limits set by the European Union. However these limits are more concerned with what incinerators can practically achieve than what is good for human health and the environment.

As acknowledged by the multi-party Environment Select Committee of the House of Commons in March 2001, the legitimate public "concern about the impacts of emissions from incinerators upon human health" cannot be assuaged or dismissed while "emissions standards are still based on what can be *measured* and what is technologically achievable, rather than what is *safe*". [6]

The Environment Agency monitoring report for SELCHP shows an average of 4.8kg per hour of dust particles being release to air. This is equivalent to almost 100kg per day. (Much of this dust is microscopically small, yet the total amount emitted every day weighs as much as 100 bags of sugar). Lead has been banned from use in petrol because of its poisonous

---

[4] Calculated from Environment Agency report "Measurements of gaseous and particulate releases to atmosphere from Onyx SELCHP Ltd". Report No, 8467/990804, 7 March 2000 (average flow rate $40m^3$/s for each of 2 burners operating 6 days a week, burning 420 000 tonnes of rubbish per annum .

[5] European Environment Agency, Feb 2000 *op cit* p 19

[6] Environment, Transport and Regional Affairs Committee, *Delivering Sustainable Waste Management*, 14 March 2001

effects on children, but SELCHP churns out seven grams a day from its chimneys. Seven grams may not sound like much. However, the US Public Health Service (USPHS) estimates measures the impacts of lead on childhood development in millionths of a gram and it has been suggested that there is no safe blood lead level.[7] In addition to lead, SELCHP also discharges significant amounts of cadmium and mercury.

In addition to the emission of heavy metals, dioxins and particulate matter, incinerators also emit acid gases. These cause environmental damage from "acid rain" and exposure to acid gases can cause respiratory problems such as asthma, both directly and by combining with oxygen in air to form ozone. SELCHP releases more than 24 tonnes of hydrogen chloride (aka. hydrochloric acid), into the air each year, as well as 800 tonnes of nitrogen oxides and significant amounts of other acid gases including sulphur dioxide and hydrogen fluoride[8].

To land

Grate ash

Incinerating municipal waste leaves ash which has about one third the mass of the rubbish entering the incinerator. This ash is contaminated with heavy metals (lead, cadmium, mercury, chromium and others[9]), dioxins and other toxic compounds. Most of it is landfilled in ordinary waste dumps where the leachable nature of pollutants in the ash pose a long term threat to groundwater. Ash is increasingly being mixed with concrete blocks and asphalt for use in the construction of roads and cycle paths. Cynically called "recycling" by incinerator operators, this practice spreads hazardous chemicals across the country, posing a threat to workers who have to dig up roads and leaving a heritage of contamination for future generations.

Incinerators in the UK between them currently create about a million tonnes of contaminated ash every year. It's not just the atmosphere that incinerators pollute. They leave a legacy of contaminated ground spread across the whole country and threaten water, food and public health for current and future generations.

Filter ash

Residues from the gas cleaning filters are even more hazardous than the bottom ash (from the grates at the bottom of the fire itself). Filter ashes are classified as hazardous waste and have to be transported across the country and disposed of in special landfills.[10] According to the European

[7] Goyer, RA (1993) 'Lead Toxicity: Current concerns', *Environmental Health Perspectives* 100: 177-187

[8] Environment Agency Pollution Inventory, Details for Authorisation AE7236, May 2000

[9] European Environment Agency, Feb 2000. Technical report No 28, Dangerous Substances in Waste p.19

[10] Air Pollution Control (APC) residues are classified as hazardous waste … APC residue has therefore to be managed in accordance to the hazardous waste regulation and placed in appropriate

Environment Agency (EEA) "the disposal of filter dust/fly ash from waste incineration plants is a serious problem".[11] It contains very high concentrations of heavy metals and chlorinated organic compounds, which have carcinogenic and other health threatening properties. According to the EEA incinerators are a major contributor of dioxin, other organic compounds, heavy metals and acid gases to the environment.[12]

The need to dispose of large quantities of both fly and bottom ash has led not only to bogus "recycling" but sometimes to even more irresponsible schemes. In Newcastle where a mixture of fly and bottom ash from the Byker incinerator has for 5 years been spread over 27 allotment sites, numerous public footpaths and children's play areas throughout the city. Tests in May 2000 not surprisingly revealed high levels of dioxins and heavy metals in the soil of affected allotments. Residents have now been told not to eat food produced on the allotments and children are barred from them. It has recently emerged that the Edmonton incinerator in North London has been mixing fly ash with bottom ash and selling on for use in road building. They abruptly stopped this practice last year after questions were asked in Parliament.

Health effects of incinerators

The European Commission and the European Environment Agency have listed some of the better studied pollutants emitted to air land and water from incinerators, and their health effects.

Dioxin: A Class 1 Human Carcinogen (known to cause cancer in humans) and a reproductive toxicant[13]. A recent study of dioxin exposure in Seveso, Italy associates it with an imbalance in the sex ratio of babies born, (50 males to 81 females for fathers who were exposed to dioxin when they were under 19).[14] The European Commission states dioxins and furans "are known to produce chloracne at high exposures and a wide-range of non-cancer effects are thought to occur at extremely low levels of chronic exposure, including adverse effects on reproduction, impacts on development of the unborn foetus and associations with impaired mental ability".[15] The World Health Organisation says that general pollution from dioxins is already at the level where it may be having adverse effects on human health.[16] The US Environmental Protection Agency has recently stated that the risk of contracting cancer from dioxin pollution may be as high as one in a hundred.[17] Their eight year study on dioxin also states

---

storage (landfill or mines). European Commission, "The influence of PVC on the quantity and hazardousness of flue gas residues from incineration", April 2000.

[11] European Environment Agency, Feb 2000. Technical report No 28, Dangerous Substances in Waste p.20

[12] IBID p29

[13] The Lancet. Vol 355 May 27 2000 p1839

[14] Paolo Mocarelli et al. Paternal concentrations of dioxin and sex ratio of offspring. In The Lancet. Vol 355 May 27 2000

[15] European Commission proposal for a Council Directive on the incineration of waste 07/10/98 p. 6

[16] WHO paper submitted to the Dioxin 98 conference, reported in ENDS 281 June 1998 p.5

[17] Dioxin Briefing for the EPA Senior Management May 10th, 2000, leaked to the Washington Post.

that they produce a variety of non-cancer effects in animals and humans including developmental toxicity, immunotoxicity, endocrine effects and chloracne and that part of the general population is at or near exposure levels where adverse effects can be anticipated.

Acid Gases (hydrogen chloride, sulphur dioxide, Nitrogen oxides or NOx, hydrogen fluoride): Exposure to acid gases can cause respiratory problems.

Heavy Metals Incinerators emit lead, cadmium, mercury, chromium, arsenic and other metals to air and land. According to the European Commission incineration is a major contributor to overall emissions of mercury and cadmium in Europe.[18] Lead is associated with learning impairment[19] and behavioural problems in children[20]. High levels of cadmium are associated with lung cancer and a range of other effects and mercury exposure has been found to affect behaviour and lead to renal damage even at low levels.[21]

Particulate matter (dust): A typical modern incinerator releases around 5kg of contaminated particulate matter into the air every hour it operates.[22] According to the European Commission "particulate matter in the atmosphere has been associated with large-scale chronic adverse effects on human health". Operators of the South East London incinerator themselves estimated they released 8.6 tonnes of the notorious PM10's (very fine dust particles) into the surrounding area in 1998.[23] The European Commission is concerned that these sort of emissions may be having health impacts on local populations.[24]

Incineration also leads to the generation and release of a number of other highly toxic and carcinogenic organic compounds such as benzene, phenols, polyaromatic hydrocarbons, benzo(a)pyrene, chlorinated organic compounds and soot.[25]

Energy "recycling" and recovery

In an attempt to disguise the real nature of incinerators they are now often called "Waste to Energy" facilities or sometimes "combined heat and power" stations. Waste to energy facilities use some of the heat to produce electricity. However this is a very inefficient way to generate electricity. To replace the materials which are burnt in an incinerator uses much more electricity than can be produced by burning it. It’s a bit like setting fire to old furniture to heat your house. It might keep you warm

---

18 *ibid* p. 7
19 European Commission proposal for a Council Directive on the incineration of waste 07/10/98 p. 7
20 see eg. The Independent 16th May 2000 p 11
21 European Commission proposal for a Council Directive on the incineration of waste 07/10/98 p. 7
22 Figure based on EA report 8467/990804 OF sampling done at the SELCHP incinerator in SE London 9 -11 Nov. 1999
23 UK Environment Agency Pollution Inventory Details for Authorisation AE7236 Feb 2000
24 European Commission proposal for a Council Directive on the incineration of waste 07/10/98 p. 7
25 European Environment Agency, Feb 2000 *op cit* p 18

for a while but it would be much better, environmentally and economically, to repair the furniture and use more efficient means to heat your house. Not many would stoop low enough to claim they are recycling furniture by burning it! Yet this is exactly what the Government is doing by calling incineration "Energy from Waste" and by attempting to include it in official recycling figures.

"Renewable energy" and "sustainability"

Building new incinerators actually works against waste minimisation and increasing re-use and recycling rates. Contracts with incinerator operators lock local authorities into long term commitments to provide huge amounts of waste each year. Intensive re-use and recycling programs could divert 80% or more of municipal waste away from incinerators, transforming them into valuable resources. But local authorities locked into incineration contracts would have to pay financial penalties to incinerator owners if they did this. Council-tax payers in areas where the local authority chooses to incinerate its rubbish must therefore pay through the nose to burn resources. A scandalous waste that at the same time creates an unacceptable environmental and public health risk.

Attempts by Government and operators to classify "waste to energy" incinerators as "renewable energy" or "sustainable waste management" are cynical attempts to pull the wool over the eyes of the public and do a great deal of harm to genuinely renewable energy sources and sustainability programs. Waste incinerator operators have for years parasitically consumed Non Fossil Fuel Obligation Subsidies intended to aid the development of real renewable energies. The raw materials, resources and energy that go into making the disposable products and packaging that create our waste mountains are often not renewable. Nor is it in any way "sustainable" to squander resources by burning them, while producing many millions of tonnes of hazardous ash dust and gases in the process.

This view was supported in the recent Environment Select Committee report, which stated that incineration "will never play a major role in truly sustainable waste management and cannot, and should not, be classified as producing renewable energy". They concluded that "sustainable waste management has as its cornerstone the minimisation of waste, and the explicit maintenance of waste streams for the purpose of incineration is a complete contradiction of this principle".[26]

The Solution

It is clear that incineration is a logically flawed and technologically backward approach to waste. Recovering some energy from heat generated during burning does nothing to bring it into the 21st century. Neither do increasingly complex and expensive filter systems, which

---

[26] Environment, Transport and Regional Affairs Committee, *Delivering Sustainable Waste Management*, 14 March 2001

merely transfer some of the pollutants from exhaust gases to fly ash, from air, to land and water. Throwing municipal waste into huge holes in the ground is hardly less primitive and has a whole set of problems of its own. So what is the modern, forward thinking solution to the waste problem facing the UK and other countries?

To meet the reduction targets set by the European Landfill directive the Government must set up an intensive drive to re-use and recycle (including composting). The UK is currently bottom of the table of recyclers in Europe managing a feeble 8% (the Netherlands recycles 46% of municipal waste). The city of Edmonton, in Canada, reuses, recycles or composts 70% of household waste.

To begin this recycling program source separation of waste (at household and commercial level) must be implemented across the country. Separate waste streams (of organic waste, paper, metals, etc) are immediately easier to deal with and straight away begin to have a value. Materials that are particularly troublesome or hazardous can be more easily be dealt with. It is the mixed nature of the waste stream we have got used to that creates many of the waste disposal headaches.

This drive to re-use and recycle must include:

- Financial and legal mechanisms to increase re-use of packaging (e.g. bottles, containers) and products (e.g. computer housings, electronic components).

- Financial mechanisms (such as the landfill tax) used directly to set up the necessary infrastructure for effective recycling.

- Stimulating markets for recycled materials by legal requirements for packaging and products, where appropriate, to contain minimum amounts of recycled materials.

- Materials that cannot be safely recycled or composted at the end of their useful life (for example PVC plastic) must be phased out and replaced with more sustainable materials.

- Materials and products that add to the generation of hazardous substances in incinerators must be removed from the waste stream and reused, recycled or dealt with in an environmentally sound manner at the cost of the producer. Such products would include electronic equipment, metals and products containing metals such as batteries and florescent lighting and PVC plastics (vinyl flooring, PVC electrical cabling, PVC packaging, PVC-*u* window frames, etc) and other products containing hazardous substances.

These are short term measures that can eliminate the need for any more incinerators while enabling the UK to meet targets set down by the European Landfill Directive.

The complete solution to waste will take longer to implement, but must be central to an integrated strategy. The target must be to eliminate the production of waste and products that cannot be re-used or efficiently and safely recycled. This means the rethinking and redesigning of products, packaging and production processes. Consumers, manufacturers and retailers all need to play their part in this. But the Government must set the process in motion by bringing in tangible incentives for clean production that includes producer responsibility for end of life products and packaging.

This challenge offers tremendous opportunities to British industry. The outcomes could be huge savings through minimisation of waste, value recaptured through re-use of materials and jobs created through booming re-use and recycling industries. It could also mean UK firms at the leading edge of innovative product design that eliminates hazardous materials and waste from product life cycles.

On the other hand failure to come to grips with this challenge now will keep the UK firmly rooted to the bottom of the European waste management league table and British industry locked in a vain struggle to keep up with its European counterparts.

A modern waste strategy should be geared towards the goal of "Zero Waste". Such a strategy could not only have an enormous affect on pollution and public health but can act as a stimulus for job creation and innovation. But to do this we must ditch the primitive "burn or bury" attitude of the past and make resources available to truly modern, innovative solutions.

Anti-incineration links

A growing number of local anti-incineration campaigns exist around the country. Links to these groups are provided below. By offering these links, Greenpeace does not endorse the contents of these web pages, merely presents them for the benefit of people who may wish to get involved in a local campaign.

If you are a member of a group working to stop incineration or to promote Zero Waste and your group's web page is not listed, please send an email message to No Incinerators for Europe at nife@trainease.com.

England:

Defenders of the Oust Valley (DOVE)

Capel Action Group

Guildford Against Incineration

Redhill Incinerator

Basingstoke Burner Action Group

Stop Kidderminster Incinerator

RABID (Sheffield)

Sheffield Against Incineration

Byker & Newcastle Waste Group

Ireland:

No Incineration Alliance

Scotland:

Aberdeen No Incinerator Group

Wales:

Stop the Incinerator Campaign (Swansea)

Campaign Against the New Kiln (Many links to other groups)

Sources for international information:

Global Anti-Incineration Alliance

Sources for European information:

No Incinerators for Europe (Many links to other groups)

Other information:

The Womens Environmental Network: Ideas for preventing waste at source

Incineration and human health

by Michelle Allsopp, Pat Costner and Paul Johnston. Abridged version

(Mr Blunt) The reason you were not able to answer Mr Benn's question directly...is that incineration is not safe, is it? If you were asked "Is incineration safe?" you cannot say yes. (Dr Whitworth) I cannot give any categoric answer that any waste management option is safe.

Martin Whitworth, Strategic Policy Manager, Environment Agency. Minutes of Evidence taken before the Environment Sub-committee, 24th October 2000 to 21 December 2000.

It is... generally accepted that emissions standards are based on what can be measured and what is technologically achievable, rather than what is safe... This point was accepted by the Environment Agency.

Department of Environment Transport and Regional Affairs Committee, March 2001 report HC 39-I, Delivering Sustainable Waste Management, Vol 1 paragraph 93.

There are... some truths which can be drawn from the debate over the health impacts of incineration. Firstly, that the health effects which result from an incinerator's emissions are not yet fully known. Secondly, that the regulation of incineration to date has been rather poor and that has resulted in poor practices developing in some incinerators.

Department of Environment Transport and Regional Affairs Committee, March 2001, report HC 39-I, Delivering Sustainable Waste Management, Vol 1 paragraphs 97/98.

I repeat, the emissions from incinerator processes are extremely toxic. Some of the emissions are carcinogenic… We must use every reasonable instrument to eliminate them altogether.

Michael Meacher, Minister for the Environment, evidence to the House of Lords Select Committee on the European Communities, 11th report, HL Paper 71, 15 June 1999, "Waste Incineration".

INTRODUCTION

The United Kingdom currently faces a wave of new incinerators with proposals for more than eighty plants already identified. This massive expansion is largely driven by the impact of the EU landfill directive which requires that by 2010 the UK will have to reduce biodegradable waste going to landfill by 25% measured against a 1995 baseline. By 2013 the reduction has to be 50% and by 2020 it must reach 65%. This legislative pressure has driven both central and local government into embracing incineration technology as a 'quick fix' without necessarily considering all of the impacts on health, the environment and the economy.

There are many powerful arguments against incineration. Some focus on how it deflects waste from being recycled, some on environmental damage and some on jobs and the economy. Perhaps the greatest concerns relate to human health. Greenpeace International has recently published a report – Incineration and Human Health – which reviews what is known about the impacts of incineration on human health and the effects of specific chemicals discharged from incinerators.

The report represents a significant overview of all the scientific material currently available and an important resource for decision-makers considering matters relating to incineration. This briefing represents a highly-edited version of the report and a more accessible resource for those who don't have the time to digest the complete text. The full report is available from Greenpeace free of charge.

A primary misconception about incineration is that the combustion process reduces the total amount of waste which needs to be disposed of. In fact, the opposite is true. The principle effect of incineration is to reduce waste to ashes of varying toxicity and to distribute chemical pollution over a very wide area through aerial emissions.

There are numerous scientific studies that confirm that a typical incinerator releases a toxic cocktail of chemicals to the atmosphere. These studies demonstrate that toxic chemicals such as dioxins, cadmium and mercury are all released along with perhaps thousands of currently unidentified compounds that form as a result of the combustion process. Other pollutants such as sulphur dioxide, nitrogen dioxide and fine particulates are also released in huge quantities.

These studies are not necessarily comprehensive; data from the monitoring of incinerator emissions can be highly misleading. For example, the monitoring of incinerators is often conducted on a 'spot-check' basis which has been shown to give far lower results than monitoring on a continuous basis.

The evidence relating to actual harm to human health from incinerators is more equivocal than the simple pollution monitoring. The problems of identifying causal links between potential environmental hazards and nearby human populations are well-known and documented. However, the Greenpeace International report has identified many scientific studies which give great cause for concern and these are described in detail.

A broad range of health effects have been associated with living near to incinerators as well as working at these installations. Such effects include cancer (among both children and adults), adverse impacts on the respiratory system, heart disease, immune system effects, increased allergies and congenital abnormalities.

A common argument put forward in the UK debate is that 'new' incinerators (ie those constructed after 1996) are much superior to older plant and that earlier concerns about aerial emissions can be discounted. This is very far from the truth. Modern incinerators still emit large quantities of toxic chemicals into the atmosphere, and where reductions in aerial emissions have been achieved it usually results in the same compounds ending up in the ashes.

When the known effects of incinerator emissions are considered in conjunction with the health studies of communities living near to incinerators it quickly becomes apparent that the evidence points in only one direction. Operating incinerators is an inherently risky business and an unacceptable option, especially when there are practical alternatives readily available. The UK Government has also indicated its support for at least two international treaties which require the reduction and elimination of discharges of toxic chemicals into the environment. This support seems largely incompatible with an increase in incineration.

Waste reduction, re-use and recycling along with the composting of biodegradable waste are far superior to incineration in terms of their impact upon health and the environment. They also generate employment, conserve resources and produce useful materials. They are also far more likely to win popular acceptance with the public who are forced to live close to waste management facilities.

INCINERATORS – WASTE GENERATORS

It is a common misconception that things simply disappear when they are burned. In reality, matter cannot be destroyed – it merely changes its form. This can be exemplified by looking at the fate of some substances in wastes which are burned in municipal solid waste (MSW) incinerators. These incinerators are typically fed mixed waste streams that contain hazardous substances, such as heavy metals and chlorinated organic chemicals. Following incineration, heavy metals present in the original solid waste are emitted from the incinerator stack in stack gases and in association with tiny particles, and are also present throughout the remaining ashes and other residues. Incineration of chlorinated substances in waste, such as polyvinyl chloride (PVC) plastic, leads to the formation of new chlorinated chemicals, such as highly toxic dioxins, which are released in stack gases, ashes and other residues. In short, incinerators do not solve the problems of toxic materials present in wastes. In fact they convert these toxic materials to other forms, some of which may be more toxic than the original materials.

All incinerators release pollutants to the atmosphere in stack gases, ashes and other residues. A multitudinous array of chemicals is released, including innumerable chemicals that currently remain unidentified. The chemicals present in stack gases are often also present in ashes and other residues. Such chemicals include dioxins, polychlorinated biphenyls (PCBs), polychlorinated napthalenes, chlorinated benzenes, polyaromatic hydrocarbons (PAHs), numerous volatile organic compounds (VOCs), and heavy metals including lead, cadmium and mercury. **Many of these chemicals are known to be persistent (very resistant to degradation in the environment), bioaccumulative (build up in the tissues of living organisms) and toxic.** These three properties make them arguably the most problematic chemicals to which natural systems can be exposed. Some of the emitted chemicals are carcinogenic (cancer-causing) and some are endocrine disruptors. Others such as sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) have been associated with adverse impacts on respiratory health.

It is a misconception that the weight and volume of raw waste are reduced during incineration. It is often quoted that the volume of waste is reduced by about 90% during incineration. Even if only the residual ashes are considered, however, the actual figure is closer to 45%. The weight of waste is supposedly reduced to about one-third during incineration. However, this again refers only to ashes and ignores other emissions in the form of gases, which result in an increased output in weight. **In sum, if the mass of all the outputs from an incinerator, including the gaseous outputs, are added together, then the output will exceed the waste input.**

ENVIRONMENTAL AND HUMAN EXPOSURE TO INCINERATOR RELEASES

The research carried out on environmental contamination and human exposure to pollutants released by incinerators is limited and has focused mainly on dioxins and heavy metals. Research has demonstrated that both older and more modern incinerators can contribute to the contamination of local soil and vegetation with dioxins and heavy metals. Similarly, in several European countries, cow's milk from farms located in the vicinity of incinerators has been found to contain elevated levels of dioxins, in some cases above regulatory limits.

Populations residing near to incinerators are potentially exposed to chemicals through inhalation of contaminated air or by consumption of contaminated agricultural produce (e.g. vegetables, eggs, and milk) from the local area and by dermal contact with contaminated soil. **Significantly increased levels of dioxins have been found in the tissues of residents near to incinerators in the UK, Spain and Japan most likely as a result of such exposure.** Two studies in the Netherlands and Germany however, did not find increased levels of dioxins in body tissues of residents living near incinerators. At an incinerator in Finland, mercury was increased in hair of residents living in the vicinity, most likely due to incinerator releases. Children living near a modern incinerator in Spain were found to have elevated levels of urinary thioethers, a biomarker of toxic exposure. Elevated levels or more frequent occurrence of certain PCBs occurred in the blood of children living near a hazardous waste incinerator in Germany.

Several studies have reported elevated levels of dioxins (total TEQ), and/or certain dioxin congeners, in the body tissues of individuals employed at both modern and older incinerators. This is thought to be a consequence of exposure to contaminated ashes in the workplace. Similarly, some studies have reported increased levels of chlorinated phenols, lead, mercury and arsenic in the body tissues of incinerator workers.

HEALTH IMPACTS

Experimental data confirm that incinerators release toxic substances and that humans are exposed as a consequence. **Studies on workers at incinerator plants, and populations residing near to incinerators, have identified a wide range of associated health impacts** (see tables below). These studies give rise to great concerns about possible health impacts from incinerators even though the number of studies (particularly those that have been conducted to appropriately rigorous scientific standards) is highly limited. These should be seen, however, as strongly indicative that incinerators are potentially very damaging to human health.

SUMMARY OF STUDIES ON OCCUPATIONAL HEALTH

HEALTH IMPACT	COMMENTS
Biomarkers of Exposure	
Elevated mutagens in urine	Incinerator ashes and stack emissions are mutagenic (have the ability to damage DNA). Workers are therefore exposed to mutagenic compounds. Elevated mutagens in urine indicate exposure to mutagenic compounds. (Study dates 1990 & 1992).
Elevated levels of hydroxypyrene in urine	Hydroxypyrene is an indicator of internal exposure to PAHs. The result suggests elevated exposure to PAHs. (Study date 1992).
Increased quantity of thioethers in urine	Thioethers in urine are an indicator of exposure to electrophilic compounds such as PAHs. The results suggest exposure to electrophilic compounds. (Study date 1981).
Cancer	
3.5-fold increased probability of mortality from lung cancer	Workers who were employed at a MSW incinerator in Sweden at sometime between 1920 and 1985. (Study date 1989).
1.5-fold increased likelihood of mortality from oesophageal cancer	Workers who were employed at a MSW incinerator in Sweden at sometime between 1920 and 1985. In conjunction with evidence from other research, the result implies an increased health threat to workers. (Study date 1989).
2.79-fold increase in mortality from gastric cancer	Workers employed at an MSW incinerator in Italy at sometime between 1962 and 1992. Some of the increase may have been due to other confounding factors. (Study date 1997).
Other Impacts	
Increased mortality from ischemic heart disease	Workers who were employed at a Swedish MSW incinerator in Sweden at sometime between 1920 and 1985. The result was statistically significant in workers with greater than 40 years employment. (Study date 1989).
Excess hyperlipidemia. A significant association between blood dioxin levels and natural killer cell activity (immune system effect). Altered sex ratio among offspring. Decreased liver function. Increased allergy.	Workers employed at an incinerator in Japan, that operated between 1988 and 1997. Excess of hyperlipidemia was significant. Change in immune system cells. Altered sex ratio was not statistically significant. Correlation between allergy and dioxin exposure must be confirmed. (Study date 2000).
Excess of proteinuria (urine abnormality) and hypertension. Possible increased incidence of small airway obstruction (unconfirmed diagnosis). Abnormal blood chemistry.	Workers at a MSW incinerator in the US. An excess of workers with significant proteinuria. (Study date 1992).
Chloracne (a skin condition due to dioxin-exposure)	Chloracne found in one worker from an old incinerator in Japan, who had high blood levels of dioxin. (Study date 1999).

SUMMARY OF STUDIES ON HEALTH OF POPULATIONS LIVING IN THE VICINITY OF INCINERATORS

HEALTH IMPACT	COMMENTS
Biomarkers of Exposure	
Elevated levels of thioethers in children's urine	Urinary thioether levels were higher among children living near a recently built incinerator in Spain. (Study date 1999)
No abnormal chromosomal damage	No excess chromosomal damage among children living near two Belgian incinerators. (Study date 1998)
Cancer	
44% increase in soft tissue sarcoma and 27% increase in non-Hodgkin's lymphoma.	Significant clusters of these cancers in residents living close to an incinerator in France. Possibly due to exposure to dioxin from the incinerator, but more research is needed to confirm if this is the case. (Study date 2000).
6.7-fold increase in likelihood of mortality from lung cancer	Significantly increased occurrence in residents living close to a MSW incinerator in an urban area of Italy. (Study date 1996).
Increased incidence of cancer of the larynx	Found around one UK hazardous incinerator of waste solvents (1990), but not nine others. In Italy, excess mortality from this cancer was found in residents living near to an incinerator, a waste disposal site and an oil refinery.
37% excess mortality due to liver cancer	A study on 14 million people living within 7.5 km of 72 MSW incinerators in the UK. Further research to eliminate possible confounders found the increased probability of liver cancer to lie between 20 and 30%. Social deprivation could not be totally ruled out as a confounder. (Study dates 1996 and 2000).
2-fold increased probability of cancer mortality in children	A study conducted on 70 MSW incinerators in the UK (1974-87) and 307 hospital waste incinerators (1953-1980). These results are consistent with another study in which an increased probability of childhood cancer was observed for hospital incinerators and large-scale, high-temperature combustion industries. (Study dates 1998 and 2000).
Respiratory Impacts	
Increased purchase of medicine for respiratory problems	A study at a village in France that had a MSW incinerator. Results suggest increased use of medicine for respiratory illness but a cause-effect relationship cannot be concluded. (Study date 1984).
Increased respiratory symptoms, including 9-fold increase in reporting of wheezing or cough	A study in the US on residents living near to a hazardous waste incinerator. The results are of limited utility because of methodological concerns about the study. (Study date 1993).
Adverse impacts on lung function of children	A study on children living near to a wire reclamation incinerator in Taiwan. Results indicate that higher air pollution, but not the incinerator itself, is linked to altered lung function in children. (Study date 1992).
Increased respiratory symptoms including lung disease, wheezing, persistent cough and bronchitis	A study on 58 individuals living near to cement kilns burning hazardous waste in the US. Significant increase in respiratory symptoms. (Study date 1998).

HEALTH IMPACT	COMMENTS
Respiratory Impacts	
No adverse effect on the prevalence or severity of asthma in children	A study on children living near to sewage sludge incinerators in Australia. (Study date 1994).
No increase in respiratory effects or decrease in lung function	A study on three communities (6963 individuals) living near to a municipal, hazardous and hospital waste incinerator in the US. The lack of association between exposure to particulate air pollution and respiratory health in this study should be interpreted cautiously due to limitations in data on individual exposures.
Sex Ratio	
Increase in female births	A study on populations living near to two incinerators in Scotland, UK. The effect was found in the area potentially most exposed to incinerator releases. Other studies have found an increase in female births where fathers were accidentally exposed to high levels of dioxins. (Study dates 1995 and 1999).
Congenital Abnormalities	
Increased incidence in orofacial clefts Other midline defects including spina bifida and hypospadias (genital defect)	The significant increase in orofacial clefts was observed for births in an area located near to an incinerator site where open burning of chemicals took place 1960-69. A link between the conditions and living near the incinerator is likely but not confirmed.
1.26-fold increased probability of congenital malformations among new born infants	A study conducted on a population living near to 2 MSW incinerators in Wilrijk, Belgium. (Study date 1998).
Increased congenital eye malformations (anecdotal report)	Reported at an area near two chemical waste incinerators in Scotland, UK. Further research in the UK found no link, although the study was hampered by lack of data on the condition. (Study date 1989).
Multiple Pregnancy	
Possible increase in rate of twinning/multiple pregnancy	An increase in twinning was significant in 1980 in a population living near to an incinerator in Scotland, UK. A 2.6-fold probability of multiple pregnancy found near incinerator in Belgium (Study date 2000). No impact on multiple pregnancy found on a survey of an incinerator in Sweden. Data from different studies is conflicting and inconclusive.
Other Impacts	
Lower thyroid hormone levels in children	Children living near a German incinerator had significantly lower blood levels of certain thyroid hormones. (Study date 1998).
Increased allergies, increased incidence of common cold, increased complaints about health in general, increased use of medication in school children	A study conducted on school children living near to two MSW incinerators in Wilrijk, Belgium. (Study date 1998).

INCINERATOR RELEASES AND REGULATION

Stack Gases

As previously mentioned, numerous chemicals are emitted to the atmosphere from incinerators through the stack gases. Important points regarding some of these chemical emissions are given below.

Dioxins

Extensive research has demonstrated that dioxins can cause a diverse array of toxic effects. They have become widespread contaminants throughout the world and are present in the body tissues of human beings across the globe. Research suggests that, in industrialised countries, dioxins have now reached levels in tissues of the women which may cause subtle, adverse effects upon the immune system, and nervous system of their babies.

Incineration, particularly MSW incineration, was identified as a major source of dioxins during the 1980s and early 1990s. **It has been estimated as accounting for between 40 and 80% of atmospheric dioxin emissions in various industrialised countries.** The true figure may be even greater because there are several methodological flaws in nearly all of the dioxin inventories that estimate atmospheric emissions from incineration.

Considerable improvement in air pollution control technologies that have been installed in new or updated incinerators during the 1990s is thought to have led to substantial reductions in the quantity of dioxins released to the atmosphere from incinerator stacks. However, recent estimates suggest that MSW incinerators are still a main source of dioxins in the environment. In the UK, it was estimated that MSW incinerators were responsible for 30-56% of dioxin emissions while in Denmark a recent mass balance study identified MSW incineration as the dominant source of dioxins to atmosphere and a highly significant contributor (via ash residues) to landfill. Moreover, reduction of dioxins emitted in stack gases has most likely resulted in a corresponding increase in dioxins emitted as contaminants of ash residues.

While measurements taken from some new or modernised incinerators have shown that they comply with limits set by the new EC directive, others have not. Those not fulfilling the EC regulatory limit include incinerators that have recently been tested in Spain, Poland, Sweden, and Belgium. In Belgium, testing was carried out on an incinerator using the routine technique of taking "point measurements" which involves monitoring dioxin levels over a period of several hours. However, when testing was carried out by "continual monitoring", over a two week period, the results were substantially different. The point measurement technique underestimated dioxin emissions by a factor of 30 to 50. **It is therefore of great concern that very few incinerators are tested using continual monitoring or tested under their normal operating conditions.** Moreover, the new EC regulations do not stipulate that measurements should be taken using this technique, so current routine monitoring of incinerator stack gases, using point measurements, could be grossly inaccurate and underestimate dioxin emissions to air.

Other Organic Compounds

For regulatory purposes, the EC has proposed a limit for total organic carbon emissions to atmosphere to regulate all the organic chemicals emitted. **This regulation, however, fails to take into account the toxicity/health impacts of known organic chemicals that are emitted from incinerator stacks. Similarly it totally ignores unknown chemicals of unknown toxicity and the potential health effects they could cause.**

Heavy Metals

Heavy metals, including lead and cadmium, are emitted in stack gases from incinerators. Many heavy metals are persistent and exert a wide range of adverse impacts on health.

With the exception of mercury, the levels of heavy metals released in stack gases from incinerators have decreased considerably over the past decade due to improvement in air pollution abatement technologies. Nevertheless, the quantities in which they are still emitted from modern incinerators potentially add to current background levels in the environment and in humans. As is the case with dioxin emissions to the atmosphere, **the reduction of levels of heavy metals emitted in stack gases causes a corresponding increase in levels in the ashes, which will, when these are disposed of, result in contamination of the environment.**

Particulate Matter

Incinerators of all types emit particulate matter into the atmosphere. The majority of this particulate matter is ultrafine in size. Current air pollution control devices on incinerators only prevent 5 to 30% of the "respirable" (<2.5 μm) sized particles from entering the atmosphere, and can do very little to prevent ultrafine (<0.1 μm) particulates from escaping. **It is these respirable particles, and especially the ultrafine particles, which can reach the deepest regions of the lungs, and which are thought to be responsible for causing adverse impacts on human health. Incinerators therefore contribute to the**

type of particulate air pollution that is the most dangerous for human health. In addition, recent evidence suggests that particles containing heavy metals, such as those emitted from incinerators are especially of concern with regard to health. **Incinerators are, therefore, likely to produce particulate air pollution which is even more toxic than, for example, that emitted from a coal-fired power station.**

The new EC Draft Directive does not set any limits for the release of fine particulate matter. Given the scale of the health impacts resulting from such particulate air pollution, this can be considered as an outstanding neglect of factors relevant to human health, and which requires rigid control and regulation.

Ash

Fly ashes from air filtration equipment on incinerators and the bottom ashes that remain after incineration contain numerous hazardous chemicals, such as dioxins and heavy metals. Despite the potential toxicity of ashes, there are no EC limits for levels of persistent organic chemicals and heavy metals in ashes.

Because of their contamination, disposal of incinerator ashes presents significant environmental problems. **The majority of ash is landfilled. This can result in contamination of sub-soils and groundwater.** In some cases, the contamination of groundwater by compounds that have leached from the waste, in particular, heavy metals like lead and cadmium from fly ash has been documented. In an attempt to reduce leaching, fly ash is sometimes stabilised in cement before disposal. Although this method reduces the immediate leaching of heavy metals and other toxic chemicals, weathering and erosion over time will ultimately cause their release back to the environment

There has been a recent tendency in some European countries to use bottom ashes and/or fly ashes for construction purposes, a practice that reduces the financial costs of "secure" ash disposal. Ash has been used in road and path construction. Again, however, **the future releases of persistent toxic substances due to erosion over time could result in the release of substances back to the environment and, therefore, potentially to human exposure. This has recently been exemplified in Newcastle, UK where fly ash and bottom ash from a presently operating, modern incinerator, were used for path making and also spread over allotments as fertiliser between 1994 and 1999. Recent analysis of ash from the allotments found that it is contaminated with extremely high levels of heavy metals and dioxins.** Clearly, the use of ashes from incinerators represents a potential threat to human health, but this practice is not being discouraged either by the EC or at a national level by the regulatory regimes proposed or currently in place.

The Way Forward

A limited amount of epidemiological research has been directed at investigating the health impacts of incinerators. Despite this, scientific studies reveal that MSW and other incinerators have been associated with detrimental impacts on health.

The new EC draft directive on incinerators is not formulated to take human health impacts into account in relation to the regulation and control of these facilities. Rather, the regulatory limits that are set for the permissible release of substances are based on what is considered to be technically achievable. In any case, the draft EC directive on incinerators, not yet in force, can be regarded as already outdated. Many European countries have already committed themselves at the OSPAR Convention to phase out all releases of hazardous substances to the environment by 2020. In this context no emissions of hazardous chemicals would be allowable in stack gases or ashes. This is likely to prove impossible for incineration technology to ever achieve.

In addition, at the Fifth Intergovernmental Negotiating Committee Meeting (INC5) on the Elimination of Persistent Organic Pollutants (POPs), held **in December 2000, a world-wide agreement was reached to reduce total dioxin releases, with the ultimate aim of their elimination. Incineration is listed as one of the main industrial source categories for dioxins**, and requires the use of BAT (Best Available Techniques) for new installations and substantially modified existing facilities. It was also agreed to promote the development and, where deemed appropriate, require the use of substitute or modified materials, products and processes to prevent the formation and release of dioxins. In this context, incineration is acknowledged as a significant source of dioxins and, in the longer term these sources should be replaced by alternatives.

To comply with the provisions of the OSPAR agreement and of the emerging POPs Convention implies a radical rethink of industrial and manufacturing processes. Instead of waste-generating "dirty" technologies, which rely upon incineration and other environmentally dubious waste disposal techniques, OSPAR implies the need to develop and use "clean-production" technologies which eliminate toxic waste. The adoption of "zero-waste" as a central tenet of environmental regulation also implies that the Precautionary Principle of environmental protection will occupy an equally key position in the development of policy and regulatory frameworks. The precautionary principle requires that the burden of proof should not be laid upon the protectors of the environment to demonstrate conclusive harm, but rather on the prospective polluter to demonstrate no likelihood of harm. On this premise of precautionary regulation it can be argued that there is already sufficient evidence of environmental contamination and adverse human health impacts to call for a complete phase out of incineration.

In the case of waste management, **adoption of a zero releases strategy and the reduction of health impacts from waste management means a move towards an environmental management paradigm based upon the three axioms of reduce, re-use and recycle** in relation to the generation of both municipal and industrial wastes.

GREENPEACE DEMANDS

A drive towards waste prevention, re-use and recycling, and therefore also towards lessening the adverse health impacts from waste management, should include the following measures:

- A permanent ban on the construction of new incinerators in the UK and the closure of those currently operating. Incineration should not be classified as a source of renewable energy and it should not be considered superior to landfill as a form of waste management (even if it does include energy/heat recovery). Post-combustion materials (eg ash and metals) should not be classified as recycled.
- Financial and legal mechanisms to increase re-use of packaging (e.g. bottles, containers) and products (e.g. computer housings, electronic components).
- Financial mechanisms (such as the landfill tax) used directly to set up the necessary infrastructure for effective recycling.
- Stimulating markets for recycled materials by legal requirements for packaging and products, where appropriate, to contain specified amounts of recycled materials.
- Materials that cannot be safely recycled or composted at the end of their useful life (for example PVC plastic) must be phased out and replaced with more sustainable materials.
- In the short term, materials and products that add to the generation of hazardous substances in incinerators must be prevented from entering the the waste stream at the cost of the producer. Such products would include electronic equipment, metals and products containing metals such as batteries and florescent lighting and PVC plastics (vinyl flooring, PVC electrical cabling, PVC packaging, PVC-*u* window frames etc) and other products containing hazardous substances.

and more generally:

- Further the development of clean production technologies which are more efficient in terms of material and energy usage, produce cleaner products with less waste and which, ultimately can be designed to operate in a "closed loop" configuration in order to fulfil the needs of society in a more equitable and sustainable manner;
- Fully implement the Precautionary Principle, such that, in the future, problems are avoided before they occur. The continuation and further development of scientific research has a fundamental role to play in identification of potential problems and solutions. Nonetheless, we must be ready to take effective precautionary action to prevent environmental contamination and degradation in the face of the considerable and often irreducible uncertainties associated with determination of health and other environmental impacts from incineration.

The complete guide to sustainable waste management

Complete guide to waste management

Cool Waste Management:

A State-of-the-art alternative to incineration for residual municipal waste- MBT

The aim of this study is to assess the possibilities for a system for managing residual waste which does not include any thermal treatment process. The study includes a review of mechanical biological treatment (MBT) systems and their potential effects.

MBT systems are not new. In their more primitive guises, they can be considered a basic evolution from the (usually failed) mixed waste composting plants of two decades ago. However, the potential for integrating systems based around biological treatment of degradable fractions with increasingly efficient mechanical separation techniques is a more recent development, as is the tendency to look to employ digestion techniques for the biological treatment phase as opposed to aerobic treatments.

Zero waste:

As a pollutant, waste demands controls. As an embodiment of accumulated energy and materials it invites an alternative.

Waste policy has become one of the most keenly contested areas of environmental politics. At a local level in the UK and abroad, new sites for landfills and incinerators have 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.

How to comply with the landfill directive without incineration:

A Greenpeace blueprint

Landfilling of municipal waste has to be reduced for a variety of reasons. The current practice of landfilling mixed municipal waste is highly polluting, as well as unpopular and ultimately unsustainable. Now the European Landfill Directive, which came into effect on 16 July 2001, demands significant reductions in the quantity of biodegradable waste disposed of in this way. As part of the drive to comply with the Landfill Directive, the Government has set mandatory recycling targets for local authorities.

Some local authorities are arguing that incineration is necessary to meet the UK's commitments under the Directive, or to deal with residual waste left after maximum practical recycling levels have been achieved. Neither of these arguments is tenable.

The Environmental Trust: Cool Waste Management

Publication date: 11 August, 2009

A State-of-the-Art Alternative to Incineration for Residual Municipal Waste- MBT

Publication date: February 2003

Summary

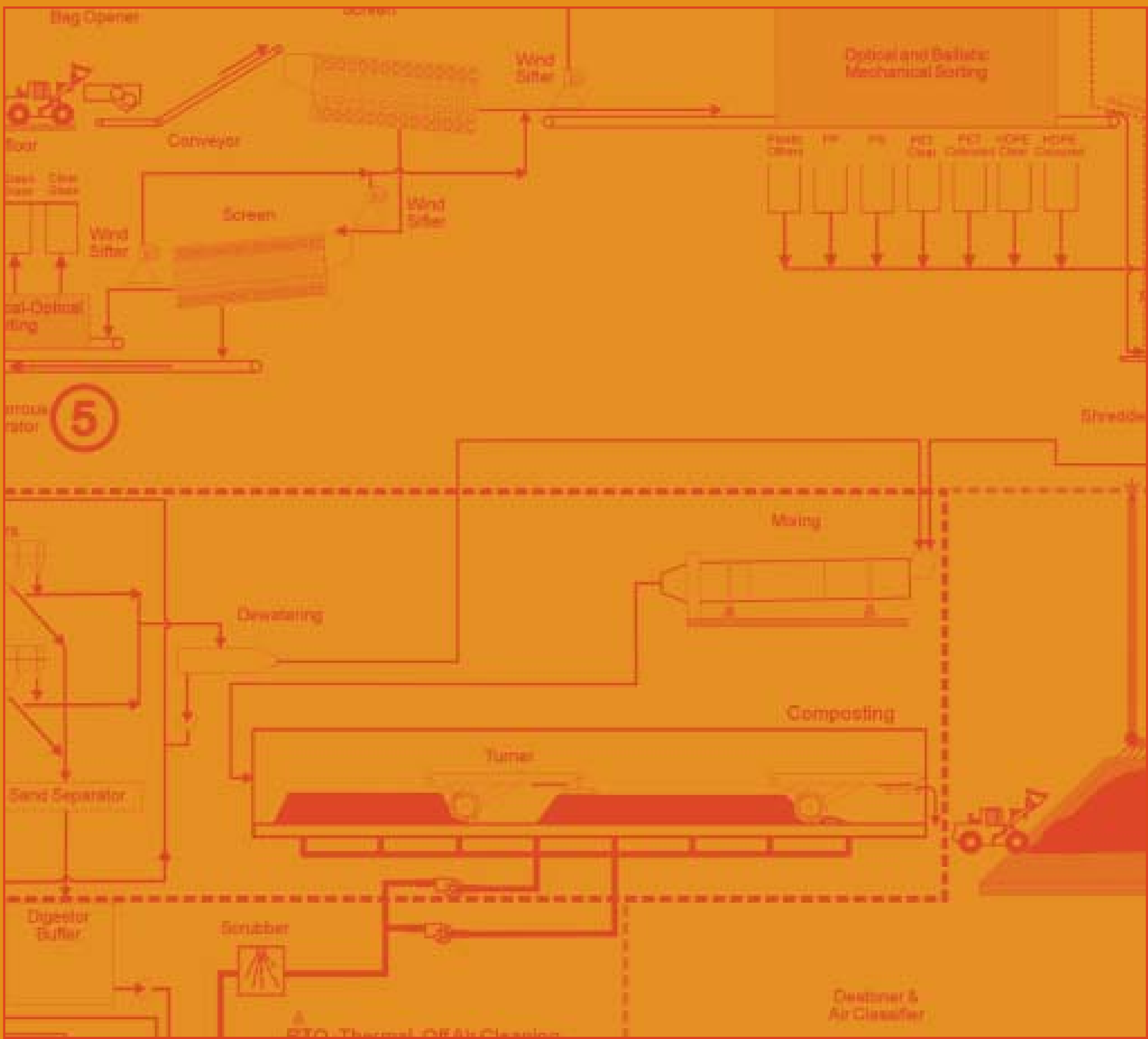
The aim of this study is to assess the possibilities for a system for managing residual waste which does not include any thermal treatment process. The study includes a review of mechanical biological treatment (MBT) systems and their potential effects.

MBT systems are not new. In their more primitive guises, they can be considered a basic evolution from the (usually failed) mixed waste composting plants of two decades ago. However, the potential for integrating systems based around biological treatment of degradable fractions with increasingly efficient mechanical separation techniques is a more recent development, as is the tendency to look to employ digestion techniques for the biological treatment phase as opposed to aerobic treatments.

Cool Waste Management

A State-of-the-Art Alternative to Incineration for Residual Municipal Waste

MBT



TBU Environmental Engineering Consultants

eunomia research & consulting

GREENPEACE ENVIRONMENTAL TRUST

February 2003

Published by the Greenpeace Environmental Trust
Canonbury Villas, London N1 2PN, United Kingdom

Registered Charity No 284934

A catalogue record of this book is available from the British Library

ISBN 1-903907-04-7

Executive summary

The aim of this study is to assess the possibilities for a system for managing residual waste which does not include any thermal treatment process. The study includes a review of mechanical biological treatment (MBT) systems and their potential effects.

MBT systems are not new. In their more primitive guises, they can be considered a basic evolution from the (usually failed) mixed waste composting plants of two decades ago. However, the potential for integrating systems based around biological treatment of degradable fractions with increasingly efficient mechanical separation techniques is a more recent development, as is the tendency to look to employ digestion techniques for the biological treatment phase as opposed to aerobic treatments.

In the system we have proposed, which no doubt can be improved upon, we have suggested that mechanical separation techniques operating on residual waste (i.e. that remaining after source separation) can extract recyclable fractions of glass, dense plastics, aluminium, steel, as well as some paper and card, and plastic films. For the latter two material types, the prospects for market utilisation may not be so great, though the paper and card can be utilised in aerobic composting.

The aim is to cleanse, through removal of useful materials, the residual fraction to leave a biowaste fraction, this being contaminated by the uncaptured materials which the process cannot recycle. In our process, this material is then treated in a digestion process before being stabilised through aerobic treatments (when the paper and card extracted could be re-introduced if there are no markets for that material). It is possible to extract from this material a fine fraction which would be suitable for low grade applications, but which should not be used on agricultural land.

This system, which generates approximately the same amount of energy as it uses (so net energy delivery would be zero), performs well when compared with other residual waste treatment systems despite the fact that other treatments can deliver more energy. Indeed, a basic greenhouse gas balance shows just how well such a system performs precisely because the emphasis is as much (if not more) on materials as it is on energy.

In the worst case scenario, this type of system still requires just less than a third of the output to be landfilled. The material destined for landfill is, however, relatively inert by comparison with untreated waste sent to landfill. The potential for generation of methane, odour and leachate is reduced with the leachate itself being less hazardous than that from other materials when landfilled. The engineering properties are also different, giving rise to reduced problems in respect of settlement (though the material requires slight changes in practice when it is placed in a landfill).

This plant does not provide an alternative to source separation. The quality of materials extracted, notably the paper and card, and organic fractions (both of which are major components of the unseparated waste stream), is lower than that obtained through source separation. It provides ‘back-up’ to that system. Set alongside an intensive source separation system, we estimate that a local authority generating 200,000 tonnes of waste would have to send approximately 15% of the total to landfill. In other words, 85% ‘diversion’ is quite feasible without any need to resort to thermal treatment systems.

Introduction

Mechanical Biological Treatment is not a new technology, but it is one that has been almost completely overlooked in Britain. Until Greenpeace published its waste management “Blueprint” in October 2001, waste managers and politicians were virtually unanimous in insisting that what could not be recycled must be buried or burned. The prevailing belief, justified by reference to an oversimplified and crude “waste hierarchy”, was that burning was the preferable option. The result was that literally scores of new incinerators were proposed across the UK.

The situation has now changed. There is a much greater awareness of the environmental impacts of incinerators and this, coupled with their unpopularity, has led to an increased interest in alternative treatment technologies for residual waste. When Greenpeace published its “Blueprint”, interest in MBT was immediately strong. But it soon became clear that waste managers wanted more details, particularly on costs and environmental impacts. This report fills that gap.

MBT is not of course a magic box that eliminates the need for a final disposal option. What it does do is greatly reduce both the quantity and toxicity of residual waste. The system outlined in this report, which is designed to deal with what is left after effective kerbside recycling, can enable rates of diversion from landfill that may seem astonishing to those locked into old modes of waste management. Some may be equally surprised that non-recyclable residues from the process are landfilled. Greenpeace does not support the practice of landfilling raw municipal waste, but we do maintain that cleansing and stabilisation followed by landfill is the best environmental option for residual waste. The life cycle and substance flow analyses in this report show that MBT followed by landfill is clearly preferable to incineration in terms of toxic emissions, climate impacts, material conservation and energy conservation.

Unfortunately, largely because of problems associated with plastics recycling, use of MBT to prepare waste for burning is common in Europe. Incineration transforms potential raw materials into pollutants and disperses them, thinly but widely, in such a way that they can never be retrieved and can potentially cause great harm. The recovery of some energy from the process does nothing to mitigate its fundamentally wasteful and polluting nature. For this reason Greenpeace opposes the burning of wastes and we oppose the use of MBT to sort and dry waste for combustion. While fuel preparation may currently look like an economically preferable option for the part of MBT output that will need landfilling, such an approach changes the environmental credentials of the system entirely and plants designed for fuel preparation should not be confused with the system proposed here.

The remaining question then is ‘can we afford MBT’?
The detailed breakdown of costs in this report should help decision makers answer that question. Greenpeace concurs with the authors conclusion that the state-of-the-art MBT plant proposed here, which generates all its own electricity and reduces the mass of waste requiring landfill by the same amount as a modern incinerator, is cost competitive and offers an extremely high environmental performance.

Mark Strutt
Senior Toxics Campaigner
Greenpeace

Contents

‘He imagined he was watching the construction of the Great Pyramid at Gaza – only this was twenty-five times bigger, with tanker trucks spraying perfumed water on the approach roads. He found the sight inspiring. All this ingenuity and labor, this delicate effort to fit maximum waste into diminishing space. The towers of the World Trade Center were visible in the distance and he sensed a poetic balance between that idea and this one. Bridges, tunnels, scows, tugs, graving docks, container ships, all the great works of transport, trade and linkage were directed in the end to this culminating structure. And the thing was organic, ever growing and shifting, its shape computer-plotted by the day and the hour. In a few years this would be the highest mountain on the Atlantic Coast between Boston and Miami. Brian felt a sting of enlightenment. He looked at all that soaring garbage and knew for the first time what his job was all about. Not engineering or transportation or source reduction. He dealt in human behavior, people’s habits and impulses, their uncontrollable needs and innocent wishes, maybe their passions, certainly their excesses and indulgences but their kindness too, their generosity, and the question was how to keep this mass metabolism from overwhelming us.’

Don de Lillo, Underworld (describing Fresh Kills landfill in Manhattan)

1.0 Techniques for treatment of residual waste

Those developing waste strategies which aim at high rates of recycling tend to be motivated by environmental goals. This being the case, an important question is 'what should be done with residual waste'? By residual waste, we refer to the waste which remains after the implementation of best practice schemes for source separation.

High diversion and Zero Waste strategies will seek continuous improvement in the performance of source separation systems. Both are likely to emphasise waste minimisation in the strategy and so would like to witness a declining quantity of residual waste to be landfilled over time. This places a premium on treatments which are relatively flexible, which do not demand a constant throughput of material, and which are environmentally friendly.

The way in which this residual waste is treated is no less important than the source separation routes in determining the environmental performance of any strategy. There are two reasons for this:
- Obviously, there are impacts from the treatments themselves and these ought to be minimised; and
- The nature of the treatment, and the degree to which its use implies high unit capital costs, determines the degree to which it forecloses options for dealing with materials in more innovative ways (if not through waste prevention itself).

In this study, funded by the Greenpeace Environmental Trust, Eunomia, along with TBU Austria, has been asked to consider the design of an environmentally sound residual waste treatment which does not make use of thermal treatment technologies. This reflects a view that the treatment of residual waste should seek to minimise the potential for generation of toxic materials.

Eunomia Research & Consulting has carried out a number of major projects on waste policy and economics in recent years. This includes assessments of external costs of treatment technologies and the assessment of the utility of life-cycle based approaches to the assessment of residual waste treatment technologies.

TBU Environmental Engineering is an engineering consultancy based in Austria. The company has 15 years' experience in pre-treatment technologies, and the design and implementation of mechanical biological treatment systems has been core business for the company for around 15 years.

1.1 Residual Waste Treatment Process Fundamentals

1.1.1 Overview

The purpose of most residual waste treatment processes is to reduce the volume of material for final disposal and to stabilise the waste such that the potential for gas formation or pollutant carriage through leachate is minimised.

Residual waste management systems are complex. A wide variety of waste fractions are generated and many types of treatment methods are available. Over the last decade, many new treatment technologies have been developed. Many have failed. The main causes of failure include:
1 Poor understanding of the properties of an inhomogeneous feedstock.
2 Inadequate planning for projected waste flows in the context of waste reduction trends.
3 Lack of comprehensive environmental assessment and understanding of emission trade-offs or regulatory trends.

The four main types of residual waste treatment are:
- Mechanical Biological Treatment (MBT)
- Thermal Treatment (Waste to Energy - WTE)
- Landfilling
- Combination of MBT and WTE

1.1.2 Mechanical-Biological Treatment (MBT)

Mechanical Biological Treatment (MBT) is a term that covers a range of technologies. Most MBT technologies have been derived from mixed waste composting. The aim of the mechanical part of the process is to optimise the material for subsequent processing, by separation (screening) of the material into a number of streams. Even when source separated collection of uncontaminated organic matter is provided, the residual waste contains significant quantities of biologically active material.

1.1.3 Thermal Treatment

Three basic processes can be distinguished: incineration, gasification and pyrolysis. These technologies all produce residues that require disposal, generally in landfills. Increasing attention is being paid to the long-term fate of these residues.

1.1.4 Landfills – Bioreactor and Encapsulation Techniques

Traditional waste disposal practice has relied on landfilling of solid waste. Management practice at modern engineered landfills has improved significantly over the past decade. The two dominant theories emerging in best practice landfill engineering are: encapsulated or 'dry tomb' landfills; and bioreactor landfills.

1.1.5 A case for MBT State-of-the-art Technologies

A number of studies have been carried out in the past 5 years that show that MBT technologies can be an environmentally friendly solution for residual wastes.

In recent work by Eunomia et al, MBT approaches perform favourably compared with other technologies. In particular, in a comparison, the performances of incinerators operating at current UK-standards, and untreated landfills, were worst.[1] Research into combination processes (mechanical-biological treatment plus various options for energy recovery) was carried out on behalf of the BMBF.[2] The study noted:

All in all, the investigation which has been presented makes it clear that combination solutions (MBT, landfill, incineration) can achieve ecologically equivalent results in comparison with mono-solutions (incineration), if the environmental protection standards of MBT, landfilling and industrial co-incineration are improved.'

A study for the Austrian Umweltbundesamt, focusing on comparison of MBT systems with mono-incineration options, made similar statements.[3] Indeed, the study commented that a clear decision as to 'what is best' was not the intention of the study, but the aim was more to see what standards should be set for MBT to ensure performance that was broadly equivalent to incineration solutions. Nolan-ITU conducted a study comparing generic residual waste treatment technologies including a comprehensive environmental assessment.[4] It was based on a review of available information and overseas experience applied to Australian conditions. One of the key findings was that all residual waste treatment technologies are better for the environment than conventional landfilling. The three leading generic technologies were ranked as follows:

1 Aerobic Mechanical Biological Treatment (MBT)
2 MBT with Refuse Derived Fuel Production and Utilisation (MBT/RDF)
3 New Thermal (Waste to Energy) Processes

Each of the above studies was based on techniques less-advanced than those in place today. Since then, technologies have developed, in particular automated sorting technologies have improved (and fallen in cost). Understanding of aerobic and anaerobic biological treatment approaches has also improved over time.

1.2 This Report
The work continues with the following sections:
Section 2: Overview of MBT Processes
Section 3: Process and Air Emissions from MBT Plants
Section 4: Plant Design Issues
Section 5: Cost Assessment
Section 6: Environmental Performance Assessment
Section 7: Conclusions
Appendix: Landfilling of MBT Residues

2.0 Overview of existing MBT processes

Although the term MBT is relatively new in the UK, the approach is actually not so new since it describes a variety of processes, some of which might have fallen under a broad definition of MBT (such as some dirty MRF / 'composting' approaches). Indeed, in some countries, the development of MBT has occurred on the back of a realization that mixed waste 'composting' is a process which is unlikely to generate valuable end-products because of the levels of contamination which tend to be found in the outputs of the aerobic treatment of mixed residual waste. Alternatively, such plants are 'adapted' to treat only source-separated biowastes.

In the 60s and 70s, waste was already being mechanically biologically treated on so-called "composting landfills". Some of these first plants are still in operation today. Operating experience was gained with concepts and landfills of this sort. The development of MBT is based on experiences which have been gained with biological treatment of waste.

An essential component of the concept is a substance-specific preparation of the waste, in which material flows of differing quality are selected by means of the mechanical stages of the process. In addition to the extraction and treatment of a biological fraction, and the separation of the iron and wood waste, a high calorific fraction is typically obtained which is often incinerated. However the focus of this work is on plants which do not require any thermal treatment process.

Where MBT technology is used as a pretreatment before landfilling, the aim is a safer means of disposal in the long-term. MBT technology should satisfy high standards as regards pollution and occupational protection. This means that all procedures which are relevant as regards emissions must be completely enclosed. It has been known for some time that biological pretreatment of waste considerably improves the behavior of landfill sites in terms of key pollutants, and in so doing reduces pressures on our environment.

MBT plants differ in:

- the type of waste to be treated (only domestic waste, all residual waste, with/without sewage sludge, preparation of waste for reclamation etc.),
- the aim of the preparation and the location of the resulting products (landfill, thermal treatment, energy recovery),
- the duration of the operating license (restricted time-wise as an interim solution, or unlimited, i.e. within the framework of regular depreciation times).

The aim of this chapter is to provide an overview of the techniques employed. There are a range of technology suppliers involved in the development and supply of MBT processes.

2.1 Waste Delivery

Because of the characteristics of residual waste, it is desirable to ensure that the direct handling of the material by operatives is kept to a minimum. Delivery typically occurs in low bunkers. It can be the case that delivery is into buildings maintained at negative pressure (and in some Italian situations, spray droplets are used to minimize problems with flies as the tipping occurs). Some hazardous materials and large metal fractions may be removed by a grab though the extent of this depends upon subsequent preparation.

In most MBT plants, loading of primary shredders is carried out using a grab, though some facilities use inclined conveyors or crane. Quality of removal of hazardous / difficult materials is dependent upon the quality of the operation of the grab, so in some cases responsibility for interruptions at the shredder is assigned to the grab operator (as an incentive to carry out removal of such materials effectively). Of course, it is not always the case that shredders are used immediately following the use of a grab.

2.2 Preparation

Manual separation of materials is to be avoided. Only in very few plants is there any such handling, usually targeted removal of hazardous materials prior to second shredding of the oversieve (sieve overflow) fraction.

As regards household waste, most material is sent for sieving without prior shredding. Primary sieving can reduce the degree to which damaging components affect the shredder, but this makes a second sieving stage necessary.

2.3 Types of Preparation Unit

Since the range of tasks across (and within) MBT plants is being diversified, a range of different units are used to suit the end-use requirements (see Table 1). The choice of units depends upon the nature of the division of materials sought, and the ultimate destination of the separated fractions.

Depending upon whether the MBT system is based upon a 'splitting approach' or a 'stabilisation approach', initial sieving generally happens before the biological treatment (splitting process) or after the stabilization process (dry stabilization). Many MBT plants use trommel sieves, and depending on the nature of the separation of materials required for each application, the sieving is either in one or two stages. In order to guarantee sufficient separation, care has to be taken in the design of the trommel to ensure sufficient lengths and gauges of sieve and the correct rotational speed. For the avoidance of belt wraps of the rotary screens (mummification), tube-jointed sleeves on the sieve areas appear to be useful, and for easier purification, the achievement of appropriate profiles along the sieve cylinders has also proved effective.

For the targeted separation of the light fractions, air classifiers, pneumatic tables, vibrating tables, ballistic separators etc. are in use in some plants in addition to a rotary screen.

Ferrous metal separation is usually carried out, normally at different stages of the process, and typically with varying quality upon extraction. Because of this, the different streams are sometimes kept separate to ensure the material can be easily marketed. Some, though not all, plants are equipped with mechanisms for non-ferrous metal extraction. Sometimes this occurs in subsequent processing of output material as a fuel.

2.4 Biological Treatment

There are two forms of biological treatment available for dealing with biowaste fractions. They are fermentation (anaerobic process) and aerobic treatment.

2.4.1 Aerobic Treatment ('Composting')

In composting, four lines of development or action have developed. Table 2 shows an overview. The lines of action essentially differ in:

- aim of the process (is the aim to dry the material, or to stabilise it through organic decomposition (in which case, the aim will be to prevent the material from drying out)?)
- the degree of the plant encapsulation (encapsulated, within a building, partially within a building, covered with membrane, open)
- emission standards (nature and extent of waste air capture and treatment through filters)

Four types were outlined by Zeschmar-Lahl et al. They are shown in Table 2 below. In essence, owing to the similarity of the technical processes, the whole range of composting systems which are available on the market are utilized in MBT plants (trommels, tunnel, box, container, clamps in rows, continually turned aerated clamps, aerated clamps etc.)

It is important to note that it would usually be the case that, where residues from the biological treatment process were to be landfilled / used for landscaping, it would be expected that any anaerobic phase would be followed by an aerobic treatment (to stabilise the output material).

The system ultimately used is typically decided on the basis of:

- planning permission requirements.
- site conditions;
- cost targets (investment and operating costs).

The systems which are offered differ as regards operating and investment costs. The differences in the specific investment costs have a strong effect in terms of either determining or restricting the possible retention times in the composting system. The higher the specific investment, the shorter the economically justifiable resting time in the system

Table 1: Overview of units in MBT plants.

Function	Unit
Primary shredding	Crushers, worm mills, rotor shears, percussion grinders
Secondary shredding	Worm mills, hammer mills
Sieving, classification	Rotary screens, 1 and 2 staged, perforation 40-300 mm
Classification	Air classifier, pneumatic tables
Fe-separation	Magnetic separators
Non ferrous-separation	Eddy current separators
Compaction of coarse fractions	Compression containers, bales (rolled bales, or bales bound with wire)
Loading of fine fractions	Open containers with HGV transport, conveyor belt transport
Mobile equipment	Wheel loaders, grab excavators, fork-lift trucks, container trucks, dumpers

Table 2: Lines of Development in Aerobic Treatment of Residual Waste

Type A:	Encapsulated, static primary composting for dry stabilization with retention time of 1-2 weeks
Type B:	One-stage, encapsulated, quasi-accelerated composting with active aeration and waste air capture, regular turning intervals (as a rule weekly, in some case every 5 days)
Type C:	Two-stage composting with a short encapsulated primary composting (static or quasi-dynamic) with composting periods of between 1 and 5 weeks and a downstream secondary composting of varying duration (7 – 26 weeks) and technique (open, covered; un-aerated, aerated; with or without turning)
Type D:	Open, static composting without active aeration and as a rule without turning, with composting times of 12 – 18 months)

Source: Zeschmar-Lahl et al. (2000) Mechanisch-Biologische Abfallbehandlung in Europa, Berlin: Blackwell Wissenschafts-Verlag GmbH.

will be. This in turn has implications for the degree of stability which can be attained in a given treatment for a specified cost since the longer the retention time, the greater the level of stability attained (though the rate at which the material is stabilised varies across processes).

Retention Time and Level of Stability

In MBT systems, the level of stability or maturation of the material which has been subjected to the biological treatment process is measured through various criteria. Discussions continue about which measure is most appropriate in a given situation. However, the intention is to specify a minimum level so as to ensure that the process contributes to the reduction of the potential for harm caused by subsequent landfilling of residues, or their use in restricted applications (such as for landscaping).

The duration of the composting until the alternative maturation criteria are reached (RS4, GF21, TOC) is dependent on the operating management and the system selected. As a rule the following applies:

- the more dynamic the process, the shorter the composting time; and
- the shorter the time in the (quasi) dynamic system, the longer the secondary composting required in the static system.

The minimum composting times which are finally required, in order to be able to definitely meet specified 'disposal criteria' with sufficient operational safety, are still the subject of current research projects. Comparison of the measurements from various plants and laboratories is still difficult since there is no agreement on a standardized methodology for analysis. Furthermore, because of these debates, it is uncertain as to what the appropriate criteria should be for material to be landfilled. This is discussed in more detail in Section 4.

Type of Aeration and Composting Control

The aim of the aeration is:

- the safeguarding of sufficient oxygen content in the clamp,
- the avoidance of anaerobic areas,
- the dissipation of the CO2 which has built up,
- the dissipation of the heat which has been released by the reaction,
- plants which prepare material for incineration make use of drying through the heat generated by biological activity.

These aims must be brought into line with the competing aim of the minimization of evaporation loss. When choosing an aeration system, and in particular the aeration base, care is to be taken that suction and pressure aeration are possible. The aeration is carried out in accordance with the activity of the material in the course of the composting. For this, segmentation of the composting areas into separately adjustable aeration fields is required. The amount of air per aeration field is adjusted by means of frequency-regulated ventilators, depending on the temperature and the oxygen content. Alternatively, phase operations are also in use.

With both encapsulated and housed systems which run a suction operation, conclusions are drawn as to the conditions in the clamp by means of measurements of the parameters of the waste air from the clamp. The correlation between the temperature in the waste air and in the clamp is, however, subject to fluctuations. It is influenced by the situation in the clamp (temperature level, water content, evaporation rate), the location of the point of measurement, and the location of the aeration pipes (warming by the sun, or cooled by the effects of frost).

On the basis of the various influencing factors, certain limits are set for the automated running of the process. The continual measurement of temperature and oxygen in the waste air has proved to be a useful means of controlling the process, beyond this, the actual control of the process lies within the area of responsibility of the operation manager.

Prefabricated Components for the Composting Process

The prefabricated components of the housed and encapsulated systems are carried out in concrete or in steel. Corresponding requirements for protection against corrosion are to be taken into account with both materials. The concrete components must, amongst others things, satisfy requirements as regards ammonium and sulphate corrosion. Some plants have added additional composting sheds made of synthetic materials. (Oberpullendorf (A), Mailand (I)).

Insulation of Composting Sheds

In order to ensure the required air-changeover rates in sheds, as a rule external air is drawn into the sheds over venetian blind flaps. Because of this, a considerable cooling of the sheds can occur in the winter, which impedes the operating ability of the units (e.g. interruption in the energy chain).

On the other hand, in the summer a considerable warming of the atmosphere in the sheds can occur due to sunshine.

For the improvement of the climate in the sheds, insulation of the roof and walls of the sheds has proved worthwhile. Increased investment costs are offset by clear advantages in the efficiency of the operation.

2.4.2 Anaerobic Digestion / Fermentation

In the area of fermentation there are several system suppliers on the market. Until now there have been few experiences of large-scale operations with residual waste. The various processes include:

- dry and wet processes
- mesophilic and thermophilic processes
- one and two stage processes
- percolation, hydrolysis and fermentation of the aqueous phase
- interval processes (aerobic – anaerobic – aerobic)

In Germany, fermentation of residual waste has only taken place in the experimental plants at Münster as well as Bassum RWT (Residual Waste Treatment Plant). At Bassum, the fermentation is carried out according to the so-called

Dranco process (dry anaerobic composting: a one-stage, thermophilic dry fermentation). After the positive experiences in the experimental operation in Münster, mesophilic wet fermentation should also now be possible commercially. A fermentation stage is an essential component of the plant concept in the planned Pohlsche Heide MBT in the administrative district of Minden-Lübbecke. In the Netherlands a fermentation process is used at the VAGRON MBT plant.

The facility at Amiens in France is a digester equipped to deal with residual waste, and though not generally considered as an MBT process, this is effectively what the plant is designed to achieve. Wannholt suggests that of the 72,000 tonnes per annum sent to the plant, 2,500 tonnes of metals and 6,500 tonnes of glass are produced. 11,000 tonnes is currently landfilled.[5] This leaves 52,000 tonnes to enter the digestion process. This results in 37,200 tonnes of output material from the process. In France, because of the somewhat lax standards applied to the utilization of compost, this material is used in arable cropping and viniculture. An additional 9,400 tonnes of residue are produced.

In comparison with pure composting processes, combined anaerobic – aerobic processes have tended to imply higher investment and operating costs. On the basis of the strong competition between the process suppliers and the improvements made in process control at fermentation facilities, the cost differences appear to be diminishing. Futhermore, the extent to which the higher specific costs of fermentation can be compensated by means of a corresponding shortening of the composting time in the secondary composting is at present being investigated (e.g. Bassum RWT). Lastly, in some countries, the potential to derive additional revenue from the sales of energy derived from digestion plants tends to reduce the cost differential between combined anaerobic / aerobic, and aerobic systems.

Further advantages of fermentation can arise in the area of the purification of waste air. Since with fermentation – in particular in thermophilic fermentation – volatile components are also carried out via the biogas path, there can possibly be savings potentials with waste air treatment in secondary composting. In practice, analytical proof of this is yet to be found.

2.4.3 Treatment of Air Emissions

With encapsulated and covered plants, the treatment of waste air used to be carried out only by means of humidifiers and biofilters. Usually, the biofilter takes the form either of a filter in an open or roofed type of construction, or as an encapsulated room filter. Table 3 shows design examples.

The experiences with biofilter technology in MBT plants which have been gathered until now can be summarized as follows:[6]

- the combination of washer and biofilter for the treatment of waste air with the aims of separating off dust and minimizing odour has proved extremely worthwhile. According to the information available the study notes that the legal requirements of the German TA Luft regulation can be fulfilled with biofilter technology. However, the biofilter does not meet the expectations for an effective reduction of all critical organic matter of Class I and II according to Article No. 3.1.7 of the German TA Luft.
- Problematically, ammonia and organic nitrogen compounds crystallize out, and they can have a hindering effect on the breakdown of materials. In such cases, the odour concentrations in the pure gas can also exceed the limit. Methane is not converted in the biofilters of the investigated MBT plants.

In many existing MBT plants, there is little or no waste air purification. In more recent plant, the biofilter is the norm, which in most of the MBT plants is supported by an upstream humidifier. The use of the term, “washer,” or even “biowasher,” which is used in many publications and descriptions of plants, is unclear, because in filter technology clearly more extravagant controlled systems are to be understood by this term.

Table 3: Construction and process variants of biological waste air purification at mechanical-biological treatment plants (examples).

Plant	Lüneberg MBP	Friesland/Wittmund MBP	Bassum RWT
Dust separation/ humidification	Spray washer	Spray washer	Two parallel spray washers
Biofilter system	Simple open area filter	Covered area filter with sprinkling	Closed room filter with sprinkling
Filter material	Coarsely broken root timber	Bark with ceramic packing	Broken root timber
Filter volume load	67 $m^3/(m^3h)$	<280 $m^3/(m^3h)$	<60 $m^3/(m^3h)$
Filter area load	100 $m^3/(m^2h)$	<280 $m^3/(m^2h)$	<190 $m^3/(m^2h)$
Direction of flow	⬇	⬆	⬆
Dissipation of pure gas	Open, near-surface	Covered, near-surface	Contained, via flue

Research into plants which are operating in Germany and Austria shows that biofilters, when they are present, show a remarkable difference in construction or sizing. Biofilters, in a similar way to physical or chemical filters, need to be constructed with regard to the appropriate dimensions relative to the waste air which they are to purify. The key issue is to guarantee a certain retention time of the waste air in the filter, in order to actually achieve a comprehensive substance exchange between the filter medium and the waste air.

The contact times in the biofilter are, in turn, achieved mainly by the relationship between the filter size (in m^3), pore volumes and the waste air which is to be purified (in m^3/ unit of time), as well as (to some extent) the presence of pressure differentials within the biofilter. Because of the variation in investment into filter dimensioning in MBT plants, contact times are sometimes under 30 s, but values over 100 s are also observed.

In addition to sufficient dimensioning of the biofilter, the construction of the filter is of importance for the purification effect. This is because it has been shown that the influence of weather in open types of construction (which currently, if there are filters present, represent the control variant) is very high. For this reason, in the cold seasons, but also in very hot and too damp weather conditions, interruptions in the performance of the filter may occur.

Recent developments include the use of thermal filters. These operate so as to effectively crack the organic components of exhaust gases. A recent Austrian study suggests that the emissions reductions achieved through this process include (quoted relative to standard biofilters, and biofilters alongside ammonia scrubbing, respectively):

- Reductions in NMVOCs (90% reduction and 80% reduction respectively):[7]
- Reduction in CFCs as follows (98% reduction in both cases);
- SOx (50% reduction in both cases)
- Ammonia (75% reduction and 0% reduction)
- N_2O (100% reduction in both cases)

This occurs at the expense of an increase in CO_2 emissions and an increase in NOx emissions associated with energy use in running the plant.

In some countries, notably Germany, there have been calls for the establishment of more stringent limits in a new regulation for MBT plant emissions. This is frequently misinterpreted as a politically motivated, skillfully packaged attack on MBT, although there are certainly interests which would like to see such regulations effectively pricing MBT plants out of the existing market.

Zeschmarr-Lahl et al report that the air quality conservation measures which are being put into action today are, from the investment and operating point of view relatively low to insignificant at German MBT plants. Even in the plants with humidifiers, closed biofilters etc., the operating costs (including depreciation) are below 3% of the total operating costs. Frequently the operating costs as regards waste air are below 1% or are not even calculable (because they are nonexistent). Such figures clearly indicate a very low proportion of expenditure in environmental protection as compared with other branches of industry and indeed, as compared with other (non-landfill) waste treatments.

Table 4 indicates the costs for a waste air volume of 60,000 m^3/h with otherwise normal capital and operating fund costs.

The figures from Table 4 are not calculated for MBT per se but for use of this type of technique. It is not expected, however, that MBT will make fundamentally new demands on such types of purification techniques. However, the ranges quoted might narrow with better information. Even the ranges shown, however, illustrate that there are interesting alternatives to the biofilters in which even the upper end of the quoted ranges imply not unreasonable levels of cost (less than 10% of the MBT treatment costs), particularly when they are successful in reducing the specific amount of waste air to be treated. For this reason, some operators have begun to replace biofilters with these more effective (though more costly) techniques.

2.4.4 Personnel Requirements

The personnel requirements of MBT plants are dependent on various factors, such as, for example, the size of the plant, the number of operating units and operating times (1 or 2 shift operation). For a mechanized MBT plant with fermentation, in a 1-shift operation the personnel requirements listed in Table 5 arise.

For the assignment of personnel, a system of giving clear assignments and responsibilities for defined functions has proved worthwhile.

With increasing demands on the treatment of waste air and process control, it becomes more necessary for the plant to hire sufficient staff of its own. For increased control over its own operations, MBT plants may have to carry out some basic laboratory analysis in house, analogous to some sewage treatment plants. Much depends upon the nature of the regulatory system applied and the destination of end products.

Table 4: Annual total costs from waste air purification plants, state of business 1993 [47].

Process	Annual total costs
Catalytic afterburning	0.11-0.99 million DM/a
Thermal afterburning	0.15-1.26 million DM/a
Regenerative afterburning	0.35-0.96 million DM/a
Stage biofilter	0.12-0.50 million DM/a
Area biofilter	0.09-0.30 million DM/a

Table 5: Personnel requirements of a mechanized MBT with fermentation.

Number	Function	Responsibility
1	Operating manager	Whole plant
1	Deputy operating manager	Fermentation
1-2	Electrician, electronics engineer	EMSR[a]
1	Fitter	Maintenance, repair
3-4	Mobile equipment operator	Wheel loader, grab excavator, container vehicles
2-3	Cleaning staff	Daily cleaning and cleaning of the grounds, externally if necessary
Proportional	Laboratory staff	Process control, material analysis
Proportional	Replacement	Estimation: ~ 25-30%
Proportional	Administration	
Proportional	Weighbridge, workshop	
Proportional	Data administration, marketing	

a Electrical, measurement, control and regulation technology

3.0 Process air emissions from MBT plants

As discussed above, the air emissions from MBT facilities have traditionally been subject to relatively weak controls, but this is now changing with combined biofilter and scrubbing systems, and more recently, thermal systems, being used to clean exhaust gases.

This Section reports on some of the emissions reported thus far in various studies.

3.1 Carbon Dioxide and Methane
The carbon dioxide emissions from aerobic MBT plants are significant, but the CO_2 emissions are all from biogenic materials. The quantities released in the pre-treatment process depend upon the nature of the process, its duration and the composition of the material itself. In general, the longer the process, the more of the carbon will be mineralized, principally as carbon dioxide as long as conditions are optimized. The emissions from components of this material, once landfilled, are discussed later in this document.

As regards MBT processes which incorporate an anaerobic phase, clearly where the aim is to generate energy, the aim is to make use of the methane generated from the process, in doing which, methane is converted to carbon dioxide.

Some studies have sought to relate the gaseous emissions from biological treatment back to the waste composition, though generally only for the methane and carbon dioxide components and rarely in the case of MBT plants. Usually, such studies have looked at the emissions from plants treating source-separated materials. The work underpinning the Swedish ORWARE model relates the emissions back to the class of organic materials being degraded (lignin, starch etc.). In the United States, work on the modelling of compost plants has concentrated on the emissions of carbon dioxide based upon the garden waste, paper and kitchen waste components.

One attempt to model emissions of carbon dioxide from aerobic MBT plants was that of AEA Technology.[8] The results of this attempt are shown in Table 6. The three cases considered were:

- **Case 1. Highly Stabilised MBT Compost,** in which about 5-10% of degradable organic carbon has been estimated to remain in highly stabilised MBT compost. The study adopted the results of the laboratory trials which suggested that MBT eliminates about 90% of the CH_4 forming potential of MSW. The rate of formation of the residual CH_4 was assumed to be such that oxidation by micro-organisms in the landfill soil was able to completely convert the CH_4 to CO_2. No CH_4 emission thus occur so there are no greenhouse gas emissions associated with landfilling of MBT residues. Remaining short-cycle carbon is assumed to be sequestered.
- **Case 2. Less Stabilised MBT Compost.** A shorter duration MBT process was assumed, resulting in some remaining CH_4 emission. This was simulated by using the same CH_4 forming potential as in Case 1, but assuming that only 25% is oxidised to CO_2 by a combination of microbial oxidation and gas collection and oxidation in bio-filters, the remaining 75% escaping to the atmosphere. Flaring would have the same overall effect but MBT compost was considered unlikely to produce landfill gas with a high enough CH_4 content (ie less than about 17% by volume) to allow combustion without a pilot fuel.
- **Case 3. MBT compost used as a surface dressing for landfill site remediation or as a restoration layer, acting as biofilter, to reduce CH_4 emissions.** In these applications, decomposition of the compost continues aerobically and resistant organic matter that would have been sequestered under anaerobic conditions decomposes. In the absence of better data, the study's authors assumed that decomposition would occur at the same rate as high-quality compost applied in an agricultural setting. This assumption implied that 8% of the carbon in the non-dissimilated degradable carbon applied in the compost would remain in the soil outside the 100 year time horizon for sequestration.

Further information on the rationale for this approach can be found in the AEA study. However, the important points to note are:

- Since the study uses as its baseline a view that 'biogenic emissions of carbon dioxide' constitute a 'zero baseline', the carbon remaining in landfills over a period of 100 years (a time-horizon chosen in the study to differentiate 'short' and 'long-term' emissions) represents sequestered carbon, so a negative contribution to emissions.
- Because of:
  (a) this sequestration effect; and
  (b) the fact that combusting material effectively releases all carbon with immediate effect. Even accounting for emissions avoided when electricity is produced at a subsequent thermal treatment plant, the greenhouse gas emissions from MBT plants, according to the study, are most favourable when the residues are landfilled. They become less favourable when residues are combusted, yet they are still more favourable than the situation in which waste is incinerated directly.

Another attempt was made in the study by AWS et al.[9] This study suggested that greenhouse gas emissions from MBT-based systems in the pre-landfilling phase would be less than for incinerator based systems, consistent with the above. However, the modeling carried out in the study went on to suggest that once landfilled, the MBT residues would continue to generate significant proportions of methane (approximately half those which were projected for untreated landfill systems over a hundred year period). This is somewhat strange, and appears to run counter to all the empirical evidence, as well as to the other modeling studies mentioned.

Table 6: Emission factors for wastes processed through MBT (kg CO_2 eq/t material or MSW treated).

Waste management option	Waste component	Short cycle CO2	Fossil CO2				Short cycle C sequestered	Sum of fossil C and sequestered C	CH4 emission	N2O emission	Total GHG flux
		(GWP=0)	Process	Energy use	Avoided energy and materials	Transport / mobilisation	(GWP=-1)		GWP=21	GWP=310	
MBT treatment with landfill of rejects and recycling of metals											
	Paper	396	0	22	-6	4	-786	-765	206.6	0	**-559**
	Putrescible	441	0	22	0	4	-251	-224	0.0	0	**-224**
	Plastic	0	0	22	0	4	0	27	0.0	0	**27**
	Glass	0	0	22	0	4	0	27	0.0	0	**27**
	Metal	0	0	22	-3038	10	0	-3006	0.0	0	**-3006**
	Textiles	147	0	22	-16	4	-503	-492	526.1	0	**34**
	Other	226	0	22	-6	4	-369	-349	206	0	**-143**
Case 1	MSW	286	0	22	-162	5	-364	-500	97	0	**-403**
Case 2	MSW	276	0	22	-162	5	-364	-500	171	0	**-329**
Case 3	MSW	551	0	22	-162	5	-99	-234	97	0	**-137**
Mean of Cases 1 & 2	**MSW**	**281**	**0**	**22**	**-162**	**5**	**-364**	**-500**	**134**	**0**	**-366**
MBT treatment with landfill of rejects and recycling of metals											
	Paper	580	0	22	-51	4	-629	-653	0	3	**-650**
	Putrescible	441	0	22	0	4	-251	-224	0	0	**-224**
	Plastic	0	2237	22	-703	4	0	1560	0	15	**1575**
	Glass	0	0	22	0	4	0	27	0	0	**27**
	Metal	0	0	22	-3038	10	0	-3006	0	0	**-3006**
	Textiles	718	718	22	-326	4	0	420	0	15	**434**
	Other	285	63	22	-26	4	-213	-149	0	5	**-144**
Case 1	MSW	358	205	22	-241	5	-289	-298	0	3	**-295**
Case 2	MSW	349	205	22	-241	5	-289	-298	74	3	**-221**
Case 3	MSW	604	205	22	-241	5	-23	-33	0	3	**-30**
Mean of Cases 1 & 2	**MSW**	**353**	**205**	**22**	**-241**	**5**	**-289**	**-298**	**37**	**3**	**-256**

Source: Smith et al (2001) Waste Management Options and Climate Change, Final Report to DG Environment, European Commission.

Note that the data are expressed per tonne of material in question. For MSW, the emission factors are estimated from the sum of the constituent waste components multiplied by their relative proportion in the waste stream.

3.2 Ammonia NH_3

MBT plants show, according to technique, specific amounts of waste air etc., a high ammonia contamination (NH_3) of the crude gas from 10 to 200mg/m^3. High crude gas values can lead to the damaging of biofilters (to the point where they become ineffective).

An additional problem is represented by the partial oxidation of NH_3 to N_2O, which is linked to the damaging of filters. This is also a potent greenhouse gas, so the minimization of this secondary emission is also of relevance. Another secondary emission is that of nitrosamines, the formation of which has been observed in biofilters.

Controlled acidic washers of a simple construction can certainly maintain values below 10 mg/m^3 of waste air. With input values below 10 mg/m^3 the danger of the filter being damaged is minimized and the remaining ammonia is more likely to be oxidized by the intact biofilters. In this way it is ensured that the MBT does not exceed an ecologically justifiable emissions level (for NH_3).

3.3 Organic Materials (TOC)

A summary of the pollutant *concentrations* which occur in the *crude gas* from mechanical biological waste treatment plants was given in a publication by Fricke et al. The data was representative of the situation as at January 1997 and was based on test results from five more detailed investigations. For all the investigated elements/compounds, the highest discharges were established within the first 14 days (the maximum values of the individual substances are in brackets):

- *Aldehyde:* maximum value > *100 mg/m^3* (Acetone: 140 mg/m^3; 2-butanone: 55 mg/m^3)
- *Terpenes:* maximum values > *50 mg/m^3* (Limonene: 56 mg/m^3; π-Pinene: 14 mg/m^3; ß-Pinene: 6.4 mg/m^3)
- *Aromatics:* maximum values > *30 mg/m^3* (m-, p-xylene: 38 mg/m^3; ethyl benzene: 13 mg/m^3; toluene: 11.5 mg/m^3; o-xylene: 10 mg/m^3; styrene: 5.9 mg/m^3; benzene: 0.3 mg/m^3
- *Acetates:* maximum values > *30 mg/m*^{3} (ethyl acetate: 32 mg/m^3)
- *Alkanes:* maximum values: > 1*0 mg/m^3* (nonane: 12 mg/m^3; decane: 43 mg/m^3)
- *CFCs:* maximum values: > *1 mg/m^3* (R11: 3.1 mg/m^3; R12: 1.7 mg/m^3)
- *Alphatic chlorinated hydrocarbons:* maximum values: > *1 mg/m^3* (tetrachlorethene: 2.7 mg/m^3; trichlorethene: 1.38 mg/m^3), evidence of di- and trichloromethane, 1,1,1-trichloroethane, 1,1-dichlorethene.

The above figures represent maximum values in the *crude gas.* There still appear to be gaps in knowledge concerning the emissions of Total Organic Carbon and the emissions values for individual materials.

A comparison between the maximum crude gas loads calculated from the tests carried out in the aforementioned study and the measurements at commercial MBT plants revealed that the loads actually emitted through the crude gas turn out lower than was established on the basis of model tests as carred out by Doedens et al.[11]

Data from the Austrian Federal Environment Office for Kufstein MBT and Allerheiligen MBT also suggest that the crude gas from MBT contains a multitude of individual organic compounds, sometimes in very high concentrations/loads, although with varying concentration profiles. The TOC (total organic carbon) presents itself as a useful monitoring parameter, which records the entirety of the organic components. The measured value of the TOC can be expressed by means of a conversion factor based on the gaseous (= volatile) organic substances emitted (hereafter referred to as VOC, volatile organic compounds). The value suggested by Zeschmar-Lahl et al for MBT is 1.25.[12]

Generally, one finds that in life-cycle analyses for the POCP category where this is applied to combination concepts, the MBT stage of the total treatment can be by far the most dominant component. An NMVOC[13] (or VOC) limit can clearly reduce this negative effect, implying the need for effective process management (for example, to prevent anaerobic conditions) and treatment of exhaust gases.

The NMVOC loading of the MBT waste air (crude gas) lies in the area of approximately 100 mg/m^3 to 500 mg/m^3, a mid-range being of the order 50-200 mg/m^3.

3.4 Methane (CH_4)

It is not yet certain whether the non methane content (NMVOC) will need to be recorded within a VOC limit. In the event of such regulations, compliance could be achieved relatively easily using optimised washer/biofilter systems. A calculation of the methane (which from the human-toxicological point of view is irrelevant as a trace element), would also lie within the logic of TA Luft (effect orientation).

Methane is a potent greenhouse gas. Life cycle assessment calculations show that the methane concentrations of from 1,000 to >50,000 mg/m^3, which are possible with open-air composting, or housed-in systems which are insufficiently supplied with oxygen (or with waterlogging in the biofilters), would have a formative influence on the results and exclude the equivalence of the measures.

In Appendix 1, we investigate in further detail the emissions following landfilling of material. Clearly, in the process stage, the aim is to minimize the potential for anaerobic conditions to develop, with the obvious exception of those plant designs where anaerobic treatment forms a part of the biological treatment process. In this case, the aim is to ensure full capture and as complete a combustion of the gasses as possible to ensure a) maximum recovery of energy; and b) a reduction in the potential for environmental damage through conversion of methane to carbon dioxide.

3.5 CFCs

The few measurements available show that CFC loads of 1-10 g/Mg input can be released from an MBT plant, dependent on the type of waste being processed (Table 7). Indicator substances here are, as expected, the frequently used old CFCs, R11 and R12.

Our life cycle assessment calculations have indicated that emissions on this scale have a noticeable influence on the total result for the greenhouse effect and potential ozone-depletion effect categories. Within the framework of equivalence considerations and sustainability aims, a reduction of these emissions should therefore be called for. On the part of the biological waste air purification processes, an effective reduction of emissions is not adopted.

Care therefore needs to be taken with MBT to ensure that waste containing CFCs is as far as possible excluded or filtered out early, but at all events that it does not enter the biological stages.

It is sometimes pointed out that the old CFCs referred to have in the meantime been banned. With that is linked the expectation that the topic of CFCs is no longer relevant for the waste industry.

Investigations relating to this show, however, that the CFCs used in building in the 1970s and 1980s are still "stockpiled" in considerable amounts (buildings, products, trade). The German Federal Office for the Environment has estimated the R11 reservoir in rigid foam up to 1986 at 70,000 tonnes (lower limit). Of this 50,000 tonnes are stored up in the building industry alone (insulation). These amounts will be introduced into the waste stream within the next 10 to 50 years.[14]

For the future, an increase of the partially halogenated CFCs/FHCs in the waste is to be reckoned on, since these are replacing the fully halogenated replacements in many areas of use. This may bring about the use of chemically related substitutes, which although they show a lower potential for the destruction of the ozone layer, also show a high greenhouse potential, particularly the partially halogenated CFCs and partially fluorinated FHCs. For this reason, the topic of CFCs/FHCs for MBT can also, for the future, not be seen as defused. The exhaust air purification of an MBT plant ought, therefore, to ensure a high separation efficiency for this type of pollutant.

Table 7: CFC emission loads from MBT plants (crude gas) – current measurements of the Austrian Federal Office of the Environment.

Parameter (g/Mg)	**Allerheiligen**[a] (Tunnel waste air)	**Siggerwiesen**[b] (Waste air – composting trommel)	**Siggerwiesen**[c] (Waste air – composting trommel)	**Siggerwiesen**[d] (Shed waste air)	**Kufstein**[e] (waste air composting module)
Sampling _	**spring**	**winter**	**summer**	**winter**	**Summer**
CFC					
R11	n.n	8.5	4.1	0.4	2.2-2.3
R12	n.n	11.3	0.2	0.4	1.3-1.4
R21	n.n	n.n	-	n.n	n.a
R113	n.n	n.n	<0.05	n.n	1.9
R114	n.n	n.n	0.2	0.4	1.2-1.4

a 7,000 m³/tonne; b 710 m³/tonne; c 480 m³/tonne; d 1,100 m³/tonne; e 6,000 m³/tonne

4.0 Plant design issues

4.1 The Objective
The brief asked for the development of a 'best practical option' which should include mechanical separation of dry recyclables, followed by biological treatment of the biodegradable fraction. Thermal treatment of any fraction should be avoided.

4.2 Key Criteria
All mixed municipal waste must be expected to have some environmental impact, which is why the objective of an environmentally sound waste strategy should be a continuously diminishing residual waste stream, with the ultimate objective being zero waste (or as close to zero as possible). In this framework a residual waste treatment would have the following characteristics:

1. Wherever practical material not separated at source should be recovered for recycling and markets for recyclate should be actively sought and developed;
2. Subject to avoiding the potential for build up of potentially toxic elements in soils, organic residues should be used to increase / replenish soil organic matter levels;
3. Emissions to the atmosphere should be minimal and have minimal impact on human health and the environment;
4. Emissions to soil should have minimal impact on human health and the environment; and
5. Emissions to water should have minimal impact on human health and the environment;
6. The assessment of the potential for harm to the environment and health should recognize the uncertainties surrounding such assessments, not least in respect of chemicals suspected of presenting significant risk on exposure to human and other life forms, or possessing intrinsically hazardous properties such as environmental persistence or potential to bioaccumulate;
7. The plant's operation should minimize the exposure of operatives to handling materials / emissions from the plant's treatment;
8. The plant should seek to minimise use of energy;
9. Any residues should be minimised and their toxicity should be minimised. Their final disposal should have regard to the potential for pollution following disposal;
10. The plant should be flexible with respect to changing waste composition.

These characteristics establish broad parameters for the assessment of plant designs.

4.3 Elements of MBT

4.3.1 Overview
Most MBT technologies have been derived from mixed waste composting. The concept of mixed waste composting (i.e. composting of unseparated municipal waste) is largely discredited since the process fails to generate valuable end-products because of the levels of contamination which tend to be found in the end-product. The aim of the mechanical part of the process is to attain optimisation of the material for the biological processes by separation (screening) and shredding to extract useful materials in the process.

Even when source separated collection of uncontaminated organic matter is provided, the residual waste contains significant quantities of biologically active material. The existence of a separate collection for dry recyclables as well as for organic materials tends to lead to biowaste concentration in residual waste being greater than would be the case if no separation of dry recyclables existed. Even the best performing source separation schemes have 10-20% biowaste in the residual. Biological treatment usually results in:

1. Reduction in the weight of waste requiring disposal by approximately 30%
2. Reduced landfill gas generation
3. Reduced leachate generation
4. Higher density of landfilled material (by 30-40%)

Biological waste stabilisation also provides an opportunity to co-treat with sewage sludge, a material which can cause serious problems in landfill management, especially in large quantities. This is of particular relevance in areas where the re-use of sludges is limited due to hygienic and contamination concerns or legislative and market constraints. This occurs mostly in urban areas with high population density and/or where industries are connected to the sewerage system.

The following sections describe typical elements of MBT systems:

Mechanical Extraction of Remaining Recoverable Materials

With a residual waste stabilisation plant as a front-end facility for a landfill, opportunities exist to extract recoverable materials which have not been separated at source. This is done by means of a magnetic separator for ferrous metals, or by diverting recyclable (or inert) items with other machinery.

Biological 'Inerting' through Decomposition of Easily Degradable Substances

MBT aims to reduce the organic carbon fraction to a minimum by means of biological decomposition. This is usually realised by the following steps:

1. mechanical separation and preparation of the residual waste;
2. intensive decomposition of the mechanically pre-treated residual refuse in a closed system (with the objective being to decompose the organic contents); and
3. open surface curing of pre-composted material with the objective of further stabilisation of remaining putrescible contents.

Easily degradable substances such as sugars, proteins, and starch are the components first attacked by micro-organisms. To have these components degraded in a controlled process means that the 'stability' of the residual waste can be significantly increased within a very short time frame (compared to the degradation of these substances in a landfill). 'Inerting' means that these components are completely broken down into, primarily, carbon dioxide and water.

Anaerobic Digestion

Anaerobic digestion is a natural process in which microbes convert complex organic matter in the absence of oxygen to simple, stable end products. In the process, methane and carbon dioxide are produced.

Traditionally, in-vessel anaerobic digestion is primarily used to process liquid wastes and relatively dilute slurries of organic materials. There are only a few MSW treatment facilities of this type worldwide.

The first proof of concept MSW anaerobic digestion facility was trialled at Pompano Beach in Florida from 1978-85. Since then, various groups have developed the technology to commercialisation. In 1993, about 15 plants (of significant capacity) were in full-scale operation worldwide and almost 20 more were planned or under construction. These included plants using registered process names such as Dranco, Funnell, Valorga and Kompogas.

4.4 Development of The State of the Art MBT

4.4.1 Conceptual Design

In accordance with the brief, a 'theoretical best' MBT has been developed. It is based on conceptual design principles as described above, and on the experience TBU has gained over the past 15 years in the design and optimisation of residual waste treatment facilities. A number of facilities are in operation or are planned which feature several of the conceptual design principles described in this Section.[15,16,17,18] The conceptual design for a plant with a capacity of 100,000 tonnes per annum is illustrated in Figure1 and described below.

4.4.2 Reception Hall

At the plant, the reception hall is a tipping floor in a covered building which is operated under negative pressure (this is indicated in the Figure of the plant by a dotted grey line).

The waste is unloaded on the tipping floor. Hazardous items are removed for special treatment/disposal. Bulky items are also separated. Untreated wood is shredded and added to the composting process, whilst metal items go to the metal recycling containers.

4.4.3 Material Pre-treatment

Once the material has passed through the reception stage, material is extracted from the waste by mechanical means. The material passes through a bag opener and Screen 1 with an aperture of approximately 180 – 200 mm. The oversize is windsifted.

The heavier fraction of the oversieves predominantly consists of dense plastics (ie. plastic bottles, other dense plastic packaging material), larger metal containers, some composite material and other, undefined large items. This stream passes through an automated sorting system employing NIR (Near InfraRed) Technology which is now also being used in some new German DSD (Duales System Deutschland) sorting plants.[19] This technology combines tried and tested optical and mechanical sorting technologies in a new form, permitting sorting based on material properties. This enables the identification and separation of all types of plastics and coated liquid paperboard packaging *(Output 1).* The light fraction from the windsifter consists of paper, cardboard and plastic film *(Output 2).*

The undersize of Screen 1 also passes through a windsifter. This windsifter removes plastic bottles and other lightweight packaging of <200 mm from the stream. This material is diverted to the oversize from Screen 1 for further separation.

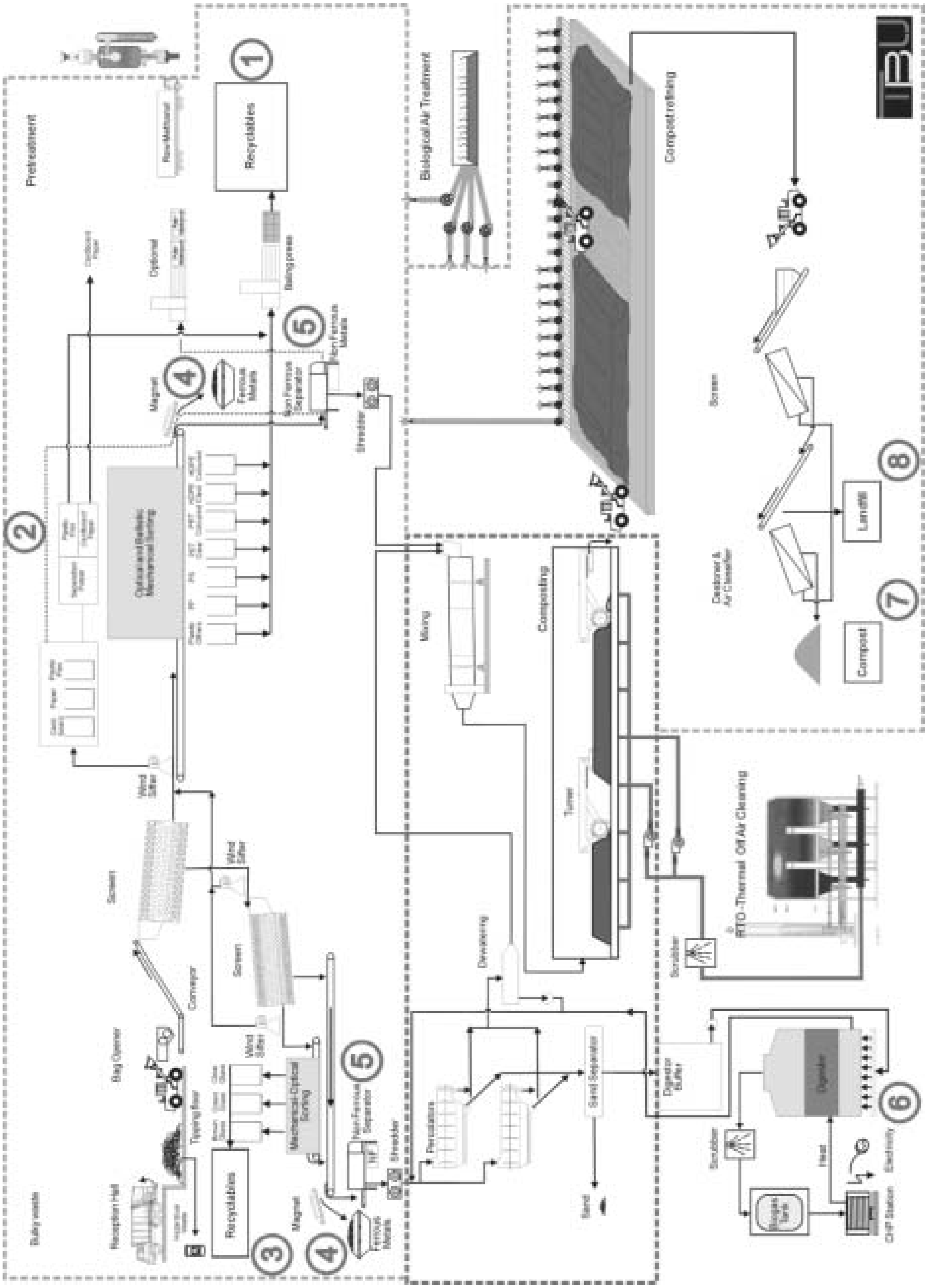
The remainder of this stream passes through a second screen (Screen 2). The oversize contains most of the glass. It is windsifted and undergoes optoelectronic sorting of the glass *(Output 3).* Subsequently, over- and undersize of Screen 2 are combined and metals separated by one magnetic and one eddy-current separator *(Outputs 4 and 5).* A similar metal separation is installed after the opto-mechanical sorting line of the Screen 1 oversize.

The material is then shredded and fed into the percolators.[20] This relatively new technology was trialed in Buchen/Germany for two years.[21] Another, similar technology was developed by the Wehrle-Company[22] and Komptech.[23] The principle is to separate easily degradable organic substance from the waste stream which is fed into a digester for biogas production.

In the percolators, water is added and the material mixed. Liquids are removed separately, the sludge is conveyed to a screw press where more liquid is removed. In the CHP (combined heat and power) plant, biogas is cleaned, stored and converted to steam and electricity *(Output 6).* Some of the generated heat (steam) is used for temperature adjustment in the anaerobic digester(s).

The remaining solids including less degradable organic substances (with a moisture content of 40 to 50%) are mixed with the remaining screen oversize after material recovery and fed into an enclosed composting hall. A turner is used for material movement and agitation. The pile (windrow) is aerated through a suction flow system. After a minimum retention time of four weeks, the material is sufficiently stable to undergo further maturation in the open, without any significant odour emissions. In the Austrian MBT Guideline,[24] the suitability of the material for maturation in non-enclosed

Figure1: The 'Ideal' MBT Plant



areas is determined by the respiratory activity, with a threshold of 20 mg/O_2/g DS over four days. This threshold can be achieved within four weeks of intensive composting.

We do not envisage any problems with this material achieving standards for 'pasteurisation' of materials which might flow from the Biowaste Directive. The regulations as they might apply under a biowaste Directive are as in Box 1. In addition, under the proposed amendment to the Animal By-products Order, there would not appear to be issues arising with the treatment process described as long as all the processes are carried out under cover (they are), and especially if the material is ultimately destined for landfill disposal. If the latter is the case, under the proposed Amendment as it currently stands, it would seem unlikely that any issues would arise. If the material was destined for use as landfill cover or for landscaping, however, it would be subject to time restrictions during which the land could not be grazed by livestock (see output 7).[25]

The temperature / time profile achieved depends very much on the mode of operation of the plant, notably, for the aerobic process, the amount of air sucked through the material. In the experience of TBU, the oxygen demand from the biowaste in the material needed to facilitate decomposition is much less than that required for cooling of the biomass (to maintain optimum conditions).

Depending on space requirements and local conditions, the outdoor maturation pile (windrow) can either be aerated or not. In our design, we have assumed the maturation area is roofed. The outdoor maturation takes an additional 10 weeks before the parameters are achieved for landfilling according to Austrian legislation implementing the EC Landfill Directive.[26] From the mature (stabilised) material, a better quality fraction may be separated *(Output 7)* and used for non-food applications (landfill cover, recultivation, erosion control etc.). The remainder is stabilised material, stripped of recoverable materials as far as possible and suitable for environmentally compatible landfilling *(Output 8).* Over time, with more materials being diverted at source, a refined technology and producer responsibility driven eco-design, this landfill fraction will be minimised.

If legislation required the maturation phase to be undertaken in an enclosed hall (to prevent access to the material by vermin etc.), we estimate that this would add less than £1 per tonne to the cost of the facility as set out in Section 5.0 below.

Box 1: Extract from Biowaste Directive 2nd Draft
Process management
Composting
The composting process shall be carried out in such a way that a thermophilic temperature range, a high level of biological activity under favourable conditions with regard to humidity and nutrients as well as an optimum structure and optimum air conduction are guaranteed over a period of several weeks.

In the course of the composting process the entire quantity of the biowaste shall be mixed and exposed to an appropriate temperature as in the following table:

	Temperature	Treatment time	Turnings
Windrow composting	≥55°C	2 weeks	5
Windrow composting	≥65°C	1 week	2
In-vessel composting	≥60°C	1 week	N/A

Anaerobic digestion
The anaerobic digestion process shall be carried out in such a way that a minimum temperature of 55°C is maintained over a period of 24 hours without interruption and that the hydraulic dwell time in the reactor is at least 20 days.
In case of lower operating temperature or shorter period of exposure:
- the biowaste shall be pre-treated at 70 °C for 1 hour, or
- the digestate shall be post-treated at 70 °C for 1 hour, or
- the digestate shall be composted.

Mechanical/biological treatment
Sanitation to be obtained as in [section for composting] in case of aerobic treatment or [section for anaerobic digestion] in case of anaerobic treatment.

4.5 Outputs and Material Properties

The plant is being assessed as a treatment to deal with municipal wastes. We have taken the output from work undertaken by Julian Parfitt of WRAP as being the most representative data for municipal waste in the UK. This was based on local authority compositional data where analysis was available for more than one season. It is based upon household waste composition, but it seems likely that this provides as good a representation as we have of the up-to-date waste analysis. The analysis is shown below:

Table 8: Waste Composition, Municipal Waste (assumed as household waste)

	'BIN WASTE' RCV residuals + kerbside recycling & non CAS bring recycling			CIVIC AMENITY SITE WASTE Total CAS residuals + Recycling Excluded: building rubble		
Category	**Tonnes**	**Kg/Household**	**% wt**	**Tonnes**	**Kg/Household**	**% wt**
Newspapers & Magazines	1,501,462	71	8.1%	71,319	3	1.3%
Other recyclable paper	1,072,998	51	5.8%	51,875	2	0.9%
Liquid cartons	77,373	4	0.4%	1,081	0	0.0%
Board packaging	228,123	11	1.2%	89,701	4	1.6%
Card and paper packaging	645,512	31	3.5%	2,161	0	0.0%
Other card	28,956	1	0.2%	5,404	0	0.1%
Non-recyclable paper	637,612	30	3.5%	13,878	1	0.3%
Plastic Bottles	387,574	18	2.1%	7,432	0	0.1%
Other dense plastic packaging	394,718	19	2.1%	9,890	0	0.2%
Other dense plastic	114,269	5	0.6%	32,637	2	0.6%
Plastic film	732,585	35	4.0%	17,764	1	0.3%
Textiles	588,806	28	3.2%	110,970	5	2.0%
Glass bottles and jars	1,463,119	69	7.9%	68,688	3	1.2%
Other glass	94,792	4	0.5%	12,718	1	0.2%
Wood	506,776	24	2.7%	488,479	23	8.8%
Furniture	49,050	2	0.3%	255,344	12	4.6%
Disposable nappies	443,532	21	2.4%	0	0	0.0%
Other Miscellaneous combustibles	110,558	5	0.6%	126,569	6	2.3%
Miscellaneous non-combustibles	381,812	18	2.1%	827,140	39	15.0%
Metal cans & foil	621,705	29	3.4%	528	0	0.0%
Other non-ferrous metals	0	0	0.0%	4,761	0	0.1%
Scrap metal/white goods	543,958	26	2.9%	535,017	25	9.7%
Batteries	0	0	0.0%	11,786	1	0.2%
Engine oil	0	0	0.0%	6,626	0	0.1%
Garden waste	2,823,990	134	15.3%	2,077,970	98	37.6%
Soil & other organic waste	210,524	10	1.1%	624,462	30	11.3%
Kitchen waste	2,234,428	106	12.1%	16,654	1	0.3%
Non-home compostable kitchen waste	1,865,300	88	10.1%		0	0.0%
Fines	681,657	32	3.7%	49,957	2	0.9%
TOTAL	**18,441,188**	**872**	**100.0%**	**5,520,811**	**261**	**100.0%**

The sorts of capture which could be achieved under much-enhanced source separation schemes were estimated and applied to the above data. This left a residual waste composition as illustrated in Table 9 below. The effect of the source separation schemes is to reduce the biowaste fraction in residual waste from 39% to 19%. This is in line with well-functioning schemes in Austria and Italy. As regards biodegradable municipal waste, the diversion rate is 74% of what is in the initial waste stream. Again, this is in line with well-operated collection systems in Austria, Italy and Flanders.

This compositional data has been used to generate a dataset for the ultimate physical and chemical composition of the input residual waste to the plant (on an 'as received' basis). For mass balance calculations, it is this waste composition which has been used. In addition, the separation characteristics of screens for the various components of the waste stream have been applied as tested in various trials and studies carried out by TBU for the design and/or optimisation of residual waste treatment plants.[27]

These compositional data by material and by physical / chemical characteristic constitute the basic material which the plant is required to deal with. Clearly, the physical and chemical characteristics cannot be specified completely owing to the inherent variation in the categories which are specified in the composition data. Furthermore, the physical and chemical analyses do not always refer to the same categories as we are considering, whilst problems may also arise from the vintage of some of the data. The analyses we have reviewed include data from the UK, Germany, Austria, Netherlands and Sweden.

Assumed separation efficiencies of metal separators and windsifters are also based on trials and experience. More information is provided in the description of the outputs below.

Table 9: Composition of Residual Waste After Effective Source Separation Schemes

Material	% Composition of Residual
Newspapers & Magazines	6.13%
Other recyclable paper	5.01%
Liquid cartons	0.53%
Board packaging	1.04%
Card and paper packaging	2.62%
Other card	0.19%
Non-recyclable paper	2.75%
Plastic Bottles	2.63%
Other dense plastic packaging	3.74%
Other dense plastic	1.51%
Plastic film	8.58%
Textiles	4.24%
Glass bottles and jars	2.05%
Other glass	0.94%
Wood	5.36%
Furniture	2.04%
Disposable nappies	4.16%
Other Miscellaneous combustibles	2.50%
Miscellaneous non-combustibles	8.44%
Metal cans & foil	2.50%
Other non-ferrous metals	0.02%
Scrap metal/white goods	2.17%
Batteries	0.03%
Engine oil	0.01%
Garden waste	5.18%
Soil & other organic waste	3.08%
Kitchen waste	9.09%
Non-home compostable kitchen waste	7.50%
Fines	5.95%
TOTAL	**100.00%**

4.5.1 Output 1

Output 1 is predominantly made up of the various dense plastic packaging items ie. HDPE and PET which are further separated into coloured and clear. The optoelectronic system sorts the items positively. Apart from the SORTEC System, UNISORT (owned by Waagner Biro Binder Austria) and KUSTA 4002 are some of the systems using an optical multiplexer which enables high speed sorting of a range of plastic types simultaneously.

The process software controls each identified item along the way and triggers pneumatic ejectors which force different plastics into predefined chutesThe chutes open to a conveyor belt from where the plastic types are transported to a baler. The quality of the materials is similar to that of conventional MRFs and therefore, no significant problems are expected for the sale. Assumed prices are listed in Table 10.

The amount of plastic bottles separated for material recycling will be around 2,000 t/a. In addition, around 2,500 t/a of other dense plastic packaging (tubs etc.) will be recovered. The revenue from this output is estimated to be 150,000 £/a.

4.6 Output 2

Output 2 is a mixture of paper/carboard (10,300t/a) and plastic film (5,700t/a). There are currently two ways of dealing with this material that do not include incineration:

1 The material can be landfilled. In some countries the high calorific value of material, or the existence of other bans on landfilling, would prohibit this.

2 The paper and plastic film can be separated. At this stage, only a wet separation system is considered sufficiently developed for separation at a commercial scale. The plastic fraction would need to be dried and subsequently baled for markets. In addition, mixed plastic film is usually only suitable for (material) 'down cycling' and does therefore not achieve attractive prices. The paper would either need to be fed into the composting unit of the plant, or sold as sludge to a paper mill. As with the mixed plastic film, the price paid for this sludge would hardly cover the transport costs.

For the purpose of this study, it has been assumed that the paper goes to a mill at a cost of £10/t. The mixed plastic film has been assumed to go to landfill at a cost of £30/t, although it may become possible to make use of this material in other (material) applications.

4.7 Output 3

The oversize of Screen 2 has a defined particle size of 80 – 200mm. Two windsifters have removed light material such as plastic film and bottles, paper, cardboard, liquid paperboard etc. From this material stream, an opto-electronic sorting unit will remove glass sorted by colours. For this study, high recycling rates at source (in the households) have been assumed and therefore the proportion of glass in the residual waste is very small. With an efficiency of 60% (which is a conservative estimate), approximately 1,500 t/a of glass can be removed from the waste stream and sold for £20/t (= £30 000 p.a.)

4.8 Output 4

Two magnetic separators are installed in the plant. Each works on a line with defined particle sizes and was assumed to have a 90% efficiency (based upon experience at other plants). In total, 1,530 t/a of ferrous metals will be separated. The material will have some degree of fouling (mainly organic residues) but no major marketing problems are reported from a number of plants we are familiar with. The market price expected is around £ 25/t (= £45 000 p.a.)

4.9 Output 5

Two eddy current separators recover non-ferrous metals. It is expected that close to 2,000 t/a of non-ferrous metals can be recovered at a price of £ 450/t (= £900 000 p.a.)

4.10 Output 6

The liquids from the percolators go to the anaerobic digestion unit. This unit will work reliably because liquids pass through the digesters and not a large proportion of solids as is often the case in conventional anaerobic digestion plants. The digesters will produce approximately 40m^3 Biogas per tonne of (total) residual waste input with a CH_4 content of up to 70%.[28]

Table 11 shows the mass balance through percolation and AD (Anaerobic Digestion). Of the input (63,000 t/a), around 18,000 t/a is process water, some of the material is converted into biogas or degraded to other substances, and some is sand. Most of the process water can be re-used in the stabilisation (composting) process where there is a need for the addition of water to maintain an optimum level of moisture for biological activity over a period of several weeks.

From the biogas, approximately 80-100 kWh of electricity and 100-180 kWh of heat per tonne of total residual waste input can be generated in the adjacent CHP plant. This means there is ample steam for heating of the digester input, and sufficient energy to run the whole of the MBT plant (aeration, shredders, equipment etc.) with the electrical power produced.

Although most of the energy generated is used in the facility, consideration could be given to the developing renewable energy market. Within the UK, the electrical energy from anaerobic digestion of waste attracts Renewable Obligation Certificates (ROCs). These are being used as 'certificates of compliance' to show that a designated minimum proportion of electricity has been supplied from renewable resources. The 'buy-out' price for ROCs (which can act as a ceiling price, but which equally can be exceeded) is 3p/kWh. Hence, by effectively 'abitraging' in the electricity market, it might be possible to make the facility more economical by running it with power bought from a utility provider, whilst in turn selling the renewable energy for a higher price into the grid. This could reduce the cost per tonne of input by £2.40-3.00/tonne.

4.11 Output 7

Output 7 and Output 8 are the end products of the biological stabilisation process. In total, 45,600t/a go into this process. This is made up of the 35,000t/a from the percolators, plus 10,600t/a residues from the automated sorting station. 70% by weight is organic matter. Therefore, this stream is combined with the solids from the percolation and goes into the stabilisation process.

During the stabilisation process (4 weeks intensive degradation in enclosed hall, additional 10 weeks of maturing in a roofed area) a 40% reduction by weight is expected. Most of the reduction is water loss (evaporation), and some of it is degradation of organic matter (CO_2). In conventional MBT systems, this weight reduction is around 30%. In the plant described here, there is more organic content going into the biological process, and the material has a higher initial moisture content. The combined effect results in this higher level of mass reduction. The output of the biological processing step is therefore around 27,000 t/a

This material is suitable for landfilling according to the latest landfill guidelines and ordinances in place in European countries (see Appendix 1). Nevertheless, it is possible to separate out a fraction with higher organic content and lower heavy metal concentrations for use as a compost in lower quality applications (such as landscaping). This can be done by screening the material (e.g. 5 – 15 mm) followed by removal of stones and glass particles in a ballistic separator. The expected yield of this better quality fraction is around 7,000t/a.

It is well known that materials derived from MSW are of inferior quality compared to compost derived from source-separated biowaste. However, the facility presented in this study will have significant removal of non-compostable items, with a high degree of separation of metals (and, with them, batteries) which does reduce the heavy metal concentration of the output relative to treatments which compost all residual wastes without mechanical separation.

4.12 Output 8

This output is the remaining stabilised material after separation of the material. It will amount to around 20,000 t/a. At this point in time, there is nothing one can do with it except landfilling. According to experiences in other MBTs, it is estimated that this output would comply with the relevant Austrian standards ie. the gross CV (calorific value) will be in the order of 6MJ/kg (Lower CV of 2.6MJ/kg). The moisture content will be between 20 and 30%, the loss on ignition, around 35%.

Apart from the stabilised material of the biological stage, Table 12 lists three more waste fractions which may require landfilling. One is a proportion of bulky waste which has been separated in the reception hall and is not recyclable. Another one is sand from the digesters. Finally, if no use for the plastic film is found, this material would be landfilled at £30 per tonne (and this is assumed in the costings below). It is possible that this material could find application. In total, the amount of material requiring landfilling after the mechanical-biological treatment is 25,300 t/a or approximately a quarter of the residual waste input into the plant, excluding plastic film. Including plastic film, the quantity increases to 31,000 tonnes, still less than one-third of the input material. The costs of disposal of these residues have been assumed at £30/t including some transport ie. a total cost of £759,000-930,000 per year.

Table 10: Market Prices for Plastics (indicative ranges)

Material	Colour	Price (£/t)
HDPE bottle	any	100 - 130
PET bottle	clear coloured	90 - 130 0 - 45
PVC		0 - 20
Mixed		0 - 35

Table 11: Mass Balance through Percolation and AD

Percolator Input	
Total tons	62,000
Percolator Output (tonnes)	
Biogas	3,700
Process water	18,000
Sand	3,000
Degradation	2,200
Into Composting	35,000

Table 12: Material requiring landfilling

Material	T/a
Stabilised landfill input	18,729
Bulky waste (50%)	860
Sand (digester)	4,783
(Plastic Film)	(5,700)
Landfill total (excl. film)	24,000
Landfill total (incl. film)	29,700

This may of course increase if the costs of landfilling rise due to scarcity and / or higher landfill taxes, though this fee is towards the upper end of current gate prices. Lastly, the sum assumes that the sand attracts higher rate landfill tax – it may well be that this could be kept sufficiently clean to justify the application of landfill tax at the lower rate (implying a saving of approx £0.50 per tonne of waste input to the plant).

With landfill taxes possibly rising to £35 per tonne, the figures could rise to £1.27 – £1.55 million, increasing the costs stated below by around £5-6 per tonne of waste input to the plant. However, it should be noted that there are interesting policy questions which might reasonably be asked concerning the status of the landfilled MBT waste. In Austria, the Alsag, or landfill tax, is levied at different rates for material which has achieved the stability standards set for waste destined for landfill, and for untreated waste. The current figure for untreated waste is €87 per tonne (approx. £55 per tonne). Where waste is pre-treated so as to meet stability criteria, the rate applied is €21 per tonne (or approx. £13 per tonne). This difference of £42 is more than sufficient to make pre-treatment an attractive (indeed preferable) option to direct landfilling, especially once one considers that for each tonne of material input to a given MBT process, far less than a tonne (depending upon the process) will remain to be landfilled. The fact that such a treatment would also reduce any risk of spread of livestock diseases might also be considered in this context.

Were such legislation to be introduced in the UK, the costs of landfilling the residual material mentioned here might be significantly reduced (the tax differential between active and inert materials at present is £11 per tonne – if stabilised biowastes were included in the materials qualifying for landfill tax at the lower rate, costs of the plant would be approximately £2 per tonne less than estimated below).

5.0 Cost assessment

5.1 Background

The economics of residual waste treatment technologies is very sensitive to site, local and regional issues and to the type of application. Costs are dependent on a range of factors including:

- Type of ownership (private/public) and hence the required rate of return and profit margins;
- Resources necessary to achieve required approvals and permits;
- Level of emission limits for air and water;
- Aesthetic (design) requirements;
- Risk sharing arrangements (level of performance guarantees determines level of built-in contingencies);
- Required buffer and stand-by capacities; and
- Difference between nominal and actual capacity.

It is therefore noted that the costs developed must be seen as guide values only. It should be emphasised that any *prices* that may be discussed in the public arena do not necessarily reflect the *costs* of a certain technology: A manufacturer/vendor's tender price may reflect a long-term marketing strategy and try to establish *a first reference facility* in a country or a region significantly below cost. It is also worth noting that vendors occasionally indicate prices well below actual levels when they are not binding.

Additional factors that frequently add to the gap between system costs and "prices" include:

- Cost of land use either not included or provided for free;
- Use of buildings not included of provided for free or at a reduced price;
- Provision of ancillary services for free or at a reduced price (power, access, wastewater treatment/disposal, landscaping, weighbridges, staff etc.);
- Landfilling of residues for free or not included;
- Vendor/operator may have successfully applied for R&D funds;

5.2 Assessment

A technology cost assessment was conducted based on modelling using the actual costs of plants established throughout the world applied to local installation and operating conditions. For technologies where no large scale plants have been established, cost estimates were based on tenders for 'real projects' and in-house estimates.

The capital expenditure for a 100,000 t/a facility will be almost £30 million. The main capital items are listed in Table 13. More information on the cost assessment and the calculations is summarised in Table 14. The assumptions forming the basis of our assessment are also contained in the Table. In addition, the following assumptions were made:

- Facility throughput of 100,000 t/a
- Interest rate of 7%
- No costs for land use

The results of the cost assessment shows annual costs (including depreciation) of £6 Mio or £60/t. If the revenue from the sale of products is deducted, then the costs amount to approximately £51/t of residual waste input.

We believe these are costed 'on the safe side', though equally, as stated above, some specific cost items are absent.

5.3 Issues of Scale

The facility was costed for 100,000 tonnes capacity. It should be noted that a major advantage of this type of facility is that diseconomies of smaller scale cut in at relatively low levels. In many MBT plants, costs would be expected to be broadly constant down to scales of around 30,000 tonnes. Because, in this plant design, there are more capital items in which investment is made, we would expect similar costs to apply down to the 40-50,000 tonnes level. No significant economies of scale would be expected for larger sized plants.

Table 13: Itemised Capital Costs (1)

Component	('000 £)
Plant Site Development	500
Receival & Separation Building	4,000
Separation	4,000
Percolation/AD Building	2,500
Percolation/AD	4,000
Electricity Generation	700
Conveyors (w/o sorting)	700
Composting Hall	3,100
Composting Equip	2,000
Maturation	1,200
Refining	500
Air Handling/Ductwork	1,000
Biofilters	500
RTO	1,500
Mobile Equipment	800
Infrastructure, Miscellaneous and Spares	1,500
Total	**28,400**

(1) Without engineering, planning or commissioning

Table 14: Cost Assessment for MBT

Capital costs			**Depreciation**		
	Capital Cost		**Period (years)**	**Costs (£/a)**	**Costs (£/t)**
Structural & Civil works	10,500,000		20	991,126	9.91
Plant & Equipment	17,200,000		15	1,888,468	18.88
Vehicles & Mobile Equipment	800,000		6	167,837	1.68
Engineering, Planning & Commissioning	1,425,00		20	134,510	1.35
Subtotal	**29,925,00**			**3,181,940**	**31.82**
Maintenance and Repair Costs	**% of C/C**			**Costs (£/a)**	**Costs (£/t)**
Buildings	1.5%			157,500	1.58
Plant Equipment	3.5%			602,000	6.02
Vehicles, mobile equipment	5.0%			40,000	0.40
Subtotal				**799,500**	**8.00**
Ongoing Costs	**No.**	**Unit**	**Rate**	**Costs (£/a)**	**Costs (£/t)**
Staff: Operations Manager	2	persons	33,000	66,000	0.66
Office	1	persons	22,000	22,000	0.22
Operator Assistants	3	persons	25,000	75,000	0.75
Tipping Floor	2	persons	12,000	24,000	0.24
Loader	3	persons	19,000	57,000	0.57
Electricians	2	persons	22,000	44,000	0.44
Maintenance	3	persons	22,000	66,000	0.66
Truck	2	persons	20,000	30,000	0.30
Total salaries	**18**	**persons**		**384,000**	**3.84**
	No.	**Unit**	**Rate**	**Costs (£/a)**	**Costs (£/t)**
Fuel		lumpsum	30,000	30,000	0.30
RTO op. costs		lumpsum	50,000	50,000	0.50
Water	0	m3/yr		0	0.00
Sewerage	0	m3/yr		0	0.00
Electricity		lumpsum	0	0	0.00
Utilities		lumpsum	100,000	100,000	1.00
Consumables		lumpsum	120,000	120,000	1.20
Insurance		lumpsum	150,000	500,000	5.00
Management fees		lumpsum	80,000	80,000	0.80
Corporate costs (Accounting etc.)		lumpsum	50,000	50,000	0.05
Quality assurance		lumpsum	150,000	150,000	1.50
Disposal to landfill (incl. transport)	24,000	t/yr	30	720,000	7.20
Subtotal				**1,800,000**	**18.00**
Revenue	**No.**	**Unit**	**Rate**	**Costs (£/a)**	**Costs (£/t)**
Sale of FE metals	1,500	t/yr	25	37,500	0.38
Sale of Nfe metals	2,000	t/yr	450	900,000	9.00
Sale of Glass	1,500	t/yr	20	30,000	0.30
Sale of paper	10,300	t/yr	-10	-103,000	-1.03
Sale of Dense Plastics/Bottles	4,500	t/yr	70	315,000	3.15
Sale of Plastic Film	5,700		-30	-171,000	-1.71
Sale of Compost	6,200		-5	-31,000	-0.31
Subtotal				**977,500**	**9.78**
Total annual costs (revenue excluded)				**6,165,440**	**61.65**
Total annual costs (revenue included)				**5,187,940**	**51.88**
Total annual costs (revenue included, taking advantage of Renewables Obligation)					**49.18**

6.0 Environmental performance assessment

The mechanical biological treatment facility presented in this study is a new design. Although the various components of the facility are in operation in other plants, the combination of components is unique. In addition, the materials passing through these components are partially different from those materials going through such components in other plants. In other words, no such facility is presently operating anywhere in the world. There is a high degree of certainty that this plant will work reliably.

However, it is beyond the scope of this study to undertake a full LCA (Life Cycle Assessment) which would be necessary to quantify all substance flows through the system, and to quantify the credits from recycled products. Therefore, a life cycle review has been undertaken which compares the facility and its mass and substance flows with other residual waste treatment options.

6.1 Substance Flow Analysis for Organic Media
In addition to the mass flow balance, TBU has carried out a SFA (Substance Flow Analysis) for selected elements to derive the expected quality of the organic media (compost) which are separated from the stabilised material. The procedure is described below.

The *material* composition of the input is known. The *elemental* composition for each material was taken from Öko-Institut.[29] This composition was then applied to the mass balance calculations. The results for the output of the biological processing are shown in the third column of Table 15. The fourth column is an estimate of heavy metal concentrations in the compost assuming a 20% reduction compared to the total output. The last column indicates the standards applied in the Publicly Available Specification for Composted Materials.[30] This shows why the material is unsuited for unrestricted application to land (though nothing in UK law prevents this as such).

Table 15 shows that the heavy metal concentrations in compost from this plant are approximately 50% lower than those of conventional MBTs. The selected elements are also indicators for some other pollutants in the compost. These are below the threshold triggers for allotments and domestic gardens listed in ICRCL 53/83 except for Nickel which is slightly above.

Again, it is noted that the compost produced in this plant is not intended and must not be seen as an alternative to composting of source separated garden and food material. However, it can potentially be used in a range of subordinate applications. These applications could include:
- Landfill cover
- Surface layer of landfill capping
- Road (and railroad) embankment cover
- Erosion control
- Sites remediation
- Soil conditioner for other non-food sites

6.2 Air Treatment
The control of air emissions from MBT systems is defined by the MBA-Richtlinie (Directive for MBT) in Austria and by the 30. BImschV[32] in Germany. To minimise the costs of air treatment systems, the cleaning should be dependent on the load and the duration of waste air generation. Generally one can distinguish between:
- *Exhaust air from the reception hall and pre-treatment,* which is lightly loaded and occurs during working hours only, and
- *Exhaust air from the biological treatment (aerobic and anaerobic)* with a high continuous load.

Table 15: SFA Results Compared

Element	Literature[31]	Stabilized Material	Compost	PAS 100
Pb	695	405	324	200
Cd	7.4	2.9	2.3	1.5
Ni	87	120	96	50
Hg	3.0	0.8	0.6	1

Figure 2 shows the principle of the proposed treatment system. Exhaust air from the reception hall and the pre-treatment (sorting etc.) can be biologically treated through biofilters. Heavily loaded air from the biological treatment (aerobic and anaerobic) requires thermal air cleaning, also called RTO (Regenerative Thermal Oxidisation). Both RTO and biofilters are supported by acid scrubbers to reduce raw gas loads.

In the RTO, hydrocarbons are oxidised to carbon dioxide and steam in a combustion chamber. Heat recovery is achieved using ceramic heat exchangers. Following successful completion of oxidation a second chamber is reheated by the hot waste air. Cyclical changeover of the direction of flow ensures permanent operation.

6.3 Air Emissions

6.3.1 Air Emissions from Plant

The air emissions were calculated based on the amount of material going into the biological processing stage. Emissions data has been obtained primarily from BZL[33] and Doedens et al.[34] The data was taken from RTO clean air monitoring results for the intensive rotting phase in the encapsulated hall (4 weeks) assuming that the biogas conversion unit will have similar emission characteristics to the RTO. Added to this are emissions data from MBA biofilter outputs adjusted for the period of maturation. Table 16 shows the results of the calculations.

Emissions of organic compounds are expected to be negligible as the majority of these emissions (in the untreated off air) occur during the first *two* weeks of rotting (see Figure 3)[35] and, over the first *four* weeks, the biological processing off air is treated in the RTO which oxidises the entire organic load). NOx emissions which can potentially occur from the biofilters will also be reduced to a non-detectable level through the use of acid scrubbers as a front-end device to RTO, and through use of biofilters.

6.3.2 Air Emissions from Landfill

As discussed in Appendix 1, a number of studies have been carried out calculating and measuring landfill gas emissions from MBT output material. All of them conclude that these emissions are reduced significantly. A recent study by Doedens et al[36] conducted long-term research on three MBTs and concluded that the overall landfill gas generation potential of MBT-material is reduced by 95% compared to untreated waste.

6.3.3 Air Emission Credits from Recovered Recyclables

Air emissions credits are large particularly for metals. With additional metal recovery at 3,400t/a, the benefit over landfilling in comparison with the overall 100,000t/a waste stream is significant. Avoided release of greenhouse and toxic emissions during refining and manufacture is also significant. Benefits attributed to other dry recyclable streams are of the same order of magnitude. It is beyond the scope of this study to quantify these benefits.

6.3.4 Comparison

For the purposes of comparison, the emissions to air of waste treatment technologies are shown in the Figures below.[37] These confirm that, in most instances, the MBT technology has the lower amount of air emissions. It should be noted that these are only the direct emissions and do not include credits for either energy or materials recovery.

In the event that avoided burdens are calculated, one has to understand the following. Firstly, the energy recovery technologies – incineration, and to a lesser degree, landfills (where collected gas is combusted for energy recovery) can be considered to lead to the avoidance of emissions which might otherwise have occurred through alternative energy generation techniques. For reasons considered elsewhere, we consider the most appropriate assumption in the UK is that new facilities generating electricity should be considered to ‘displace’ a mixture of gas fired generation and renewables, though here we use the assumption that gas fired generation is displaced.[38]

Figure 2: Proposed Air Treatment Principle

Clean Air referring to MBA-Richtlinie (A) / 30. BImschV (D)					
Threshold value:	**Dust**	**TOC**	**NH_3**	**N_2O**	**Odour**
Total load g/t Input (A / D)	–	100 / 55	–	100	–
Concentration mg/m^3 (half-hour- / daily mean)	30 / 10	40 / 20	–	–	500

Specific amount of exhaust air per tonne defines the maximum permissible concentration

↑

Biological Air treatment	**Regenerative Thermal Air Treatment**
Treatment step slightly loaded air 8 h/working day (1-shift-day)	Treatment step highly loaded air 24 h/day 8.760 h/a

↑ ↑

Raw exhaust air from Pretreatment						**Raw exhaust air from Biological treatment**					
Dust	N20	NH3	TOC	CH4	Odour	Staub	N20	NH3	TOC	CH4	Odour

Table 16: Indicative Air Emissions of Plant

	g/t Input
Mercury	2.50E-03
Other heavy metals	0.00E+00
TOC	1.62E+01
NH3	6.54E+01
Dioxins I-TEQ	1.35E-08
Dust	4.72E+00
TOC cont.	1.89E+01
CH4	5.34E+01
NO	2.64E+02
NOx	2.07E-04
CO	5.67E-05
CO2	1.22E+05
SO2	8.77E-08

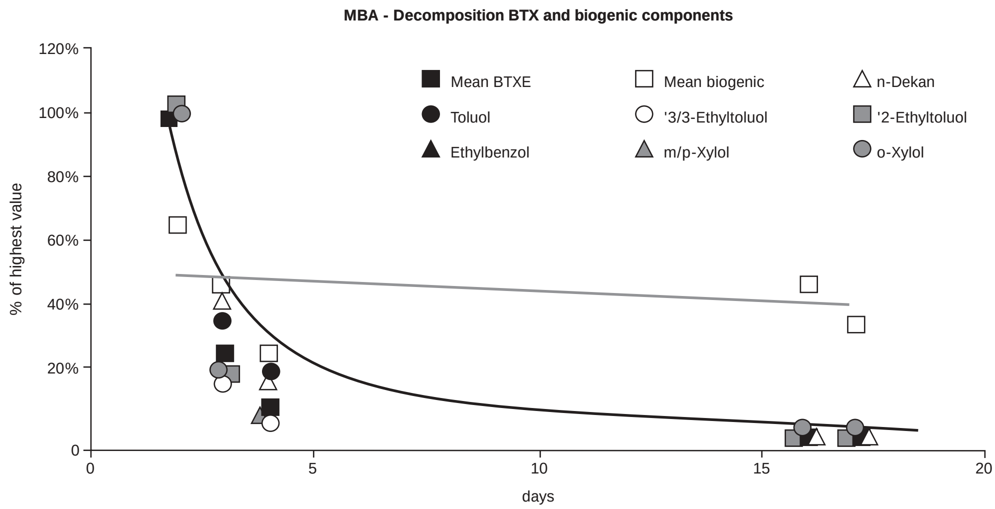


Figure 3: Decomposition of biogenic components over time

Figure 4: Quantitative Analysis of Direct Emissions of Carbon Dioxide

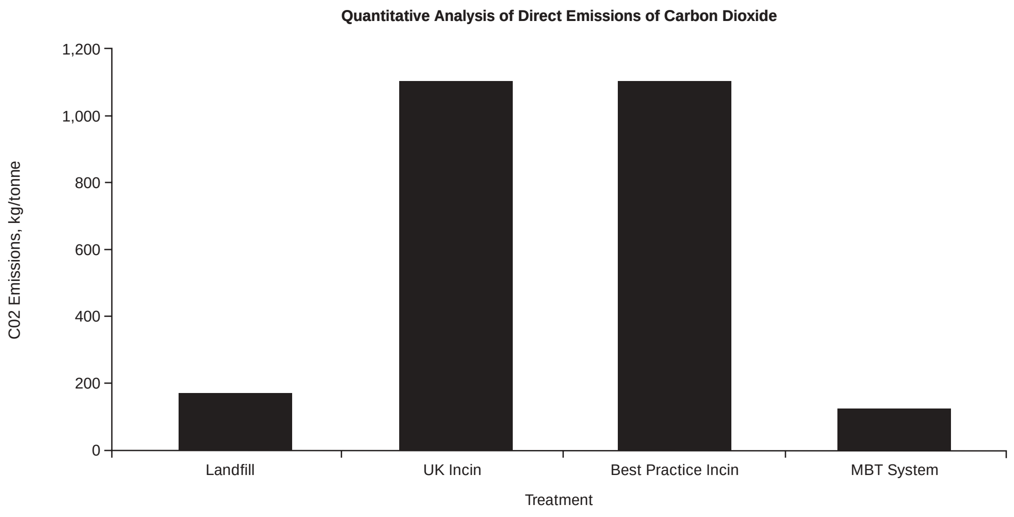


Figure 5: Quantitative Analysis of Direct Emissions of Methane

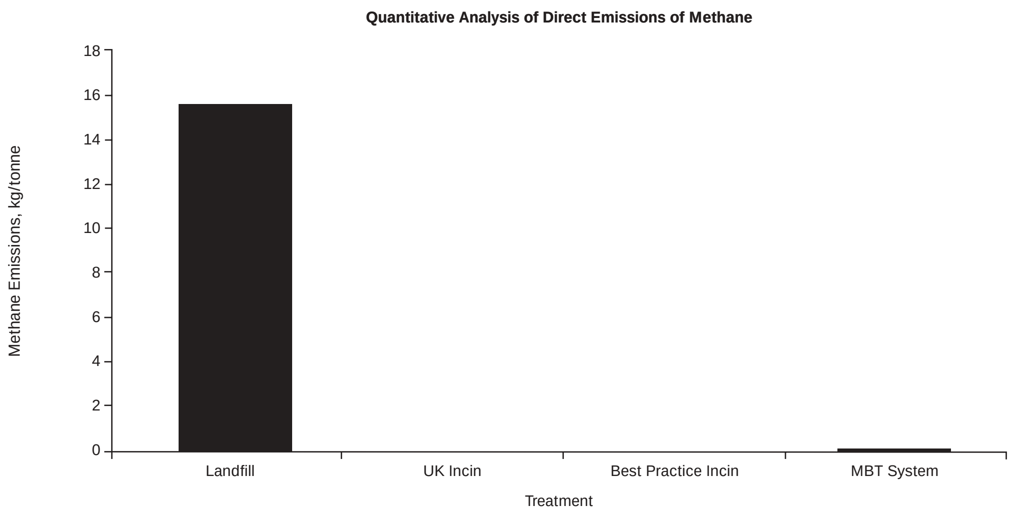
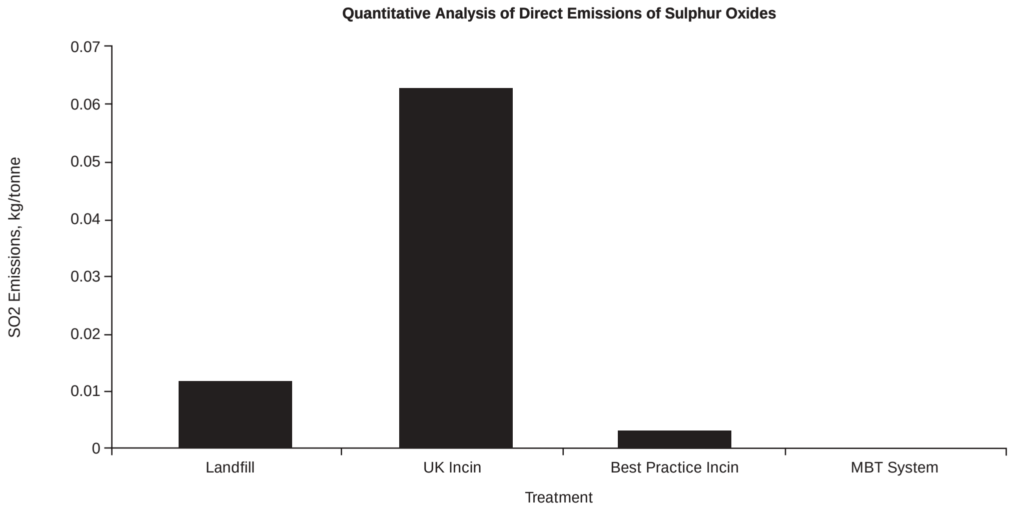


Figure 6: Quantitative Analysis of Direct Emissions of Sulphur Oxides



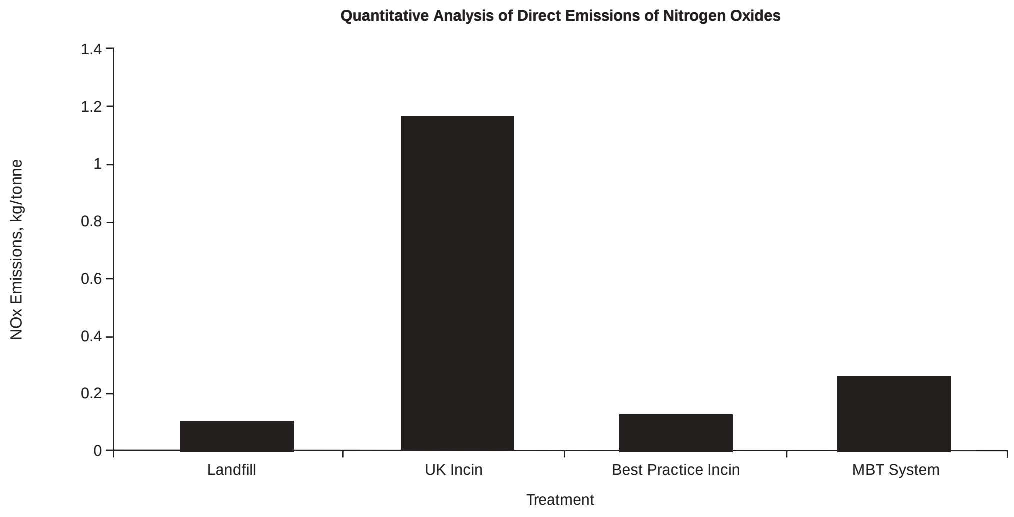


Figure 7: Quantitative Analysis of Direct Emissions of Nitrogen Oxides

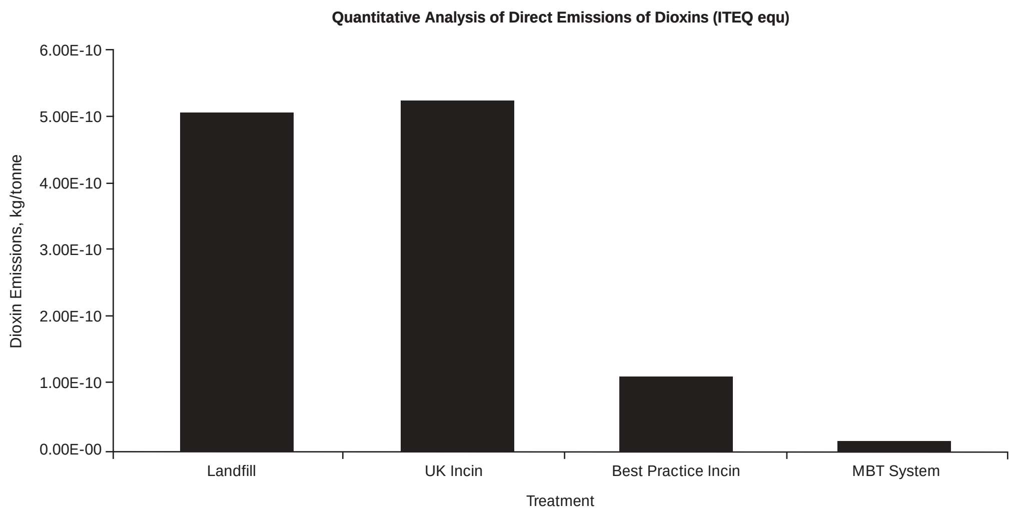


Figure 8: Quantitative Analysis of Direct Emissions of Dioxins (ITEQ equ) to Air

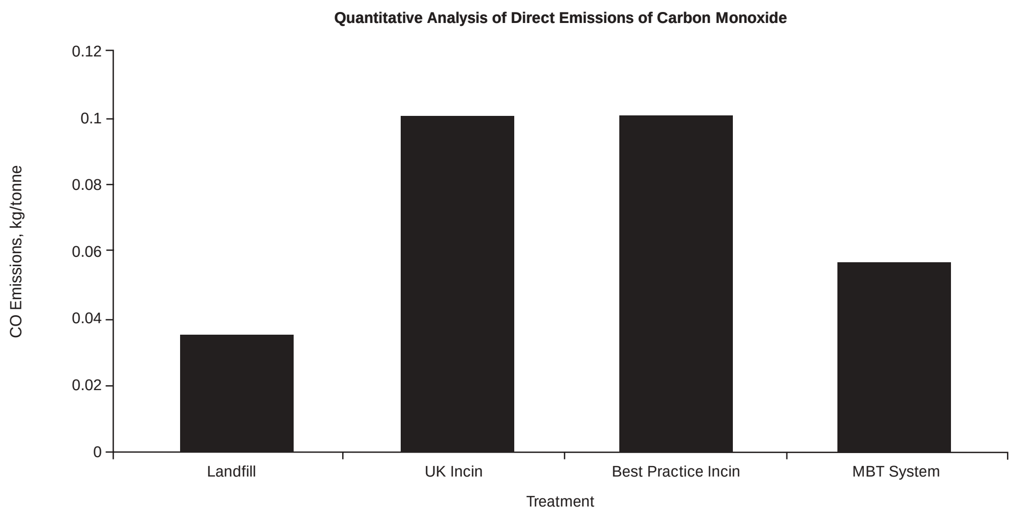


Figure 9: Quantitative Analysis of Direct Emissions of Carbon Monoxide

Figure 10: Quantitative Analysis of Direct Emissions of Volatile Organic Carbons

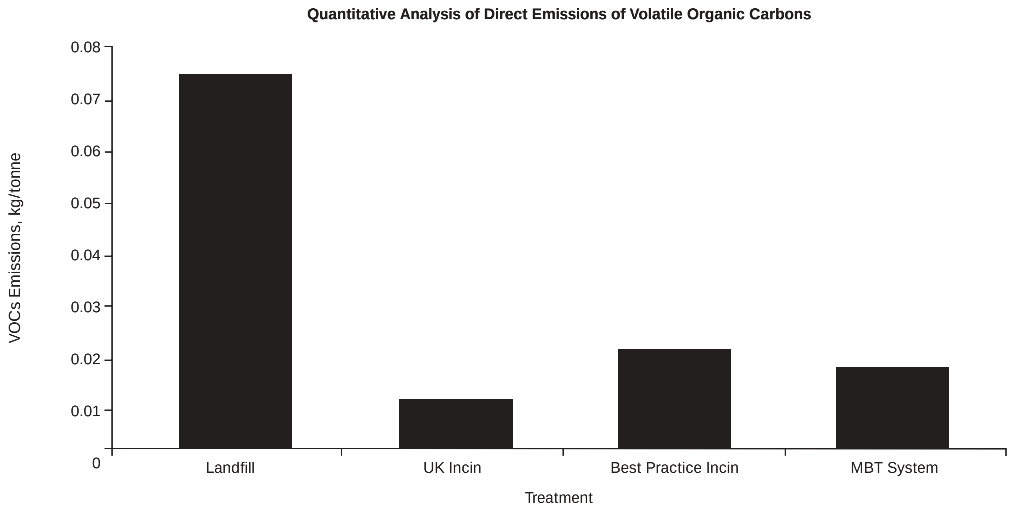


Figure 11: Quantitative Analysis of Direct Emissions of Particulate Matter to Air

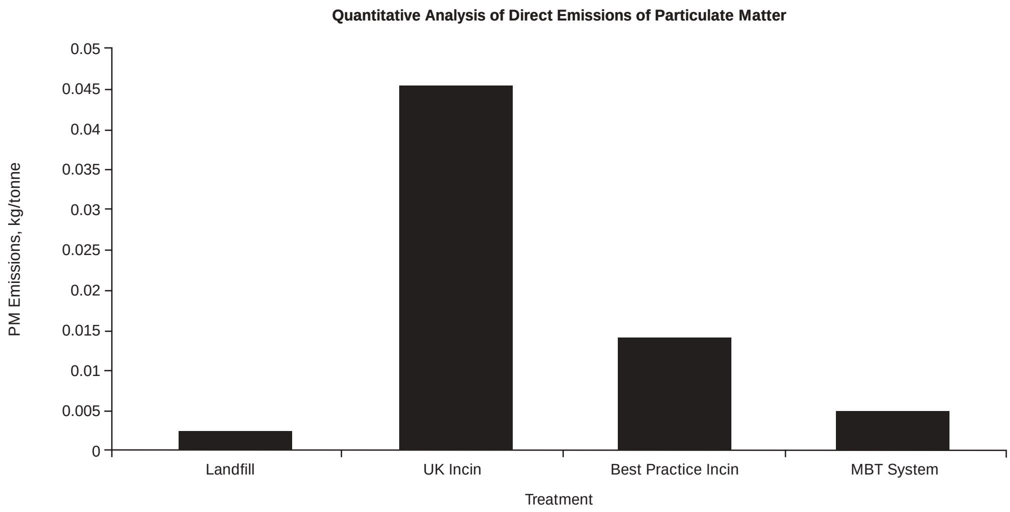
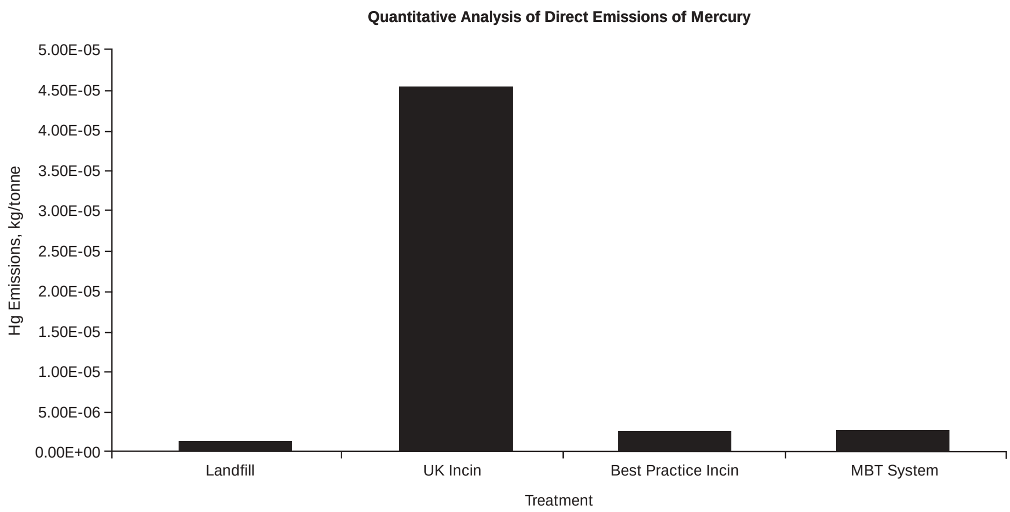


Figure 12: Quantitative Analysis of Direct Emissions of Mercury to Air



When one considers these 'displaced' emissions, the picture is altered. Yet one must also consider the avoided emissions associated with the use of secondary materials rather than primary ones. For the MBT facility as we have designed it, these are much greater than for the other facilities. The following are worthy of consideration:

- Recycling a tonne of aluminium may save the equivalent of 53,000 kWh;
- Recycling a tonne of textiles may save the equivalent of 15,000 kWh;
- Recycling a tonne of steel may save the equivalent of 4,700 kWh;
- Recycling a tonne of lead may save the equivalent of 7,500 kWh;
- Recycling a tonne of glass may save the equivalent of 900 kWh.[39]

In terms of greenhouse gas emissions, recent work by AEA Technology gives the following estimates:[40]

- Recycling a tonne of aluminium may save the equivalent of 9.074 tonnes CO_2 equivalent;
- Recycling a tonne of textiles may save the equivalent of 3.169 tonnes CO_2 equivalent;
- Recycling a tonne of steel may save the equivalent of 1.487 tonnes CO_2 equivalent;
- Recycling a tonne of PET plastic may save the equivalent of 1.761 tonnes CO_2 equivalent;
- Recycling a tonne of paper may save the equivalent of 0.600 tonnes CO_2 equivalent;
- Recycling a tonne of HDPE may save the equivalent of 0.491 tonnes CO_2 equivalent;
- Recycling a tonne of glass may save the equivalent of 0.253 tonnes CO_2 equivalent.

Hence, recycling can generate significant benefits in terms of savings in energy use and climate change emissions, larger than can be achieved through energy from waste incineration. This is part of the logic of the argument for the prior claim to recycle rather than send materials for disposal.

Table 17 shows the net balance of greenhouse gas emissions for the MBT facility and an incinerator. They show the situation where the avoided electricity source is gas. The result is that for each tonne treated in the MBT facility, savings of the order 940kg per tonne CO_2 equivalent can be realised. On the one hand, these estimates are conservative in that they only attribute CO_2 savings to materials where markets seem assured. They also attribute the same material recovery rates at the incinerator for steel as for the MBT plant. Lastly, they assume no net delivery of energy from the MBT plant. Under these assumptions, and assuming a displacement of 500g CO_2 equivalent per kWh, the net avoided emissions are broadly similar for the two plants and direct emissions dominate.

If one posits that the avoided electricity source is coal rather than gas, then the avoided emissions are of the order 1kg CO_2 equivalent per kWh. In this scenario, the differential falls, but is still 674kg CO_2 equivalent per tonne of waste throughput in favour of the MBT plant. Even if direct (process) emissions from the plant were trebled, the net balance would still be in favour of MBT by 427kg CO_2 equivalent per tonne of waste throughput. Such a trebling more than accounts for the fact that our analysis has not considered emissions of greenhouse gases over the very long term, including those which arise following the application of landscaping material to land.

Table 17: Greenhouse Gas Balance for MBT Facility and Incineration

	MBT	**Incinerator**	**MBT Avoided CO2**	**Incinerator Avoided CO2**
Materials	**Tonnes**	**Tonnes**	**Tonnes**	**Tonnes**
Steel	1,500	1,500	2,230	2,230
Aluminium	2,000		18,148	
Glass	1,500		380	
Paper	10,300			
Dense Plastics	4,500		5,067	
Plastic Film	5,700			
Landscaping material	6,200			
Electricity (net, gas displaced)		539		26,950
Total Avoided CO2 (tonnes)			25,825	29,180
Avoided CO2 (kg CO2/tonne waste)			258	292
			Direct Emissions	**Direct Emissions**
CO2			122	1,101
CH4			0.05	0.00
Total Direct Emissions (CO2 equ.)			124	1,101
BALANCE (CO2 equ.)			**-135**	**809**
DIFFERENTIAL (CO2 equ.)			**943**	

6.4 Water Emissions

6.4.1 Water Emissions from Plant

The facility would be operated without any waste water discharge. The 18,000 t/a of process water from the anaerobic digestion is partially recirculated in the percolators (after nitrification/denitrification) and partially used for maintaining appropriate moisture levels in the stabilisation stage where substantial quantities of water are required to maintain moisture levels as the aeration tends to dry out the material. There are a number of other new MBT plants combining aerobic and anaerobic technologies which operate waste water free.[41,42]

6.4.2 Water Emissions from Landfills

Ehrig and Witz[43] state that both quantity and composition of leachate from landfills with MBT-output is not significantly different from that of landfills containing untreated waste. However, this does not consider the reduced quantity of MBT-output as compared with untreated residual waste. Other studies such as Binner[44] conclude that both the amount and the quality of the leachate from landfilled MBT-material is markedly different to leachate from untreated waste. Binner shows that the differences are also significantly dependent upon the time and intensity of the treatment.
On the balance of evidence available from a range of studies, it can be concluded that

- The leachate generated from MBT-landfills contains about 50% less pollutants than leachate from untreated waste landfills;
- The quantity of leachate generated from one tonne of MBT-output is lower than from one tonne of untreated waste. Even if this reduction cannot be precisely quantified at this stage, there is at most no more than one quarter of leachate generated per tonne of residual waste if it is treated in the MBT facility presented here (only 24% of residual waste requiring disposal).

Water emissions from other treatments have not been considered. The issue of long term emissions from landfilled waste is currently a major theme in life-cycle modelling, yet the analysis is fraught with difficulties and uncertainties. Results thus far do suggest, however, that emissions from landfilled waste following MBT pre-treatments are much reduced than those from untreated waste.

6.4.3 Water Emission Credits from Recovered Recyclables

As with the case of air emissions in the previous section, the net benefit is significant. The full extent of the credits would need to be determined in a larger scale study.

6.5 Energy Use and Balance

Approximately 40-50m^3 of biogas can be generated per tonne of waste input. Assuming an energy content of 6 kWh per m^3 of biogas and a 30% efficiency for electricity generation, around 80 kWh[45] of electricity can be generated per tonne of input material. The internal use of electricity for residual waste treatment plants is in the order of 50-80 kWh/t input,[46] hence the plant is likely to be self sufficient in term of electricity use. Some additional energy is required in the form of diesel fuel to run mobile equipment. There may be some scope to utilise the off-heat (steam) generated from the electricity generation, however this is very much dependent on whether there is demand for the steam in close proximity of the plant.

7.0 Conclusions

Perhaps the key conclusion of this report is that there are ways of designing treatment facilities which can provide solutions for specific purposes. The range of technologies available for screening, sorting and treating materials lends itself to increasingly careful design of facilities through integration of complementary elements.

The facility which we have designed makes contributions to materials and energy recovery. The total contribution to materials recovery depends somewhat upon the markets for the materials. The input composition assumed a rate of source separation in excess of 60%. An additional contribution to the recycling/composting rate of between 3-8% would be likely.

Of the input waste, between 25 - 30% of the input material by weight would still require landfilling. Of this, however, between 63-74% of the material would be stabilised material with much reduced environmental impact once landfilled. Another 16-20% of the material would be sand from the digester. Hence, both the quantity of the material to be landfilled and its potential for environmental harm would be much reduced.

Relative to both an incinerator or a landfill, the direct emissions to the atmosphere are low. Once one accounts for the avoided emissions associated with materials and energy recovery, the net benefits relative to incineration in respect of, for example, CO_2 emissions appear significant irrespective of the source of energy which one assumes is displaced by energy from waste technologies. Further analysis would need to be undertaken to ascertain the full impacts (in absolute and comparative terms) of the plant as designed here. However, we believe that this plant exhibits considerable potential in that it offers to local authorities a treatment which is:

- A high performer in environmental terms;
- Shows limited visual disamenity;
- Able to function at relatively small-scales without significant diseconomies of small scale; and
- Competitively costed given the low atmospheric emissions and positive environmental features.

This type of treatment should be of significant interest to authorities who recognise the potential for public disquiet arising from conventional incineration and other thermal treatment technologies and who are concerned to ensure that technologies used are environmentally sound and relatively flexible in terms of their ability to operate using different waste mixes.

An interesting aspect of the facility is that it is compatible for use with other waste inputs such as sewage sludge and other commercial and industrial wastes. As such, changes in throughput and composition could also be made through changing the mix of input materials, though always with the prior aim of ensuring that materials do not need to be sent to the facility in the first place.

There are a number of policy instruments which might help the development of this type of plant. Most pertinent, given the pre-Budget Report, would be a landfill tax designed to encourage pre-treatment rather than the landfilling of untreated waste. This would, in turn, require a system of standards designed to specify the criteria (in terms of stability) which waste would have to conform to in order to qualify for a lower rate of landfill tax. The differential (between treated and untreated) would help drive forward pre-treatment and reduce the problems associated with landfilling. It ought also to be the case that standards for compost are given some statutory basis so that residues from plants such as these are not used as ‘compost’, with all that this might imply for the long-term build up of potentially toxic elements in soil. In this context, the European Commission’s Communication to the Council and the Parliament

‘Towards a Thematic Strategy for Soil Protection’, issued in 2002, states:

> *By the end of 2004 a directive on compost and other biowaste will be prepared with the aim to control potential contamination and to encourage the use of certified compost.*

The plant offered here is not a ‘treatment plant of the future’. It is very much of its day. The plant and the principles behind it, give some insight as to how (and why) it makes sense to consider options beyond the ‘off-the-shelf’ techniques such as mass-burn incineration. We ought to be entering a period of ‘post-Fordist’ residual waste management. In this period, residual waste technologies would not be selected for mass treatment of all waste in one process, but increasingly residual waste will be split into constituent parts for more tailor made treatments. Such treatments will not supplant source separation approaches. Source separation will ensure quality of materials recovered (especially the major fractions, biowaste and paper), and enable the introduction of incentive measures, such as charging, which encourage both minimisation and source separation. Residual waste management technologies like MBT should complement source separation approaches and, in doing so, reduce the environmental impact of residual waste treatments, and the demand for primary resources.

In support of intensive source separation activities, the front end recycling and moisture loss from this type of plant could ensure that from 200,000 tonnes of waste in a given area, something of the order of only 25,000-30,000 tonnes would require landfilling. This illustrates the potential for non-thermal treatment systems to deliver enormous reductions in the quantity of landfilled waste, with that waste which is to be landfilled being significantly less likely to generate major concerns.

Appendix 1: Landfilling of MBT residues

If the management of waste is to be environmentally responsible over the long-term, landfill sites should be safe on a long-term basis.

Both Austria and Germany have given this objective a key role in the development of their legislation. The same type of legislation is emerging in Italy (and is already in place in the Veneto District).

Germany
In Germany, the TASI (*TA Siedlungsabfall*, or Technical Data Sheet for Urban Waste) limits the volatile organic solids content of waste for landfilling to 5% (assessed by loss on ignition) as of 2005. So residual waste has to be treated and the organic fraction has to be collected (the TASI also lays down that biowaste should be collected separately). From a technical standpoint, this 5% limit would only have been achieveable by incineration. However, since 2001, mechanical-biological treatment has been officially accepted as an adequate treatment procedure (in comparison to incineration) to reach the target of a stable landfilling material via a so-called 'law of equivalence'. In 2001 over 20 pre-treatment plants were processing more than 1 million tonnes of residual waste and several more are presently under construction.

Austria
MSW-compost may not be mixed up with the generation of mechanical biologically stabilised waste. MSW-compost serves as amelioration for the construction of the final reclamation layer on landfill sites. Mechanical biologically stabilised waste is dedicated as stabilised waste material allowed for regular disposal or parts of it for incineration. Both processes must be conducted in MBT plants.

Following the targets laid down in the *EC Landfill Directive, the Austrian Landfill Ordinance*[47] lays down the restriction for the disposal of waste:

> '*with an organic carbon content greater than 5% /m/m'* with the exemption for waste *'originating from mechanical-biological pre-treatment, that is disposed in separated areas within a mass waste landfill site, if the upper calorific value gained by combustion of the dry matter is below 6,000kJ/kg. The mixing of waste originating from mechanical-biological pre-treatment with materials or waste of low calorific value in order not to exceed the limit value, is not admissible.'*

In order to determine criteria for an environmentally sound process design and the suitability of MBT material in accordance with the requirements of the *Austrian Landfill Ordinance,* a working group chaired by the Ministry for Agriculture and Forestry, Environment and Water Management has outlined *a Guideline for the Mechanical Biological Treatment of Waste* (Federal Ministry for Agriculture and Forestry, Environment and Water Management, 2001). The main tasks and provisions of this guideline are listed in Table 18.

Table 18: Provisions of the 'Guideline for the Mechanical Biological Treatment of Waste'

Area/provision	Scope/task/objectives
Receipt control	• Visual receipt control before any treatment. • Removal and separation of eventually hazardous fractions. • For sludge and industrial waste: approval of origin and identity.
Input materials	• Non-hazardous waste only. • No waste from source-separation systems that could be recycled. • Detailed list of admissible waste and input materials. • List A: suitable waste without restrictions. • List B: suitable waste with certain restrictions and additional requirements. • Exclusion of specified waste which may not be treated in a MBT plant.
Requirements for construction, equipment and processing	• Licensing of MBT plants. • Waste transport within the facility. • Requirements for the limitation of emissions in physical and mechanical treatment processes. • Requirements for the limitation of emissions in biological treatment processes. (a) Closed-in vessel system and cleaning of the entire waste air at least for the first 4 weeks of aerobic treatment; after that period an open rotting technique may be authorised by individual authorisation if the respiration activity (AT_4) of the pre-treated material is below 20 mg of oxygen/g dm. (b) After anaerobic pre-treatment the same requirements for the aerobic rotting and stabilisation phase apply.
Limitation of waste air emissions	• Total organic compounds: half-day mean value: 40 mg/m^3; day mean value: 20 mg/m^3; relative mass: 100 g/t_{waste}). • Nitrous oxides (NO_x): calculated as NO_2: half-day mean value: 150 mg/m^3; day mean value: 100 mg/m^3. • Ammonia (NH_3): 20 mg/m^3. • Dioxin/Furans: for 2, 3, 7, 8-TCDD equivalent (I-TEQ) ≤ 0.1ng/m^3. • Dust: ≤ 10 mg/m^3. • Odour emissions: ≤ 500 odour units /m^3.
Waste water capture and treatment	• Detailed requirements for the collection, storage and treatment of wastewater.
Determination and control of waste air emissions	• Definition of continuous and single measurements. • Requirements for continuous measurements for the determination of half-day and day-mean values (see above). • Requirements for discontinuous measurements for dust, NH_3, PCDD/PCDF and odour-emissions depending on throughput of the plant.
Requirements for the disposal residual waste	• In addition to the provisions of the waste-management-act of (organic carbon ≤5% m/m; upper calorific value ≤6,000 kJ/kg). • The following parameter stability criteria apply: (a) Respiration activity after 4 days (AT_4): ≤7 mg O_2/g dm. (b) Gas generation or fermentation test (incubation 21 days): ≤20 Nl/kg dm. • Provisions for self-controlling, external monitoring and analytical methods.
Protection of labour	
Protection against fire and explosion	
Documentation and compulsory records	
External monitoring and control measures by the responsible authority	
Analytical methods	

Italy - Draft Decree on Bio-stabilised Materials

In Decree n.22/97, (the current National Waste Management Act) new regulations on the application of materials from MBT are foreseen, and have actually been drafted, but have not yet been enforced. Therefore, as mentioned above, the law in force regarding the application of stabilised materials from mechanical-biological treatment of mixed MSW – including land reclamation and final restoration of former landfilling sites – is the old technical regulation, DCI 27/07/84, which defined:

- features of composted materials;
- possible applications and restrictions;
- a maximum rate of application;
- a maximum allowable concentration of heavy metals in soil and a maximum annual load of heavy metals by means of compost application; and
- a maximum concentration of heavy metal and inert materials in compost.

The main goal of such provisions is the protection of the environment and of human health. Some provisions actually deal with agronomic features (e.g. humification and content of nutrients), although they were mainly aimed at justifying a minimum agronomic benefit of compost application, and do not constitute the main body of regulations. Table 20 and Table 22 below show the relevant limit values.

It is commonly thought that the new regulations to be issued on stabilised organic fractions will keep the main structure of DCI 27/7/84, namely in the case of health and safety issues, whilst the most important changes are likely to cover:

- possible applications (with restrictions to non-food and fodder crops; the only applications allowed would be in land reclamation, restoration of landfilling sites, etc.);
- humification (not likely to be included any more, due to its low reliability; it will probably be substituted by parameters on stability);
- nutrients (minimum amounts are unlikely to be included any more due to their relative lack of importance for a soil improver; moreover nitrogen actually constitutes a constraint to loads of compost due to its potential release into the groundwater);
- heavy metals (maximum allowable concentration in compost likely to be diminished); and
- loads (to be increased for one-off applications in land reclamation projects, see later).

Some regions and provinces have already issued guidelines and/or technical regulations to allow the use of MSW compost for land reclamation. Their principles have also been taken up by the draft national regulation which is expected to be issued in the near future. Such regulations rely upon the hypothesis of one-off applications with high loads in order to promote biological activities in surface soil layers on exploited mines and finished landfill sites, slopes to be consolidated, anti-noise barriers, etc.

As for the technical requirements of such applications, regulations address above all the need to check both:

- heavy metal loads; and
- nitrogen load.

Loads have to be calculated in order to stay within the maximum desirable concentrations of heavy metals in the soil and to prevent large releases of nitrogen to the groundwater.

A brief description of main features of such regulations follows.

Key Aspects of the Draft Decree

The decree is to be issued according to Article 18 of Decree 22/97, which requires the government to set technical regulations for waste management activities. The Draft Decree has already been endorsed by the Ministry of Environment and has been discussed among all the relevant Ministries (Health, Agriculture, Industry, Environment) during the past legislative period in order to finalise its shape. In the last draft (April 2000) two types of *'Biostabilizzato',* or SOF, were defined:

1st quality SOF, to be used *as an amendment* in Land Reclamation projects (therefore, an *agronomic* use);

2nd quality SOF, to be *landfilled* or to be used *as a daily cover material* (according to the expected need to 'treat' waste before landfilling).

The basic qualifying parameters for the two types are listed below.

In addition, some microbial limit values are listed but these are still hotly debated, due to the lack of reliable reference test methods. Therefore, limit values are focusing especially on the fermentability issue.

Table 19: Limits for concentration in compost and soil for heavy metals and maximum annual load, according to DCI 27/7/1984

Element	Maximum permitted concentration		Maximum load
	In compost	in soil	
	mg/kg dm	mg/kg dm	g/ha per year
Arsenic	10	10	100
Cadmium	10	3	15
Chrome III	500	50	2,000
Chrome VI	10	3	15
Mercury	10	2	15
Nickel	200	50	1,000
Lead	500	100	500
Copper	600	100	3,000
Zinc	2,500	300	10,000

Table 20: Physical, chemical and microbial features of compost (DCI 27/7/1984)

Parameter	Limit	Parameter	Limit
Inert material	≤3% dm	Relation C/N	<30
Glass (size)	≤3 mm	Total N	<1% dm
Glass (quantity)	≤3% dm	P_2O_5	>0.5% dm
Plastics	≤1% dm	K_2O	>0.4% dm
Metals	≤0.5% dm	Particle size	0.5– 25 mm
Moisture	<45% fm	*Salmonella*	absent in 50 g
Organic matter	>40% dm	Weed seeds	absent in 50 g
Humified OM	>20% dm	pH	6–8.5

dm: dry matter, fm: fresh material

Table 21: Limit values for 1st quality SOF:

Parameter	Limit value[1]
Cadmium	3 ppm dm
Chromium VI[2]	3 ppm dm
Mercury	3 ppm dm
Nickel	100 ppm dm
Lead	280 ppm dm
Copper	300 ppm dm
Zinc	1,000 ppm dm
Plastics	0.5% w/w
Inert materials (including plastics)	1% w/w

1 Many people from research centres and institutions are asking that the limit values for heavy metals be increased by at least 1.5 (e.g.zinc: 1500 ppm; copper 500 ppm), which would be much more consistent with limit values to allow sludge application on croplands (zinc: 2,500 ppm; copper: 1,000 ppm; nickel: 300 – see also later concerning the regulations issued by Region Veneto).

2 Many technicians and institutions are proposing that the total chromium be considered as a more prudential approach and the final regulation seems likely to reflect this.

Table 22: Limit values for 2nd quality SOF

Parameter	Limit value
Moisture	less than 65%
Respiration index (UNI method)	less than 400 mg O2/kg Volatile Solids / hour

Use of SOFs

First quality SOF can be used, *under permitting procedures,* in one-off applications in landscaping and land reclamation projects. The maximum load stated in the Draft Decree is 100 t/ha of dry matter. Many technicians and institutions are asking for a higher maximum load, based on scientific assessment. Proposals include:

- a maximum load of 100 tonnes dry matter per hectare with the sole requirement that the landscaping project be subject to permitting procedures;
- higher loads, up to 300 t/ha of dry matter (some say 500 t/ha), have to be supported by 'risk assessment', evaluating the release of nitrogen, its transportation to groundwater, and its dilution, according to geological site-specific conditions. A further calculation has to be made to assess final concentration of heavy metals in the soil, though the nitrogen related risk is in general much higher and therefore more usually defines the actual restriction for the admissible load.

This latter proposal is supported by many sound scientific surveys and insights into the potential effects. Second quality SOF can be used, under permitting procedures, as a partial or total substitute for inert materials used as a daily cover, according to 'good practice' in management of landfilling sites.

Ordinance Region Veneto, 766/2000

The approach of the Draft Decree can already be found in the DGR (Ordinance of the Regional Government) #766, 10 March 2000, issued by Region Veneto. Maximum loads for the *agronomic* use of SOF are defined at 200 tonnes/ha (fresh matter) with no further procedure other than permitting the project, and up to 2,000 tonnes/ha (fresh matter) where this is accompanied by a risk assessment. Limit values for the so-called *'Biostabilizzato Maturo'* ('Mature SOF', corresponding to 1st class SOF) are shown in Table 23.

The table shows that the same limit values for heavy metals apply here as they do for sludge and the same limit values for inert materials are used as in the previous legislation on 'controlled' use of mixed MSW compost.

A *'Biostabilizzato da discarica'* ('SOF for landfilling sites', corresponding to 2nd quality SOF) is defined through reference to limit values shown in Table 26.

Table 23: Limit values for 'Biostabilizzato Maturo' ('Mature SOF', corresponding to 1st class SOF)

Parameter	Limit value[1]
Cadmium	10 ppm dm
total Chromium	500 ppm dm
Mercury	10 ppm dm
Nickel	200 ppm dm
Lead	500 ppm dm
Copper	600 ppm dm
Zinc	2500 ppm dm
Plastics	0.5% w/w
Inert materials (including plastics)	3% w/w

Table 24: Limit values for 'Biostabilizzato da Discarica'
('SOF for landfilling', corresponding to 2nd class SOF)

Parameter	Limit value
Moisture	between 30[1] and 65%
Respiration index (UNI method)	less than 600 mg O2/kg Volatile Solids / hour

1 Below such moisture content the material gets too dusty, hence off-site transportation becomes more problematic.

European Commission
The Second Draft of the Biowaste Directive also contains within it specific provisions regarding materials treated through MBT. The document states, regarding 'Residual municipal waste':

> *The amount and contamination of residual municipal waste should be reduced to the minimum extent possible via the separate collection of municipal waste fractions such as biowaste, packaging, paper and cardboard, glass, metals and hazardous waste.*
>
> *If residual municipal waste undergoes a mechanical/biological treatment prior to landfilling, the achievement of either a Respiration Activity after four days (AT_4) below 10 mg O2/g dm or a Dynamic Respiration Index below 1,000 mg O_2/kg VS/h shall deem that the treated residual municipal waste is not any more biodegradable waste in the meaning of Article 2 (m) of Directive 1999/31/EC.*
>
> *If residual municipal waste is incinerated prior to landfilling, the achievement of a Total Organic Carbon value of less than 5% shall deem that the incinerated residual municipal waste is not any more biodegradable waste in the meaning of Article 2 (m) of Directive 1999/31/EC.*

Gaseous Emissions from Landfill and Links to Stability
After mechanical-biological pre-treatment, in addition to mineral or biological inert material, there still remains a certain proportion of organic substances which can be broken down biologically. Gas emissions and temperature increases are therefore still possible once the material is landfilled, albeit at a much reduced rate.

Furthermore, the pre-treated waste still contains a series of organic and inorganic pollutants which could be emitted via the gaseous and aqueous pathways. For this reason, for the planning, operating and after-care of pre-treated waste landfill sites, information is needed concerning the pollutant loads which are to be expected long-term (emissions potential) and their speed of release (emissions kinetics), depending on the environmental and boundary conditions.

Amongst the biological parameters, the measure of the compost respiration activity is undoubtedly an important parameter for the evaluation of stability. The aerobic micro-organisms, by using the substratum's organic substance as a source of energy and nourishment, use oxygen and emit carbon dioxide. The metabolism is more intense when the organic compounds are more easily biodegradable, while it is slow in presence of organic substances with higher molecular and structural complexity, such as the humic substances present in the mature compost. Therefore the measure of the biodegradability of organic substances present in the material is an index of the degree of evolution of the product or of its stability.

The respirometric test evaluates the stability of the organic content through the determination of its most easily degradable fraction. Compared to other methods this enables one to calculate the speed of the transformation, otherwise possibly determined only through a continuous control of the oxygen consumption, which enables one to evaluate the period in which the degradation speed is at the maximum.

In this way the test enables one to make a judgement not only on the quantity of organic substances, but also on the biological capacity of the material, as indicated by micro-organisms' presence and activity.

As indicated in Section 2, the duration of the composting process until the alternative maturation criteria are reached (RS_4, GF_{21}, TOC) is dependent on the operating management and the system selected. As a rule the following applies:
- the more dynamic the process, the shorter the composting time to achieve a given level of stability;
- the shorter the time in the (quasi) dynamic system, the longer the secondary composting required in the static system to achieve the same level of stability;

Unfortunately, comparison of measurements from various plants and laboratories continues to be impeded due to an uncoordinated, unstandardized or differentially applied methodology for analysis. Furthermore, there remains some discussion as to what constitutes an adequate measure of stability.

It is quite clear from the previous section that different nations make use of different criteria for assessing the stability of biowaste in the context of MBT pre-treatments prior to landfilling. The Italians tend to use a dynamic index, the Dynamic Respiration Index. This was also considered in the EC Working Paper on Biological Treatment, alongside the German AT4 (Atmungsaktivitaet vier = respiratory activity on 4 days). Austria uses AT7.

Table 25 shows the potential reductions in key emission characteristics associated with biologically pre-treated waste. The actual level of reduction in gas generation potential and other factors is significantly affected by the time for which the material is treated and the nature of the treatment. It is important to understand, however, that the degree to which reductions in gas generation potential are achieved over time follows something akin to an exponential decay curve. This means that successive reductions in gas generation potential are achieved over progressively longer periods. This has implications for the costs of pre-treatment. Hence, there remains a debate concerning the appropriate standard to set for stability.

The crux of this debate is neatly encapsulated in the comparison between German and Italian standards shown in Table 26. From the Italian perspective, both the German and the Austrian threshold values are far too low (stringent), and both require very long maturation times (in exceptional cases, up to 8 months!). This has the effect of increasing the costs of MBT where the intention is to send some of the residual mass to landfill / landscaping etc. The Italian threshold value (DRI = 1000 mg O_2/kg VS/h) requires shorter time periods, depending on process optimisation. This delivers a reduction in gas production (as assessed through the Generation Sum test method) by 80% (this is on a reduced mass, hence the overall environmental benefit is even higher relative to direct landfilling).

The reasons for this are illustrated clearly with reference to graphical illustrations of the behaviour of landfilled MBT waste as observed in Austrian experiments. Figure 13 below shows how the gas generation varies with the length of time for the pre-treatment process at different plants. The reduction in gas generation potential with increasing treatment duration is notable. Note also, however, that the incremental reduction in gas generation potential falls with increasing time. This is also shown in Figure 14.

Table 25: The effects of biological pre-treatment

Feature	Final outcome [source]		% reduction (as compared to initial)
Respiration rate	5 mg O2/g d.m. (96 h) about 400 mg O2/kg VS.h	[1] [2]	80-90%
COD, Total N in leachate	< 100 mg/l < 200 mg/l	[1] [1]	about 90%
Gas production attitude	20-40 l/kg d.m	[1,2]	90%
Volume	final density (compacted): 1.2-1.4 t/m3 mass loss (due to mineralisation): 20-40%	[1] [1]	up to 60%

Source: Adani F. (2001) Personal communication with E. Favoino; Leikam K., Stegmann R.(1997). “Landfill behaviour of mechanical-biological pretreated waste”. ISWA Times, Issue 3/97, pp.23-27; Wiemer K., Kern M.: Mechanical-biological treatment of residual waste based on the dry stabilate method, in Abfall-Wirtschaft: Neues aus Forschung und Praxis, Witzenhausen, Germany, 1995

Table 26: Comparison of German and Italian Standards for Stability of MBT Output

Standard for Stability	Residual Biogas (kg TS-1)	Biogas Reduction (%)	Treatment Time
Germany 5000 mg kg TS 96hr^{-1}	20	90-95	2-6 months
Italy (proposed) 1000 mg O2 kg VS^{-1}h^{-1}	60-80	95-85	15-40 days

Source: Adani et al (2002) Static and Dynamic Respiration Indexes – Italian Research and Studies, Paper to the European Commission Technical Workshop on Biowaste.

Gas Generation Potential in Incubation Test Impact of Mechanical Biological Pretreatment

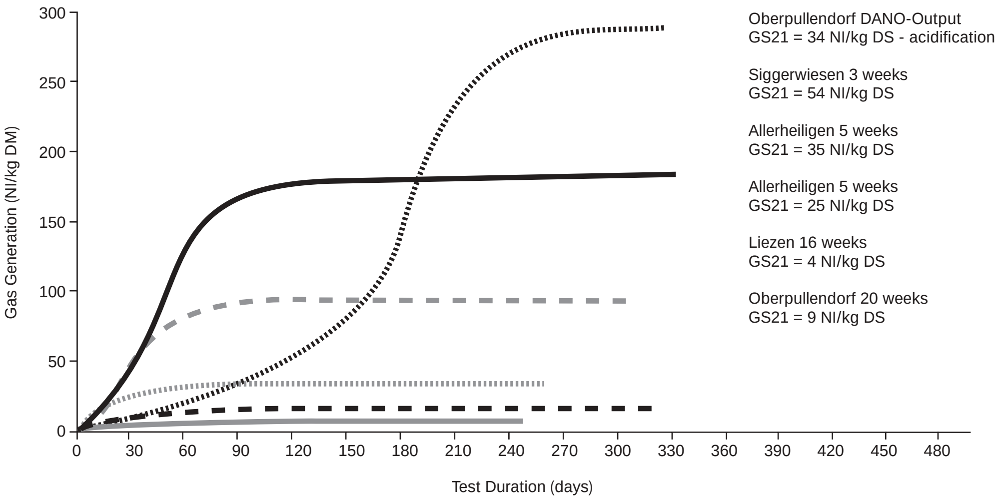


Figure 13: Impact of MBT on Gas Generation Potential as Measured in Incubation Tests
Source: Erwin Binner (2002) The Impact of Mechanical-Biological Pre-treatment on Landfill Behaviour, Paper Presented to the European Commission Biowaste Workshop, May 2002.

Impact of Pretreatment on Gas Generation Potential

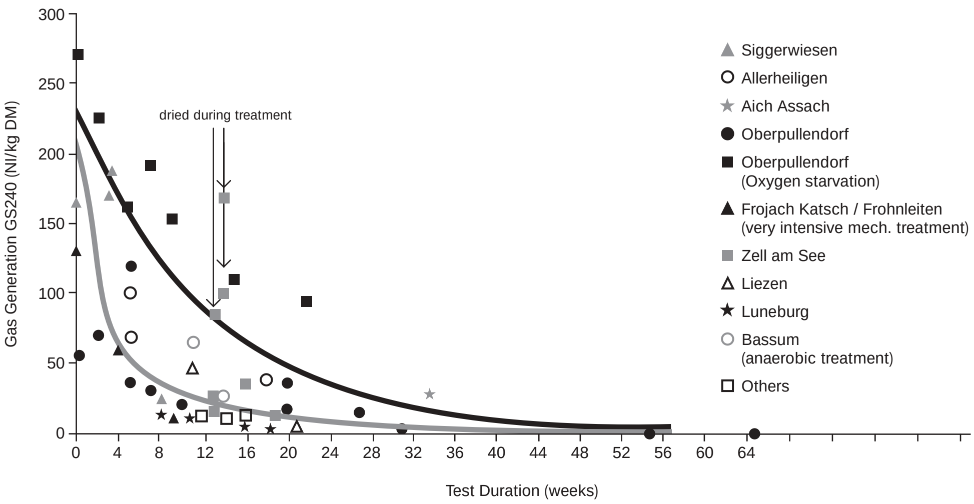


Figure 14: Illustration of Impact of Length of Pre-treatment on Gas Generation Potential
Source: Erwin Binner (2002) The Impact of Mechanical-Biological Pre-treatment on Landfill Behaviour, Paper Presented to the European Commission Biowaste Workshop, May 2002.

Recalling the discussion concerning stability limits, the cost implications of the setting of a standard at one or other level are made clearer. The longer the pre-treatment time, the higher the cost of the pre-treatment. Yet, as mentioned above, the incremental reduction in gas generation potential with increasing duration of pre-treatment falls over time. Effectively one reaches diminishing marginal returns where the incremental gain in terms of reduced gas generation potential exceeds the costs of those further reductions. This is the argument used by the Italians to support their standard – the costs of achieving such a standard are significantly lower than those required to meet German or Austrian standards for stability yet the environmental gain is not significantly less.

These results are broadly consistent with those from German studies, in which fermentation tests were carried to assess gas generation.[48] According to the regulations in Germany, gas formation (GF) should be observed for at least 21 days = GF_{21}. Importantly, because of the low level of fermentability of waste after MBT, no statement was considered possible concerning a gas potential during this period.

Interestingly, in these tests, the "extensively stabilized" sample of waste led to no more measurable production of gas after 8 weeks of the test. Up to this point in time, on average 2.69 Nl/kg DS gas was formed. By the end of the test, the methane content was at ~40 vol.%. In Figure 17 below, the volume of gas produced was expressed in relation to the organic dry matter (oDS), as only this can be potentially converted into landfill gas. In so doing, a better comparability of the test results can be achieved. The plots refer to outputs from plants achieving differing levels of stabilization. The shape of the curves is similar to Binner's above.

Figure 15 demonstrates that the gas formation rates of the "less-well stabilized" waste, MB-QB2, MB-HP1 and MB-LF1 show similar orders of magnitude and are initially in the region of ~0.15-0.6 Nl/kg oDS x d.

The gas formation of the test materials was also measured under high compression in landfill simulation reactors (compression pressure = 250 kN/m^2). The tests were carried out under mesophilic conditions of 35˚C and with an average water content in the reactor of 30-35 wt. % (WS). The materials in this were mostly incorporated with their original water content and, due to the release of water within the framework of the infiltration tests, were saturated to the water content referred to above.

Figure 16 shows a comparison of the measurements with reference to the gas formation on the organic dry materials. The gas formation of the landfill tests with the "less-well stabilized" waste, MB-QB2-D-1, MB-LF1-D-1, and MB-WS1-D-1, was initially between 0.01 and 0.15 Nl/kg oDS x d. A comparison between the two figures shows that the results in the fermentation test at 35˚C and 90 wt. % (WS) water content, intended to mimic 'real conditions', reveal that the initial gas formation rates in the fermentation test are lower by a factor of 4-15 (the linear projections bounding the plots in the two Figures show much shallower gradients in Figure 15 than in Figure 16).

One of the measures of stability, the dynamic respiration index (DRI), aims to assess stability in a quick test of the material. DRIs for different materials are shown in Table 29. This clearly shows the effect, in Italian waste management systems, of source separation on the fermentability of the residual material. Furthermore, it shows that door-to-door source separation systems reduce the DRI of residual waste much more effectively than systems which are based upon road containers (effectively communal bring schemes). Conversely, the DRI of separated organic fractions from door-to-door systems is much greater than those where the collection approach is through road-containers. Hence, not only does the DRI Table illustrate the value of stabilization of the residual waste through MBT / BMT, but it also shows how source separation can, through reducing the biowaste content of residual waste, significantly alter the nature of residual waste.

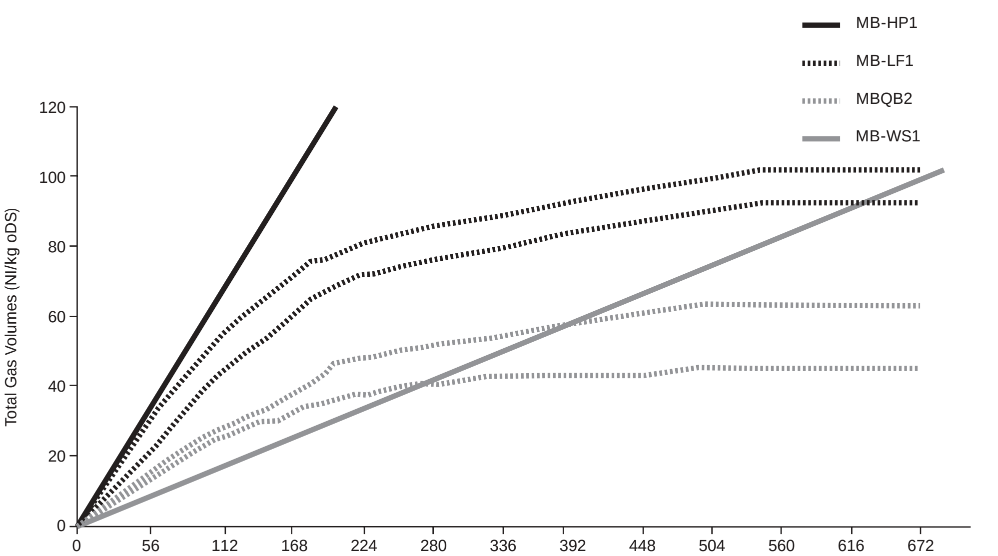


Figure 15: Comparison of the fermentation test with reference value oDS.
Source: Zeschmar-Lahl et al. (2000) Mechanisch-Biologische Abfallbehandlung in Europa, Berlin: Blackwell Wissenschafts-Verlag GmbH

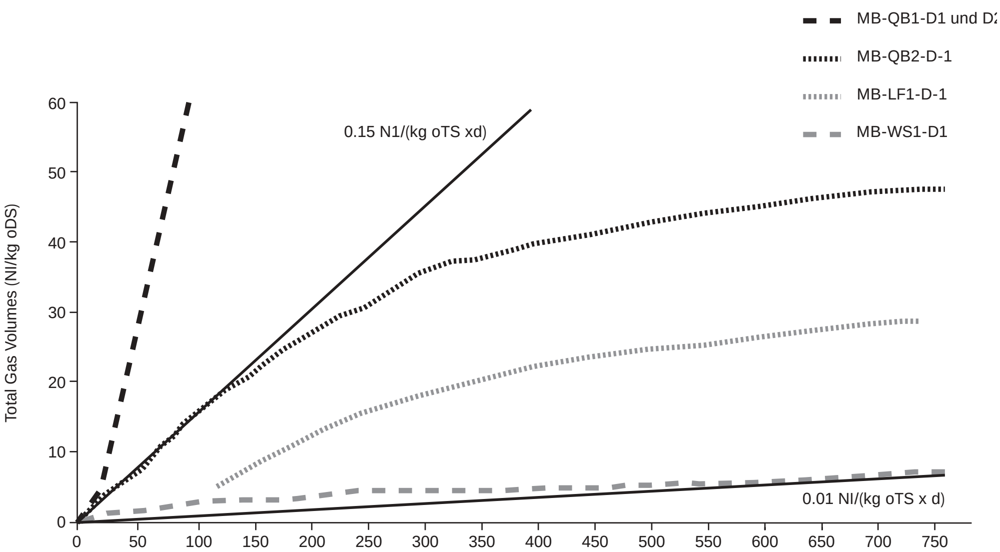


Figure 16: Comparison of the gas formation of the landfill tests with reference value oDS.
Source: Zeschmar-Lahl et al. (2000) Mechanisch-Biologische Abfallbehandlung in Europa, Berlin: Blackwell Wissenschafts-Verlag GmbH

Table 27: Dynamic Respiration Indices for Different Waste Fractions

DRI (mg O 2 kg VS -1 h -1)	Typology
70-150	MSW landfilled (age : 20 years)
200-500	Evolved compost (OMEI > 0.6)
300-400	Residual waste from door separate collection (dry fractions)
500-700	MSW Biodried/biostabilized (10-12 days)
800-1000	Residual waste from double road containers (dry fractions)
800-1200	Stabilized OM from mechanical separation (15-30 days)
1000-1300	Residual waste from road containers (dry + wet fractions= MSW)
2000-2800	Organic matter from mechanical separation of the MSW (Ø < 50-60 mm)
2500-3500	OM sep. collection/lignocellulosic (2:1 p/p)
4000-5000	Separate collection (OM= 80-85 % p/p)

Source: Adani et al (2002) Static and Dynamic Respiration Indexes – Italian Research and Studies, Paper to the European Commission Technical Workshop on Biowaste.

Leachate Emissions from Landfill
AEA Technology report that long-term behaviour of highly stabilised MBT residue has been predicted from a series of detailed experiments using landfill simulation reactors.[49] Consistent with the above discussion, the results showed that:

1 MBT reduces the landfill gas emission potential by 90% compared with untreated MSW. The remaining emission potential is characterised by half-lives of 15 – 30 years, about 10 times longer than for untreated MSW. The authors conclude that the slow rate of residual CH_4 emission means that methane oxidising organisms in the cover soil will, in all probability, oxidise all of the CH_4 released (as discussed above, this should be contextualised by knowledge of the duration of the pre-treatment process);
2 MBT residual waste can be compacted to very high density in landfills (ca 1.5 tonnes / m^3, which results in very low hydraulic conductivities (in the range 1 x 10 -10 to 5 x 10 -9 m/s). As a consequence of the low infiltration of water, leachate production is minimised and the total nitrogen and total carbon content of the leachate reduced by up to 95% and 80 - 90 % respectively.

The latter findings are confirmed by Binner who reports on the lower permeability of landfilled waste from mechanical biological pre-treatment.[50] This can however lead to problems of placement and the smaller particle size reduces the friction angle giving rise to problems of stability of large quantities of the material.

Some illustrations from Binner's report are given below. The first shows that mechanical biological pretreatment (MBP) reduces ammonia-nitrogen concentrations in leachate significantly relative to the situation in which no pre-treatment occurs. The age of the site also affects the concentrations.

Studies by the German Federal ministry of Education and Research (BMBF) and the state of Hessen, discussed earlier in the context of gas formation, also investigated leachate pollution in compacted bodies of waste of mechanically-biologically pretreated waste.[51] During tests in landfill simulation reactors, the heavy metal concentrations in the leachate decreased over the course of the tests, with all materials. However, with the organic substances contained in the leachate, the COD (chemical oxygen demand) level, the nitrogen parameters and the anionic salt components, relevant concentrations in the leachate are still detectable in later phases of the tests, in all cases.

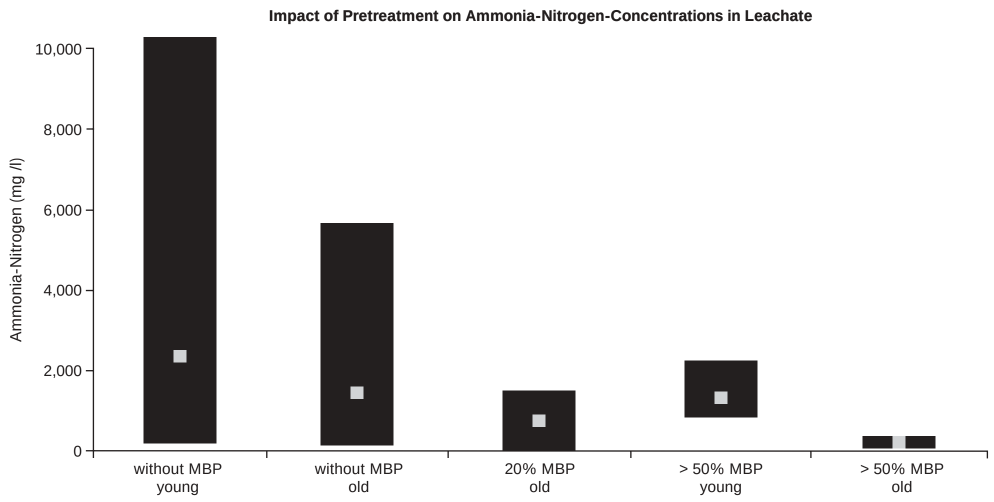


Figure 21: Impact of Mechanical Biological Pre-treatment on NH3-N Concentrations in Leachate
Source: Erwin Binner (2002) The Impact of Mechanical-Biological Pre-treatment on Landfill Behaviour, Paper Presented to the European Commission Biowaste Workshop, May 2002.

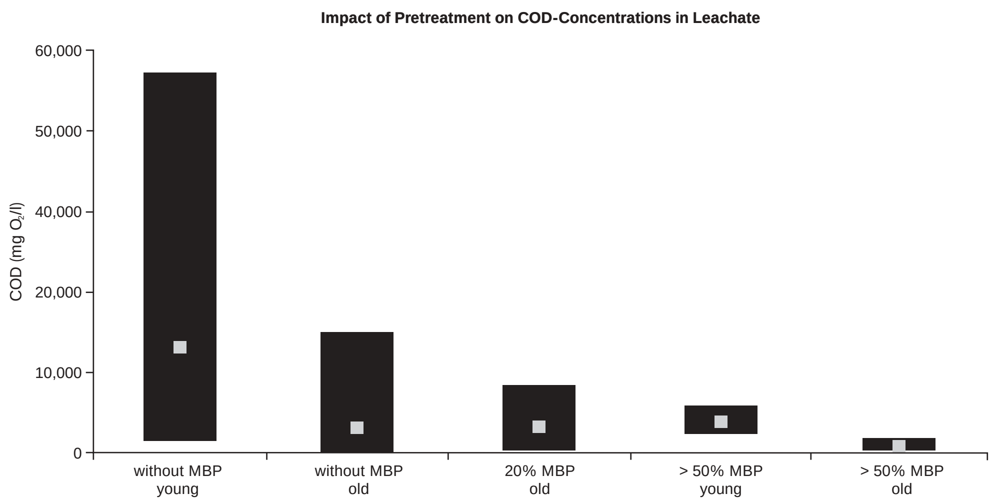


Figure 22: Impact of Mechanical Biological Pre-treatment on COD Concentrations in Leachate
Source: Erwin Binner (2002) The Impact of Mechanical-Biological Pre-treatment on Landfill Behaviour, Paper Presented to the European Commission Biowaste Workshop, May 2002.

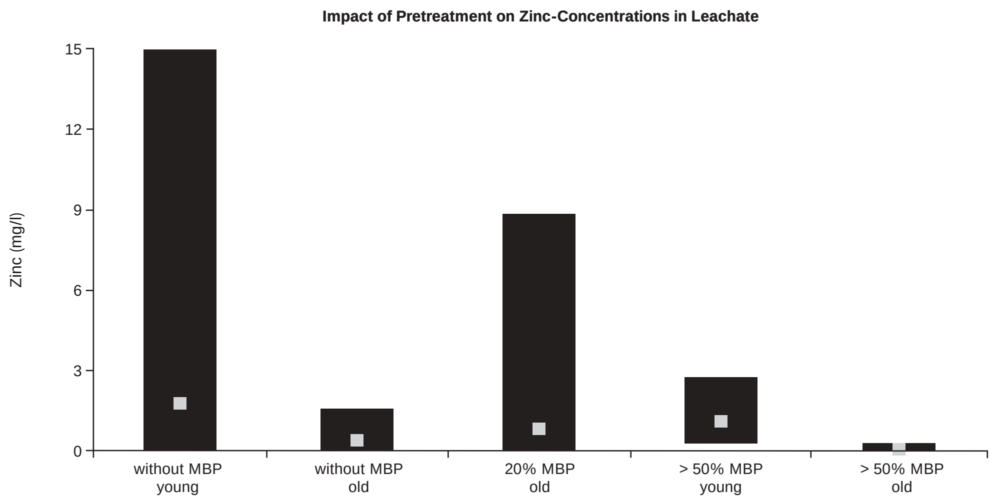


Figure 24: Impact of Mechanical Biological Pre-treatment on Zinc Concentrations in Leachate
Source: Erwin Binner (2002) The Impact of Mechanical-Biological Pre-treatment on Landfill Behaviour, Paper Presented to the European Commission Biowaste Workshop, May 2002.

Physical Characteristics

After MBT, in comparison with untreated municipal waste, waste becomes a relatively homogeneous mixture which is optically somewhat similar to composts derived from surce separated materials. Waste after MBT could only be differentiated from composts by an increased proportion of synthetics, textiles and composite materials. Even when this material strongly shapes the appearance of the waste, its proportion of the bulk of the waste is relatively low (0.5-3 wt. % of the DS or 3-10 wt. % of the oDS). A mathematical estimation of the synthetic fraction from the sort analysis before the pretreatment produced proportions of 5-8 wt. % of the DS or ~15-25 wt. % of the oDS. This leads to its own problems since clearly the 'invisible' contamination suggests that in terms of specific qualities of environmental and agronomic relevance for the application of such material, MBT residues are quite different from biowaste composts (and hence, residues ought to be restricted in the way in which they may be applied, as indeed they are in many countries with standards for quality compost).[52] A clear need for some form of standards exists.

Table 28 gives an overview of the incorporation characteristic values of reactor tests from the studies by the German Federal ministry of Education and Research (BMBF) and the state of Hessen,[53] Germany. Proportionally high permeabilities were measured in the bodies of the waste which had been incorporated in a relatively dry condition. Different columns relate to different pre-treatment concepts and durations.

With waste which was incorporated in a damp condition, generally very low permeability values for water became apparent, from 4.2 x 10^{-8} to 1.0 x 10^{-10} m/s (see Table 29). It is however to be assumed from it that the water permeability is likely to be greater under landfill conditions than the values measured under laboratory conditions.

With the waste which was incorporated in a damp condition, high water *saturations* were shown from the beginning onwards, of sometimes > 90 vol. %. With some of these tests, consolidation water came out during the compression. Mathematical estimations revealed that with the given incorporation densities, a complete saturation from around 35 wt % (WS) water content can occur. In exceptional cases such as MB-WS1 even from around 30 wt % (WS) (see water content with full saturation in Table 29). This means that with the incorporation and compaction of materials with a water content of around 30-35 wt % (WS), a compression water discharge must be reckoned on, which was also confirmed in the tests.

Model considerations further showed that with a low hydraulic conductivity of the body of the waste and with a very damp incorporation of the waste, there is a danger of consolidation settlements over a long period. From tests it was estimated that this danger can be clearly reduced by the reduction of the water content before the incorporation of the waste.

The incorporation conditions also have consequences for gas permeability. This is heavily dependent on the proportion of gas pores of the waste input to the landfill. Experimentally determined diffusion resistance factors for compressed bodies of waste are in the region of 30-50 with gas pore proportions of 30-40 vol. %. The gas pore proportion diminishes with increasing water content. With high water contents the diffusion resistance factor increases to values which lie one to two orders of magnitude above this value. In particular with high saturation (> ~80% total pore volume), an active degassing of the landfill body becomes awkward. Model calculations show that even in MBT landfill sites without surface insulation, and with very low respiration rates of 25 mg O_2/kg DS x d (RS_4 – value of 0.1 mg O_2/g DS), anaerobic conditions are to be expected in the body of the landfill.

On the basis of the very low gas formation rates in combination with the low gas permeability rates, the planning of a conventional active degassing is advised. It can be expected that an active degassing for an MBT landfill site with "well stabilized" waste is not practicable. For this reason, it seems more promising to implement a passive degassing by gas drainage at the landfill surface and base. With large landfill heights and very low permeability, flat degassing elements or trenches in the body of the waste should additionally be envisaged.

Binner reports that relative to untreated waste, waste pre-treated through MBT has:

- higher compactability (1.3 t/m 3, facilitating a reduction in volume)
- lower permeability (10^{-10} m/s, reduction of leachate)
- low particles size (< 15 - 35 mm, calorific value)
- problems in placement (rainfall)
- problems in structural stability
  (a reduction of friction angle is experienced related to the smaller particle size as follows)
  - < 12 mm ➡ ø = 31°
  - < 25 mm ➡ ø = 32°
  - < 40 mm ➡ ø = 37°
  - < 80 mm ➡ ø = 40°[54]

Hence, waste pre-treated using MBT experiences changes which are positive, as well as ones requiring new management approaches.

Table 28: Incorporation characteristic values of the bodies of compost at the beginning of the test.

Waste batch		MB-MH1		MB-QB1		MB-QB2	MB-LF1	MB-WS1
Test		**D-1**	**D-2**	**D-1**	**D-2**	**D-1**	**D-1**	**D-1**
Water content *w*		Dry	original	dry	original	original	original	original
Wet weight *ww*	wt %	7.4	34.0	16.9	30.1	27.7	35.6	27.8
Dry weight *wd*	wt %	8.0	51.5	20.3	43.0	38.3	55.3	38.5
Incorporation density								
Wet density *Qw*	kg/m^3	1,032	1,385	1,062	1,218	1,155	1,479	1,610
Dry density *Qd*	kg/m^3	956	914	883	852	835	952	1,163
Pore level								
Total pores ψ *tot*	vol %	52.4	54.5	50.4	52.1	55.4	52.9	49.0
Gas pores ψ *g*	vol %	44.7	7.4	32.5	15.5	23.4	0.2	4.3
(absolute)								
Avg. saturation S								
w at full saturation	vol %	14.6	86.5	35.6	70.3	57.7	99.5	91.3
Wet weight	wt. %	35.4	37.3	36.4	38.0	39.9	35.7	29.6
*w*w,max								
Dry weight	wt. %	54.8	59.6	57.1	61.2	66.3	55.6	42.1
*w*d,max								
Height of waste Δz	m	0.71	0.70	0.60	0.73	0.67	0.64	0.62
Discharge of consolid ation water on incorporation		no	yes	no	no	no	yes	Yes

Source: Zeschmar-Lahl et al. (2000) Mechanisch-Biologische Abfallbehandlung in Europa, Berlin: Blackwell Wissenschafts-Verlag GmbH

Table 29: Permeability coefficient and permeability on addition of water.

Waste batch		MB-MH1		MB-QB1		MB-QB2	MB-LF1	MB-WS1
Test		**D-1**	**D-2**	**D-1**	**D-2**	**D-1**	**D-1**	**D-1**
Permeability Coefficient ko,w	m/s	2.0E-06	7.2E-09	8.0E-09	4.9E-10	4.0E-06	>1.0E-10	4.5E-08
Permeability ko	m^2	2.4E-13	8.6E-16	9.6E-16	5.9E-17	4.8E-13	<1.2E-17	5.4E-15
Hydraulic drop I		2.7	3.3	7.2	7.3	6.5	6.9	7.0

Source: Zeschmar-Lahl et al. (2000) Mechanisch-Biologische Abfallbehandlung in Europa, Berlin: Blackwell Wissenschafts-Verlag GmbH

Summary of Appendix

MBT landfill fractions still show residual emission potential over a period of time (both to atmosphere and water), although at a much lower level than for untreated wastes. This needs to be taken into consideration in future landfill concepts and in the passing of legislation, particularly as it affects environmental issues. These facts also ought to influence the choice of residual waste management.

Research suggests that pre-treatment of waste through MBT prior to landfilling leads to:

- reduction and stabilization of organic solids;
- better input-control at landfills;
- reduction of gas generation;
- reduction of leachate (both the amount and concentrations);
- lower consumption of landfill volumes;
- lower settlement; and
- reduction of harmful substances.

The low gas and water permeability have relevant consequences for landfill practice. Some serious engineering problems have already arisen in isolated cases in Germany, where MBT output has been used for landfill. In Bavaria, for example, in the spring of 1998, approximately 100 m^2 of a steeply laid-out embankment constructed from MBT output slipped at the Bad Tölz/Wolfratshausen landfill site. The embankment was afterwards laid out less steeply, and there have been no further problems.

The above considerations highlight the fact that MBT should be considered as part of an altered landfill concept. Combinations of questions related to this new concept and highlighted by Zeschmar-Lahl et al include those of:

- Structural stability control,
- Incorporation with controlled water content
- New concepts of leachate containment, gas drainage and surface insulation,
- Toxicological and ecotoxicological assessment of the individual substances in the TOC of the leachate; and
- Reduction of the residual methane emissions (through management processes).[55]

Bibliography

AEA Technology (2001) *Waste Management Options and Climate Change, Final Report to the European Commission,* DG Environment, July 2001.

Austrian Ministry for Agriculture and Environment (2002): MBT *Guideline*

AWS, IFIP & GUA (2000) *Bewertung abfallwirtschaftlicher Maßnahmen mit dem Ziel der nachsorgefreien* Deponie – BEWEND. Unpublished case study Institute for Water Quality and Waste Management TU Vienna, Institute for Public Finance and Infrastructure Policy TU Vienna & Gesellschaft für umfassende Analysen GmbH, Vienna, Austria

BSI, WRAP and Composting Association (2002) PAS 100 – *Specification for Composted Materials,* London: British Standards Institution.

BZL (2000) *Thermisch-Regenerative Abgasreinigung für die mechanisch-biologische Abfallbehandlung.*

Erwin Binner (2002) *The Impact of Mechanical-Biological Pre-treatment on Landfill Behaviour,* Paper Presented to the European Commission Biowaste Workshop, May 2002.

C. Cuhls, H. Doedens et al. (1999) Bilanzierung von Umweltchemikalien bei der mechanisch-biologischen Abfallbehandlung *(Balancing Environmental Chemicals in Mechanical-Biological Waste Treatment)*, in: Verbundvorhaben mechanisch-biologische Behandlung von zu deponierenden Abfällen, Ergebnispräsentation 7.-8.Sept. 1999, gefördert vom BMBF, Hrsg. Universität Potsdam, Zentrum für Umweltwissenschaften, Potsdam 1999.

H. Doedens, C. Cuhls and F. Monkeberg (1998) *Bilanzierung von Umweltchemikalien bei der biologischem Vorbehandlung von Restabfallen,* BMBF-Statusseminar, Potsdam, March 1998.

H. Doedens et al. (2000) *Mechanisch-biologische Vorbehandlung von Restabfällen in Niedersachsen – Abschlussbericht.*

H.-J. Ehrig et al. (1998) Verbundvorhaben "Mechanisch-Biologische Behandlung von zu deponierenden Abfällen, Teilvorhaben _: Anforderungen an und Bewertung von biologischen Vorbehandlungen für die Ablagerung

H.-J. Ehrig and U. Witz (2002) Aufkommen und Behandlung von Sicker- und Oberflächenwässern von Deponien mit MBA-Material

EnBW (2000) *Innovation Report 2000. Generation and Utilization of C-Plus Material.*

K. Fricke, W. Muller, M. Turk and R. Wallmann (1997) Stand der Technik der mechanisch-biologischem Restabfallbehandlung, in BWK-Arbeitsgruppe 'Restabfallbehandlung', B. Bilitewski and R. Stegmann (eds) Mechanisch-biologische Verfahren zur stoffspecifischen Abfallbeseitigung. *Beihefte zu Mull und Abfall,* 33: 26-56.S. Hellweg (2000) *Time-and Site-Dependent Life-Cycle Assessment of Thermal Waste Treatment Processes,* Dissertation submitted to the Swiss Federal Institute Of Technology.

Hoering, K, Kruempelbeck, I and Ehrig, H-J. (1999) Long-term emission behaviour of mechanical-biological pre-treated municipal solid waste. In: Proceedings Sardinia 99. *Seventh International Waste Management and Landfill Symposium.* S Margherita di Pula, Caligari, Italy, 4-8 October 1999. pp 409-418.

D. Hogg, D. Mansell and Network Recycling (2002) *Maximising Recycling, Dealing with Residuals,* Final Report to the Community Recycling Network.

D. Hogg et al (2002) *Comparison of Compost Standards within the EU, North America and Australasia,* Final Report to WRAP.

K. Ketelsen and C. Cuhls (1999) Emissionen bei der mechanisch-biologischen Behandlung von Restabfallen und deren Minimierung bei gekapselten MBS-Systemen, in *Bio- und Restabfallbehandlung III,* M.I.C. Baeza-Verlag, Witzenhausen.

U. Lahl, B. Zeschmarr-Lahl and T. Angerer (2000) *Entwicklungspotentiale der Mechanisch-biologischen Abfallbehandlung: Eine Okologische Analyse,* Umweltbundesamt: Wien

O. Muck (2002) Restmüllverwertung mit dem BTA-Verfahren, in Thome-Kozmiensky (2002) *Reformbedarf in der Abfallwirtschaft.*

Nolan-ITU (1999) *Residual Waste Stabilisation: Comparison of Generic Technologies,* for the Southern Sydney Waste Board.

Öko-Institut (1998) *Systemvergleich unterschiedlicher Verfahren der Restabfallbehandlung für die Stadt Münster* (Residual Waste Treatment for the City of Münster – System Comparison).

W. Plehn (1989) FCKW zur Kunstoffvershaumung, in UBA (eds.) *Verzicht aus Verantwortung,* UBA-berihte 7/89.

Ch. Quittek (2002) Vergärung nach dem VALORGA-Verfahren, in: Thome-Kozmiensky: *Reformbedarf in der Abfallwirtschaft.*

Th. Seifermann (2002) MBA ISKA Buchen mit Perkolation, in K. Wiemer and M. Kern (2002) *Bio- und Restabfallbehandlung VI.*

P. Schalk (2002) Das BIOPERCOLAT-Verfahren in der Restabfallbehandlung, in K. Wiemer and M. Kern (2002) *Bio- und Restabfallbehandlung VI.*

SORTEC 3 Technology: DKR Deutsche Gesellschaft für Kunststoffrecycling (www.dkr.de)

L. Wanholt (1999) *Biological Treatment of Domestic Waste in Closed Plants in Europe – Plant Visit Reports,* RVF Report 98:8, RVF, Malmo.

K. Wiemer (1995) *Mechanical Biological Treatment of Residual Waste based on the Dry-Stabilate Method,* Witzenhausen, 1995.

B. Zeschmar-Lahl et al. (2000) *Mechanisch-Biologische Abfallbehandlung in Europa,* Berlin: Blackwell Wissenschafts-Verlag GmbH.

References

1 D. Hogg, D. Mansell and Network Recycling (2002) *Maximising Recycling, Dealing with Residuals,* Final Report by Eunomia, Avon Friends of the Earth and Network Recycling to the Community Recycling Network.

2 IBA GmbH, Hannover, BZL GmbH, Oyten, CUTEC GmbH, Clausthal-Zellerfeld (1998) *Moglichkeiten der Kombination von mechanisch-biologischer und thermischer Behandlung von Restabfallen,* F + E Vorhaben Nr.1471 114 im Auftrag des BMBF/UBA.

3 U. Lahl, B. Zeschmarr-Lahl and T. Angerer (2000) *Entwicklungspotentiale der Mechanisch-biologischen Abfallbehandlung: Eine Okologische Analyse,* Umweltbundesamt: Wien.

4 Nolan-ITU (1999): Residual Waste Stabilisation. Comparison of Generic Technologies. For the Southern Sydney Waste Board.

5 L. Wanholt (1999) Biological Treatment of Domestic Waste in Closed Plants in Europe – Plant Visit Reports, RVF Report 98:8, RVF, Malmo.

6 K. Ketelsen and C. Cuhls (1999) Emissionen bei der mechanisch-biologischen Behandlung von Restabfallen und deren Minimierung bei gekapselten MBS-Systemen, in *Bio- und Restabfallbehandlung III,* M.I.C. Baeza-Verlag, Witzenhausen.

7 U. Lahl, B. Zeschmarr-Lahl and T. Angerer (2000) *Entwicklungspotentiale der Mechanisch-biologischen Abfallbehandlung: Eine Okologische Analyse,* Umweltbundesamt: Wien

8 AEA Technology (2001) *Waste Management Options and Climate Change,* Final Report to the European Commission, DG Environment, July 2001.

9 AWS, IFIP & GUA (2000) *Bewertung abfallwirtschaftlicher Maßnahmen mit dem Ziel der nachsorgefreien Deponie – BEWEND.* Unpublished case study Institute for Water Quality and Waste Management TU Vienna, Institute for Public Finance and Infrastructure Policy TU Vienna & Gesellschaft für umfassende Analysen GmbH, Vienna, Austria.

10 K. Fricke, W. Müller, M. Turk and R. Wallmann (1997) Stand der Technik der mechanisch-biologischen Restabfallbehandlung, in BWK-Arbeitsgruppe 'Restabfallbehandlung', B. Bilitewski and R. Stegmann, Mechanisch-biologische Verfahren zur stoffspezifischen Abfallbeseitigung. Beihefte zu Müll und Abfall, 33: 26-56.

11 H. Doedens, C. Cuhls and F. Monkeberg (1998) Bilanzierung von Umweltchemikalien bei der biologischem Vorbehandlung von Restabfäallen, BMBF-Statusseminar, Potsdam, March 1998.

12 Zeschmar-Lahl et al. (2000) *Mechanisch-Biologische Abfallbehandlung in Europa,* Berlin: Blackwell Wissenschafts-Verlag GmbH.

13 NMVOC = non-methane volatile organic compounds.

14 W. Plehn (1989) FCKW zur Kunstoffverschäumung, in UBA (eds.) Verzicht aus Verantwortung. UBA-Berichte 7/89.

15 Seifermann Th. MBA ISKA Buchen mit Perkolation, in Wiemer K., Kern M. (2002) Bio- und Restabfallbehandlung VI. ISBN3-928673-38-6.

16 Komptech Waste Processing Facility in operation in Padova/Italy

17 Vagron Plant, Belgium. Raba Plant, Germany (for details refer to Appendix A)

18 NECS (2001): Environmental Impact Statement for proposed UR-3R facility at Eastern Creek, Sydney

19 SORTEC 3 Technology: DKR Deutsche Gesellschaft für Kunststoffrecycling (www.dkr.de)

20 EnBW (2000): Innovation Report 2000. Generation and Utilization of C-Plus Material.

21 Seifermann Th. MBA ISKA Buchen mit Perkolation, in Wiemer K., Kern M. (2002) Bio- und Restabfallbehandlung VI. ISBN3-928673-38-6.

22 Schalk P. (2002): Das BIOPERCOLAT-Verfahren in der Restabfallbehandlung, in Wiemer K., Kern M. (2002) Bio- und Restabfallbehandlung VI. ISBN3-928673-38-6.

23 Komptech Waste Processing Facility in operation in Padova/Italy.

24 Austrian Ministry for Agriculture and Environment (2002): MBT Guideline

25 Strictly interpreted, things may not be so clearcut since the definition of the 'compost' and 'composting' under the Animal By-products Order suggests something which includes MBT plants, so that the fate of the waste is potentially irrelevant. The interpretation in the main body of the text is based on discussions with DEFRA officials.

26 European Council Directive 1999/31/EC. Based on this, national implementation eg German and Austrian Landfill Ordinances – see Section 4 above. It should be noted that the time period here is time to meet the Austrian requirements, for which the requirements are especially stringent. A shorter time period might be reasonable to meet Italian standards, reducing unit costs somewhat (because of the shorter maturation time required).

27 Trials for the City of Vienna, as part of the development of additional residual waste treatment facilities.

28 Seifermann Th. (2001): MBA ISKA-Buchen mit Perkolation – Anlagenbeschreibung und Allgemeines Verfahrenskonzept. In: Wiemer K, Kern M (2001): *Bio- und Restabfallbehandlung V.* ISBN 3-928673-34-3

29 Öko-Institut (1998): Systemvergleich unterschiedlicher Verfahren der Restabfallbehandlung für die Stadt Münster (Residual Waste Treatment for the City of Münster – System Comparison).

30 BSI, WRAP and Composting Association (2002) PAS 100 – *Specification for Composted Materials,* London: British Standards Institution.

31 Ehrig et al. (1998): Verbundvorhaben "Mechanisch-Biologische Behandlung von zu deponierenden Abfällen, Teilvorhaben _: Anforderungen an und Bewertung von biologischen Vorbehandlungen für die Ablagerung

32 Bundesimmissionsschutzverordnung (German National Immissions Ordinance)

33 BZL (2000): Thermisch-Regenerative Abgasreinigung für die mechanisch-biologische Abfallbehandlung.

34 Doedens et al. (2000) Mechanisch-biologische Vorbehandlung von Restabfällen in Niedersachsen – Abschlussbericht.

35 Derived from: C.Cuhls, H. Doedens et al. (1999): Bilanzierung von Umweltchemikalien bei der mechanisch-biologischen Abfallbehandlung *(Balancing Environmental Chemicals in Mechanical-Biological Waste Treatment),* in: Verbundvorhaben mechanisch-biologische Behandlung von zu deponierenden Abfällen, Ergebnispräsentation 7.-8.Sept. 1999, gefördert vom BMBF, Hrsg. Universität Potsdam, Zentrum für Umweltwissenschaften, Potsdam 1999.

36 Doedens et al. (2000): Mechanisch-biologische Vorbehandlung von Restabfällen in Niedersachsen – Abschlussbericht.

37 Nolan-ITU (1999): Residual Waste Stabilisation. Comparison of Generic Technologies. For the Southern Sydney Waste Board.

38 See D. Hogg, D. Mansell and Network Recycling (2002) *Maximising Recycling, Dealing with Residuals,* Final Report to the Community Recycling Network.

39 Sources are: GEMIS Database (maintained by Oko Institut, Darmstadt, Germany) (metals other than steel); IISI Life Cycle Inventories (steel); and AEA Technology (2001) *Waste Management Options and Climate Change, Final Report to the European Commission,* DG Environment, July 2001 (textiles).

40 AEA Technology (2001) *Waste Management Options and Climate Change, Final Report to the European Commission,* DG Environment, July 2001.

41 Muck O. (2002): Restmüllverwertung mit dem BTA-Verfahren, in: Thome-Kozmiensky: Reformbedarf in der Abfallwirtschaft. ISBN 3-935317-05-0.

42 Quittek Ch. (200) Vergärung nach dem VALORGA-Verfahren, in: Thome-Kozmiensky: Reformbedarf in der Abfallwirtschaft. ISBN 3-935317-05-0.

43 Ehrig H.-J., Witz U. (2002) Aufkommen und Behandlung von Sicker- und Oberflächenwässern von Deponien mit MBA-Material

44 Binner E. (2002): *The Impact of Mechanical-Biological Treatment on the Landfill Behaviour.* Paper at the EU Biowaste Workshop, Brussels, April 2002.

45 Aumonier (1997): Life Cycle Assessment of Anaerobic Digestion.

46 White et. al (1999): IWM-2 Model Guide.

47 National Law Gazette 325/1990 rev. NLG 164/1996.

48 The studies are reviewed in Zeschmar-Lahl et al. (2000) *Mechanisch-Biologische Abfallbehandlung in Europa,* Berlin: Blackwell Wissenschafts-Verlag GmbH., which we rely upon here for the key results.

49 Hoering, K, Kruempelbeck, I and Ehrig, H-J. (1999) Long-term emission behaviour of mechanical-biological pre-treated municipal solid waste. In: Proceedings Sardinia 99. *Seventh International Waste Management and Landfill Symposium.* S Margherita di Pula, Caligari, Italy, 4-8 October 1999. pp 409-418.

50 Erwin Binner (2002) *The Impact of Mechanical-Biological Pre-treatment on Landfill Behaviour,* Paper Presented to the European Commission Biowaste Workshop, May 2002.

51 Again, we refer to the review in Zeschmar-Lahl et al. (2000) *Mechanisch-Biologische Abfallbehandlung in Europa,* Berlin: Blackwell Wissenschafts-Verlag GmbH., for the key results.

52 See D. Hogg et al (2002) *Comparison of Compost Standards within the EU, North America and Australasia,* Final Report to WRAP.

53 Again, we refer to the review in Zeschmar-Lahl et al. (2000) *Mechanisch-Biologische Abfallbehandlung in Europa,* Berlin: Blackwell Wissenschafts-Verlag GmbH., for the key results.

54 Erwin Binner (2002) *The Impact of Mechanical-Biological Pre-treatment on Landfill Behaviour,* Paper Presented to the European Commission Biowaste Workshop, May 2002.

55 Zeschmar-Lahl et al. (2000) *Mechanisch-Biologische Abfallbehandlung in Europa,* Berlin: Blackwell Wissenschafts-Verlag GmbH

Greenpeace Environmental Trust
Canonbury Villas, London N1 2PN
URL: www.greenpeace.org.uk/trust

TBU
Defreggerstrasse 18, A-6020
Innsbruck, Austria
Tel: +43 512 393 733
Fax: +43 512 393 022
E-mail: office@tbu-australia.com
URL: www.tbu-austria.com

Eunomia
120 Cotham Brow, Cotham,
Bristol, BS6 6AR
Tel: +44 117 942 6678
Fax: +44 117 942 6679
E-mail: dominic@eco.u-net.com
URL: www.eunomia.co.uk

bwa design
Tel: 020 7490 3148

February 2003

The Environmental Trust: As a pollutant, waste demands controls

Publication date: 7 February, 2002

As an embodiment of accumulated energy and materials it invites an alternative.

(The whole file is 1mb; the report is broken down below for easier download)

Summary

Waste policy has become one of the most keenly contested areas of environmental politics. At a local level in the UK and abroad, new sites for landfills and incinerators have 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.

As a pollutant, waste demands controls.
As an embodiment of accumulated energy and materials it invites an alternative.

£12.50

Greenpeace Environmental Trust
Canonbury Villas, London N1 2PN, United Kingdom
www.greenpeace.org.uk/trust

Zero Waste

Robin Murray

Acknowledgements

This book is dedicated to those who helped make it: to Keith Collins and Alan Watson whose work and perspectives I hope are adequately reflected here; to Bob Argue, Enzo Favoino, Kathy Killinger, Worku Lakew, Jack McGinnis, Cheryl Nash and Marco Ricci; and to the members of the CRN and Zero Waste UK who, with direct experience of the old waste order, have been so central to the shaping of the new one.

I would also like to thank Zero Waste New Zealand, the members of Zero Waste International and Greenpeace for their support.

London, February 2002

February 2002

Published by Greenpeace Environmental Trust

Canonbury Villas, London N1 2PN, United Kingdom

Registered Charity No. 284934

A catalogue record of this book is available from the British Library

ISBN 1 903907 01 2

Design by Paul Hamilton at One Another

Printed in the United Kingdom by Russell Press

Printed on 100% post-consumer recycled paper

Front cover image © Barbara Morss
Back cover image © David Hoffman

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 CO2 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 CO_2 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.

IV The Road to Zero Waste

1. Setting the compass

The first feature of all successful high diversion programmes is the strength of the idea. For a programme to have roots and direction it has to have a shared idea of its environmental and social purpose. Although individual incentives play a role, it is the common goals which are the raison d'être and generate the mobilising energy for the project. They also provide the criteria that inform waste strategies.

This is an important point for waste managers in the UK. Too often waste plans in this country have set as their primary tasks the meeting of EU and government targets and directives. This places local authorities in the role of a subordinate, whose goals and values are determined elsewhere. The danger is that the targets become detached from the intention behind them, so that an authority will be concerned more with meeting the targets than with whether the route they have chosen reflects underlying priorities.[41]

For those outside local government, particularly householders, who play a key role in the new waste arrangements both as voters and waste producers, bureaucratic objectives such as meeting government targets have less meaning than environmental objectives such as reduced toxicity and emissions of CO2. It is not that government targets should not be met: the initial recycling targets are statutory and binding. It is rather that they should be seen as a consequence, not a prime reason, for any strategy.

Sustained political leadership has been particularly important in recycling for this reason, in articulating and keeping to the fore the central meaning of the programme. But it has also been important that the establishment of the programme is not treated simply as a technical matter, and that the broader values are internalised in its design and conduct. In order to achieve this, many programmes have been designed (and in some cases operated) in close partnership with the communities they serve.

2. Targets as staging posts

Once the overall goals are clear, targets have a context. They have often been a point of contest. Innovators want to set targets beyond the horizon. Bureaucracies prefer to remain well within it. But in terms of achieving high recycling, targets should be ambitious – so-called 'stretch targets' in order to encourage radical innovation. They should be set in relation to what is required. They embody the goals. In the words of Gerry Gillespie, one of the promoters of Zero Waste policies in Australia and New Zealand, the Americans and the Russians did not aim to send a man halfway to the moon. They were advised by their scientists on the potential feasibility of the project, but they were setting a goal not on the basis of existing levels of technology, but on what might be developed in the future.

Good targets reflect an impatience with the present. They then become the yardstick against which advance can be measured. Japanese manufacturers do not care how low the bar is to begin with. Their interest is in how high it can go, and with the closely observed ups and downs of the progress towards it.

High recyclers have set ambitious targets – usually 50%, in the first instance, to be achieved within a decade. Many found they reached that level more quickly, and target dates have been brought forward – to five years and even less. Individual municipalities find that they can reach 50% within two years of launching. For places still in the early stages of recycling, reaching 50% diversion in five years is a reasonable first stage target in the light of current experience and techniques.

In the long term, many places are now confident that they can reach much higher levels. In California, the 50+% municipalities are planning for 70-80% diversion, with some districts and cities (notably Del Norte and Santa Cruz) targeting Zero Waste. In Canada, districts like Quinte, that have reached 70%, are now planning for 85%. The Nova Scotia county of Annapolis Royal is aiming for Zero Waste by 2005. Zero Waste has now become the goal for 40% of all municipalities in New Zealand, following the lead of Canberra.

The above suggests that in addition to a first stage target of 50% within five years, further stretch targets should be set of 70% diversion within ten years, 85% in fifteen and Zero Waste in twenty.

3. The S-curve and the Pareto Principle

Behind these targets lies a proposition that the expansion of recycling follows an S-curve. The curve describes the fact that, after an initial slow growth, the recycling rate can climb steeply to 50% and 60%, and then continue at a slower rate as waste reduces towards zero. It is a description of the growth of individual recycling programmes to date.

The rationale reflects the Pareto Principle that a small number of causes are responsible for a large proportion (commonly 80%) of the effects. In the case of dustbin waste, five materials (organics, paper, glass, cans and textiles) account for 80% of the weight. For bulky waste taken to civic amenity sites (CA sites), 70% of the weight comprises three materials (organic waste, builders' waste and wood), with a further three materials taking the figure up to 80% (paper, metals and furniture). In broad terms, if an authority sets up a small number of core programmes that capture 80% of these '80% materials' from 80% of its residents, it will reach the first target of 50%.

Those authorities that have pursued intensive programmes of this kind have found that their household diversion rates rise rapidly to reach 50% or more, with commercial rates increasing even more sharply. This represents the steep part of the S-curve.

After that the household rate is pushed further by two factors. First participation and capture rates increase in the existing programmes, often aided by the introduction of user pay systems. Second, new materials are added to the collection and new programmes are started aimed at items that become significant in the residual stream. An example would be nappies, which account for 4% of the domestic dustbin, but 10% of the residual once a 60% target has been reached. The rate of expansion slows as programmes have to deal with the more difficult materials, and less participative households.

4. The four-stream system

The most common core programme for the first stage is described as the four-stream system, of which three streams represent dustbin waste:

- organic waste
- dry recyclables
- residual dustbin waste and a fourth stream represents:
- bulky goods

These all need to be dealt with separately, with further sub-divisions in each category. While in each case it may be possible to arrange for householders, firms and institutions to process their own waste (as in the case of on-site composting) or to bring their waste to a common collection point (to recycling banks, civic amenity sites, shops for returnable bottles or to roadside Eurobins for residual waste in Mediterranean Europe), the core of the intensive recycling structure is kerbside collection.

The first priority is organic waste. This makes up 30-50% of dustbin waste throughout Europe, and in the UK 40% of civic amenity site waste. High levels of organic diversion will not only reduce the toxicity of landfill, it will propel municipalities towards the 50% target. Many North American authorities that have reached 50% or more have done so without kitchen waste collections, relying rather on home composting programmes and the kerbside collection of garden waste. The same is true of Canberra in Australia. But home composting alone will never achieve the levels of diversion of doorstep food waste collections, so that for Zero Waste, a regular food waste pick-up is the first building block of the new system, with seasonal collections of that garden waste which cannot be composted at home.[42] Separate food waste collections have been the reason why so many Italian cities have reached 50%-plus targets of waste diversion within three years.

The second stream is dustbin dry recyclables. Kerbside collection of recyclables should aim to reach an average of 2.7kg per household passed per week within three years, and 4kg per household within eight years, yielding a dustbin recycling rate of 17-25%. The priority material is paper – both newspaper and magazines, and other mixed paper, followed by textiles, cans and lastly glass.

The third stream is residual dustbin waste, which will dramatically fall in volume, and whose collection needs to be integrated with the organics and dry recycling collections. Within the residual stream, special arrangements are required to remove hazardous waste. Some is collected in bags attached to the dry recyclables collection (batteries and old pharmaceuticals for example). A growing number of municipalities have assigned special areas of their civic amenity sites for the full range of hazardous items that can be recycled or disposed of appropriately.

The three-stream system for the collection of dustbin waste is the core programme for intensive municipal recycling. In the spirit of smart recycling it does not necessarily mean three separate collections. In some cases two streams can be collected in separate compartments of the same vehicle. In others, there may be four or five collections: for food waste, garden waste, fibres and containers, and residuals. What matters is that the streams remain separate to avoid contamination.

In respect to the fourth stream, bulky waste, it is primarily handled throughout Europe, North America and Australasia via a small number of designated bring sites, often at landfills, supported by doorstep collections for those without cars or who live in rural areas. Recycling is relatively straightforward in this case, with residents and traders instructed to source-separate their waste and place it in the relevant containers. As a result, diversion rates of 60-70% can be rapidly achieved, provided that the layout of the sites is re-organised and sufficient green collar staff employed.

The problem with this system is that while it is cheap for local authorities, it is a major generator of traffic (accounting for nearly 1% of car traffic in outer London for example). There is an environmental case for introducing a more systematic doorstep collection scheme for bulk goods, as well as extending take-back systems through commercial delivery vehicles as producer responsibility regulations come onstream.

In the USA and Canada bring sites of this kind have been refashioned into recycling and reuse centres. They have become transfer sites for the recycling of consumer durables, as well as places of recreation – a market for reuse goods, an education centre and a waste museum.

The above four-stream system has been adopted for trade and institutional waste as well as waste from households, often using the same vehicles and facilities.

5. Mapping

Intensive recycling needs to give as much priority to mapping its waste as the nineteenth century General Staff in Prussia gave to mapping their territories. In the case of waste, the primary mapping will have three main parts:

- an analysis of the composition of waste
- an identification of the main sources and quantities of waste
- an audit of existing assets

(i) waste composition

In the era of mass waste, what mattered was not the composition of waste but its volume and weight. Increased awareness of pollution led to new classification of special and hazardous wastes, but these mainly applied to industries, not households. For the most part waste was waste. The issue was quantity not quality.

Incinerators were a partial exception. They did have an interest in the combustibility of their feedstock, and undertook periodic studies to distinguish the main elements of waste in relation to their calorific values. But the studies remained aggregated, with categories such as combustible and non-combustible, and with large residual categories such as ‘miscellaneous’ and ‘fines’.

The starting point for Zero Waste has been disaggregation. Sorting techniques have been developed which can identify the composition of each of the waste streams, as mineralogists identify their metals. It has been found that an adequate analysis requires hand sorting. It cannot be done satisfactorily by machines. Hand sorting allows the breakdown of waste into fifty or more components, and gives the planners of recycling direct experience of the materials with which they are working. Like opinion polling, waste composition sampling is done regularly as a measure of progress and a guide to practice.

(ii) estimating quantities

In the past, mass waste has been measured at the point at which it has to be paid for – at the point of transfer and/or disposal (although in the UK as in other parts of

Europe by no means all landfills have weighbridges). Yet the lorries that bring in the waste often have mixed contents from different streams. Household collection rounds include some trade clients. Street sweepings may be added to a trade or domestic round. Civic Amenity (CA) sites may mix trade and domestic waste. Few have their own weighbridges. Some streams unofficially switch into others. A major cause of the large rises recorded in household waste since the introduction of the landfill tax in Britain has been the seepage of trade waste into street litter, estate paladins, CA sites, or into the household dustbin stream. Some waste avoids official disposal altogether by being dumped illegally.

As a result, waste data is notoriously unreliable. Waste managers and government planners have no firm knowledge of the absolute quantities of particular streams, let alone their composition. Some years ago the UK Government had to increase its estimate of municipal waste by a third. Waste Strategy 2000 (and the Environment Agency) continue to use mechanical waste composition analyses undertaken for dustbin waste in the early 1990s as a proxy for the composition of all municipal waste, and consequently underestimate the quantity of organic waste by some 4-6 million tonnes. Twenty-year strategies in Britain are being based on quantities measured as household waste going over a weighbridge – whatever their source. Producers required to fund recycling under the packaging regulations have been in continuous conflict with the Environment Agency over the quantities of packaging waste.

Recycling cannot operate in such informational darkness. It needs to know waste quantities and compositions from its various sources not just in aggregate but for different rounds, streets and even households. For planning it has to know about waste trends by stream and also be able to estimate its 'reserves' of resources – how much newsprint, or cardboard or clothing there is in any town or city. For operations it has to be able to monitor the impact of diversion and what material is not being captured. For charging, it has to know how much each household or trader or institution is producing, since the principle that the polluter pays depends in practice on knowing the quantities produced by each 'polluter'.

The new waste economy has therefore become a close tracker of quantities. Some can be estimated by the size of bin (regularly re-sampled), some by statistical analyses using postcode marketing data.[43] Some municipalities have introduced on-board weighing of individual containers and expanded the number of weighbridges. All of them aim to produce detailed, real time data to allow them to track and adjust their systems promptly.

(iii) an audit of the current waste system

One of the principles of intensive recycling is that it should transform a local authority's (or a firm's) waste system and not be treated as an add-on to existing waste management. Many of the savings of the recycling-led systems have come from persistently inefficient features of the mass waste system – for example, from the practice of adding on the handling of mini-waste streams (such as special collections) piecemeal, to the mass waste system; from the reduction in 'defects' (such as missed pick-ups), or from the introduction of new systems into areas where waste management has broken down (high rise estates, urban street litter, and the fly-tipping of bulky goods). The costs of intensive recycling can also be reduced if it calls on, or increases its use of, existing assets – the corner of a local depot, for instance, or a well maintained collection vehicle which is available on weekends. The devil of 'smart recycling' is in the detail.

An initial audit is a survey of this detail. It will include:

- the assets held by the existing waste departments (lorries, depots, workshops, bulking bays, containers, databases, landfills) and by other waste generating/waste managing departments (notably housing, education, parks and highways). Most housing estates, for example, have unused collective areas – empty shops or garages that can be used as mini recycling depots. Parks have space and machinery suitable for composting. Highways have specialist vehicles and depots that could be rented for recycling;

- the operating patterns, schedules, capacity utilisation, breakdowns, distance to disposal and maintenance arrangements;

- the costs and income not just of the waste departments, but of all sections of the authority producing waste (one study in a London borough found that the per tonne cost of waste management on estates was nearly ten times that for ordinary domestic refuse rounds). Authority-wide costing will be the base marker or bottom line against which the costs of any new waste system have to be judged.

6. Social marketing

Earlier I discussed the central place of environmental values in the design and operation of successful recycling schemes. However, no service of this kind can succeed on ethics alone. The experience of both environmental and ethical trading is that the qualities normally expected of a service or commodity are the primary issue. Ethical market research shows that there are a small minority (often no more than 1%) who will buy recycled paper or fairly traded coffee whatever the quality. A further 30% are actively sympathetic to the ideas in question, and may even be willing to pay a little more (say an extra 10%) if the item in question is equivalent to conventional goods in quality. Another 40% will buy if both price and quality match the competition. A residual cohort remain indifferent or are even hostile. These proportions can change over time but the principle of an ethical 'bell curve' still holds.

Recycling has learnt similar lessons. For most people, the environmental value of the service is not enough if the service is irregular or inconvenient. To achieve high levels of participation recyclers have had to ensure that, in addition to the focus on 'meaning', they also offer a high quality service and employ the skills and social marketing techniques required. If recycling is in competition with the dustbin, then it has to be organised in a way that maximises its advantages and minimises its drawbacks. Among the points of importance are the following:

- *simplicity.* The highest participation rates come from a weekly service, preferably on the same day as a residual collection;

- *convenience*. Recycling boxes and organic containers need to be designed to take account first and foremost of householder convenience, with vertical boxes for flats for example, or small 'compostainers' for collecting organics in the sink;

- *design*. Good services require good design – of equipment, containers, workwear, and leaflets;

- *advice*. If householders are producers, then some aspects of recycling require advice. In the case of composting, the best schemes have employed compost doctors to help establish a compost bin, and to troubleshoot for those with problems; for recycling the collector can usually advise on materials that should be left out or included;

- *tracking*. Bar codes on recycling boxes have allowed collectors to monitor participation rates, with thanks to those who participate regularly, and direct approaches to those who don't;

- *feedback*. Regular feedback on the quantities of material collected and its use has been found to increase participation rates. This can be done through a newsletter left in the recycling box (boxes are now available with message slots so that they become a weekly vehicle for communication);

- *support groups.* Many recycling programmes have been organised with a supporters network, which acts as a point of advocacy and feedback from the street. Its views, along with those of the collectors and the customary focus groups, are important in assessing and expanding the service.

These approaches take one beyond a common view that only a minority of the population will engage in recycling, and that the issue is one of educating an ill-informed public. There are issues of information and education, but the lessons of environmental and ethical business are that a service like recycling must always present itself as both householder-friendly and a bearer of meaning. Like Oliver Cromwell, it must trust in God and keep its powder dry.

7. User pay and paying the user

The substance and quality of a service is more important for many householders than the relative 'effort price' of recycling. Yet many of the high performing programmes internationally have introduced user pay systems ('pay as you throw') for residual waste and/or some form of compulsory regulation. The advice of programme designers is to ensure that convenient systems are in place before introducing user pay or prohibitions, since it will otherwise lead to increased fly-tipping or free loading on others. Carefully introduced user pay (whether or not supported by regulation) shifts the form of payment for waste from a lump sum tax charge to a per-unit fee, and increases participation and capture rates by 10-15%.

There are some restrictions on the introduction of user charges in the UK, since local authorities are required under the Environmental Protection Act of 1990 to provide a free waste collection service. Paradoxically, this encourages a broader view of incentives than a simple mixed-waste user fee.

There are a number of ways in which a local authority in the UK can change the 'price' of recycling relative to the residual dustbin, in addition to the aspects of service quality outlined above. It can:

- charge for the provision of sacks or other containers (thus some authorities make a charge for plastic sacks for residual waste, but provide recycling and composting containers free. In North America householders are often charged different annual rates according to the residual bin size that they agree to use – a similar effect can be achieved by using the instruments legally open to local authorities in the UK);

- charge for collecting green waste and bulky goods;

- raise the level of annual charge for waste services and provide discounts for those households which join a recycling scheme (the discounts can be financial or in kind – a pilot of this kind is currently underway in the London Borough of Brent);

- introduce the Australian tag bag system and organise a prize draw for recycling. Each recycling bag is secure with a tag that carries a bar code on it. There is a weekly draw, the winner's bag is then checked, and if it is properly sorted, he or she receives substantial prizes – holidays to the Caribbean, a new low-emission car and so on. The savings resulting from introducing the scheme are shared with householders in this way;

- other forms of incentives along similar lines include free or subsidised goods and services for regular recyclers (water butts or extra composters for example, compost that can be collected free on certain days of the year, free energy saving advice, access to discounts on environmentally friendly goods negotiated on a bulk basis by the local authority, street/estate/village awards for good recyclers);

- many authorities in the UK and continental Europe have introduced town cards that act as a tool for providing resident discounts and for promoting public facilities and/or local and less recognised goods and services. Recycling and composting can easily be added to such 'smart cards', giving waste managers the flexibility of awarding bonus points and special offers to encourage participation;

- incentives of this kind can be used not simply to promote recycling in general, but to support particular 'campaigns' through 'targeted incentives' just as a firm would do when launching a new product;

One striking example of the incentive approach was introduced by the Mayor of Curatiba in Brazil. Faced with a crisis in waste collection, the municipality offered to pay residents for their waste if it was delivered to a local collection point. This generated an informal economy of collection, with low-income groups offering to take other people's waste so that they could collect the municipal payment. In effect it was a funded bring system – and in Curatiba's case part of the payment was made in food tokens which could be used to purchase the produce of local farmers. Bottle deposit schemes are another example of 'paying the user' rather than 'user pay', but the idea could be extended for particular materials such as aluminium (cans or foil), or – with expanded producer responsibility – for returnable consumer durables, in each case the price paid being covered by savings in collection costs.

In addition to flexible price and bonus schemes of this kind, the same goals can be approached using regulations and relative service differentials. A local authority in the UK has a variety of ways of strengthening recycling relative to the residual dustbin. Even with current legislation it can:

- require householders to use particular types of container (such as a blue box for recyclables or a plastic bin for food waste);

- limit the size of the permitted residual container if other recycling containers are provided;

- refuse to pick up waste that is not properly sorted (this has been important to the success of the organic scheme in Bury St Edmunds; the collectors explain that they will not pick up organic bins contaminated with non-organics and this has led to a rapidly improved quality of set-outs);

- schedule waste collections that are more regular for recycling than residuals (a fortnightly collection of residuals and careful monitoring of dry recyclable and organic put-outs will encourage householders to recycle).

In some North American schemes, regulations are enforced by 'recycling police' who inspect dustbins in order to enforce bans and separation orders. For highly toxic materials, bans are important, but the lesson from successful programmes overseas is that the carrot of incentives and the imaginative use of social marketing are as important as the stick of controls.

8. Material marketing

Recycling in its initial stages is supply-led. It is an alternative way of dealing with waste, and provides materials for which, in some cases, there is no ready domestic demand. In the early 1990s on the West Coast of the USA, plastics piled up in warehouses and were eventually shipped to China. Germany found its supply of old newspapers outstripped the capacity of local reprocessing mills. The separate organic collections introduced in the Netherlands in the mid-1990s led to a surplus of compost, and so on. The story is a common one in the early period of expanded recycling and is particularly daunting for those in municipal recycling facing the market for the first time.

There are three points to keep in mind. First, imbalances of supply and demand are the norm in areas of new growth. This is the way the market works. Planners in the past have tried to limit these imbalances by ensuring that demand expanded in tandem with supply (it was referred to as balanced growth). But other economists (who favoured unbalanced growth) pointed out that these balances were difficult to gauge and that imbalances provided signals for innovation and expansion in unforeseen areas.

This has certainly been the case with recycling: the initial over-supply of recyclate, which resulted in unsustainable exporting or downcycling, nevertheless provided a secure source of material which prompted industries to convert to recycled inputs. The newsprint mills in North America, for example, took five to ten years to realise that recycled newsprint was the area for future growth. De-inking technology developed, and now it is the recycled mills that are earning the returns on Wall Street. The growth of demand for plastics, tyres and glass has followed a similar pattern.

Market development institutions like the Clean Washington Centre, The Materials for the Future Foundation in San Francisco and The Recovered Materials Foundation in Christchurch New Zealand, hasten the transition. Latecomers to recycling can also sell on the growing international market for recyclates. As a general proposition, the supply of recyclate creates its own demand. The initial depression of prices should be treated as a start-up cost and an issue of investment finances rather than an inherent limitation of intensive recycling.

Second, there is an issue of quality. In spite of its supply-driven origins, recycling needs to be designed and managed in relation to demand. In some cases that demand will need to be developed, but in others it is already there and the critical issue is quality. Paper that arrives wet and contaminated at a mill will be rejected. Glass bottle recycling is sensitive to stone and colour contamination. Tin cans recovered after incineration are degraded. In other words, the issue of markets and price is not just a question of external demand but of the quality of supply.

Recyclers should not see the market as a quasi-dustbin for offloading recyclates already collected. They have to be like any other supplier – attentive to quality, to delivery and to the requirements of the market. A good example is compost. The best compost programmes have been market-led. There are a wide variety of compost products, each with a different formula and requiring particular inputs. A good organics scheme should be able to supply composters with the requisite mix and without contamination. Where the supply of compost exceeds market demand, the need to restore soils means that there is still a use. Yet using compost for regenerating agricultural soils makes equal demands on the compost makers with respect to quality, standards and so on. The most common problem with compost is that its level of contamination is such that it is unfit to re-enter the biological cycle.

In these examples, what appears as a problem of markets is in fact a displaced problem of production. Even when local markets are slow to develop, there will always be outlets for good quality products. The only issue is price.

As a general rule, recycling programmes have experienced a secular increase in the level of material prices. For instance, a package of household recyclables in Canada, which in 1990 was worth on average £10-£15 a tonne, has now risen to some £40 a tonne.

There are four reasons for this type of effect:

- new investment that is made in response to cheap secondary materials prices expands demand, thereby pulling up the price;

- the development of new uses of secondary materials (up-cycling), such as glass as a filtration medium, can yield higher prices than feeding the materials back into their original use;

- improved quality should be reflected in higher prices;

- recyclers have found ways of reducing their dependence on the monopoly purchasers who dominate many of the secondary materials markets. In the short run, recyclers have formed supply consortia to improve their market knowledge and bargaining power. Such consortia have also been able to make arrangements for alternative outlets (export markets for paper and glass for example) and to reduce the impact of price fluctuations by negotiating long-term supply contracts at guaranteed prices.

The overall conclusion is that successful recyclers have been market makers as much as market takers. They see material markets not as a barrier but as a competitive space which demands sales expertise and the idea of the 'product as service'.

9. Disposal

Policies for Zero Waste need a strategy for the disposal of the residual waste that is integrated with the expansion of recycling. There are six principles of importance:

- *rapid diversion.* Recycling and composting should be expanded as quickly as possible in order to conserve existing disposal capacity;

- *cleaning the residual.* Priority should be given to the removal from the residual of those substances that are harmful in landfills, notably biodegradables and hazardous materials;

- *pre-treating the residual.* Further sterilisation of the residual can be achieved through establishing modular mechanical biological treatment (MBT) plants (now widely used in Germany, Austria, Italy and Canada), that sort the remaining organics from the residual waste stream and compost them prior to landfill or digestion. These plants should be designed so that they can be converted to in-vessel composting units for separated organics as the residual stream is reduced.

- *waste analysis centres.* Residual wastes should be continuously monitored on their entry to landfills as a form of quality control and a means of assessing the progress of the policies of diversion;

- *flexible disposal options.* Disposal is the safety net under Zero Waste. As such it is subject to multiple uncertainties – of composition and mass and of quantities rising or falling. It is important that the means of disposal be flexible, capable of being rapidly brought on-line, or held in abeyance, with low capital costs;

- *landfill as warehouse.* Landfills should be designed so that they can be economically excavated as technology advances for the further extraction of materials, unless they have been primarily intended to reclaim land using low value inert materials. They can also be used as holding areas for inert materials in temporary oversupply, like green glass.

10. Finance

There are five main features of recycling finance:

(i) *start-up costs.* There are initial deficits in intensive recycling. At the margin, recycling costs money. Municipalities and firms will expand recycling up to a point where market income and avoided disposal costs equal the marginal cost of collection. To go beyond that, by introducing separate collections of organics or dry recyclables, will lead to extra budgetary expenditure. This sets up a budgetary block to transition;

(ii) *declining costs.* Initial recycling costs tend to be at least double those of traditional forms of waste disposal (between £110 and £150 per tonne according to studies of UK recycling pilots, compared to £50-£60 a tonne for traditional waste management). But these costs fall as participation and capture rates increase, and high value materials are targeted. In economic terms, recycling enjoys economies of scale (the more throughput the cheaper the unit cost), economies of scope (lower unit costs per material as higher quantities of different materials are collected), economies of density and economies of communication. The benchmark norm for established collecting and processing of dry recyclables is a gross cost of £70 a tonne;

(iii) *dual income streams.* There are two sources of long-term revenue: core budgetary funding and material income. As the latter rises, the former can reduce;

(iv) *investment in intangibles* rather than fixed assets;

(v) *long-term system viability.* As collection and processing costs fall, income rises and savings increase through reduced residual collections.

What this means is that intensive recycling has almost everywhere required initial finance to launch it. Among the range of sources are the following:

- capital grants or subsidised finance for initial investment;
- grants for intangibles such as the development of information systems, training, and social marketing;
- revenue guarantees for material income;
- operating cost sharing;
- Producer Responsibility payments (as with the Green Dot scheme in Germany and the industry stewardship agreements in Canada);
- transfers of savings in disposal costs (as in the UK recycling credit schemes);
- hypothecated taxes or charges.

This finance has been aimed at two things. First, the incremental transition costs of running multi-stream systems and second, risk management instruments to provide municipalities with income security. In general, systems costs savings have been most readily made when there is unified management of all collection (since this allows the extra costs of separate collections to be partially offset by savings on residual rounds), and when there are means for recyclers to capture the savings in disposal.[44]

Conclusion

Recycling and composting are now taking off in an increasing number of places. The turning point comes when diversion reaches 50% and becomes the principal form of waste management. Those involved by then have confidence in the practicality of recycling. Through experience they have an understanding of the alternative paradigm which has brought them this far and will take them further.

The leading authorities are committed to further expansion. They do not recognise a limit beyond which recycling cannot go. Latecomers have seen this and are setting more demanding targets. Toronto, with a current level of only 24% diversion, has just finalised its plans to achieve 60% by 2006 and Zero Waste by 2010. The leading recycling municipalities now see Zero Waste as a realisable target and no longer just a slogan.

They will not realise it alone. There needs to be change at the front end of production to match the advance at the back end. There are some materials – notably plastics – which have an unsustainably high recycling cost (over £300 a tonne in the case of one Canadian study of plastic bottles, more than ten times the cost of collecting mixed waste), just as there are products which are difficult to recycle. The main drivers in waste reduction will be designers and producers rather than the discard collectors. Fortunately these changes are already in train. Major innovations are taking place in the industrial sector that run parallel to the expansion of recycling. They provide the second route to Zero Waste.

V The Green Materials Revolution

The transformations of the waste industry, though remarkable, are in many ways subordinate to the changes taking place in the field of materials. Like 'smart' recycling they reflect a change in the industrial paradigm.

Every long wave of industrial development, driven by a leading new technology, brings with it its own innovation in materials. Cotton, iron, steel, oil-based plastics and chemicals were the leading materials of previous long waves. The current fifth wave – centred on electronics – is marked not so much by a new material (although modern materials can now be composited for particular uses to an unprecedented extent) as by the pressure to reduce materials and their toxicity.

We live in an age – as far as materials are concerned – that strives for absence. It speaks of 'de-materialisation', of finding ways of avoiding production, of making more with less. Instead of labour productivity, its attention is turned to material productivity as a new frontier of innovation. Its interest is in 'clean production' rather than more production, in quality not quantity. The economy of space (reducing material extraction, minimising transport and cutting environmental pollution) is at long last emerging as a challenge to the long ascendancy of the economy of time.

What we can now see, with hindsight, is that the old mass production model which reached its social and economic limits in the late 1960s and early 1970s was also having problems with its material limits. The volume of industrial minerals, metals, non-renewable organics and agricultural and forestry products in the USA had doubled to 600 million tonnes p.a. between 1945 and 1970. It continued to grow. By 1995 it had risen by nearly as much again,[45] but by then the twin 'thunderclap' of Rachel Carson's Silent Spring and the Club of Rome's 'Limits to Growth', and all that followed from them, had been heard and internalised.

The controversies about waste and what to do about it should be seen in this context. Waste was one of the most tangible symptoms of the material excesses of mass production. Its volumes climbed with growth. The rising resistance to its disposal was one expression of the limit to the old industrial order and contributed to the elaboration of the alternative. Waste reduction is part of the new paradigm now being put into place.

From the time of the Rio Earth Summit in 1992, the full extent to which the environment is bearing on the direction of industrial development is becoming clear. Initially it was particular industries that most felt the pressure of the environmental critique – agriculture, chemicals, energy, oil and mining – and the industries reacted with defensive hostility. But post-Rio, leading corporations have come to recognise that the environment is a more general issue, and that environmental policy propositions can no longer be resisted in particularistic ways. Climate change, the depletion of the ozone layer and accumulating toxicity in land and sea have multiple sources and universal effects.

Eco-efficiency

A significant development in this period has been the expansion of the World Business Council for Sustainable Development (WBCSD), a congress of multinationals which sought to develop a positive corporate view of the environment, 'by business for business'. In 1997 two of its leading members published a major statement arising from the WBCSD discussions, called 'Eco-Efficiency'. It opened with the following explanation of the term:

'Its essence … is contained in seven simple guidelines:

- reduce the material intensity of goods and services
- reduce the energy intensity of goods and services
- reduce toxic dispersion
- enhance material recyclability
- maximise sustainable use of renewable resources
- extend product durability
- increase the service intensity of products

'Following these guidelines can give companies a competitive head-start into the next century – but not if they are treated as an add-on to "business as usual"… Eco-efficiency does require a profound change in their theory and practice of core business activities.'[46]

Like the early manifestos of Taylorism and Scientific Management, this sets out an entirely new way of thinking about production. The WBCSD has become a significant player in the movement to incorporate environmental issues within the industrial dynamic.

All seven of the above principles bear on the goals of Zero Waste. The reticence in the old waste industry to think in terms of Zero Waste is absent in the wider commercial world. 'Zero Waste' has become one of the watchwords of eco-efficiency. In the words of Edgar Woolard Jr, former chairman of DuPont, 'The goal is zero: zero accidents, zero waste, zero emissions.' As noted earlier, the language adopted and the approach is that of Japanese Total Quality Management extended to eco-efficient management.

Major companies have begun to adopt zero targets. Bell Canada, Kimberley Clark, Du Pont, Honda, Toyota, Hewlett Packard, the Ricoh Group and Interface Carpets are all aiming for Zero Waste. Xerox set the goal of 'waste-free products from waste-free factories' and has introduced targets for solid and hazardous waste reduction, air emissions, waste water discharges, low energy usage and the inclusion of 25% post-consumer recycled material in its parts and packaging. Increasing numbers of firms are adopting medium-term waste reduction targets of 50% or more – in parallel with the municipal sector. The eco-efficiency literature is full of examples of firms cutting waste and toxic emissions by orders of magnitude.[47]

Eco-efficiency and innovation

In its early phases of application, eco-efficiency is applied to on-site processes and later to products.[48] This has led to the criticism that eco-efficiency merely provides a 'greenwash' to the existing industrial system. Running a chlorine factory with fewer emissions cannot obscure the fact that chlorine-based products are major sources of pollution as they pass down the chain. Or to take a recent British example, one of the UK incinerators was recently awarded the ISO 140l standard for environmental performance at the very time when it was mixing its highly dioxinated fly and bottom ash, storing it in the open air and allowing it to be used in urban domestic construction projects as a means of waste reduction.

Were eco-efficiency to remain limited in this way, the criticism would be well founded. Yet when a new way of looking at production and product design comes into play, with new touchstones and sensitivities, it is impossible to confine the approach to the role of propping up old production. For a fresh paradigm of this sort opens up whole unexplored territories for development – for technology, for products and for 'productive systems', similar in many ways to those created by electronics. As with electronics, the industrial firms that fail to respond to the new opportunities will be sidelined by the firms that do. By the end of the 1990s environmental performance had become recognised as a key element of the new competition.

Clean Production

Clean production is one way in which eco-efficiency has moved beyond the old. The WBCSD guideline 'reduce toxic dispersion' is the weakest formulation of the seven and reflects the vigour with which some branches of the chemical industry have defended their products in spite of their prevalent toxicity.[49] Yet the pressure to develop green chemicals and alternative non-toxic products has been intense and increasingly successful. Environmental pressure has forced the phasing out of toxic products such as DDT, leaded petrol, CFCs and halons, and the Stockholm Convention on Persistent Organic Pollutants will now target a further twelve organochlorines.

At the same time new products have been developed – as alternatives to banned and threatened substances (examples would be wet cleaning as an alternative to dry cleaning, plant-based inks and dyes, lead-free paint, as well as the remarkable rise of organic and till free agriculture). While the Stockholm Convention covers only twelve out of the 70,000 chemicals now in use, this should not diminish its importance. It lays down a marker for greener production. It shows a readiness to phase out toxic materials whatever their economic significance, and it means the eyes of the world now have the full range of chemicals in their sights.

The commodity-service economy

A second area that is being transformed is that of durable goods. In many of the durable sectors waste has been handled beneath the managerial radar line, since the cost of disposal has been minimal. The introduction of producer responsibility legislation, and demands for increased recycling and resource efficiency, are changing this. Firms are being forced to re-assess their products from the viewpoint of product life and recyclability. A new 'durable' industrial paradigm is emerging as a result, variously described as de-materialisation, the access economy, and the 'servicising' economy. Each of these formulations points to the increasing significance of knowledge-based services to modern production and the declining economic significance of material products.

One of those closest to these changes is Walter Stahel, of the Product Life Institute in Geneva. He and his colleagues outline a picture that is defined not only by absence and the avoidance of production, but also by a whole series of reversals. There is reverse logistics, reverse manufacturing and reverse retailing. There are also many other 're-' words – not only the three Rs (reduce, reuse and recycle), but repair, remanufacture, refine and so on. In this looking-glass economy it is as though all the established processes of production are being connected up to those same processes, going the other way.[50]

Walter Stahel identifies four strategic paths that are being pursued, each running alongside and reinforcing the others.

(i) *production avoidance.* His examples include ploughing at night, which reduces weeds and weeding, zero energy housing, and health maintenance organisations. There are many other spheres of the economy (such as transport, water and of course waste) where production can be avoided through smart systems. At the level of systems, this involves the redesign of 'productive systems' so that they require fewer material inputs to produce a desired outcome.

(ii) *extended product life.* This can be achieved by concentrating on another series of 're-s' – repair, re-manufacture, re-covering, refining and reuse. To facilitate these, increased product life needs to be incorporated in the initial design. For example the cost of repair can be lowered through the modularising of design and the automation of fault diagnostics. The modularising of components across products will help repair and remanufacture. In cases where product life is heavily influenced by changes in appearance (fashion) rather than functional operation, products can be designed to allow for skin changes or re-covering. Dynamic modularisation allows technical advances to be incorporated into a re-covered product.

Activities such as repair can be carried out by the user, but repair is most likely to be expanded if it is made the responsibility of the original producer. If a producer's goal is to extend product life (and the market should be shaped so that there is an incentive to do so), then we should expect there to be an increase in the leasing, rather than selling, of durable goods. Leasing would encourage long life design, and allow the manufacturer to plan the periodic activities such as maintenance, overhaul, re-skinning and so forth, that are necessary for continued product effectiveness. In the case of refining (of oils and solvents for example) renting the substances allows the manufacturer to remove the contaminants so that they can be reused.

(iii) *extended material life*. This is where recycling is relevant. In the case of end-of-life durable goods, recycling involves the reverse engineering of the assembly or flow processes by which they were produced. Industry symposia on the subject discuss such issues as the establishment of disassembly lines, new types of binders (such as glues and solders) that can be readily cracked open, and ways of decomposing composites or replacing them with recyclable materials. These processes are again often best undertaken by the original producers (using take-back, buy-back or leasing arrangements of the original commodities). They can then use more expensive but longer lasting materials (which would otherwise be lost to scrap) and 'learn from undoing' in order to revise product design to ease disassembly and recycling.

(iv) *increased product utilisation.* Many durable products are severely underused. One approach to increasing utilisation is through share schemes, like Lufthansa's car pool, or user friendly hire schemes. Another is through actual or de facto borrowing or leasing schemes. The disposable camera is one example; another would be the supply of equipment from a leasing company on request. These are all means of improving resource productivity, defined as an increase in outcomes per unit of material input.

The commodity-service economy

One of the results of these strategies is the emergence of a 'new service economy' in which manufacturers sell not commodities but service packages to achieve required outcomes. Manufacturing is transformed into a branch of the service sector, producing goods that are judged primarily on their performance as part of a service package.

In the case of energy, facilities managers offer target levels of power and comfort, and then employ an array of technologies in addition to (reduced) energy inputs in order to meet them. Rentokil offers pest control and security rather than rat poison and locks. Dupont is moving from supplying paint to the auto sector to supplying painted car bodies. Xerox supplies copying services. Fleet management offers mobility services for the transport of goods. As with leased buildings and elevators, such product + service provision is established and growing.

These examples largely come from the commercial sector, which is where the new commodity-service economy has first taken hold. It is now extending to consumer goods. Electrolux is supplying 'washing services' to households. Unilever has launched a cleaning service, which it hopes to extend into gardening services, providing the equipment and inputs in each case. A leading oil company is considering renting out oil as part of a lubrication service. Car companies are preparing to sell mobility services, with the consumer renting a given number of miles, supplied through a leased car, with insurance, fuel, maintenance and repairs provided.[51] In all these cases the commodity moves away from the centre of the commercial transaction and becomes what the industrial ecologists describe as 'a service delivery platform'.

One of the factors underlying this change is that so much consumption involves work. Cooking, washing, cleaning, gardening, house and car maintenance, travelling, shopping, child rearing, home caring and household information management are all part of the domestic economy. Toffler called it 'pro-sumption' and it now extends not just to the daily tasks but to self-education, to healthy living, and the management of a household's energy, water and waste.

The rise of commodity-plus-service reflects both changing work patterns and the application of modern technology in the home. Firms are now offering a 'three star' service package or a package of commodities, with guarantees and advice. In doing so they are changing their orientation, placing a premium on the continuing service-provider/customer relationship instead of the one-off commodity sale.

These changes place the responsibility (and risk) for product performance back with the manufacturer. As such they are parallel to the movement towards producer responsibility in waste. Taken together they enable issues of product and material life cycles to be re-integrated with the function of product design, opening out extraordinary opportunities for design innovation geared to increased material productivity and Zero Waste. For once the revenue of service providers is based on outcomes and they take responsibility for risk and waste, they have an interest in minimising both as well as the specialist capacity to do so.

The changes involved in such a shift are summarised in Table 2, drawing on the work of Walter Stahel and his colleagues.

Table 2
Characteristics of the new commodity-service economy

Commodity-based economy economy	**Service based**
Efficiency	Sufficiency
Output	Outcome
Vertical integration of integration of producer and supplier customer	Vertical producer and
Doing things right thing	Doing the right
Labour productivity productivity: resource input per unit of outcome produced	Resource
River economy (cradle to grave) (cradle to cradle)	Lake economy
Cost reduction production based asset management	Performance- management
Flow process and assembly reverse manufacturing	Disassembly and
Global factories	Local workshops
Commodity as inflexible service delivery mechanised service package	Commodity as platform
One-off sale service contracts and guarantees/take-back and buy-back	Long-term
Purchase	Lease
Risk borne by consumer producer (caveat emptor)	Risk borne by (caveat factor)
Individual consumption consumption	Shared
Product specific components components	Standardised
Product-based standards based standards	Performance-
Private and public property and collective responsibility	Rights of access
Material and discard intensive	Zero Waste

The expansion of commodity-service

In 1999-2000 the Product Life Institute undertook a study of the significance of the new commodity-service economy. The results were the following. The EU market for products sold as services in 1998 was 10% of GDP, of which 6% was accounted for by selling the function of products (such as fleet management) and 4% by re-manufacturing (principally in the building and construction sector). The shift to services has gone further in the USA, with a share of products sold as services up to 15% of GDP, and the re-manufacturing of components worth an estimated $50 billion.

The survey of leading edge companies in this field, which was part of the study, reported that they expected to double or quadruple their share of revenue selling services instead of products by 2010. The report concludes:

'If the existing trend continues, we expect to see by 2010 a European economy with a technically and socially perfected material recycling system for waste, in competition with a perfected Japanese "inverse manufacturing" technology sold on a global level to companies that drive a "loop economy" e.g. a multiple reuse of upgradable components and products in a system context; and many US companies selling performance instead of goods on a global level, through a generalised fleet management approach for several product groups which enables them to reach down to the customer.'[52]

Designing for cycles

The trends identified by Walter Stahel apply not only to durable goods. The example of oil and solvents shows the way in which a non-durable good can be changed into a durable one – or, in the new vocabulary, how every commodity can become a 'delivery platform' capable of repeat services, just as materials can be reconceptualised as delivery platforms for a succession of functions.

But there are other cases where the design is geared to switching materials from the technical to the biological cycle. This is one of the aims of the movement to replace the hydrocarbon with the carbohydrate economy, by substituting renewable materials for non-renewable or hazardous ones. Whereas leading economies in the early nineteenth century used two tons of vegetables to one ton of minerals, by 1970 they were using six tons of minerals to one ton of vegetables. Now there are pressures to throw this trend into reverse. The rise of oil prices, the advances of biological sciences, and environmental regulation directed at the polluting effects of oil and mineral-based production are all making vegetable-based products more competitive.[53]

Ethanol production using specialist biomass is likely to have reached 5 billion gallons by the end of 2001, and 10 billion by 2004. Vegetable inks now account for 10% of all printing inks. Lubricants are being made from decomposable vegetable oil. Starch-based biodegradable plastics made from wheat, maize and potatoes are expected to expand rapidly in food packaging (and in the management of waste). The first commercial foams made from soy oil are now appearing on the market.

Because packaging has been one of the first sectors to be covered by producer responsibility, accounting for more than a fifth of domestic dustbin waste, it has been the subject of a wave of innovations, many of them aimed at increasing its compostability. In addition to the starch-based plastic bags, the most recent innovation has been in the use of biodegradable calcium carbonate (chalk) combined with potato starch to produce disposable food packaging (including food boxes for McDonalds). A variant using calcium carbonate with a natural gas-derived plastic has been launched by the former owner of Tetra-Pak, to cut energy in production and reduce waste.[54]

Conclusion

The movement for eco-efficiency began as a managerial tool for environmental improvement. What transpires from the many eco-efficiency initiatives during the 1990s is that examining production from the perspective of materials, waste and hazards rather than simply flow, cost and time provides a stimulus to innovation which may also improve flow, save cost and cut time. Certainly, once external pressures force firms to look at their operations from a Zero Waste/zero emissions perspective, the rate of return on the time and investments involved can be remarkably high.

The eco-efficiency drive has also led to inter-firm collaboration, where the wastes of one producer become the inputs of another (in some instances centred in and around ecology parks) and to the creation of a demand for environmental advisory services and equipment. Eco-efficiency requires its own environmental managers, engineers, auditors and capital goods sector which together constitute a new industry.

The impact, however, has gone much wider than this – to the redesign of materials, products and whole processes of production. The purpose of these many new developments is not confined to waste, but they have major implications for it. Not only are they already creating a means of reducing waste, they are facilitating the way that discards can be reintroduced to material cycles. With some 70% of dustbin waste already being biodegradable, the gradual replacement of glass, metals and plastics by vegetable and chalk-based materials will give a further impetus to composting as a means of recycling waste.

Eco-design, clean chemicals and other aspects of the new biological and material sciences are set to transform the nature and quantity of waste over the next two decades. Factor Four and Factor Ten may underestimate the extent of the gains that will be made. One application of enzyme technology, for example, has allowed milk-whey waste to be used as a fuel, with a Factor 37,000 gain. Leading firms are integrating Zero Waste into the core of the industrial dynamic and moving rapidly up the Zero Waste mountain from the other side.

VI The Transition to Zero Waste

There is no longer any dispute about the need for a new waste order and for industrial processes that radically cut down on their use of fossil fuels and non-renewable resources. The pressures for change are persistent and accumulative. Nor is the feasibility of the alternative any more in question. For anyone doubting the reality of intensive recycling, examples in practice are only a plane trip away. Similarly Factor Four innovation and the new commodity-service economy are no longer subjects for Tomorrow's World. Many of them are already available.

Yet it is one thing to show the technical and economic feasibility of a new way of doing things. It is another to diffuse it beyond the pathbreakers. Those from an old industry commonly cannot conceive how their work could be organised in a different way. The process would not work; it is dangerous and too expensive; consumers wouldn't want it.[55] These interests usually have economic power and political influence derived from the old order. The inherited infrastructure reflects past needs, as does the balance of skills and organisational structures. As a result the advance from one paradigm to another has in the past taken place at the margins, where the old order is weaker.

One type of transition has depended on industrial pioneers who have developed the alternative in the face of such barriers, with market processes then diffusing the successful innovation, and the regulatory regime within which the industry operates being revised to take account of the innovation. In such market-led restructuring, interests seeking to defend old forms of production, even when they have political support, have been brought to heel by the market.

In the last thirty years a new type of environment-led industrial transition has emerged with a different dynamic. The primary innovators have been environmental and consumer movements. They have had some direct influence on the market, through 'green consumption' and ethical investment. But the key channel for change has come when the demands of these movements are translated into government policy and from there into the economy. A new fiscal and regulatory regime is necessary for the environmental economic dynamic to move from the margin to the mainstream. 'Green restructuring' is a politics-led not market-led process, even if it is carried through by a market that has been reshaped by economic instruments and regulations.

In any jurisdiction the tipping point comes when governments signal their intention to introduce new measures reflecting environmental goals. Political statements of intent are an invitation to industry to develop strategies and technologies that reflect these goals. It is then that the dynamic switches to the corporate sector. The new publicly signalled direction means that environmental performance becomes a central determinant of competitivity.

The above applies directly to the waste industry. In all OECD countries environmental movements have played a pioneering role, highlighting the hazards of landfills and incinerators, and proposing a recycling-intensive alternative. In many areas, activists started their own recycling and composting schemes. They have also proposed an alternative regulatory regime. As we can now see from a decade of experience elsewhere, the issue is not the practicality of the Zero Waste option. It is rather the readiness of government to introduce the regulations and price adjustments that will allow this to happen. Contrary to neo-liberal models of the economy, the direction of development in environmental industries such as waste will be determined by the government and the institutional and fiscal framework it sets for the market. It is not a question of government versus the market. The market can only operate within publicly established parameters. The two are complementary not alternative.

What I argue here is that new regulatory regimes for waste are emerging, with Europe now in the lead, which run parallel to increasingly far reaching international environmental agreements. Along with continued pressure from environmental and consumer movements, and the growing recognition of the environmental issues lying behind the agreements, these new public policy directions have led to an autonomous dynamic developing within the market economy. Year by year we can see that the world of waste and materials is moving from an era of pilots and prototypes into one of generalised innovation and diffusion.

A new regulatory regime

In the late 1980s it was not clear in any country whether or how a major shift from disposal to recycling would take place in the waste sector. Public opposition to landfill and incineration had emerged in North America and parts of continental Europe, but the stage of new government regulations had only begun to be reached.[56]

The key date, as with so many other events in East and West, was 1989. This was the year of the EU's Incineration Diretives followed two years later by the revised Waste Framework and Hazardous Waste Directives, which together became the marker for pollution control in Europe. From then on many European countries began to introduce their own laws and policies promoting recycling. Austria introduced its radical Waste Management Act (whose objectives mirror those of the Zero Waste option outlined above) in 1990, at the same time as the introduction of Switzerland's order banning the landfill of unsorted waste by 2000, as well as its beverage container order. Germany passed its packaging law in 1991. In North America the Californian recycling law was introduced in 1989. Seattle adopted its intensive recycling policy in that year. Shortly afterwards, Canada set 50% targets for all states by 2000.

Viewed historically, these were the years when policy opened up. In the USA shortages of landfill space and the difficulty in siting new landfills led to policies to promote incineration. In 1990 the US Environmental Protection Agency forecast that the proportion of waste incinerated in the USA would rise from 8% to 26% in 2000. Yet the degree of public opposition and the rising cost of incineration relative to landfill and recycling has meant the plans have largely been abandoned. During the 1980s and 1990s more than 300 incinerator proposals were halted through local opposition. After a brief expansion in the early 1990s, the number of plants fell from 170 in 1992 to 132 in 2000, and incineration's share of disposal is now back to 7%.

In Europe, Germany was likewise faced with landfill shortages and adopted a plan to build 120 incinerators. Strongly opposed by the Greens, the government managed only two dozen by the end of the 1990s, with many Länder abandoning incineration and turning to intensive recycling instead. The coming into force of the EU's tighter incineration standards led to widespread closures of incinerators and the costly upgrading of those that remained.

For landfill-oriented countries, the scope for an incinerator-led strategy was limited. Instead they turned to intensive recycling. The initial waste diversion legislation of the late 1980s and early 1990s was followed by a succession of national laws and ordinances promoting the new policies. Germany passed a 1994 Product Recycling and Waste Management Act, which focused on minimising the use of products that cannot be recycled or reused and on maximising recycling. This was followed by the 1996 'Closed Loop Economy Act' which sought to consolidate the industrial opportunities opened up by recycling. Austria introduced two ordinances on packaging (1993 and 1996) and on the collection of biogenic waste.

A second group of countries (the Netherlands, Denmark, Switzerland, Sweden and France) had a large numbers of incinerators, principally because of the difficulties of landfill. Landfill accounted for 13% or less of municipal waste tonnages in the Netherlands, Denmark and Switzerland. In these cases, the impetus to change came not so much from landfill shortages as from concern about the hazards of incineration.[57]

From the start of the 1990s, these countries followed a policy of closing or upgrading their incinerators and promoting the kind of recycling that did not undercut the incinerators' needs. Switzerland introduced user pay and producer responsibility legislation in 1995. Denmark implemented policies on the take-back of glass bottles and on construction and demolition waste, and approved an incinerator tax to aid recycling. The Netherlands passed a law in 1994 requiring all municipalities to organise separate organic collections, removing a low calorific material out of the waste stream.[58]

The 1990s, then, was the time for the spread of new environmental waste legislation. In Europe the lead was taken by a number of northern countries. The legislative innovations were then taken up and generalised in an amended form by the European Union.

The thrust of European policy has been in line with Zero Waste. It has had two elements. First the Commission has further tightened the performance standards required of landfill (in the Landfill Directive 1999) and incineration (2001) and is now preparing legislation that ensures that the liability for pollution resulting from disposal facilities is taken by the operators.

Second, it has promoted a shift towards producer responsibility and recycling through the Packaging Directive, the Waste Electrical and Electronic Goods Directive, and the End of Life Vehicle Directive. A Bio Waste Directive is being prepared and a recycling Directive is promised.[59] There is also the prospect of a further extension of the radical producer responsibility Directives, covering other products (such as batteries) and particular materials, like plastics. The latest EU policy signals a shift in emphasis from pollution control to the sustainable use of resources.[60]

These measures set in place a new waste regulatory regime. It has six features:

- strengthening pollution control of waste disposal – both of landfills and incinerators – as well as some forms of composting and recycling, and ensuring that the operators bear responsibility for any resulting pollution;

- a revised fiscal and regulatory regime that reflects the waste hierarchy: taxes, subsidies and regulations are being structured to reflect the generic waste hierarchy (reduction/reuse/recycling/recovery/landfill) and sub-hierarchies within each;

- producer and consumer responsibility: there is an emerging shift of financial responsibility for municipal waste disposal and diversion from the state to producers and consumers (shown in the extension of producer responsibility measures and in systems of 'user pay');

- from mass to niche waste: rather than a general regulatory structure for mixed waste, sub-regimes are emerging for particular types of waste, such as special and hazardous waste, organic and biodegradable wastes, and particular production chains and materials;

- multiple criteria underlying waste policy: traditionally pollution control and local health impacts have been the dominant criteria, but now the impacts of waste management methods on greenhouse gases, soil depletion, and the use of non-renewable resources are taken into account;

- proximity principle: the promotion of local disposal and recycling of waste, as a form of 'community responsibility'. This entails limiting international trade (including internal trade) in waste, and measures against waste dumping.[61]

What is striking about this process is that Europe is now able to gain some of the flexibility of federal states such as

Canada, the USA and Australia. New policies are developed at a regional and national level. They are then diffused through European legislation, but are implemented back through the national governments. This is an open structure, which allows for variety and innovation within an overall strategic framework.

The economic dynamic

The movement to cleaner production and resource economy in the industrial sector has been a response less to this new waste regulatory order, than to the anti-pollution campaigns and regulations introduced over the past thirty years. These have prompted innovations in products and processes and provided much of the impetus behind the $50 billion worth of green industry technology that now exists worldwide. The regulations were directed at particular pollutants (such as lead and CFCs) or at media (clean air and clean water), processes (through improved scrubbing technology) or products (such as numerous pesticides).

Suppliers of the 'cleaner' technologies led the revolution. Many of the large corporations were more defensive, phasing out some products, substituting others, but for the most part continuing their trajectories of growth. The chlorine industry, for example, lost much of its gasoline-additive and pesticide business in the 1980s but recovered in the 1990s through the promotion of PVC plastic.

In the past decade, however, the impact of the resource revolution has widened, and it has developed its own market momentum. In the business sector, the implications (and potential) of the central environmental issues are no longer solely the focus of pioneers of green production and those sectors and places most subject to the force of environmental politics. They are being recognised now in terms of new areas of profitability and a new scale of risk.

One risk is climatic. The cost of natural disasters is forecast to rise to $53 trillion by 2050 primarily as a result of global warming. That cost will have to be covered – at least in part – by the corporate sector. Another risk is the threat of market collapse, where materials or products prove to be hazardous, and lead to compensation claims against their producers. A third is the effect of environmental and consumer 'buy-cotts' and campaigns centred on firms in contentious industries (from oil to life sciences).

All these are forcing a change in the level of corporate response. A window onto this change is provided by the shifting role of corporate environmental managers. In little more than a decade they have seen their job descriptions expand from responding to particular issues (such as pollution incidents or the threat of legislation) to the promotion of cost-reducing eco-efficiency initiatives, to audits and systems design within the context of total quality management, and most recently to the much wider strategic issues of assessing whole production systems against the criteria of 'sustainable development'.[62]

Firms are recognising that they can no longer consider environmental issues simply as external 'threats' or even as prompts to operational best practice, but must consider wider systemic questions. Those that do not respond are now under pressure – from institutional and other shareholders as well as from new entrants. The issue of environmental risk and how it is managed has now entered the corporate bottom line.[63]

The insurance industry is an important source of pressure. It is at the centre of the new 'risk economy'. Without major changes in the way the economy is run, it faces levels of claim which threaten its future and the very concept of insurability. Insurers are now using their market power – through fund managing intermediaries – to make corporations accountable for their environmental practices. In early 2001, for example, Morley Fund Management, a leading UK fund manager owned by the largest UK insurer, CGNU, and managing £100 billion worth of assets – equivalent to 2.5% of the UK stock market – announced that it will vote against the annual accounts of any of the top 100 companies which does not file an environmental report (only 37 currently do so), and abstain on those in the top 250 which are in high risk sectors (including oil and gas, electricity, chemicals, automobiles and construction).[64]

A parallel pressure comes from the pension funds, which are required under recent UK law to disclose in their annual accounts whether they are taking environmental, ethical and social considerations into account in making their long-term investments. They, too, are pressing fund managers to focus on the 'green bottom line' through the use of vetoes at annual shareholder meetings and direct negotiation.

Conclusion

The regulatory and economic dynamics are increasingly marching in step. Producer responsibility initiatives take the process further. Packaging is already being transformed by the impact of regulations. The trends evident in the consumer durable sectors will be spread further by the new EU Directives on electrical and electronic goods and end-of-life vehicles. Those firms considering their ten- and twenty-year strategies can see more clearly the shape of the landscape ahead and are making their plans accordingly.

VII Re-orienting UK waste

The political 'crisis of transition' has come later in Britain than it has in much of Europe and North America. Until the late 1990s waste was not a national political issue. Britain's geology and widespread mineral production allowed a continual replenishment of landfill space. When incinerator capacity contracted in the mid-1990s, landfill was available to take up the slack. There was some local opposition to new landfills, but this was fragmented and lacked a national presence. The environmental movement focussed on other issues such as road building and food, and was in any case weakly represented in formal politics because of the first past the post voting system.

There was, as a result, no strong internal pressure for British waste policy to engage with the new resource economy. While other EU countries have been transforming waste into secondary materials at a level unmatched since the Second World War, Britain remains stuck in the bottom four of the EU municipal recycling league and is in danger of missing out on the economic potential of 'closed loop industrialisation'.

In 1990 the UK household recycling rate was an estimated 2.5%. In line with the turn towards recycling, the Government set a target rate of 25% by 2000. By the time of the next White Paper in December 1995 ("Making Waste Work") the rate was estimated at 5%. The White Paper was still confident, however, that the 25% target could be achieved by 2000 and set a range of other targets for particular materials.

The results are now in for the target year 2000. Household recycling has risen to 10%, still at the foothills of the S curve, and less than a quarter of the rates of leading continental countries. Only Portugal, Greece and Ireland in the EU have lower figures than the UK. If Britain were an American state, it would find itself seventh from bottom of the interstate recycling league.

For individual materials the picture is similar. In the case of packaging materials – which had been targeted for recycling by many countries and by the EU – Britain still only recycled 27% from all sources in 1998 (bolstered by paper and cardboard from the commercial sector), way below most other European countries (see Tables 3-5). In 1998 the UK recycled 38% of its aluminium cans as against 89% in Switzerland, despite having the largest aluminium can recycling plant in Europe. By 1999 Britain was still only recapturing 25% of its glass containers compared to 93% in Switzerland, and 30% of its steel packaging as against 80% in Germany.

In the construction sector, the UK rate of recycling of 43% is less than half the 90% achieved in parts of Denmark and now adopted as a national target by 2005 in Holland. In newsprint, which has traditionally had higher rates of recycling, Britain is noted for having the largest untapped supplies of old newspapers of any country in Europe. Composting organic waste remains a marginal activity in both the commercial and household sectors, with only 80 centralised compost sites compared to more than 1,000 in

Table 3 European steel packaging recycling

Country	Recycling rate 1999 (%)
Germany	80
Netherlands	78
Austria	75
Belgium	70
Luxembourg	69
Switzerland	66
Sweden	62
Norway	59
France	47
Spain	32
UK	30

Source: APEAL in FoE 2001

Table 4 European aluminium can recycling

Country	Recycling rate 1998 (%)
Switzerland	89
Sweden	87
Germany	86
Finland	84
Norway and Iceland	80
Benelux	66
Austria	50
UK	38
Spain	21
France	19

Source: European Aluminium Association in FoE 2001

Table 5 European container glass collection

Country	Recycling rate 1999 (%)
Switzerland	93
Netherlands	86
Austria	84
Sweden	84
Norway	83
Germany	81*
Finland	78
Denmark	63
France	55
Portugal	42
Italy	41
Spain	40
Ireland	35
Greece	27*
UK	25

Source: FEVE in FoE 2001 *1998 figures

Germany.[65] Only 8% of household organics in England and Wales was centrally composted in 1999/2000, principally garden waste taken to CA sites.

As a result of this poor recycling performance, the lead in developing new sorting and processing technologies has been taken by North American and continental European countries. Germany, Holland, Scandinavia, Canada and the USA dominate the international trade fairs in these fields. In the case of electrical and electronic goods, for example, the reluctance of the UK Government and UK firms to move on producer responsibility until the EU required them to do so means that other EU countries that introduced national legislation early have been given a ten-year start in developing the requisite technology. The same thing has happened in closed vessel composting, in the electronic sorting of plastic and paper, in the technology for recycling container glass and in a wide variety of new uses for recycled material that have been developed in North America.

On any count, British recycling policy is a case study in failure. The targets set for municipal recycling were half those of more ambitious jurisdictions, and only a third of the modest targeted increase was achieved. If a school or hospital had failed to reach its targets to this extent it would no doubt be subject to Special Measures. But in the case of waste, the Special Measures need to be applied to the government itself.

If things are to change, the starting point has to be a recognition of the reasons for failure, and the need for a quite different policy approach. It is not as though civil servants were unaware of the environmental advantages of recycling, or of the principal reasons why it has remained so little developed. In the second half of the 1990s there were numerous national and international studies on the subject, and on policies which had been successful in stimulating recycling elsewhere. The question is why so little came out of them, and why the international examples of successful recycling were read less as a guide to good practice than as exceptions that could not happen here.

The explanations of policy failures of this kind usually include failures of political will, the conservatism of the British civil service, and the power of threatened economic interests. In the case of waste, none of these is sufficient. The two environment ministers in the second half of the 1990s, one Conservative and one Labour, were both committed to increasing recycling and did what they could to advance it.[66] Many of the civil servants involved played a central part in one of the most radical periods of British government. And as for economic interests, the traditional waste industry does not have large numbers of sponsored MPs or an economic presence that carries weight in the calculus of politics.

Rather, two wider questions should be examined: the first is the type of policy and institution necessary for environmental transition; the second is the model of government that determined the way issues were approached during the 1990s.

(i) the process of transition

For a new waste order to become established, there must first be clear directives from government and/or incentives strong enough to force old institutions to change and attract new entrants to the industry. In the UK there has been neither. The non-mandatory targets set for household and commercial recycling during the 1990s were largely ignored, and the structure of incentives was such that it is surprising that recycling increased at all.

The economic point is the important one. The first and immediate reason why recycling targets have not been met is that those involved in the management of waste have had little incentive to promote them. In terms of the commercial market, as it is currently structured, only low level recycling can break even, and even then it lies at the bottom of the hierarchy of profitability. In the words of one financial analyst of the waste sector, "Recycling remains a commercial leper in the UK".[67] Since intensive recycling also demands a profound change in industrial organisation and methods as well as cutting into the industry's core business, it is a triply unattractive proposition to existing waste companies. Not surprisingly their focus has remained on mass waste collection and disposal.

From a municipal perspective, intensive recycling has been seen as prohibitively expensive by collection authorities and saves no money for disposal authorities, since the money saved by diverting waste from disposal has to be passed on to the collectors as recycling credits. Nor have disposal authorities welcomed a proposition that threatens to shift the axis of waste management from disposal to collection, and thus undermine their traditional function.

As a result, collection authorities have by and large restricted recycling to what can be afforded with a balanced or small incremental budget, using low cost methods of bring banks and/or periodic kerbside collections of the most marketable dry recyclables. Few have been able to afford three stream systems or provide the working capital necessary to benefit from the resulting 'system economies'. For the most part they remain caught in the low-level recycling trap.

Major waste companies and disposal authorities, for their part, have confined recycling to bring schemes at CA sites and to methods that fit in with the traditional way of doing things. They have not promoted recycling but have introduced it only when required to do so as part of a larger contract or in response to regulatory requirement. They favour capital-intensive sorting and composting plants, with limited source separation, and large collection vehicles. They have not invested in social marketing and frontline advisory services, nor in the management information systems required by 'smart' recycling systems. The result is relatively poor participation and capture rates and low levels of recycling. Organising recycling using the old methods has led them to see recycling as difficult, expensive and limited in what it can recover.

Although kerbside collection has expanded in the past five years, it still accounts for only 3% of household waste. The bulk (71%) of the household recycling that has taken place has relied on householders travelling to bring banks and CA sites.

The 1990s have seen substantial change in the waste industry: in the technology of landfills and incinerators; in the beginnings of new forms of pre-treatment of waste; and in the concentration of ownership in the industry. But the response to the new regulatory regime emerging from Brussels has been within the framework of the old waste paradigm. Thus the requirements of the Landfill Directive to divert biodegradable waste from landfill (65% of 1995 levels by 2020) have been primarily considered in terms of mixed waste treatment alternatives rather than the development of intensive source-separated recycling. The provision of capital intensive mixed waste treatment plants means that the forms of collection, compaction, transport, labour and contracting can be left largely unaltered. Change is confined to methods of disposal and their technologies. Administratively, the planning and organisation of waste disposal is able to continue as before.

This is why the new taxes, regulations and charges that lie behind the changes of the 1990s have been accepted without demur, even when in the case of disposal authorities, they have led to steeply increased costs. For the waste industry, disposal authorities, central Government and waste consultants, business has been able to continue as usual. Like Lampedusa's Prince, they have embraced change so that things can remain the same.

It is not that the waste industry or the waste profession will not take up recycling; rather that the returns must be such that it worth their while to restructure their assets and skills. Strikingly, one of the major UK waste firms has invested heavily and successfully in recycling and composting operations in Belgium and the Netherlands, where returns are high, while remaining oriented to disposal in the UK where the incentives are absent. Another of the waste majors has gone further, redefining its long run strategy as secondary resource management, but has been restricted by perverse waste markets and institutions from putting this into practice.

So a change in incentives is the first necessary condition for a transition to Zero Waste. To speed up the change it is also necessary to have transitional institutions, unencumbered by past interests and outlooks, to provide the knowledge and resources required by the new paradigm. Five types of institution have been important for the development of Zero Waste programmes elsewhere:

- those promoting new uses of secondary materials, and innovative market instruments;
- those supplying know-how in waste reduction and the establishment and operation of high capture/low cost recycling systems;
- those forming a new resource-oriented profession (such as training and management programmes, research centres and professional journals);
- champions of clean production and pollution control (through a network of testing centres, laboratories, research institutes and consultancies); and
- those providing transitional finance.

The first four of these are means of introducing the knowledge economy into traditional waste management, and until recently were either non-existent or ill developed in the UK. The fifth has taken a variety of forms overseas – direct grants, price supplements, investment finance – and is directed to provide start-up capital in a sector in which neither government departments nor private financial institutions have the instruments or knowledge to function effectively.

(ii) light government

The above list summarises the requirements for switching Britain from a waste disposal to a ‘closed loop’ resource economy. It poses a challenge to government, which during the 1990s was largely sidestepped. The reason was not to do with individuals but rather with a distinctly British approach to governance.

In the case of waste, there have been two forces shaping policy:

- the neo-liberal model of government that developed during the 1980s, which sought to reduce the role of the state and commercialise wherever possible the administration of government and public services;
- the trends in EU environmental policy that ran against such precepts by requiring more regulation, less trade and increased environmental taxes.

In the former, government took a back seat in determining how a sector developed; in the latter it became the driver. The tension between the 1980s model of government in Britain and that of 1990s Brussels – a tension which is still at the heart of British politics – is present also in the governance of waste.

The problem faced by the administrators was how to translate Brussels directives and their consequences into a neo-liberal framework. The result, as elaborated in successive white papers and policy guidances, had five features:

- *non-directive government*. The White Papers showed a reluctance to direct industry or local government as to the direction of their waste management. They set down criteria to inform those choices and established indicative parameters through non-mandatory targets. But the final ‘mix’ of waste management options was not to be determined from the centre. It would in any case vary with circumstance and should be judged against the principle of the Best Practical Environmental Option (BPEO).

- *marketisation.* All waste should be managed 'on a commercial and competitive basis', which meant enforcement of compulsory competitive tendering and the commercialisation/privatisation of local authority waste disposal operations. It also meant that those responsible for waste should have to pay for it ('the polluter pays'), substituting a market where possible for the tax/subsidy-based administration of household waste. The prices that ruled in such markets should, however, be adjusted to reflect the external costs and benefits of alternative means of waste management. This was the justification for the Non-Fossil Fuel Obligation (NFFO) as applied to energy from waste that ran from 1989, and for the landfill tax introduced in 1996. Where targets were compulsory as the result of EU Directives, quasi-markets were introduced to increase flexibility. The system of Packaging Recovery Notes gave 'obligated' firms a range of options in meeting their targets, and was seen as an instrument to achieve equilibrium between rising targets and the supply of recyclables. Similar proposals have been made for the trading of landfill permits.

- *private financing.* In parallel with this process of marketisation, direct government grant programmes were restricted. Instead the government used its fiscal and regulatory influence to re-route the flow of private funds. Thus in the case of waste, the NFFO was a charge paid by electricity supply firms to the operators of energy-from-waste (EfW) plants; the landfill tax credit scheme was a payment by landfill operators to environmental trusts; the Packaging Recovery Notes (PRN) system channelled money from the 'obligated parties' that produced and sold packaging to material reprocessors. These were innovative forms of finance, that effectively privatised the tax and spend function of government, subject to government guidelines. The expansion of the Private Finance Initiative (PFI) in the late 1990s followed a similar principle with respect to the funding of public capital projects, although in the case of waste it needed substantial public subsidy to make it work.[68]

- *restricted regulation.* Regulations were limited to tightening the standards of landfill and incineration, and were not used to promote recycling or composting. The enforcement of regulation was centralised in the Environment Agency in 1996, as was the planning function for new waste facility proposals as they related to environment and health.

- *information.* Market models acknowledged that imperfect information could restrict the efficient working of markets (and the operability of targets). The government therefore undertook to promote the ideas of waste minimisation and improve data on waste arisings and composition as well as diffusing information and advice about waste minimisation in the industrial and commercial sectors.

The most interesting part of this approach in practice is how it handles those areas of policy where there are state requirements – principally as the result of European Directives. In the case of pollution control, regulatory regimes were established in close consultation with industry. They left scope for a considerable degree of self-inspection under a generalised duty of care. The Environment Agency, as the guardian of environmental health on behalf of the government, has interpreted its role as a narrow enforcer of regulations rather than a pro-active promoter of good environmental practice.[69]

Where the Directives set compulsory targets (as with the Packaging Regulations and the Landfill Directive), their application in the British context was put out to extensive consultation, and trading mechanisms proposed which increased the flexibility of those subject to the targets. In this way, the market was introduced into the process of target enforcement.

The important point to note is that while the EU issued Directives, the UK Government acted as a diffuser of direction. It neither wanted to, nor did it, take the lead. The 1995 White Paper, 'Making Waste Work', was explicit in saying that leadership in waste policy should be provided by the market and not by the government.

The principal role for the government was to establish the means of decentralising how waste is managed and financed, and how resources are distributed. Decisions about direction and operations were to be left to the market or the agencies, within guidelines and parameters established at the centre. It was and is a subaltern model of government.

The limits of light government

The British failure in recycling has highlighted four major flaws in this model of government. First, at a time when there were clear signals that the old waste order could no longer continue, the lack of government leadership on a new direction and of an explicit government goal for waste, left those involved in the old waste industry, as well as others who might participate in the new one, unclear about the future course of government policy in a sector whose direction is determined by government. The market cannot lead in the environmental field when the parameters within which the market works are set by government fiscal and regulatory policy. The market has to be 'made' before it can be a maker, particularly in an area like waste, which requires the industry to change so radically, and new types of industry to emerge. Neither established firms nor new entrants are likely to invest heavily in the closed-loop economy if they are not clear how far a government wishes recycling to go.

The hole at the centre of policy has also had consequences within Whitehall. There has been no coherent approach running across government. As a result, throughout the 1990s, government was fragmented. Departments pursued their own interests, often in conflict. The Department of Trade and Industry (DTI) promoted incineration as an easy way of meeting renewable energy targets rather than encouraging recycling industries as part of a green industrial strategy. The former Department of the Environment, Transport and Roads (DETR) developed its climate change strategy and its policies on regeneration with only passing reference to waste – a lack of connection even within a single Department. The Treasury resisted hypothecation of the landfill tax to permit public sector support for recycling within the central government budget, and left the problem of initial financing unresolved.

As in the time of a weak mediaeval king, the lack of leadership left power in the hands of contending public and private baronies, none of which had an interest in advancing the new economy. The only coherence was provided by Brussels. Their Directives have become the principal drivers of waste policy in the UK. Lacking confidence in innovation, Whitehall has been preoccupied with how to manage the Directives within the context of the British model of light government and the multiple conflicting interests. Britain has not only remained a follower in waste policy, but has acted as a conservative force in the formation of the Directives themselves, arguing for lower targets, extended time periods, and in some instances discouraging Directives in the first place.

Secondly, the lack of a government identity has meant that it has looked to the established interests to advise on ways to meet the Directives put out by Brussels. The advice that was given has been in terms that reproduce the existing structures. It is not a question of policy being private sector- as against public sector-led, but rather one of how to introduce policies which require major changes in both the public and the private sectors. The issue is old and new, not private and public. In transitions of this kind the problem is that the new has yet to be established. In the endless round of consultations, the interests of the new are barely there to consult.

What this has meant is that the setting of the parameters and the construction of markets – which are the key independent variables in the model of light government – have not been independent at all. Prices in the waste market have not been adjusted to reflect externalities, nor have the flows of public and private resources redirected by government. Neither have planning procedures remained independent. Rather, they have been determined by an implicit policy that, far from encouraging recycling, is in danger of setting limits to its expansion and to the economic and environmental opportunities it opens up.

Thus on the one hand 'light government' has argued that waste policy should be led by a market adjusted to take into account environmental externalities. On the other, the market has been adjusted to reflect a policy formed to meet the Brussels Directives, in consultation with an existing public and private industry whose traditional interests could only be changed by a radical revision of incentives. There is a circularity here. The system of incentives that could help transform an old industry into a new one is set with the advice and on behalf of the old industry to reflect what currently exists. This is the source of the deep conservatism at the heart of British waste policy: it is to be found neither in the civil service, nor in the waste companies, nor the disposal authorities, but rather in a system of government that as far as waste is concerned cannot accommodate the force of the new.

Thirdly, it is finance and statutory regulations rather than indicative targets and information that have influenced the conduct of the industry. As many local authority waste managers pointed out, the 25% recycling target for 2000 was not mandatory and therefore had low priority in cash limited councils. The provision of improved waste data (however necessary) made little impact on waste strategy, nor did the production of recycling plans. Regulations are only as strong as their enforcement and penalties, and both have been weak. It is compulsion and cash – whether in the form of grants, subsidies, taxes or penalties – that have changed behaviour. They need not be alternatives – regulation versus market instruments – but can be linked to each other, as the permit mechanism illustrates.

Lastly, the experiments with privatising the government's public financial functions have each been problematic. The most notorious has been the Landfill Tax Credit scheme. Under the scheme, the Treasury forgoes up to 20% of the revenue due from the tax, if the landfill company chooses to pay the money to an environmental trust for a range of specified purposes. This is a variation on eighteenth century tax farming – in this case the government farming out grant giving to the owners of landfill.

Not surprisingly, the scheme (which is worth £100 million per year) has been subject to gross abuse. Landfill companies and their trade associations have established their own trusts, which they have used to advance their interests (including waste-related road building, research on landfilling and the promotion of incineration). They have used the grants for targeted PR, and have restricted sums going to recycling and to community competitors. Local authorities with access to the funds (for example through clauses in disposal contracts) have used them to finance public services. All this has happened in spite of provisions designed to restrict both the waste companies and the local authorities from abusing the funds. Given the Treasury's concern to control public spending and link it to outcomes, it is astonishing that some £400 million, which would otherwise have been paid to government over the five years of the scheme, has been allowed to be used on miscellaneous projects or the promotion of waste company interests.

The second experiment, the issue and sale of Packaging Recovery Notes, designed to implement the packaging regulations, has also faced difficulties:

- *conflicts over information.* The scheme depends on accurate figures for the quantity of packaging in the waste stream, both in aggregate and for each 'obligated party'. As might be expected, the amount declared by the industry has been less than that estimated by the Environment Agency, and has given rise to lengthy haggling between the two;

- *minimising costs, not advancing a strategy.* The scheme was established not to contribute to the costs of conversion by funding kerbside collection schemes of domestic packaging as in Germany, but to minimise the costs of complying with the EU Directive. This has meant that the targets up to now have been loose, and have been met largely from industrial and commercial waste and more recently from expanding bring banks for domestic waste. As the Chief Executive of VALPAK put it, 'There has been an excess of supply over demand, so therefore the targets, you could argue, have not been tight enough. They should have been set much tighter in retrospect.'[70] The scheme has been successful in its purpose of cost minimisation. UK packagers are contributing less than one-tenth as much as their German counterparts. But Britain's packaging recycling has only increased modestly since the scheme was started (see Table 6).

Table 6 Estimated packaging recycling rates in the UK 1998-2006(%)

	1998	1999	2000	2001	2006*
Aluminium	13	14	15	18**	50
Steel	25	30	32		
Glass	23	27	33		70
Paper	47	47	49		60
Plastic	8	12	12	18**	20
Wood			44		N/A.
All recycling	29	33	36	45	60
EfW	4	5	5		-
All recovery	33	38	42	50**	60

Source: DEFRA Consultation Paper on Packaging, Sept 2001
* amended option targets from EU ** minimum target

Britain's packaging recycling rate is less than half that of Germany and there is doubt whether it will meet its legal recovery target by the end of 2001.

- *sidelining local authorities.* The scheme was set up explicitly to marginalise local authorities. Money was paid into the scheme by the packaging-related firms in the form of the purchase of packaging recovery notes, a marketable certificate issued by processing firms to say that they had received secondary materials for recycling. This was in effect a quasi-money, and processors were given the profits of the mint. They did not have to give these notes to local authorities that supplied them with materials, only to industry bodies representing the packagers if they supplied recyclable materials. The result is that economic power in this quasi-market has been placed in the hands of processors and the 'obligated' packaging firms,[71] and few of the contributions that have been paid out have gone to local authorities. Much of the profit has remained as a windfall to processors who were already receiving substantial flows of recyclate.

The third scheme, the Private Finance Initiative (PFI), has been even more problematic. As studies undertaken for the DTI pointed out, the construction of large waste facilities, particularly incinerators, was in any case almost all undertaken, owned and financed by the private sector, and underwritten by a local authority-guaranteed gate fee. It was difficult therefore to argue that there could be an extra productivity advantage from private provision using private finance when this was already the norm in the industry. Until September 2000, the seven PFI schemes that had been approved provided large subsidies for incinerator-led packages of provision, whose impact was not to encourage private finance into formally publicly financed projects, but to introduce a bias towards capital-intensive waste plant, contrary to the knowledge-intensive needs of recycling.

All three schemes have similar characteristics. They are innovative experiments in privatising the functions of public finance, they have (with the partial exception of PFI) kept down the size of the public sector budget, and they have each led to a serious squandering of an estimated £1 billion of resources that could have provided the finance necessary to fund the conversion to recycling.

Conclusions

The argument of this chapter is that Britain's failure in recycling is primarily due to the model of light government in place throughout the 1990s. The traditional waste industry cannot be expected to introduce innovations when the incentives are perverse and recycling threatens established functions and interests. It was the responsibility of the government to change the incentives and promote institutions that had an interest in and commitment to the change. Yet it was reluctant to take this on, save when forced to do so by Brussels. What is surprising is that a model of government that is primarily economic in conception failed to address the perverse system of incentives that has been at the root of the problem.

Given this administrative context, and in the absence of a politically significant external environmental movement, no British Government in the 1990s was able to establish strong targets or innovative institutions which would drive the transition to a new waste paradigm. UK waste policy remained oriented to problems of disposal and to the formal fulfilment of EU Directives. As a result Britain finds itself tied to a policy that is now threatening to abort intensive recycling and Zero Waste for a generation.

VIII The integrated option

As a result of the failure to expand recycling, an alternative policy emerged, which came to govern both central government policy and that of the great majority of waste disposal authorities in the UK. It now stands blocking the path of intensive recycling, and is the focus of increasingly bitter dispute throughout England, Wales and Northern Ireland.

The policy is similar to those advanced in the face of perceived landfill shortages in the USA and Germany in the late 1980s. Its centrepiece is the construction of a new generation of incinerators. Estimates of the numbers required vary. The Environment Agency's regional waste plans forecast the need for capacity of 18 million tonnes annually, an eightfold increase on current incinerator capacity of 2.3 million tonnes. This is equal to 60 plants of 300,000 tonnes each, or 90 plants of 200,000 tonnes. The model drawn up for the government's Waste Strategy estimated that between 94 and 121 new incinerators of 250,000 tonne capacities would be needed if municipal waste continued to grow at 3%, compared to the 132 estimated in the Landfill Directive RIA model, assuming the same rate of growth and plant capacity.[72]

The forecast numbers vary with the assumed rate of growth, but since incinerators have a lead time of seven to eight years, the municipal waste plans and contracts now being put in place usually assume a 3% rate of growth in their forecasting (in line with municipal waste arising over the past five years) and estimate the size and number of incinerators accordingly.

Given current government planning guidance and the requirements for diversion from landfill, there are few disposal authorities that have not included incineration or some other form of thermal treatment in their long-term waste plans. It suggests that the range of 94 to121 new incinerators given in the Waste Strategy model is the likely outcome in terms of present planning and contract strategies. What this amounts to is a proposal to build incineration capacity of between 27 and 33 million tonnes per annum, sufficient to take all the municipal waste which is now produced.

The current evidence from waste disposal authorities and their unitary counterparts throughout the country is that at a time when a new regulatory framework for minimising waste is being put in place in Europe, and when incineration as an industry is stagnating internationally, Britain is set to embark on the largest new incinerator building programme in the world. Investment costs for a programme of this size are estimated at £8 billion. The waste contracts attached to them have a forecast value of £50 billion. In pursuing this path, Britain now finds itself running against the political, regulatory and industrial tide.

The focus on incineration is the other side of the failure to develop recycling in the UK. Faced with the targets of the Landfill Directive, neither the government, nor the disposal authorities nor the major waste industry see that it is possible to meet these targets with recycling alone. Each presents a similar picture: a graph showing the past five years trend line in municipal waste extending to 2020; a second line describing the landfill diversion targets over the same period and a third one showing the maximum likely level of recycling. Between the assumed level of recycling and the targeted levels of diversion is a gap, one that it is suggested can only be filled by incineration or a similar form of capital-intensive treatment.

This simple model of forecasting is now driving waste strategy at every level in Britain. It has come to be known as the 30:50:40 model, with recycling usually accounting for 30%-35% of total waste arisings (40% in the more ambitious schemes), processing for 40-60%, and landfill for 30%-50%, the totals adding to plus or minus 120% because of the need to process and then landfill part of the residual waste.

The strategies based on this model are referred to as 'the integrated option'. They comprise the three elements of the forecasting model:

- low-road recycling, in the form of mixed waste recycling, bring banks and supplementary multi-material kerbside collections;

- an expansion of some form of mixed waste treatment (principally incineration, supplemented by other types of thermal treatment, and/or anaerobic digestion);

- continued landfill, since all these treatment methods have substantial residues that for the most part are unacceptable as recyclate (incinerators have a bypass of incombustible waste plus ash that amounts to 45% of the waste tonnage for treatment; mixed waste composting produces a low quality output which at the moment is not permitted even as landfill cover).[73]

The standard arrangement is for all three to be combined in a single municipal contract running for 20-25 years. To guard against possible shortfalls in the supply of waste for the incinerator, they are required to include minimum tonnage contracts and a guaranteed gate fee, on the basis of which the contractor can raise finance for the construction of the incinerator. Contracts of this kind effectively protect the financiers and operators of the facilities from the dangers of waste diversion, and from competitors for waste. Where this has not taken place, as in a number of the US states, in Germany and in Switzerland, incinerators have found themselves short of waste and have had to import waste or, in some cases, to close down.

The timing and length of the contracts are determined by the incineration component, as are the companies who bid for them. Only the large old-order waste firms are in a position to bid for and operate a contract of this size. To date this has meant that the recycling and composting components are provided as large-scale facilities established to meet the targetted requirements of the contract.[74]

The attraction of these arrangements for the existing order should be immediately clear. The priority given to disposal, to fixed investment, and to technologies for mixed waste treatment all fit within the existing organisational and technical paradigm. In this sense they appear to be a more reliable option than recycling. Combined in a single package, they are easier for a disposal authority to administer than multiple 'unbundled' contracts, they are more straightforward to finance, and they confirm the disposal authority as the dominant institution in the management of waste.

There are, however, profound environmental problems with this option:

- waste is still viewed as 'end of pipe' and managed from the vantage point of the terminus of linear production. In spite of the new language of resource recovery and waste minimisation, the driving problematic of the industry remains disposal;

- the mass production paradigm which governs the industry cannot cope with the complexity of the processes required to achieve high material and energy productivity;

- thermal treatment, by whatever method, remains problematic because of the fluctuations in feedstock and the control of hazardous emissions to air, water and land that are produced;

- the traditional model of environmental regulation, which is designed to reduce the hazards of waste disposal, is itself limited, reflecting as it does the old paradigm of production that it is seeking to control.

These limitations leave the strategy open to criticism on all three of the main environmental criteria. Pollution problems are not eliminated. The majority of recyclable material is still lost to disposal, as is the grey energy contained within it.

The integrated option is a way of preserving a modified 'business as usual' at substantially higher cost. It represents a major environmental opportunity foregone.

There are also a number of practical problems:

- incinerators are unpopular. The strength of anti-incinerator feeling and its political consequences is one of the main reasons why the building of incinerators has virtually stopped in English-speaking countries and why previous national programmes to use incinerators to fill the gap between expected waste growth and recycling have had to be abandoned. As the waste industry acknowledges, only one new incinerator has been built in the UK in the past ten years;

- the current and future Directives extending producer responsibility and promoting recycling and composting threaten the size of the residual waste stream. By 2010 the achievement of the proposed level of recycling for packaging, increased recycling of newsprint and the separate collection of organics as set out in the draft for the Bio Waste Directive are likely to cut the residual waste stream by 50%, irrespective of other methods of reduction. The risks entailed are borne by the disposal authority;

- the costs associated with other fiscal and regulatory changes also fall to the disposal authority, as the cost of incinerator upgrades have done in the past. Possible changes of this kind include: further upgrading of emissions control; the reclassification of incinerator fly ash as hazardous and bottom ash as special waste; further increases in the landfill tax; the introduction of a tax on incinerators as part of a more general disposal tax; the declassification of pyrolysis and gasification plants as sources of renewable energy; and increased costs to the operator of more rigorous enforcement, including the introduction of continuous monitoring and compulsory public liability insurance for incinerator operators;

- single contracts over 20-25 years bind an authority in to a waste company which may be competent at managing an incinerator, but is not an effective operator of recycling and composting plants. The contracts present a long-term barrier against the adoption of current best practice in recycling and composting technology, where it is not in the interests or the capacity of the contractor to adopt it.

The costs entailed in these risks and rigidities fall outside the gate fee settled in the initial stages of the contract. If they were factored in, for example through mandatory insurance, then the thermal treatment options would be likely to become prohibitively expensive.[75]

From the viewpoint of Zero Waste, the primary drawback of the integrated option is that it places a cap on the expansion of recycling. This is not just a formal cap, based on the percentage of waste guaranteed to the incinerator. Nor is it just a question of a conflict over materials – although an incinerator will seek to preserve recyclable paper and plastic which raise the thermal value of the combustible waste stream.[76] The real issue is that long-term 'integrated' contracts centred on an incinerator preclude the development of the new approach to recycling and clean production that is the subject of this book. Incineration and Zero Waste represent two alternative paradigms that are in continuous tension.

The principal case for the integrated option is that high levels of recycling are impossible. Even were levels of 60% to be achieved this would still leave 40% of the waste as residual, which would need some form of treatment, not least to meet the EU targets. Depending on the assumed rate of waste growth, the required incinerator capacity could be assessed and the size restricted in the contract. This is the core argument. Other parts of the case – about the composition of municipal waste, the assessment of overseas experience, and the likely rates of waste growth – follow from that.

As presented to planning inquiries, citizens' juries, parliamentary debates and Select Committees, the integrated option has raised other, wider issues, such as the relative costs and safety of incineration compared to intensive recycling, and its relative environmental value. Table 7 summarises the arguments presented for the integrated option and those advanced for intensive recycling.

In the end, however, it is not an issue of costs, or environmental and economic benefit. Few people now claim, as many did in the 1990s, that incineration is on a par with recycling in the waste hierarchy. Those arguing for the integrated option can readily agree that recycling and composting are environmentally preferable to incineration, that they generate more jobs, that they cost less in the long run and that they are more popular and create space for citizen involvement.

For the advocates of incineration these points are not relevant, since incineration and recycling are not in competition. As they stress, incineration takes over where recycling stops. The only point at issue is a practical one: namely the maximum level that can be expected for recycling. This defines the point at which the integrated option begins, since it is driven by one overriding question – namely what can be done with the residual.

At the moment there is an impasse on the issue. Those responsible for disposal are incredulous that recycling rates of 40% let alone 60% can be achieved in the UK.[77] Consultants' reports have been commissioned to examine the robustness of claims to high recycling, and to identify supposed reasons why they are not applicable here. The excuses are varied: one high performer has user pay (Switzerland). Another has large suburban gardens (Canberra). A third is small town/rural and not comparable to large urban areas (Quinte). A fourth includes large quantities of commercial waste in its municipal totals and the results cannot be compared. A fifth may be a city but it is Canadian or German and the culture is different from that in Britain.

These inquiries are defensive. They are not intended to learn from best practice in order to adapt it here at home. Their aim is rather to establish a limit to recycling (whether 40% or 70% of the waste stream is in a sense immaterial), so that a planning space is defined in which disposal options can be pursued in isolation as before. The maximum recycling rate forms a frontier between two separate economies, which are not operationally integrated at all.

Behind the studies of recycling rates, waste growth and landfill capacity, lies a quest for certainty – the certainty needed for planning long life, capital-intensive, inflexible facilities. But if one thing is clear from all the discussions of the last five years, it is that so little is certain.

I have already touched on some of the uncertainties with respect to technology and regulation. There is, too, uncertainty over waste growth, over its future composition, over the changing nature of materials, over the extent and impact of producer responsibility, and of the hazards associated with different forms of waste treatment. We do not know where the corporate attention to Zero Waste will lead, or the shift to biodegradable packaging, or to home delivery and take-back, any more than the Germans could have predicted in 1990 that their waste would fall by 36% in six years and that their incinerators would be starved of waste.

Equally, there are uncertainties about recycling and composting. It may be that the systems of Canberra, or San Francisco or the Milan region cannot be transferred to Oldham and Tower Hamlets. On the other hand, Tower Hamlets, with 70% of its residents living in high-rise blocks, may find a method of recycling like that of Hounslow, which will be more effective and cheaper than any low-rise alternative.

The likely shape of the next twenty years cannot be settled now. The question is how to proceed amidst such uncertainty, particularly where the environmental stakes are so high. There are two key words: flexibility and timing. Flexibility has been post-Fordism's answer to uncertainty. If the future is unpredictable, then concentrate on mobility and keeping options open. Investment in large capital-intensive treatment plants runs right against the trends in the modern knowledge economy of keeping fixed assets flexible and investing in information- and knowledge-based service capacity.[78]

At the very moment of the most rapid change in the nature and use of materials, the incinerator programme threatens to freeze the future for a generation. Large thermal plants are a mid-twentieth century response to a twenty-first century circumstance. As such, they risk being stranded by change.

The issue of flexibility is also linked to timing. Incinerators and large-scale capital projects take seven to eight years to bring on-stream. A four-stream recycling system can be in place within a year. The current pressure on local authorities to conclude incinerator-based disposal contracts is such that, given long lead times, early decisions have to be made to meet landfill targets ten to fifteen years ahead. The mammoth of the future comes back to block the present.

Disposal authorities and the national governments of England, Wales, Scotland and Northern Ireland should follow a different timetable. They should focus all energies on establishing four-stream systems, declaring a moratorium on long-term disposal contracts for five years. By the review year of 2006/7 the pre-treatment gap between achieved diversion and the 2010 targets can be better judged and filled with short lead time facilities, and the same goes for the 2015 targets.

Table 7 Key issues in UK Waste Strategy and contrasting approaches

Topic	Argument of incinerator-led strategies	Intensive recycling approach
Waste growth	High and sustained No disaggregation to identify which if any waste is growing	Need to disaggregate to identify which streams/materials are growing, to assess most suitable form of treatment Key role of trade waste diverted into household stream since 1996
Waste composition	Use of early 1990s national data with low biodegradables and aggregate categories 56% recyclable	Hand sorted waste composition studies, showing high organics 30-45 categories differentiated 80%-85% immediately recyclable
Upper limit to recycling	35%-40%	Rates of 50%-60% readily achievable, rising over 10-20 years
Link between recycling and disposal	Recycling and disposal in separate compartments. Strict boundary between the two	Focus diversion on hazardous and biodegradable waste from landfill Rapid diversion programmes to preserve landfill space Flexible disposal options
Landfill	Lowest in hierarchy Emphasise shortage of landfill space	Landfill fine for inert, non-hazardous waste Priority to remove non-inert Critical view of landfill availabilty figures
Incineration & health	Modern incinerators safe and well regulated No evidence of new incinerators causing ill health	Significant emissions to air, and toxicity of ash (also danger to water) Repeated failure of regulation Evidence of health impact of toxic gases/elements coming from incinerators
Incinerators and crowding out	Incinerators sized in accordance with maximum recycling levels	Difficult to prevent crowding out for organisational, professional, financial and technical reasons Incinerators want paper and plastic for high calorific values
Flexibility and incineration	Flexibility issue does not arise because incinerators sized solely for long-term residuals	Incinerators require minimum tonnages and 20-25 year contracts. Monopoly of municipal solid waste (MSW) quantities at time of rapid change Size sets ceiling on recycling Need incinerator moratorium
Other disposal technologies	Gasification and pyrolysis as favoured alternatives (plus anaerobic digestion)	Thermal treatment of mixed waste has faced technical difficulties, and has toxic ash and air/water emission problems
Recycling	Limited potential Play down performance elsewhere or argue exceptional circumstances Favour more capital intensive recycling (centralised sorting) Low value recycling & pressure for reclassification (e.g. ash)	Rapid high recycling possible Learn from best practice at home & overseas Barriers as challenges
Composting	Limited because of low organic volumes and public reluctance to source-separate. Stress dangers from bio-aerosols	Home composting plus separate doorstep collection with neighbourhood closed-vessel compost systems
Disposal Contracts	Long-term and inclusive (aim also to include collection, CA sites and trade in disposal contracts)	Short-term to ensure flexibility Bespoke contracts for different functions
Economics	Incineration same cost as landfill Recycling high cost and persistent	Recycling declining cost industry. Intensive system cuts waste budgets. Issue is financing transition. Incineration and landfill have uncosted risks borne by client authority or public. Should fall to contractor or be mandatorily insured
Economic growth	Not discussed	Green industrial revolution for waste reduction. Recycling creates green-collar jobs and import-substituting reprocessing industry

Climate change and materials saving	Significance played down. No generalisation possible: BPEO for each case. Static LCAs. Incinerators save CO2. Better to burn paper than recycle it	Waste reduction & recycling can have major impact on CO2 reduction and materials savings. Cuts in CO2 from substituting virgin materials greatly outweigh reductions resulting from power generation from thermal treatment Clear environmental benefits of recycling, composting & minimisation. Dynamic LCAs
Overall strategy	Integrated/'balanced' approach including all main management options	Recycling- and composting-led, with industrial co-operation on ecodesign and waste minimisation. Detoxify landfill
Disposal strategy	Immediate action for new disposal facilities because of long lead time for incinerators	Rapid diversion to safeguard existing landfill capacity Detoxify residual waste stream Moratorium on incineration to focus on diversion. Use of MBT.
Planning	Streamlined planning procedures to avoid hold-ups in permission for new thermal treatment Environment Agency continues to assess polluting aspects of proposals	Need for community concensus for waste initiatives Planning should include assessment of impact of pollution (currently the primary responsibility of the Environment Agency). Financial support to community in assessing plans
Implementation	Strengthening powers of disposal and central authorities, particularly through RTABs	Zero Waste Trusts with funding flows to multiple delivery agents Strong role for community sector

Government policy and inflexible integration

The implicit government policy that emerged during the 1990s was to support 'the integrated option'. Whatever the wording of the White Papers giving primacy to waste minimisation, the central thrust of policy, finance and planning was to solve the disposal problem through incinerator-led packages.

Incineration faced three practical issues if it was to take its place at the centre of such packages: these related to its environmental credentials; its expense relative to landfill; and the difficulties of getting planning permission because of its unpopularity. The UK Government devoted more time to addressing these questions during this period than it did to promoting recycling.

(i) **policy**

The arguments advanced in favour of incineration have followed those summarised in the first column of Table 7:

- modern incinerators are safe;
- they make a significant contribution to the reduction of CO2 through energy recovery, and even more so when they supply district heating. In relation to energy and the Kyoto targets it is EfW rather than recycling that has been emphasised. The saving of energy from replacing primary with secondary materials from recycling was omitted from the principal study undertaken for the DETR on the significance of waste policy for climate change;[79]
- incinerators may be environmentally and economically preferable in certain circumstances. In the words of the 1995 White Paper, EfW 'will increasingly represent the best practicable environmental option (BPEO) for many wastes. This will especially be the case where final disposal becomes more limited and in situations where the environmental and economic costs

(including collection and transport) of recycling are high and where the practical optimum for materials recovery has been reached.'[80]

For this argument to hold, much depended on life cycle analysis as applied to particular materials, waste management methods and places. The second half of the 1990s thus saw an increasing use of these tools to determine the BPEO, largely using static LCAs, and culminating in the Environment Agency's WISARD, a model that disposal authorities were required to use to determine the optimum mix of methods.

On the basis of these three arguments, local authorities were encouraged to include EfW in their disposal plans and to consider the need for long-term disposal contracts as a condition for financing the large-scale investment required.

All three arguments are now in question. The revelations about the operating conditions at the Byker and Edmonton incinerators, of the exceedances and the practices of ash disposal, have raised major questions about the safety of 'actually existing incinerators'. These concerns have been compounded by the fires at the Dundee incinerator and the Wolverhampton plant, and by the problems of persistent exceedances at the Coventry and Sheffield plants.[81] The precautionary principle now hangs like a cloud over the safety claims about modern incinerators as they actually operate.

Secondly, the US EPA 1998 report and the idea of environmental opportunity cost would counsel prudence in arguing for EfW's contribution to CO2 reduction, relative to recycling and composting.

Similarly the critique of static LCAs and the controversy surrounding WISARD makes the concept of BPEO a less reliable support for EfW than was once thought.

(ii) finance

The principal practical problem for incineration has been its high cost relative to landfill, an underlying differential that has increased as emissions limits have tightened. The government – through both the former DETR and the DTI – has concentrated on reducing this gap. The increase in the landfill tax assisted in this. But the two ministries have, between them, provided a range of subsidies or decisions on classification that have lowered the costs of incineration.

The subsidy and classification measures have included:

- awards under successive tranches of the NFFO, which for the two London incinerators alone were worth £14 million p.a.;
- exemption of incineration from the proposed Climate Change levy;
- the inclusion of pyrolysis and gasification in the Renewables Obligation;
- the provision of government funds under the Private Finance Initiative;
- the classification of incinerator bottom ash as inert, thus reducing the landfill tax to £2 a tonne;
- the classification of incinerator ash for construction purposes as recycling (ceased 2001) and the promotion of its use as a means of reducing the costs of disposal;
- the classification of energy from waste as recovery rather than disposal. (The EU Commission argued that it was disposal, on the grounds that the low thermal value of municipal solid waste did not qualify it to be considered as a fuel.) This allowed EfW plants to issue and sell packaging recovery notes for the packaging element of their combusted waste (a proportion estimated at 19%);

- the exemption from business rates;
- the provision of normal capital allowances on all forms of fixed investment.

The sums involved, estimated at £1 billion over seven years, dwarfed those provided for recycling.[82] In cases where there was an opportunity to fund intensive household recycling, through the Landfill Tax compliance scheme or the packaging regulations, local authorities and recycling collection were marginalised.

(iii) planning

The process of obtaining the necessary planning permission and consents has been a significant hurdle for the constructors of incinerators. The government used two main approaches to ease the process:

- it encouraged local authorities to include EfW in their waste local plans, (current planning guidance, PPG 10, specifies that local authorities should make provision for all forms of waste treatment, a clause frequently quoted in planning inquiries in support of incinerator applications);[83]
- there has been persistent pressure for the environmental and health impacts of an incinerator application to be dealt with solely by the Environment Agency under the IPPC regulations, a move which leaves them less open to public scrutiny than in the customary planning process.

Throughout the 1990s there was strong official support for a revival of incineration. In 1993, the Royal Commission on Environmental Pollution advocated the increased use of incineration with energy recovery for the disposal of controlled waste, and the 1995 White Paper endorsed these conclusions.[84] The 1999 Consultation Paper, 'A Way With Waste', although relegating EfW below recycling for the first time in the waste hierarchy as the result of political pressure, nevertheless stated that EfW, 'will need to play a full and integrated part in the local and regional solutions'.[85] It underlined the importance of the 'integrated approach' and the need to include a mixture of waste management options and 'avoid over-reliance on a single waste management option'.[86]

With the focus on re-establishing incineration, the DETR and the DTI had little time and less money to advance recycling. In using public funds and directives to level the economic playing field between landfill and incineration, it tilted it further away from early stage recycling, relative to incineration. The resulting poor performance of recycling confirmed the view of the limitations of recycling and gave even greater significance to alternative disposal options. In this sense the policy, financial and planning frameworks all combined towards a self-fulfilling recycling pessimism, leading to the current dominant option being that of 'inflexible integration'.

Changes in political climate

Early in 2000, the politics of waste began to change. Until then, local campaigns against incinerators and in favour of recycling had remained local. They received wide coverage in their local press, but scarcely any nationally. In March 2000, the Guardian carried the first coverage of the ash scandal at the Byker incinerator in Newcastle. In May the results of the independent testing of the ash and allotment soils on which the ash had been spread were announced, and filled the national press.

Since then not only the broadsheets, but BBC radio and television have covered waste stories, from alleged corruption in the Landfill Tax Credit scheme and the continuing revelations about Byker and Edmonton ash, to the growing number of anti-incinerator campaigns in Surrey, Sussex, Kent, Essex, Cornwall, Kidderminster, Wrexham, Liverpool, Lancashire, Sheffield, Humberside, Newcastle and Neath Port-Talbot.

At Byker and Neath, protestors chained themselves to the incinerator gates. At Edmonton and Sheffield, Greenpeace occupied the chimneys. A national network was formed in May 2001, bringing together all these groups in Britain and Ireland. In July 2001 Greenpeace was acquitted of charges of criminal damage by a north London jury, on the grounds that its crime was justified since it was preventing greater harm to those living near the plant.

The strength of local feeling was reflected politically. In May 2000, the Conservative Party published a waste policy that proposed a five-year moratorium on incineration, kerbside recycling for every home in Britain, and a dense network of compost sites throughout the country. The Liberal Democrats published a similar manifesto at the same time.

From mid-2000 there was a marked change in government policy. It departed from the 'light government' approach in three principal ways:

1. compulsory recycling targets for local authorities were included in the Waste Strategy 2000 in May 2000;

2. the first specialised recycling institution was announced in the Strategy, the Waste Resources Action Programme (WRAP), to promote markets for recyclate;

3. the Spending Review in July 2000 announced direct government support for recycling, reportedly in excess of £500 million over three years, supplemented by £50 million for community recycling schemes.

In the areas of targets and finance, there were administrative moves to weaken the support of these measures for recycling. The targets were set much lower than was hoped (25% in 2005, 30% in 2010 and 33% in 2015) in line with the maximum levels officials believed could be achieved, and consistent with '30:50:40' packages being advanced under the integrated option.

More strikingly, it was found that DETR officials had classified incineration ash used in road building and construction as recycling, with the result that those authorities with large incinerators rose overnight to the top of the recycling league.

Similarly, when the Spending Review allocations were broken down, it transpired that £220 million was to be allocated to PFI waste projects, all of which to that date had been incinerator-led packages, £140 million was reserved for recycling, and the remainder was part of a package of £1.127 million allocated to local authorities to spend on environmental and cultural services at their discretion. Given the relatively weak position of recycling within the context of local authority budgetary politics, this left collection authority waste officers with few potential earmarked funds on which to base a radical re-orientation of their collection systems, so that an important opportunity for promoting recycling was lost.[87]

In spite of these difficulties, the shift in government outlook was marked. WRAP was established rapidly and appointed as its leading adviser the principal US expert on secondary material market creation. In October 2000, the Government 'de-listed' incineration as eligible under the Renewables Obligation (although as a compromise pyrolysis and gasification were still included).

The proposed shift in the EU packaging targets from recovery to recycling signals the end of the PRN subsidy for incinerators. The Parliamentary Select Committee that considered Waste Policy, reporting in March 2001, urged the Government to adopt the more ambitious recycling targets of 50% by 2010 and 60% by 2015, and re-iterated the call of an earlier Select Committee to impose a tax on incineration as part of a more general disposal tax. The Welsh Assembly in May 2001, as part of its response to the Kyoto targets, agreed a planning 'presumption against' incineration to secure the space for the development of 'recycling and sustainability'[88].

Concerned over the widening conflict over waste strategy throughout the country, and the lack of progress being made in meeting the EU Landfill Directive's diversion targets, the Government called a Waste Summit in November 2001, and announced a review of policy to be undertaken by the Performance and Innovation Unit in the Cabinet Office.

None of this is yet sufficient to slow the momentum behind the incinerator-led plans and contracts being advanced by the disposal authorities. Yet it signals a change in the political climate, which provides the context for immediate measures that would switch Britain's waste economy from its current preoccupation with incineration to intensive recycling and the advance of each of the aspects of Zero Waste.

IX A Zero Waste Policy for Britain

The second term Labour Government has announced that it will focus on delivery. Waste is a sector in which it can tangibly deliver. To do so it will have to radically extend the initiatives of the past two years, and to provide leadership both for its civil servants and those involved in the day-to-day management of waste.

The municipal sector

Municipal waste represents only just over a quarter of industrial, commercial and municipal waste combined (and only 7% of total waste if agricultural, mining and construction waste is taken into account). But it is the starting point for an alternative policy for three reasons:

- government has a more direct influence over the way waste is managed in the municipal sector;

- municipal recycling and composting provides a core infrastructure which should be made available for industrial and commercial waste;

- household waste is the interface between citizens and the waste problem. It affects everyone. If the problems of waste do not start under the kitchen sink, they can be seen there, as can part of the solution. Recycling provides a way for everyone to contribute to alternative environmental policies. It is a form of productive democracy, whose impact extends beyond the home, to work, to public spaces and to the ballot box.

For these reasons, the first step towards Zero Waste is to change the way in which municipal waste is managed. In the UK this requires two major sets of changes:

- a shift in strategy from intensive incineration to intensive recycling, from 'inflexible fragmentation' to 'flexible integration';

- the introduction of measures to put this strategy into practice.

Intensive recycling

Municipal waste needs to be re-oriented around four primary policies:

1. The diversion and composting of organic waste

The first aim of the initial stage of the UK's conversion programme should be to:

- **introduce separate organic collections throughout the UK by 2006 together with a network of local closed vessel composting units**

Hand sorted studies of the composition of UK municipal waste suggest that organics account for between 30% and 45% of dustbin waste, and some 40% of civic amenity waste. Diverting a high proportion of this waste should be a first target. In addition to the environmental benefits, there is another technical reason for the importance of this approach. By reducing the fermentable element in residual waste, it makes a switch to fortnightly collections possible, and transforms the economics of diversion.

The key change that is needed is that proposed for implementation throughout the EU in the Commission's draft Bio Waste Directive: separate kerbside organic collections. Introducing this immediately in this country would shift the UK from the bottom quartile of European recyclers to the upper half, alongside regions and countries already collecting organics (the Netherlands, Flanders, Germany, Austria and a growing number of regions in Italy). It would make Britain a leader, not a follower, of European policy. It would also ensure that all authorities met their recycling targets by 2005/6.

The most effective model for organic collection to date is that developed in Italy (see inset 1). It is centred on a low-cost food waste collection system, home composting and a supplementary periodic garden waste collection service at weekends. More than 1,000 municipalities have adopted this system in all parts of Italy, in many cases with a reduction in waste costs.

2. The diversion of dry recyclables

- **multi-material kerbside collections of dry recyclables should be extended to all households in the UK and current average capture rates should be doubled**

The highest rates of capture of dry recyclables are achieved by multi-material kerbside collection (MMKC). Even a dense system of bring banks will nowhere match the capture rate of properly resourced kerbside schemes.

Currently only 19% of available dry recyclables in the dustbins of England and Wales are being source-separated. This is mainly due to the low level of MMKC. While 44% of all households have some form of kerbside collection of dry recyclables, many of them are sporadic, single material, not user friendly, and geared more to minimising cost than maximising recovery. Only 3% are served by multi-material collections.

The national average weight of dry recyclables collected at the kerbside for all households is 32 kg p.a. out of an estimated 336 kg p.a. in the dustbin. The average for all existing kerbside schemes is 73 kg per household serviced p.a, and 94 kg for multi-material collections. Well run kerbside schemes should capture 120-140kg per household p.a. in their early stages and build up to 200-230kg per household p.a. as the scheme matures.[89]

Policy should be focussed on doubling the number of households covered by kerbside collections and doubling the amount captured from each household served through extending the coverage and effectiveness of multi-material collection.

Inset 2

Italian food waste collection systems

Although the first initiative to collect food waste separately in Italy took place in 1993, the main cause of its expansion has been the 1997 Waste Management Law, which set recycling targets of 35% for local authorities to achieve by 2003. This target made it necessary to separate organic waste. In Northern Europe kerbside organic collections accept garden waste and food waste in the same container (usually a dedicated organic wheeled bin). The Italian innovation has been to treat them separately.

The argument for this is that food waste is the priority. It is the main contaminator of what the Italians call 'restwaste' in the regular dustbin. Once food is removed, restwaste does not have to be collected so often, and its fermentability in landfills – which is the major problem for emissions – is radically reduced.

Focusing on food waste also allows for much cheaper and more effective collection systems. Because food waste has a high density and water content, it does not need compaction. As a result the Italians have developed small micro vehicles, with a 3-5 cu metre capacity, and costing between 10%-15% of an ordinary refuse lorry.

The food waste vehicle shown is from the commune of Cupello in the Abruzzi region on the Adriatic, and is one of the larger models. It can be operated by a single person, collecting 3-4 tonnes a day from some 2000 households. Residents place their waste in small plastic bags in a six-litre bin near the sink. This is then transferred to a 30-litre collection bucket that can be easily lifted by hand. The bags are transparent to allow the collector to check their content, and are biodegradable so that they rot down with the food.

The vehicle has a bin lift on the back so that food waste, placed in the water tight bags, can be collected on the same rounds from wheeled bins at apartment buildings as well as restaurants and food shops. The vehicle also has a tipping mechanism, so that once it is full, it can offload into an ordinary refuse lorry for long distance carrying to the central compost plant. A further cost saving could be made by developing local closed vessel compost systems which could be fed by the micro vehicles directly.

The average yield of the food waste schemes is 150-200 kg per household per year, or from 60%-80% of food waste in the average dustbin. Little if any of this is garden waste (not least because of the small size of the plastic bags). Garden waste is largely composted at home or taken to civic amenity sites. The Italians argue that providing mixed organic or garden waste collections makes it easy for householders not to compost their garden waste and invariably increases the quantity of waste that a local authority has to handle. The iron law of garden waste is that special collections increase the recycling rate but also total waste arisings. In some instances, Italian councils provide a fortnightly or monthly garden waste service, usually with a charge, using a regular off duty compactor at weekends.

Many of the municipalities who have adopted this model have achieved 50% recycling levels. The food waste collections have commonly saved money, since a food waste team may cost as little as a third of that of an ordinary refuse round, yet service the same number of households. The halving of rest waste collection frequencies therefore releases resources from which the food waste collections can be funded.

The system has also provided a high quality feedstock for compost, (with contamination rates of only 2%, significantly lower than the wheeled bin systems in Northern Europe), the need for which is reflected in the fact that three Italian regions now provide subsidies of up to £120 a tonne for the application of compost on agricultural land.

3. The recycling of bulky waste

- **the disposal-oriented system of civic amenity sites should be converted to a dispersed network of reuse and recycling centres, integrated with regular doorstep collections of bulky items**

Bulky waste, including consumer durables, rubble, wood, scrap metal, cardboard and garden waste, is largely disposed of through civic amenity sites, supplemented by special collections, pick-ups as part of weekly dustbin collections, and fly tipping. Civic amenity waste alone accounts for 23% of household waste or some 275 kg per household p.a.

Since they were first established over thirty years ago, civic amenity sites have been designed primarily as drop-off sites for disposal. Under the Environmental Protection Act of 1990, it is the responsibility of disposal authorities to provide such drop-off points. Many households have no ready access to these sites – particularly in cities where property prices are high, and in rural areas – or where a household has no car.

Many CA sites now have containers in which householders can deposit source-separated materials for recycling. The diversion rate on CA sites in England and Wales has risen to nearly 20%, with a growing number of authorities reaching 50-60%, and some exceeding 70%.

The aim in the UK should be to raise the average recycling rate of bulky waste to 60% by 2005/6. This will entail:

- increasing the number of sites to a density of one per 30,000 households in urban areas and one per market town in rural areas;
- re-designing the sites as reuse and recycling centres, with layouts that permit vehicle flow, an enclosed area for storage and security and increased staffing for advice and control;
- increased special collection services with free pick-ups for households who separate their waste for recycling;
- a shift of responsibility for civic amenity sites from disposal to collection authorities to allow for their integration with kerbside collections of bulky waste, organics and dry recyclables;
- the co-ordination of bulky waste recycling services with manufacturers and distributors covered by producer responsibility legislation.

4. Management of residual waste through Mechanical and Biological Treatment (MBT)

A central goal of a transition policy for Zero Waste is to 'clean' the residual stream of waste going to landfill. High diversion of organics, supplemented by the recycling of paper, textiles and wood will contribute to this, as will the introduction of special collections of hazardous household waste as part of the recycling and redesigned civic amenity services. But the residual will need further treatment. In the initial years at least, residual waste is likely to contain 15-20% organics even with food waste and garden waste collections.[90] This needs to be neutralised before disposal.

Article 6a of the Landfill Directive requires that 'only (non inert) waste that has been subject to treatment is landfilled'. It states that this be understood in terms of the objectives of the Directive which are to reduce the quantity of waste, or the hazards to human health or the environment. Those countries that have put reduction of environmental pollution at the centre of their waste strategies have interpreted article 6a to mean that the fermentability of all residual waste is reduced to a minimum. Germany has banned the landfilling of all untreated organic waste by 2005. Austria, Italy and Sweden have introduced similar provisions. The UK should do likewise.[91] The government should:

Inset 2

Mechanical and Biological Treatment in Milan

The MBT plant in Milan began production in 1997. It was established in response to a landfill crisis in the mid 1990s, as a means of both reducing the quantity of waste sent to landfill and stabilising its organic element. The plant is the largest in Europe with a capacity of 600,000tpa, and handles all the residual waste from Milan (population 1.6 million).

In MBT plants, the mechanical treatment is normally in two stages. The first is a processing stage where the mixed waste is passed through a drum or pulveriser – often with heat added – in order to loosen the waste and evaporate some of its moisture. The second is a separation stage where materials are recovered through the use of screens, air blowers, magnets and similar processes. The separated organic fraction of the waste is then composted.

In Milan, the mixed waste first moves through a 20mm screen to take out the 'fines'- much of it organic, and through an 80mm screen to remove larger items, mainly paper, cardboard and plastic (the so called 'oversieve'). The remaining 'undersieve' is then treated in a large, hot bio-reactor for 15-20 days (the dry stabilisation method), screened at 40mm, and moved to a second bio-reactor for a further 40 days, prior to a final screening at 10-12 mm to capture the remaining contaminants such as plastic and glass.

As a result of the process, there is an overall loss in weight of 15% (which with landfill at £100 a tonne is a substantial saving) and a reduction of fermentability by 90%. MBT plants can be distinguished according to what they do with the separated materials. Some are oriented towards bio-waste neutralisation, using the grey compost for land reclamation or forestry growth, while others gear the process to producing high calorific feedstock for incinerators. Milan (like the Siggerwiesen MBT plant in Austria) is an example of the former. In both these cases all materials are sent to landfill.

The Milan plant was built rapidly. It started operations in 1997 and the contract runs only until 2003, with the initial investment of £20 million equipment being depreciated over 5 years. At the end of this time the plant can either continue as a mixed waste treatment plant or be converted for the processing of source separated organic waste and further sorting of dry recyclables.

Milan's MBT plant is not an alternative to source separated recycling and composting. The recovered materials have considerable cross contamination. Even the final, sieved, composted fraction has significant quantities of fragmented glass and plastic in it making it unsuitable for agricultural or horticultural use. The function of the plant has been rather to 'neutralise' the residual waste that remains after recycling and composting.

- **introduce a ban on untreated municipal waste going to landfill by 2006**

All forms of mixed waste treatment have their drawbacks (and hazards) which is why Zero Waste seeks to eliminate all waste for disposal. Treatment plants should therefore be seen as transitional, to be reduced as diversion increases. The principal requirement of treatment technologies is that they should not crowd out recycling and composting, but be geared to respond to the changes in residual waste volumes over the transition period. They should:

- have short capital turnover times (being quick to bring onstream and amortisable rapidly);

- have multipurpose equipment (to allow sections of the plant to process source-separated material as diversion increases and residual volumes fall);

- contribute to environmental goals, notably the reduction of greenhouse gases and of air and water pollution;

- keep treatment costs low over the transition period.

In other words, they should aim to be clean, cheap and flexible.

The method that comes closest to these requirements is mechanical-biological treatment (MBT).[92] MBT plants are now widespread in Germany, Austria and Italy (see inset 2). Through a process of tumbling and screening, organics in the residual waste are separated off and processed in a closed composting plant or anaerobic digester in order to reduce their fermentability by at least 90% of the original level. In the process of screening, some other materials are recovered (such as metal, glass, paper and plastic) and the overall quantity of waste for disposal can be reduced by some 30-40%.

The advantage of MBT plants is that they are a simpler and therefore cheaper option than incinerators and other complex treatment technologies. They are modular, with different equipment being added depending on the type and quality of materials that are to be separated. Much of this equipment and the enclosed compost facilities/digesters can be converted to the treatment of source-separated materials as levels of diversion increase.

Like all mixed waste treatment facilities they need to operate to high health and safety standards, with bio-filters to reduce odours, bioaerosols, and VOCs. If they can be operated to these standards (and much depends on an effective inspectorate) then their advantages make MBT the preferred option to meet the treatment goals by 2006.[93]

The Draft Directive on Composting and Biological Treatment makes clear that those materials that have undergone MBT and achieved the limit values on fermentability, will no longer be considered as 'biodegradable' and hence will be regarded as contributing to the diversion targets of Article 5. A disposal authority and its constituent collection authorities which treats its residuals through an MBT plant will meet the requirements of Articles 5 in addition to those of Article 6 more rapidly, more cheaply and with a more positive environmental impact than any thermal treatment alternative.

Flexible integration

The above strategy stands in contrast to the 'integrated option' that has governed UK policy to date. The contrast is not between a single form of waste management (recycling) and an 'integrated' package. Rather it is between flexible integration and inflexible fragmentation. With incinerator-led packages, the main integration is formal – through a single contract. Strategically and operationally, diversion and disposal remain separated, planned independently of each other, and, as diversion increases, in tension.

With flexible integration on the other hand, recycling priorities are set to reduce the hazards of disposal (hence the emphasis on composting and the separation of hazardous waste), while disposal is planned with technologies which can respond promptly (and economically) to changes in residual tonnages, and with equipment that can be converted for use with source-separated materials as recycling and organic capture rates increase. Where flexible integration has been put into practice, as in Halifax, Nova Scotia (see inset 4), community opposition to new landfills has turned to support because of the twofold character of the strategy: a commitment by the city government to high diversion and a neutralisation of waste going to landfill using MBT.

The conditions for delivery

To deliver the above strategy of flexible integration, four things are needed:

- clear direction
- transformed incentives
- transitional finance
- specialised institutions

The first two are about expectations and interests. The second two are about finance and knowledge. Immediate, decisive action is needed in all four areas if the redirection of Britain's waste economy is to be achieved by 2006.

1. Clarification of goals and strategy

The process of environmental transition gives a privileged place to government direction. It indicates to those making the long-term industrial decisions the character of the regulatory and fiscal regime within which they will be operating. It sets the parameters of the future.

Waste Strategy 2000 does not perform this function. Like the White Papers that preceded it, it contains the language of waste minimisation, but its substance promotes 'the integrated option'. This is partly due to its absences – to what it does not say about finance and incentives – but it is also because of what it does say.

The key sentences – quoted in council meetings and public inquiries throughout the country – are those insisting on the 'important role' of incineration. The words aim to present incineration as subsidiary, but in practice it is always dominant. It determines the length and size of contracts, it restricts the field of contractors, it encourages old era technology, and it signals unequivocally that for the next twenty years there will be an irremovable cap on the expansion of recycling. Whether in London or Stockton, in Lerwick or Birmingham, experience shows that the hare of intensive recycling cannot run with the hounds of incineration. Through the gap opened up by these sentences are pouring proposals that place incineration in the lead.

The core message of Waste Strategy 2000 is the 'integrated option'. This is the perspective shaping the long-term strategies of waste companies and disposal authorities. They are having to take on board the household recycling targets, but these are set at levels which leave 70% of municipal waste available for disposal, a volume which is then compounded by assumptions of two decades of an annual 3% growth.

If the Government wants waste companies and local authorities to redirect their strategies then it must give an unambiguous statement to that effect, especially as what is being signalled is a change of paradigm. It should be made clear that incineration and complex technologies of mixed waste treatment are not the path to be taken and that the problems which the profession should be confronting are those of high quality composting and up-cycling, not how to control emissions and prevent explosions at thermal treatment plants. The Government needs to indicate that it is looking for a new technological trajectory.

Inset 4

Halifax, Nova Scotia

In the late 1980s, the Halifax region in Nova Scotia (population 350,000) faced intense civic opposition to an expansion of its landfill site in Sackville. The joint councils proposed a 500 tonne per day incinerator as an alternative, but this, too, was strongly opposed. The local action groups raised money and hired their own consultants from Seattle who laid out a cheaper, alternative plan for a recycling led strategy. Subsequently, the councils turned down the incinerator proposal because of its costs and its threat to the development of intensive recycling and agreed in principle with the Seattle plan.

They also decided to involve the action groups in designing the scheme. Decisions were made by consensus. The key conclusion from the process was that no organic waste, or toxic waste or recyclables should go to landfill. Anything going to landfill had to first be treated to remove all toxics, organics and recyclables, and to stabilise the remainder through composting.

The system that emerged followed these recommendations. It was a three stream system with all households being served by kerbside collection of dry recyclables, 72% of them having kerbside collection of organics (using special aerated wheeled bins), access to a strong home composting programme plus collection of residuals.

95 Enviro depots were set up to receive beverage containers (all of which other than milk containers have a deposit on them) , and there were tyre pick ups from auto stores (the tyres being recycled in a new plant that freezes and produces a high quality crumb rubber). There are drop off sites for hazardous waste, places for the recycling of 2nd hand building materials, a MRF handling 18,000 tonnes a year and two centralised composting sites.

For residual waste there is a screening plant, which pulls out bulky items, recyclables, and toxics, and then stabilises the residual using a trough system with 14 bays. The landfill has been renamed a 'residual disposal facility' and is notable for its lack of odour and birds.

A key development role has been played by the Resource Recovery Fund which acts as promoter of recycling and processing, organises logistics, finances new projects and passes back savings to municipalities.

The result is that Halifax from a diversion level of 3% in 1997, reached 60%within three years. Its drink container system recovered 80% of the deposit containers and 96-98% returns of reusable beer bottles. The main improvements sought locally have been to have smaller, local compost facilities, particularly in the rural areas where the composting could be done by farmers. With a programme to increase capture rates and extend the facilities for the recycling of bulky goods, the civic groups estimate that recycling rates should increase to 88% within ten years.

In shifting the vision, it must also explain the reason for doing so – in terms not of EU Directives but of environmental imperatives, that are likely to intensify as time proceeds. These provide the material basis for the change in strategy, a basis that all governments will have to address whatever their political aesthetic. This, too, requires a change of tone from Waste Strategy 2000.

What is called for is a new White Paper that does three things:

(a) **clarifies the scope and purpose of intensive recycling and the goals of Zero Waste**

It should ground the strategy more firmly in the goals of cleaner production, the global reduction of CO2, increased resource productivity and soil restitution. These become the criteria of conduct, and should determine the action of each Department of government. Instead of a government policy approach that has argued down targets and weakened Directives, while aiming to meet limited targets at least cost, each Department – and the Environment Agency – should become a promoter of intensive recycling within its sphere of responsibility.

(b) **converts the current local authority recovery targets of 45% by 2010 and 67% by 2015 into mandatory municipal waste recycling targets**

The dropping of recovery goals and their replacement by demanding recycling targets is the present lead proposal for the revision of the 2006 Packaging Targets within the EU. Adopting the conversion proposals for household waste in the UK would put Britain's targets broadly in line with the 50/60% proposals of the Select Committee and would give all those involved in municipal waste a clear signal as to the strategic path to follow.

(c) **sets out the fourfold strategy for diversion and treatment for 2006/7**

The broad goals and the strategic targets need to be reinforced by an outline of the principal steps to follow. These are the programmes for organics, dry recyclables and bulky waste set out above, and approaches for treating the residual. As far as treatment is concerned there are two priorities:

- **the early construction of a new generation of mechanical and biological treatment plants;**

- **a moratorium on all new forms of thermal treatment until a Strategic Review in 2006/7.**

Many of the states and regions that have promoted intensive recycling have done so in conjunction with a ban on incineration, in order to leave space for recycling to take root and to leave no ambiguity about the required change in direction. A similar clear statement is needed in the UK.

The construction of incinerators (and even the potential for construction) creates an interest for the companies and the disposal authorities involved which has consistently come into conflict with strategies for intensive recycling. In the UK this has been evident in the policy debates on waste, in the conflicts between collection and disposal authorities and in the recycling performance of those areas covered by incinerators.

A Zero Waste Strategy needs to focus on the many challenges posed by diversion. It requires a consensus of all those involved – from the householder to waste companies. Recycling and composting have met with widespread support. Incineration has been divisive. Since the function of treatment can be met more flexibly and cheaply through MBT, without the need for long-term contracts, the incineration option is a diversion from the main issues in Zero Waste and should be set to one side.

2. Restructuring incentives

There will be no change on the ground, whatever the wording of a new Strategy, without a radical restructuring of incentives. The long-term shift to producer responsibility for waste is part of this, and the changes already taking place to minimise waste through process and product innovation in the packaging industry exemplify the point.

A complementary shift to consumer responsibility by introducing user pay would also provide an incentive to residual waste minimisation (albeit on a smaller scale). Certainly, overseas experience has often been that introducing user pay helps boost recycling rates. In the UK, this should be a second stage rather than first stage change for two reasons:

- introducing user pay before established, convenient kerbside collections are set up encourages fly-tipping;

- there is already scope for introducing charges and discounts within the terms of current legislation (see Chapter IV, Section 7 above). The inability to charge directly for the collection of residual waste will also encourage innovation by waste collectors in the incentives they offer to householders.

Instead the focus for immediate action should be on changing the incentives to the principal decision takers on waste disposal – the disposal authorities and the waste companies. The first thing that has to be changed is the perverse hierarchy of profitability. If landfill offers the greatest returns (over 15% p.a.) and recycling the least, then it is to be expected that recycling remains the Cinderella sector of the waste industry.

To reverse this there are two issues that need to be kept distinct:

(i) levelling the playing field between recycling and disposal

There are wide divergences in relative costs per tonne between landfill, incineration and the initial stages of recycling. This is the short run position. In the long run, recycling costs fall, and the costs of residual waste management rise (due to tighter environmental controls and increased unit costs as disposal waste volumes fall).

Three steps are necessary to correct the present imbalance between initial recycling and disposal:

- the introduction of a disposal tax with levels reflecting the relative external environmental costs and benefits of each waste option. Studies by the US EPA and Coopers Lybrand for the EU provide a measure of the relative weights to be attached. As a first step, the UK could follow the Danish model, by introducing a further escalator in landfill tax when the current escalator expires, to bring the level up to an average of £30 a tonne. On the USEPA and Coopers Lybrand evidence, the tax on incinerators should be set at or near the figure for landfill;

- ending subsidies and ambiguous classifications designed to lower the costs of incineration This includes ending the exemption of incinerators from the Climate Change levy, ending PFI awards for large scale incinerator-led contracts, and ending the eligibility of incinerators to issue Packaging Recovery Notes;

- internalising risk in disposal contracts by shifting risks to contractors and requiring mandatory insurance for landfills, thermal treatment plants and large composting and recycling facilities as a means of quantifying environmental risk.

(ii) recycling incentives for waste disposal authorities

Currently, waste disposal authorities (other than unitary authorities) have no interest in the expansion of recycling by collection authorities or community groups because they are required to pay the incremental disposal savings to the collector in the form of a recycling credit. An urgent task of policy is to restore an incentive to disposal authorities.

There are the following possibilities:

- a rebate of landfill tax to disposal authorities on tonnages equal to those on which they have paid recycling credits;

- a graduated landfill tax with low rates for base volumes, and rising rates to marginal levels as high as £45 a tonne. This is a variant of the Wallonia model where the regional government offers zero tax landfilling for a proportion of residual waste, and then a high marginal rate. The landfill tax could be extended to a disposal tax by giving rebates for pre-treated waste, scaled to reflect the environmental benefits of the treatment option;

- the replacement of Disposal Authority precepts based on council tax charges by a charge per tonne. This measure would be aimed at disposal authorities owned by constituent boroughs (such as those in London, Merseyside and Greater Manchester) and would apply 'the polluter pays' principle to the funding of disposal authorities. A change of this kind would involve one or more of the constituent authorities suffering a loss, which the government should offer to fund on a four-year tapering basis while the losers increase their rate of waste diversion;

- the combining of collection and disposal functions in a unitary Waste Minimisation Authority charged with advancing the government's strategy and achieving the targets within the area concerned.

3. Finance

Lack of finance is the main disincentive to collection authorities expanding composting and recycling schemes. At any committee meeting, waste hearing or public discussion on recycling, both councillors and officers will cite problems of funding and markets (which is another way of talking about finance) as the two reasons why they cannot at the moment proceed further. In local government terms, this is a budget rather than a price disincentive.

The main counterweight has been provided by local pressure on politicians. As a general rule, an incinerator proposal in any borough or district will increase local resources devoted to recycling. This may be enough to encourage some pioneers: it is not adequate to fund a countrywide transition. If collection authorities are to promote intensive recycling, then they, too, need access to transition finance, on terms that outweigh the disincentives to change.

There are two issues:

- the demand for funds (the requirements of transition finance)

- the source of funds

(a) the demand for funds

In the long run, landfill and other disposal taxes should be set at a level that makes efficient recycling and composting competitive with mixed waste disposal. The waste industry has estimated the incremental cost of running kerbside recycling schemes at £10 per household, which (assuming an initial collection of 140kg per household annually) equates to £70 a tonne, and a similar amount could be assumed for organic collections. With existing costs of landfill-oriented waste management at £50-£60 a tonne, this suggests that the landfill tax that is set to rise to £15 a tonne by 2004 should be doubled in order to make recycling and composting financially 'competitive' with landfill.[94]

If a £30 landfill tax were to be in place by 2007, a five-year programme of transitional finance would be needed in the short and medium term, to fund the costs of converting to an intensive recycling system.To estimate these conversion costs, the Consortium of eleven Collection Authorities in Essex undertook a study into the five-year incremental cost of a 60% diversion programme for the waste system as a whole. There were four main conclusions:

- the net system cost declined over time, in line with the experience of recycling as a declining cost industry;
- the bulk of capital costs could be covered through either private sector investment or leasing. The main need was for working capital to fund the deficits over and above the council's current waste budgets;
- the system costs were sensitive to the speed at which the residual rounds could be reduced, and to the range of savings discussed above in the section on smart recycling;[95]
- the aggregate transition funding requirement for a 60% diversion programme for all Essex is £40 million in revenue funds over five years, assuming all capital is privately financed. Of this, £22 million would cover the capital servicing costs and £18 million the working capital requirements of the collecting authorities.[96] This is equivalent to £8 million p.a. for a county of 615,000 households, and represents an increase of just under 50% on the existing collection authorities' spending on waste of £17 million p.a.[97].

Translated nationally and including the recycling credits transferred by the disposal authority, the Essex study suggests the need for conversion finance of £2.2 billion, or £440 million per year.[98]

(b) the sources of funds

There are four main sources from which the £2.2 billion could be raised:

(i) the landfill tax

The landfill tax should source £0.9 billion of the conversion programme, or 40% of the total. It could contribute in two ways:

- **The landfill tax credit scheme should be radically revised, and the funds channelled through a body independent of the waste industry with its prime focus on the expansion of recycling.**

Currently the landfill tax credit scheme has a potential yield of some £100 million p.a. This is likely to rise to £135 million p.a. by 2004. If £30 million were to remain for non-waste related projects, £70 million p.a. would be available to fund conversion. The sum would rise to £105 million p.a. by 2004, and – with an increase of landfill tax to £30 per tonne but falling landfill volumes – should average at least £100 million p.a. through to 2007. The target sum to be earmarked for intensive recycling should be set at £500 million over five years.

- **£400 million should be earmarked from the revenues derived from an increase in the landfill tax above £15 a tonne, and from its extension to other forms of pre-treatment, for the completion of the conversion programme.**

(ii) producer responsibility payments

- **The Packaging Recovery Notes (PRN) system under the packaging regulations should be adapted to contribute at least £350 million to the municipal conversion programme over five years.**

Since the inception of the PRN scheme in 1997, its contribution to the changes required in the municipal sector has been derisory. Even with the increased demand for municipal packaging to meet the 60% recycling target by 2006, the amount going to municipal recycling over four years is likely to be modest. The amount of packaging recyclate that the industry estimates it will need from municipal sources is 1.2 million tonnes p.a. by 2006. Were compliance schemes to pay the average municipal recycling cost of £70 a tonne, this would yield £84 million p.a. If, however, PRNs remain at their current average of some £21 a tonne, the level in 2005/6 will be only £25 million p.a., no more than a fifth of the total funds being contributed.

The total four-year sum going to local authorities at existing PRN prices would not exceed £100 million, out of a forecast £500 million to be paid in by the packaging-related firms, compared to an equivalent of £4.4 billion from their packaging counterparts in Germany.[99 100] Significant funds will continue to go to processors, either to finance low cost/low capture forms of recycling or as windfall gains.

The PRN system and its administration need to be changed. The following measures should be considered:

- **raising packaging targets to the 80% level already achieved in Germany rather than the 60% figure for 2006 likely to be agreed in Brussels;**

- **establishing a PRN sales intermediary to provide greater co-ordination between the supply and demand of the compliance schemes, and to establish a guaranteed floor price for PRNs of £40 a tonne.Any operating deficit of the intermediary would be funded retrospectively by the compliance schemes;**

- **directing all processors to issue PRNs directly to suppliers of recyclate, at the same time requiring compliance schemes to purchase the PRN rights for municipally funded recyclates for at least 1 million tonnes up to 2004 and 2 million tonnes up to 2007 at a minimum of £40 a tonne.**

These sums, amounting at least £320 million during the period to 2007, would be supplemented by similar arrangements under the producer responsibility directives due for introduction by 2006.

(iii) direct government funding

- **Direct funding of £700 million over five years, or £140 million a year, should be contributed directly by central government.**

This would include the current programmes:

- £140 million for recycling in 2002/3 and 2003/4;

- £220 million for PFI schemes up to 2003/4 (the PFI finance promotes capital intensive investment and long contracts; the remaining funds that have not been committed should be switched and added to the £140 million recycling programme);

- £50 million of New Opportunities finance for community-led recycling schemes.

These should be supplemented by support from Single Regeneration Budget (SRB) allocations, Public Service Agreements and a further tranche of programme finance in the next three-year spending review.

(iv) local authorities

Disposal authorities are already set to make a major contribution to recycling through the recycling credit scheme. They should not be required to contribute further. Some collection authorities also make significant contributions (in Essex in 1999/2000 the eleven consortium boroughs were already providing £1.6 million a year for recycling). Nevertheless:

- **unitary and collection authorities should take responsibility for contributing £250 million to the**

conversion scheme from their share of the £1.127 billion allocation made in the current spending review, and or any similar allocation in the subsequent round

The government should ensure that this happens and if necessary issue the requisite guidance for the final two years of the current review period.

Conclusions on sourcing

There are already substantial waste-related funding flows circulating in the economy, all of which are set to expand. The landfill tax credit scheme and the packaging recovery arrangements have together generated some £750 million in the past five years, and the Government's current spending review was planned to inject a further £500 million over the three years up to 2003/4. This finance is substantially lower than that available in high performing recycling economies like Germany, but could have had a major impact if it had been used 'smartly'. This has not been the case. The funds have remained unco-ordinated, their control and use shaped more by concerns to increase commercialisation and limit public expenditure than by achieving a major shift to waste minimisation.

A five-year conversion programme to intensive recycling should not therefore be held back by lack of funds. What is required is a 're-wiring' of existing funds, and a clear direction be given for their use. This in turn would provide the context for a major programme of private investment – in all stages of the 'closed loop' economy – which government leadership on recycling has stimulated elsewhere.

4. Institutions

One of the developments in the field of industrial policy over the last decade has been a shift from the arguments about state versus markets, to the question of the design of institutions. The literature on successful long wave transitions from one industrial era to another has similarly moved beyond a primary emphesis on technology to focus on the interplay between new organisational paradigms and emerging technologies. Historically, the countries that have been able to develop appropriate organisational structures have been best able to capitalise on contemporary technological possibilities.

The economists' new interest in organisations cuts across the former poles of debate. It is no longer a question of the shift from the public to private sector (or vice versa), or from tax/grant-based economies to markets. It is rather an issue of the nature of the institutions in which markets are embedded, or that undertake public/non-market functions.

In the case of waste this poses a particular challenge. On the one hand it requires a state that can play a creative public role as long-term strategist, a setter of parameters and a guardian of public and environmental health. On the other it requires the opening out of the former waste sector to the knowledge industries and to the dynamic of the third 'social-market' sector, whose innovative ways of reconciling the market with social and economic goals are so pertinent to Zero Waste.

New governance

As far as the public functions are concerned, my argument is that there have been serious limitations to the neo-liberal model of government as it operated in the waste field in the 1990s. There are three institutional problems that need to be directly addressed:

- the relegation of the government function of strategic direction, and the redefinition of its role as market facilitator, has led to a subaltern culture in government. It is skilled in critical faculties and the management of meaning, and in the application of market analysis to external propositions. But it has been leached of know-how and strategic confidence, and has therefore failed to establish an autonomous public identity for a function that demands it;

- there has been a consequent fragmentation of policy and ineffectiveness of implementation;

- a large, Weberian, rule-based organisation (the Environment Agency) has been created to administer the entrepreneurial function of environmental protection and promotion of clean production.

What is needed is a new model of waste governance. This would build on the positive features thrown up by the innovations of the 1990s (the readiness to consult widely, to decentralise and to experiment) and the developments of the past two years.

Central Government

- The Policy and Innovation Unit in the Cabinet Office is in the best position to develop the long-term government strategy for intensive recycling which up to now has been so lacking. It needs to be complemented by two things: (a) resource innovation units in each of the principal Departments concerned with waste, staffed by specialists who understand the new paradigm – since their task is to help make it work – as well as those with direct experience of the new paradigm in practice; and (b) a small group of staff in the Central Delivery Unit to work with the resource innovation units from the Departments in implementing the strategy.

Local Government

- Waste Minimisation Boards should be created for each waste disposal area that would combine the strategic waste functions of collection and disposal authorities. The main task of the Board would be to advance Zero Waste within that area. Control of the bodies would rest primarily with the existing collection authorities, which would delegate the operational side of disposal to the present disposal authorities.

- The central government resource innovation units would form the core of a network of waste minimisation units attached to the Waste Minimisation Boards throughout the country.

'Disposal rights' to local community trusts

- A new model for the administration of disposal assets is required, based on the principle that the 'pollutee controls'. The waste disposal rights attached to sites with disposal facilities would be placed in the hands of local community trusts. The facilities would be managed under contract by specialist disposal companies, and jointly administered by the relevant local authority body and the trust.

The principal benefit of this arrangement would be that those most affected by the existence of a disposal facility would have ownership rights vested in them as custodians of health and environmental protection. They would enjoy the 'locational rent' generated by the planning permissions granted to particular sites, and would be required to use that rent to employ specialist technical advisers and finance an independent testing regime. They would also be able to invest in the betterment of the area affected by the facility. All liability for the sites would rest with the facility operator and the local authority.

The trusts should be elected by and report to the relevant parish councils. They should include on their council of trustees people with environmental knowledge whose role would be to contribute to the delivery of the environmental aims of the trust.

Granting ownership over waste disposal rights represents an internalisation of externalities which complements the principle of 'polluter pays'. In this case the internalisation is not restricted to the receipt by those subject to pollution of post-facto compensation payments (the 'pollutee paid'). It offers the pollutee the ability to reduce the dangers of pollution in the first place, through control of the terms of operation and monitoring of practices.

The Environment Agency

- The planning, protection and enforcement functions of the Environment Agency with respect to waste need to be redefined and re-organised;[101]

- the function of providing IPPC certification for new and expanded facilities should be subject to greater public scrutiny by introducing a 'call-in' mechanism and provision for third party appeal;

- the monitoring of facilities should be undertaken by a strengthened inspection and testing service, whose terms of service should preclude it from later working for companies for which it had the responsibility of inspection;

- the prosecution function should be spun off as a stand-alone Environmental Prosecution Service to which both the EA inspection service and the neighbourhood trusts could submit evidence;

- the Environment Agency should extend its remit to include an advisory function on pollution control and waste minimisation innovations.

Intermediary institutions for Zero Waste markets

In addition to institutions to promote clean production, there are four functions that have to be fulfilled in facilitating the conversion to a Zero Waste paradigm:

- market development

- systems know-how

- a re-oriented profession

- financial intermediaries

The nature of the new waste system that is established will depend on which institutions perform these functions and how far they are open to the kinds of knowledge and social economy on which Zero Waste depends.

Market development

The first of the functions is now being undertaken by WRAP, a not-for-distributed-profit company limited by guarantee, set up in late 2000, and already providing a level of leadership in market development which had been absent from either the public or private sectors. WRAP has rightly given priority to exploring uses and markets for compost including the establishment of standards, and is in the process of allocating seed funds for a substantial expansion of newsprint capacity by tender.

Developing the supply side

WRAP represents the demand side of the new recycling. It is on the supply side that new initiatives are needed. There is still a serious shortage of know-how in both recycling and composting, in a field which also calls for the new ways of working outlined in Chapter Four. The large waste companies have had difficulty in entering this field effectively, relying as they do on traditional collection techniques and capital-intensive sorting and processing. The highest recycling and diversion rates have been achieved by the community sector and by creative council officers working with Direct Services Organisations (DSOs).

Yet their numbers are still limited, and their resources restricted. The community sector has been successful in areas such as social marketing, the development of new types of collection vehicle, the reskilling of collectors, waste composition analysis, local composting, joint materials marketing and the publication of an excellent new journal. They are, however, with one exception, still relatively small organisations, working with limited finance and not yet with the capacity to offer a full four-stream Zero Waste service for any district or borough. Similarly, the innovative councils and their DSOs are necessarily confined to their own boundaries and operate within the local authority financial restrictions. Neither of them yet constitutes a developed supply side for the extension of smart recycling throughout the country.

A new intermediary institution is needed to develop the supply side in the same way that WRAP is developing demand. In many jurisdictions abroad this role has been played by an animating agency. The customary functions are the development of operating manuals, of recycling software and management information systems, of social marketing materials, technological search and training. They play a role similar to that of the 'real service centres' in the industrial districts of Italy and Spain, providing a range of information, strategic planning, training and advice to small firms, similar to that supplied internally in large firms by central service departments. In the UK context this would be part of the job description of a Zero Waste Agency.

Investment finance

There is also a question of finance. The 'new wave' recyclers have not attracted finance from the conventional banking network, partly because of a low asset base (in the case of the community sector) or because of statutory restrictions on borrowing (in the case of local authorities).

Nor has recycling been seen as a bankable proposition, as compared to a large disposal contract with guaranteed gate fees over 25 years. Instead, community and Direct Services Organisation (DSO) recycling has grown on the basis of working capital advanced by client councils, supplemented by grants. Grant funding rather than private investment has been the rule for the expansion of municipal recycling.

This remains an option for the kind of conversion programme outlined above. The funds realised from central government or the landfill tax could be granted directly, or through an intermediary institution such as a Zero Waste Agency. The latter has the advantage that the grant giving is undertaken by those with knowledge of the sector, and can be supported with other intangible services. Innovation is further stimulated if grants of this kind are administered through flexible bidding systems, in conjunction with specialist advice provided to applicants, and specialist adjudicators.[102]

An alternative option would be to shift the bulk of available funds away from grants to investment. The rationale for this approach is that in the long run intensive recycling should reduce council waste budgets as in the leading North American municipalities. If this is the case, and if service fees paid by municipalities for integrated collection services are held at current budgetary levels, then there is money to be made. The market for waste management services should be structured so that recycling and composting remain economically attractive for municipalities while providing a positive rate of return to the service provider. In this case intensive recycling becomes bankable.

Social venture capital

The investment approach opens up a new range of possibilities for the technical support and finance of intensive recycling. Because of the economic uncertainties of a new sector and the long payback period, a transitional institution is needed based on the model of social venture capital and development banking. It would be set up, like WRAP, as a company limited by guarantee. Its task would be to promote social enterprises to undertake inregrated, recycling-led collection systems, working in the first instance with client local authorities to expand existing enterprises or to promote new ones that would draw together on their boards and in their management the many skills and cultures required.

In some instances the new enterprise might be a joint venture between an existing community recycler, a DSO and an overseas established recycler. In others it might be a subsidiary of an existing waste company in conjunction with the community sector. Or the interest of a range of suppliers might prompt a local authority to break up a borough wide contract into smaller areas for the suppliers to manage independently.

The financial package would have four features:

- the contract between the social enterprise (‘the contractor’) and the local authority would cover all aspects of waste management within the collection authority, to allow the full system economies of intensive recycling to be realised;

- the contractor would guarantee to provide a comprehensive service to the collection authority for the existing budgetary cost (in real terms) over a ten-year period;

- the contract would be based on partnership working, with the council contributing agreed resources (such as publicity, depot and bulking space, maintenance services and some working capital) as a condition for the contractor’s financial guarantee;

- the social investment trust as the venture capital instrument would provide capital in the form of equity, preference shares, unsecured loans, and (for some types of expenditure) grants, and would also act as guarantor for the financial and performance package to the client authority.

The advantage of this arrangement is that it would remove financial risk and the transitional cost premium from the client authority – both of which have been such barriers to the expansion of recycling. With this on offer, the contractor would be in a position to negotiate use of council assets at a low marginal cost, and at the same time would be encouraged to adopt smart recycling techniques in order to minimise debt.

More generally, while the goals of both the social investment trust and the contracting enterprise would be the expansion of intensive recycling and regeneration, this would be subject to commercial constraints. As the experiences of the social enterprise sector indicate, the combination of social and environmental goals subject to trading disciplines encourages production efficiency. Whereas grant applicants tend to inflate costs in their applications, those receiving a loan have an interest in containing them. The investment model would build in a drive for innovation and efficiency that has often been lacking in grant based organisations.

Another relevant social enterprise lesson is that other investment can be attracted by the goals of the organisation rather than its profitability. The pressure on large corporations to observe a triple bottom line has meant that they are increasingly looking for well-managed outlets, which meet social and environmental criteria, for support or investment. Both the Zero Waste Investment Trusts and the new generation of recycling enterprises would be attractive to corporate and ethical investors from this perspective.

Initially a Zero Waste Investment Trust would be established nationally and used as an instrument for the placing of funds channelled from the Landfill Tax Credit Scheme and a reformulated Private Finance Initiative (PFI). It would form local trusts, aiming to attract onto their Boards leading entrepreneurs from the commercial and community sectors who have an environmental orientation. The Trusts – like good development banks – would employ technical specialists, as well as business and financial managers, to provide advice and support to the recycling enterprises and to the Trust’s financial arm.

The overall advantage of this approach is that it would introduce an economic dynamic directed towards Zero Waste. It would not be dependent on a continuing flow of grant funding. Returns from the investments would be channelled back into an expansion of the project.

Although its initial focus would be on local authority recycling, it would be expected to diversify and invest in commercial and industrial recycling projects (which commonly have a much shorter payback than the municipal sector).

A supply side Investment Trust would have an interest in promoting training programmes for the management and operation of intensive recycling systems in its area, either as part of existing courses and institutions or as a stand-alone Zero Waste Academy. An Academy, like a specialist technical school on the continent, would combine teaching and research on the full range of Zero Waste issues, and act as a catalyst for these issues in other universities and colleges.

With WRAP promoting the demand side, and the Investment Trusts facilitating the supply, the UK would have the potential to implement a programme of conversion to intensive recycling which would be economic and innovative. This would provide a step change in the movement towards a Zero Waste economy.

X Beyond Recycling

I have argued that municipal waste is the first step for a Zero Waste policy. It is centred on householders, (who have a key role in the post-waste order as recyclers, voters and consumers) and local authorities (who are the local public interpreters of environmental imperatives). It is a segment of waste more open to direct government influence than other parts of the waste flow, and at the same time connects to small firms and local institutions and their waste practices via the municipal trade waste service.

But even a radical transformation of municipal waste policy can only take things so far. The next step is to promote increases in recycling and composting in the commercial, industrial, construction and agricultural spheres. Alongside that, policy has to reach back to promote reduction of waste in the first place. Recycling in this sense is only a staging post. It is new production processes, material substitution, materials efficiency and design for extended product life that will be necessary to carry Zero Waste further.[103]

One estimate of the relative impact of different Zero Waste measures on greenhouse gas (GHG) reduction has been made for Western Europe by the Delft Group using the Markal model. Table 8 presents its results based on several hundred case studies in the second half of the 1990s.[104] The Delft Group was not able to analyze product reuse and product substitution in any depth, and its recycling category (accounting for less than a sixth of potential reductions) is narrowly defined to refer primarily to plastics recycling.

What these results show, nonetheless, is the importance of moving beyond recycling. Recycling is part, but only a part, of a wider green materials revolution. As the 1998 USEPA study confirms, while there are major GHG savings to be made from recycling and composting, GHG reduction will always be greater if waste is prevented rather than managed.[105] The Delft research highlights the

Table 8 The significance of different elements of Zero Waste strategies to GHG emissions reduction

Design for Environment Strategies	Emission reduction potential (MtCO2e)
Increased feedstock efficiency (less energy intensive processes, reduced losses during materials production)	50 - 100
Increased material efficiency (high strength materials, new alloys, composites, improved quality control to reduce variations in materials quality, reduced waste of materials during production, higher design strength, less material intensive design, materials standardisation)	100 - 200
Increased product efficiency (such as new packaging concepts, car sharing, increased product life, multi functional products)	50 - 150
Materials recycling/energy recovery (mainly plastics recycling)	100 - 200
Product reuse (renovation of buildings, design for disassembly)	25 - 50
Feedstock substitution (biomass feedstocks for plastics, solvents, fibres)	50 - 100
Materials substitution (renewable materials, less CO2 intensive materials, materials with improved physical characteristics, recyclable materials, material innovations and substitution leading to emission reductions in the use phase of vehicles and buildings)	200 - 300
Product substitution (product service concepts, less material-intensive products, products requiring less maintenance, long life products)	100 - 200
Total	675 - 1300

Source: Gielen, Kram and Brezet (1999)

major savings that can be made from changes in the resources used in industry, the efficiency with which they are used, and the types of goods – their durability and level of performance – that are produced to service consumption needs.

Policies to promote the new green materials economy are more complex than those involved in the expansion of municipal recycling. The changes required are pervasive. They reach throughout the economy, covering multiple facets of production and consumption. They have necessarily to work with industry for it is the producers who have to introduce the new paradigm. Policy is therefore directed at re-shaping the terms under which the market operates in order to provide the framework, the incentives and the information to encourage change.

In addition to the traditional government instruments such as regulations, generalised tax breaks and standardised grant programmes, three innovative approaches to environmental policymaking have had relevance for the encouragement of waste minimisation and materials efficiency:

- extended producer responsibility;
- innovations in public finance;
- knowledge economy instruments.

Together these provide the means to speed up changes already underway.

1. Extended Producer Responsibility

The concept of private property has from its inception had to identify the rights of 'quiet enjoyment' conferred by ownership, and the limitations on the use of that property if it harms others. The principles of environmental liability and 'polluter pays' marketise the infringement of these limits, expressing damage in monetary terms so that it can be internalised in the accounts of the polluter.

This has been effective when pollution can be traced to an identified source, such as a large factory, and its impact quantified. But what if the pollution has multiple sources? Are the harmful effects of CFCs from a discarded refrigerator the responsibility of the manufacturers of CFCs, of the fridge maker, the retailer for selling it, or the user for discarding it? Who is responsible for the pollution caused by nappy waste – Proctor and Gamble for producing the disposables, or the baby for using them? For issues such as resource productivity and waste, there are many points of responsibility in any product chain. We can speak of the socialisation of responsibility.

Extended Producer Responsibility (EPR) addresses this problem in an original way. It shifts the focus away from production facilities to product systems and design. In the words of Gary Davis, a leading contributor to the ideas and practices of Clean Production:

"Extended Producer Responsibility as a broad principle states that producers of products bear a significant degree of responsibility for the environmental impacts of their products throughout the products' life cycles, including upstream impacts inherent in the selection of materials for the products, impacts from the manufacturer's production process itself, and downstream impacts from the use and disposal of the products. Producers accept their responsibility when they design their products to minimise the life-cycle environmental impacts and they accept legal, physical, economic or informational responsibility for the environmental impacts that cannot be eliminated by design."[106]

He then outlines a set of principles to use in applying EPR, which include the following:

- schemes should create effective feedback to product designers to stimulate clean production;
- they should take a life cycle approach and be directed at producing life cycle benefits;
- there should be a clearly defined locus of responsibility;
- policies should be tailored to specific product systems;
- they should increase communication between producers throughout the product chain;
- policies should stimulate innovation by concentrating on improved outcomes not processes;
- there should be means of assessing the environmental and economic results of the policy, particularly where schemes are voluntary;
- policy should be framed with stakeholder involvement.

From this it should be clear that EPR is a policy instrument that reaches right back into product design and to issues that are at the centre of any industrial Zero Waste Strategy. How directly it does so will depend on the design of any particular scheme and the target levels set.

In the case of the EU's Packaging Waste Directive, targets are primarily set in terms of recycling and recovery levels, but the fact that the cost of meeting these has to be paid for by those in the packaging chain means that there is an increased monetary incentive for each of them to reduce the amount of packaging and improve its recyclability. The impact of the Directive, and of earlier national packaging measures, is reflected in the technical changes that are already taking place in the packaging industry, partly through light-weighting and partly through the substitution of biodegradable materials.

The EU has taken the lead in reducing the quantity and hazardous nature of waste through sectoral Directives. It is requiring producers to take responsibility for meeting graduated recycling targets for batteries, end of life vehicles and electrical and electronic equipment, as well as adopting 'design for recycling' and the reduction or phaseout of heavy metals and other hazardous substances. The use of EPR to control and reduce hazardous waste in British Columbia is summarised in inset 5.

As an instrument, extended producer responsibility can be tailored to specific products and substances, it is flexible in its application, and encourages collective responsibility within a product chain for the environmental impact of that chain. It can be used to reduce or phase out a wide number of substances, and substitute them with alternatives, from chlorine based materials like PVC and solvents, to non biodegradable plastics and chemicals in babies' nappies.

In the UK, the government has relied primarily on encouraging voluntary producer responsibility arrangements. By the late 1990s schemes existed in vehicles, batteries, tyres, newspapers and electrical and electronic equipment, but in most of these cases the advances have been limited, and less effective in changing the course of the sector and developing new technologies than the legislative programmes on the continent.[108]

The one legislative scheme has been in packaging in response to the EU Directive. In this and other forthcoming Directive-led programmes, the principal question remains how to shift government policy from being a passive implementer of EU Directives (and in some cases a force for diluting their terms) to being a proactive promoter of EPR as a means of achieving environmental goals and of stimulating new technology. In practice, the dominant emphasis of UK policy in EPR, as in other waste-related directives, has been on minimising costs rather than on maximising environmental outcomes.

In this regard it is striking that the recent assessment of EPR in Packaging in the UK by DEFRA's Advisory Committee on Packaging began by stating that 'one of the key objectives for the UK has been to achieve its environmental targets at the lowest possible cost to industry', without any assessment of the environmental impact or the priorities that should be set in implementing the Directive. It was unclear at the time the report was written that the UK would meet its targets, which would anyway leave it 'below the level of many other Member States'. What the Committee was certain of was that the scheme had minimised the cost.

The report reflects all that is weakest in the 'old order' approach to recycling in the UK. It sets incineration in direct competition with recycling in its recommendations on targets, resisting the EU Commission's proposals to replace 'recovery' tonnages by recycling. It warns against any attempt by the Commission to reduce the amount of packaging, and against any attempt to introduce reuse rates, and argues against high targets for individual materials. Rather it proposes that glass is given priority over paper and cans since paper would involve kerbside collection and, like cans, would be a lighter material when the targets are set by weight. There is no mention of the relative contributions of each of these materials to resource conservation and GHG reduction, which is one of the prime purposes of the Directive in the first place.[109] The predomenantely corporate Task Force represents a product chain which is not taking full extended responsibility for its environmental effects.

Rather than this approach, the government should outline a programme of EPR which leads rather than follows EU Directives. This is the policy which has been followed so successfully in Germany, and to a lesser extent in Sweden and Holland, and which has placed those countries in the lead in new recycling and waste reduction technology. The programme should be developed out of the joint waste minimisation and materials efficiency initiatives discussed below, and cover products as well as materials that have been difficult to recycle or that cause hazards in disposal.

Inset 5

Producer Responsibility and Household Hazardous Waste in British Columbia

During the 1990s the Government of British Columbia targetted the removal of hazardous waste (accounting for 1%-2% of household waste) from residuals sent for disposal. Initially in 1990 they established 8 pilots depots for households to deposit hazardous items, but these were only partially successful and were later closed. They also provided recycling incentives for tyres and batteries, which led to the recycling of 20 million tyres and 5 million vehicle batteries between 1991/2-1998/9.

But from 1992 they adopted a producer responsibility approach, putting the onus on manufacturers to administer and fund the waste reduction programmes:

- Used lubricating oil. Sellers of oil either had to take back used oil at no charge or arrange for agents to accept it. Each year this diverts more than 40 million litres of used oil.

- Paint. Paint brand-owners were required to take responsibility for the safe disposal of used paint. They established a not for profit company to do so for paint, aerosols and empty containers. The company has 103 depots throughout the province, and is financed by a small eco fee per can, which is paid by producers. In four years they collected 11 million litres of paint. Oil based paints are shipped to hazardous treatment/disposal facilities; latex paints are recycled into construction products; paint cans go to steel mills; and some paint is re-used.

- Pharmaceuticals. In 1996 the industry established a voluntary stewardship programme, for hazardous drugs to be returned to 650 pharmacies for safe collection and disposal.

- Solvent/flammables, domestic pesticides, gasoline and pharmaceuticals. The Government required producers to establish stewardship programmes for waste products. They jointly opened 35 depots, financing them either by an eco fee or through producer subscription.

These schemes have to be independently audited. In some, such as paint, there are reuse and recycling targets. The long term aim is to encourage the switch by consumers and producers to less hazardous materials and products (from water based to oil based paints for example.)

2. Innovations in public finance

Green tax proposals aimed at encouraging the closed loop economy have focussed on raising taxes on material inputs and waste. We have already discussed waste taxes. At their current levels, they are not a significant enough cost for most industries to encourage a radical redesign of the product chain. Similarly, there is limited scope in the UK to pursue the proposals considered elsewhere for raw material charges and subsidy reduction, or virgin material import ceilings.

The exception is the construction sector, whose use of materials can be significantly influenced by taxes on primary aggregate and waste disposal. The tax of £2 a tonne on inert waste taken to landfill introduced in 1996 has led to a fall in landfilling of this class of waste by a third (more than 12 million tonnes) in the two years between 1997/8 and 1999/2000.[110] This has led to some increase in recycling, which will be reinforced by the introduction of an aggregates tax in 2002 at a level approaching 50% of the ex-works value of virgin stone.

For commercial and industrial producers, reliant on material imports and for most of whom waste costs are trivial, the measures that promise to have a significant effect on resource productivity are those introduced in Britain to reduce CO2 within the context of the Kyoto targets. There are five elements here:

- the climate change levy (CCL), taxing electricity, gas and other non-renewable energy sources used by business;
- the exemptions to the levy granted to energy intensive businesses which sign energy efficiency agreements;
- the earmarking of part of the levy to finance a Carbon Trust to take the lead in energy efficiency (and waste reduction) advice and in low carbon innovation;
- the earmarking of another part of the levy to provide capital allowances for energy saving technology;
- the provision of start-up finance for an emissions trading scheme, through which firms which have exceeded their CO2 emission reduction targets can sell the excess to those who have fallen short.

There are a number of innovations here: the primary resource tax, which partly reflects the carbon intensity of fuels; the use of tax explicitly to change business behaviour with the tax revenues hypothecated to further the same goals; the use of negotiated agreements with firms to change corporate behaviour in return for tax reductions; the establishment and funding of a not-for-profit Trust to act as an animator of innovation; and finally the marketisation of target performance through emissions trading. In the history of public finance this package would qualify for a chapter on innovative instruments. Many have been advocated by environmental economists, but few in the mid-1990s could have expected they would be introduced so rapidly.

The above measures have been put in place to increase energy efficiency. The question is how far they can be developed to improve material resource productivity. As the Dutch research suggests, the two are closely related and a major impact on energy reduction can be made through improved material productivity. It is not just a question of getting heavy energy users to improve their energy efficiency, but of changing manufacturing production so that it uses less of the energy-intensive primary materials and/or extends their life through reuse and recycling. This is the reason why Zero Waste is important for Climate Change policy.

There is a parallel here between pollution control and emissions reduction. The first stage in both is to cut down the emissions of the major polluting plants and processes. In each case, the plants and their emissions can be readily identified (and for this reason they are likely to be the early core of players in the emissions trading market). The challenge comes when the cause of the emissions cannot be ascribed to a single plant but to the product chain as a whole. Can the UK climate change measures be widened to take in such product chain issues and waste reduction/resource productivity more generally?

The question can be posed first in relation to emissions trading. For such trading to work, firms have to register current emission levels and agree targets for their reduction. There have been 44 agreements in the UK to date, and there is a view that the existing criteria of eligibility that allows firms to trade reduction targets for tax concessions should be widened. Under the likely terms of the international trade in permits, once a reduction target is agreed a firm (or country) will have the option to meet it by emissions reduction, sequestering carbon or by buying credits. As a result major GHG emitters in North America are already preparing for the new trading regime by investing in projects that will promote sequestration or large emissions reductions (such as forestry and agriculture) and hence offset their own shortfalls.

With respect to waste and materials, it should be possible in principle for firms, either individually or as a product chain pursuing the Design for Environment Strategies outlined in Table 8, to register their current CO2 emission levels and reduction targets and to generate surplus certificates for sale. Given that the price of the certificates when they are internationally traded is forecast to be substantial, this would provide a major incentive for the adoption of industrial Zero Waste policies. The issue is whether the registration and target regime in the UK can take such policies into account. How could the benefits of substituting biodegradable plastics for oil-based plastics be included in the scheme; or the production of a fully recyclable car with a thirty-year lifespan?

Similar questions could be asked of other parts of the UK's fiscal package: could such material productivity initiatives be granted the Climate Change levy reductions in return for an agreement covering material efficiency as well as energy efficiency improvements? Could firms that provide lifelong guarantees on products with take-back agreements qualify for the extra capital allowances? Could those firms which agree to standardise components to ease remanufacture and repair receive funding from the Carbon Trust?

The answers to these questions must in principle be yes. Waste minimisation and materials efficiency agreements could be replicated on the model of those for energy efficiency, and indeed would overlap. But, as with the producer responsibility approach, the challenge comes when no one firm can make the necessary changes on its own. In such cases, the agreements and incentives need to be collective.

Instruments of the information economy

A third approach sees the generation, interpretation and distribution of information as the critical point of entry for Zero Waste policy. The starting point for any re-orientation of productive practices, it argues, is to make their current environmental impact visible. Where economists have sought to marketise environmental costs and benefits which have been hitherto outside the market, so in parallel the same thing needs to happen with environmental information, to make visible what has hitherto remained unseen.

In relation to Zero Waste this entails the qualitative and quantitative study of the impact of different types of product and productive system on the environment and an assessment of how they can be improved. In the past thirty years this has generated a wide range of new ways of looking at the material flows of the economy and their effects. (The ex post quantification of material flows is one example, along with life cycle analysis and dynamic ex ante estimates of flows and processes to judge the impact of alternative paths of technical change.) It has also generated new ways of counting (through the development of environmental reporting and performance indicators) and a new level of scientific testing of hazardous effects.

For some writers the project of increased environmental knowledge is parallel to that of increased social knowledge which accompanied the expansion of government social policy in the nineteenth century, with its extended apparatus of statistics, inquiries, inspectorates and institutional controls.[111] For others it represents an endless task of trying to control (carry on business in spite of) the uncontrollable effects of modern technology, where each new attempt produces its own hazards.[112] Much of the debate has centred on the identification of risk and how its potential impacts are assessed and distributed.[113] For all these writers the role of science and information about the environment has become the pivotal point of environmental politics. It is also the starting point of any project of ecological modernisation. In this context government policy towards the production of information, its interpretation and circulation becomes the critical instrument for environmental reform.[114]

This informational economy feeds into the process of Zero Waste production in six ways:

- as the stimulus for action by civil society;
- as the basis for subsequent development of government policy and regulation;
- as an input for ecodesign and new environmental technologies;
- as productive information for re-oriented producer strategies and practices;
- as a source of data for public monitoring and surveillance;
- as information to consumers to inform purchasing decisions.

These represent the political, governmental and economic dimensions of environmental transition and each can be strengthened through government support.

A starting point for considering a policy on information and Zero Waste are the conclusions of the Cabinet Office report on Resource Productivity. Although the report raises the possibility of extending the principles of environmental taxation to the field of materials, its prime recommendations reflect the knowledge economy approach. The list of recommendations includes the following: the development of Material Flows Analysis and environmental accounts, further research on the role of natural resources in the economy and the barriers to improved resource productivity, the development of resource productivity proxies and measurements, an assessment of existing information providing bodies (and by implication a strengthening of the function), a programme of awareness-raising around resource productivity issues, an extension of environmental reporting by major companies, a connection of sustainability issues across departments and their internalisation into Treasury assessments, possible indicative targets, and support of conversion initiatives through advice, finance, public procurement and improved training and education.[115]

These are all necessary elements for a new resource productivity policy, but as a programme they need more specificity and scope. The impact on waste minimisation of the proposals for self-monitoring through the publication of environmental reports, for example, will depend on the nature of the reporting: what is covered, how far it extends into the issues covered in Design for the Environment and so on. As we noted earlier there is pressure for environmental reporting from insurance companies and pension funds, which have an interest in the real progress being made rather than its presentation. Thus, much rests on the degree to which the format and substance of reporting reflects the wider perspectives of Zero Waste.[116]

Self-reporting needs to be supplemented by enhanced rights and resources for independent environmental auditing bodies, and by schemes such as eco-labelling, or the successful environmental league tables in Indonesia in which a ranking of the environmental performance of major firms is published, with those at the bottom given notice before publication to provide them with an opportunity for improvement. In an era when major companies are more than ever dependent on the integrity of their brands, the opening of the environmental books becomes a powerful policy lever that works through the market, via the impact of both green consumers and ethical investors.

Secondly, the data on industrial and commercial waste needs to be regularised and extended. Waste Strategy 2000 set a target of a 15% reduction on 1998 levels for commercial and industrial waste going to landfill by 2005, which is some five million tonnes. The way in which this might be measured is by data from landfills, but this does not allow the targets to be made firm or sector specific. As far as data on the latter is concerned, the Environment Agency carried out a National Waste Production Survey of 20,000 firms in 1998, the first of its kind for many years. But this is not being repeated, it is said, because of a shortage of finance. Yet it has to be recognised that information of this kind is as critical for effective policy and industrial change in this field as it is in the macro control of the economy.

Thirdly, the proposals for further research and for technological support need to be brought together and responsibility for them placed in a Clean Production Centre. This is an idea proposed by the OECD and implemented in a number of OECD member countries. The main purpose of such centres is to act as an entrepreneurial driver of the new materials policy. The Centre would promote clean production research, design for the environment initiatives, and the extension of Zero Waste advisory services, and in particular would:

- undertake and/or sponsor sectoral, material and process specific research;
- provide a link between independent research institutes and firms on the model of the successful Steinbeis foundation in Germany;
- produce manuals and provide advice on waste reduction, feedstock substitution and materials efficiency;
- supply relevant market and technical information to small and medium firms.

Above all it would be charged, like the Carbon Trust, with animating change.[117]

One option would be to attach it to the Carbon Trust, whose terms of reference already include advice on waste reduction. As we have seen there is a strong interconnection between advice on energy, water and waste reduction, and between their effects. The scope and resources of the trust could be expanded to take in the promotion of innovations for increased materials productivity as well as energy efficiency.

Even if established separately the trust should remain closely linked to the Carbon Trust (and to WRAP) and would be funded in a similar way with resources drawn from the Climate Change levy and from increments in the landfill/disposal tax.

A policy package

The three approaches outlined here are not alternatives. Nor are they mutually exclusive. Each provides an innovative entry point for policies that promote the changes necessary for Zero Waste. They also provide a range of instruments, which largely complement each other, and which can be further linked to more established policy tools such as regulations and public purchasing. As can be seen in the case of energy efficiency, once the goals are clear, a variety of tools can be drawn on to change the course of production and the nature of innovation in any industry.

The central point again, as in the case of municipal waste, is a clarity about goals. There may be strengthening independent pressures upon the corporate world to improve environmental performance, but these need to be contextualised within a clear government perspective. The government alone can provide leadership and purpose on issues that span the range of particular interests.

Business itself recognises this. The Advisory Committee on Business and the Environment gave priority to its recommendation that: 'government makes clear to business the broader goal of resource productivity in its policies on waste minimisation and reducing waste to landfill'.[118] The role is one of intellectual and policy leadership.

In the case of energy and climate change the ground has been well set, and the work of translating it into immediate policy was undertaken by a small task force led by Lord Marshall.[119] In the case of materials productivity and materials substitution, the new perspectives are less widely known.

- **The government should establish a Design for the Environment Commission.**

The Commission should identify the potential of these innovations in the UK context, draw up a programme for conversion, establish a set of targets and develop the policies needed to achieve them. The Commission would be made up of leading international specialists in the field of the green materials economy together with their equivalents in the UK. Their report should set out the new paradigm of green production. The policies to promote it should provide the incentives and make the sources of advice and information available for those who choose to pursue the approach. A report of this kind would provide the basis for synthesising the work of government and industry in this field.

This is a first step. At the same time, an immediate start should be made on extending the idea of industry agreements introduced as part of the Climate Change levy. In this instance the agreements should not be negotiated solely with firms, but with groups of firms engaged in a particular product chain or production of materials.

One initiative of this kind which has been in operation for more than a decade is taking place in Holland. In 1989 the Dutch Parliament established a waste minimisation target of 10% by 2000 which was applied (flexibly) to 29 priority waste streams. For each of the streams, waste minimisation plans were drawn up through consultation between industry and government, and these were then translated into individual company environmental plans. The sectoral plans were embodied in covenant agreements between the industries and the government, and all companies in the sector or chain were issued with a handbook setting out the goals of covenant and a list of possible minimisation measures. Headway was made most rapidly with sectors which already had integral environmental tasks, such as the chemical industry, paper and paper goods and the dairy industry, but the work was then extended to other groups.[120]

Processes of this kind are already taking place in the UK around producer responsibility programmes, but there is a strong case for widening their scope and extending them to other sectors within the framework of national waste reduction targets. In particular sectoral working groups should consider how actions taken in the field of materials efficiency, product performance, product life extension and feedstock substitution could be linked to the $CO2$ reduction targets and future emissions trading.

National and local

The emphasis of industrial Zero Waste policy has been on actions to be taken by national government. But within a new policy framework there is much that local and regional government can also do. The national Clean Production Centre should be established with a network of regional sub-centres. Local and regional government, and the regional development agencies, can play a role as a link between existing environmental research institutions and local industry. There is scope for using public purchasing to encourage Zero Waste companies, and to work with them and other institutions on local reuse and CO2 reduction schemes.[121] Above all, they can use their central information and material role as recyclers and disposers of municipal waste, to connect into the wider project of Zero Waste.

XI Conclusion

The environmental critique of modern production has advanced on two fronts: sources and sinks. One has highlighted industrialism's devastation of certain natural resources and ecosystems, the other the pervasive pollution from its wastes. There have been attempts in each case to provide remedies in isolation: to develop sustainable forestry at one end, for example, or to install pollution control equipment at the other. Both have had an impact – but both find themselves holding back the growing demands for new resources, and the growing quantity of wastes, as a sea wall holds back the pressures of a rising tide.

If the relentless growth of global material production is to be outpaced, the problems of sources and of sinks cannot be solved in isolation. They have to be seen as parts of a wider chain of production and consumption that must be reconfigured as a whole. The issue is one of changes in productive systems – how products and processes are designed, how they operate and how products and materials, once used, return again to the circuit of production.

The major transformation now being demanded in agriculture, where intensive farming is both depleting the soil and leaving residues – whether in the area of nitrogenous run-off or toxic middens – illustrates the point, as do the shifts taking place in the energy sector and in transport. In each case, the critique has broadened from an identification of particular environmental problems to a challenge to the economic architecture of the productive system as a whole. Whether for food, power or mobility the movement for reform is now being framed in terms of how needs are being met – and how they could be met differently in ways which would work with the grain of social and natural ecosystems rather than against them.

Beyond the waste ghetto

Zero Waste should be seen in this light. Much has been done since the early 1970s to reduce the pollution stemming from waste disposal and to encourage the reduction of waste. Yet the volume of waste and the problems resulting from it have continued to increase. This is how Joke Waller-Hunter, the OECD's Director of the Environment put it in 1999:

"Despite nearly 30 years of environmental and waste policy efforts in OECD countries, the OECD-wide increase in waste generation is still in 1:1 proportion to economic growth. A 40% increase in OECD GDP since 1980 has been accompanied by a 40% increase in municipal waste during the same period …Consumer spending also follows these trends. According to our colleagues in the Economics Directorate, there is expected to be a 70%-100% increase in GDP by the year 2020 in the OECD area. I would personally not like to imagine a world where municipal waste generation is also 70%-100% higher than the already high levels of today".[122]

What was initially conceived as a confined policy problem had by the late 1990s become a gathering environmental nightmare, which led to waste being named as one of the 'red light' issues in the OECD's Environment Strategy in 2001.[123]

The first policy focus has been to improve the safety of the waste disposal sinks, the second to reconnect waste to industrial production through recycling. These have both been advanced from the end of the pipe – through the conduct of waste management. Yet, in Britain at least, the connections between recycling and the processing industries have been weak. Municipal recycling has been treated first and foremost as an 'option' for waste management. Its main perceived significance has been as a means of reducing the quantities of waste for disposal rather than providing high quality feedstock for industry. Only now, with the establishment of WRAP, are the connections between the recyclers and industry being systematically constructed so that the market for materials becomes not a problem but a raison d'être of municipal recycling.

'Low road' recycling has always faced difficulties as long as it remained primarily a waste disposal option. The various attempts to recycle or compost mixed waste have been gradually abandoned, in favour of a policy of source separation. Once waste materials are examined separately, the problems of quality and marketability are continually posed. What is the market for municipal compost if it contains high herbicide residues in garden waste, or contaminated meat in putrescible scraps? What is the value of plastic lined steel cans and plastic composites? What is it in the construction of a toaster that makes it difficult to repair? What are the economics of glass and plastic bottles that makes the industry so reluctant to reuse?

In each case, waste managers may conclude that the materials are unrecyclable, or that it makes no economic or even environmental sense to do so. But the problems of disposal push the question back on the table and pose it the other way round, namely: what would be required to make such a material technically and economically recyclable? Such a question takes waste managers beyond the end-of-pipe boundaries. It leads necessarily to questions about waste production, and waste production in turn leads on to issues of industrial design and manufacturing processes.

This is the first connection. The second is that between recycling and the other great arena of environmental concern – the sustainability of resources. Composting comes to be recognised as important not simply as a means of diverting bio-degradable waste from landfill, but of contributing to soil restoration and the fight against desertification. Or take paper. Recycling one tonne of waste paper preserves 17 trees. A modern recycling mill therefore saves five million trees a year. That is a measure of the importance of recycling. It shows how the problems of sinks and sources are linked and how they both, in their own way, flow into the wider questions of production.

The argument of this book is that waste cannot be treated in isolation. Attempts to do this whether using old or new technologies are necessarily limited for three reasons: first, the landfilling and incineration of mixed waste has been unable to eliminate the hazards associated with each. They can confine and attempt to manage them, but as regulations tighten, costs increase and the problems of everyday operation – of accidents, fires, malpractice, material failure, seepage and the scattering of toxic residues to air and water – continue to reappear.

Secondly, the disposal of waste removes materials from their cycle. Modern forms of disposal and pre-treatment are designed to generate some energy or material from the waste stream they deal with. Landfills produce harvestable bio-gas. Incinerators generate energy and extract low grade metal from their ash. Mixed waste composting produces a grey compost high in heavy metals which is sometimes used for landfill cover or land reclamation.But these represent no more than the salvage of resources during a process of destruction and bear no comparison with the resource savings from source separated recycling and composting.

Thirdly, restricting the problem of waste to that of its disposal is to sacrifice its role in the environmental transformation of industrial production. Landfills and incinerators ask no questions. They take what comes to them. They are driven by the requirement to operate within regulations at least cost. There are few prizes given for the cleanest landfill or the lowest emission incinerator. They have no incentive to hunt out the batteries in a consignment of mixed waste. If a load of PVC arrives at an incinerator, the issue is how to phase in its combustion in order not to exceed emission limits, rather than whether or not to divert it elsewhere. Far from having an interest in reducing hazards, disposers stand to benefit from them, hazardous and clinical waste disposal being at the top of the waste price hierarchy.

Much the same can be said of 'low road' recycling, whether its aim is to divert from landfill or to meet government targets. It, too, is passive. Its dynamic is not to connect back to the industrial circuit to recover high value material or pre-empt toxic waste. Rather the effort is put into contesting regulations, and once they are set, into finding ways to meet their formal requirements at least cost. In this context a target or regulation is seen as a burden, not as an invitation to innovate.

Zero Waste has a different perspective. Waste is a sign of failure of industrial design. It is a symptom of wider issues. While waste has to be managed, the aim of Zero Waste is prevention, and the development of circuits that slow down the entropy of energy and materials and enhance nature's metabolic process. As Michael Braungart remarks, waste must equal food:

"The amount of organic waste produced by ants is more than four times higher than that produced by the six billion people in the world. But ants are not an ecological problem – they return all products of metabolism to various cycles. Nature knows no waste. All products of metabolism are recycled as 'food' for other organisms.[124]

Zero Waste seeks to understand why these circuits have broken down and how they can be restored. Whereas traditional waste management was geared to making waste invisible, Zero Waste aims to increase its visibility. Recyclers undertake waste audits and follow material flows. When they collect, instead of the closed wheeled bin, they use open plastic boxes. Instead of black bags, the new Italian collection systems provide transparent bags for food waste and residuals. The civic amenity sites (and in New Zealand many of the landfills) are no longer organised as inaccessible places for disposal, but as reception centres for recycling, reuse and repair – extensions of the car boot sale. The last few years have seen the reclamation of waste as a source of education and entertainment. Schools establish wormeries and include waste in their curricula. Communities ask for transparency in the monitoring of waste facilities and finance their own testing. Never has waste been so closely inspected, watched, tested and discussed.

The reason for this renewed visibility is so that all those involved in producing and handling waste can distinguish those parts of it that can be returned to production, from those parts which should not have been produced in the first place. I have argued that one of the important things about waste is that it is a vantage point for assessing the sustainability of modern industrial processes. Waste and its management serve as a stage of quality control for the whole system, tracing back defects (bad waste) to their source. To confine waste management to disposal or to passive recycling is to neglect its role as a point of innovation for clean production.

A similar point applies to waste management's new role as a link in the biological and technical circuits. It is no longer a terminus but a critical interchange in the process of material circulation. As such it needs to be integrated with the producers of waste on the one hand, and the users of the reclaimed materials on the other. Modern recycling no longer acts solely as collector and merchant, but as an active player in the system of knowledge production. Its starting point may be the channelling of unwanted material back into useful production, but it then acts as a promoter of new uses for old materials and of new materials (and products), both of which serve to increase the resource productivity of the system as a whole.

The most innovatory institutions in the new waste management have played this intermediary role, with engineers, material specialists and market researchers working alongside local industry on secondary material use. They have combined technical advice and research and advised regulators on new standards. In parallel, producer responsibility legislation encourages industries to assume these functions on their own behalf – sub-contracting the collection and sorting function – while undertaking their own programme of research and re-design to improve the life cycle of products and materials.

Zero Waste is not simply a form of waste management. It is a programme for innovation and industrial transformation. The construction of an incinerator or any of its chemico-energy variants undercuts this dynamic. It rests on the proposition that waste can be dealt with on its own terms, without venturing into the territory of how it is produced, or how materials could be reused most effectively. It poses its own set of questions – to do with economies of scale and how to control pollution – and maps its own political territory (covering planning permissions, local opposition and the terms and enforcement of regulations). It is inward looking, defending its interest politically against external pressures, rather than outward looking with a focus on wider industrial change.

As a result, while the construction of a new incinerator claims to answer some immediate issues of waste disposal, it sidesteps the association, in Waller-Hunter's words, 'between waste generation and climate change, deforestation, toxic substance releases, biodiversity loss, increased soil erosion and other problems.'[125]

It also fails to connect to the social and economic potential of Zero Waste. Waste prevention and recycling offer scope for local and regional industrialisation, urban regeneration, a range of 'green collar' jobs, and a means of improving environmental equity. One of Walter Stahel's main points is that lengthening product life entails a major substitution of labour for energy and materials, requiring as it does the development of regional repair workshops and the development of local loops for dematerialised fashion goods, and the taking back of goods for remanufacturing.[126]

Productive systems

Through waste, as through the pressures on natural resources, the environmental imperatives have forced a redefinition of the categories used to analyse the economy. Instead of the segmentation of linear production – primary materials, manufacturing, distribution, consumption and waste – environmental economists distinguish between different productive systems. They classify by sector or by material or social need, within a wider environmental system, and speak of an industrial metabolism and of material circuits, rather than the monetary flows of macro economic analysis.[127]

Zero Waste is therefore at root a productive systems perspective. As such it deals with complexity and multiple connections. It is also centrally about change. In terms of economic thought it speaks the language of Schumpeter rather than Smith, of destruction and innovation rather than market equilibrium. In its mainstream form, its analytical dynamic comes from the tension between the material demands of modern industrial production and the ecological limits of the natural world. Out of this tension comes the problematic of alternatives. Zero Waste is about different paths of development of productive systems.

New approach to policy

I have suggested that Zero Waste also involves a new approach to policy. This is necessary for three reasons. First, attempts by a central body – whether state or corporation – to manage a complex system by means of traditional forms of centralised command and control are bound to fail. As corporations have grown they have faced this core organisational problem, and the history of the current industrial era is one of experiments in organisation which combine decentralisation and synthesis in a way that allows innovation to flourish. States have faced a similar problem, one that is at the centre of discussions on the shape of a new regime for waste.

Secondly, waste and the green materials revolution pose questions of interdependence that cannot simply be solved by market instruments based on individualised property and responsibility. As Ulrich Beck puts it, technology has advanced to the point where individualised liability breaks down. This is true both of environmental effects and of changes in productive systems that are needed to minimise these effects. Policy therefore has to find new ways of dealing with socialised responsibility and interdependent production.

Third, the reduction in waste and changes in material production – because of their systemic character – have multiple impacts which demand a rewiring of traditional departments of the state. Joined up government is a way of talking about the need for new means for governing productive systems. An initiative may not meet the economic criteria in terms of the desired outcomes of a single department, but would pay its way if multiple outcomes were taken into account. Zero Waste produces multiple dividends, and this poses a challenge to existing structures and forms of assessment within government.

The discussion of British policy has explored some of the issues and innovations in the instruments of government in relation to waste and materials productivity, with the following conclusions:

- there is a central place in modern environmental policy for government leadership and a clear vision of the long term alternative. This provides the synthesis of perspective which is necessary for systemic change. Without it both government and industry will fragment into particularistic policies;

- producer responsibility is an innovative way of dealing with interdependence. Policy identifies groups of actors – in this case firms in a product chain – who can be collectively held responsible for a set of environmental effects, and asks them to develop alternative solutions. Government sets the parameters and targets and the group of actors decides how to meet them;

- fiscal policy can be used to support the process of environmental transition by recycling funds through hypothecation, or other tax/benefit packages, from one set of practices (or actors) to another. to another.

- Central government intervenes in the process of these financial flows, and may negotiate directly with large firms or groups of firms as to the terms on which the financial benefits are forthcoming. The energy efficiency agreements are an example of this and instruments of this kind could have wide ranging application in the field of materials and municipal waste, in the latter case through an expansion of public service agreements. They are a form of collective contract or, as the Dutch put it, a covenant;

- considering the conversion of industry towards Zero Waste through the lens of the knowledge economy places information and its circulation at the heart of new systems of government. How information flows within the system, particularly to those governing the system from the centre (whether government, industry or civil society) becomes a central issue, as do the sources of knowledge of those with responsibility for production (from households which compost, to large scale manufacturers). Zero Waste is information-intensive both as a system of production and a system of government;

- a key role is played by institutions that mediate between the three main spheres of the economy – the private market, the state and the household. These may be non profit companies carrying through entrepreneurial public functions on behalf of the government (as in the case of WRAP or the Carbon Trust), or community recyclers working at the interface between households, local government and material markets. The new form of governance has a central role for the third sector;

- finally there is the issue of the role of the market and regulation. My conclusion here is twofold. First markets and regulations are not alternatives. They are inter-dependent. The issue is not market versus regulation, but what kind of market and what kind of regulation. Second, Zero Waste requires more of both; on the one hand a greatly expanded use of market instruments adjusted to provide the necessary incentives; on the other a strong environmental state to provide direction, to structure the market and administer a limited range of regulations. The market cannot do these things on its own.

As far as waste in the UK is concerned, the post neo-liberal period in the 1990s simultaneously weakened government in a sphere of environmental policy that required strong public leadership, and failed to structure a system of incentives which would encourage markets to work towards ends that were commonly agreed. This is the reason why British waste policy has failed in its own terms, and has left the UK so far behind in the progress towards a waste minimising economy.[128]

At the same time a range of policy instruments were developed, which, if reformulated, have the potential to create the economic climate, the incentives, the intermediary institutions and the social knowledge necessary for the programme of conversion which Zero Waste entails.

I have suggested that there are multiple outcomes from Zero Waste. There are also multiple paths towards it. An immediate one is the recycling and composting of municipal waste. The targets for this should be set high, both because of the urgency of the environmental issues at stake, and in order to focus the attention of all those engaged in municipal waste management on the central issues of transition. But industry itself should advance in parallel. It, too, should have ambitious targets, not just for each firm individually, but for the product chains of which they form a part.

For all those engaged in this work, Zero Waste should be understood, in a pragmatic sense, both as a target and a methodology. But it also represents a wider project - the redesigning of the system of industrial production and consumption to meet the imperatives and desires of a post-industrial age.

Endnotes

[1] For a brief summary of the scientific evidence, see P.Montague, 'Landfills are Dangerous', Rachel's Environment and Health Weekly no 617, 24th September 1998. This includes British cases.

[2] P.Elliott et al, British Medical Journal, August 17th 2001 and the Department of Health website. This study was commissioned in 1998 after the results of a major European study which looked at 21 sites, 10 of them in the UK, and found an increase of foetal malformation for women living within 3 km of a landfill site. Other UK government studies are now attempting to measure the air emissions and leachates from landfill sites.

[3] M.Ritter and B.Gugele, 'Annual European Community Greenhouse Gas Inventory 1990-1999', European Environment Agency April 2001.

[4] 'NIMBY' is an acronym for 'not in my back yard'.

[5] Among recent major campaigns against landfills in the UK, particularly notable have been those preventing the expansion of major landfill sites in Belfast, Cornwall, Kent and West Lancashire, and the closure of the Nant-y-Gwyddon landfill in the Rhondda.

[6] For Europe see European Environment Agency, 'Environment in the European Union at the turn of the Century', Copenhagen 1999 and J.Schmid, A.Elser, R.Strobel, M.Crowe, 'Dangerous Substances in Waste', Technical Report no 38, European Environment Agency, February 2000.

[7] A good recent survey of the scientific evidence on incinerators and pollution can be found in: M.Allsopp, P.Costner and P.Johnston, 'Incineration and Human Health', Greenpeace 2001.

[8] In the case of the largest UK incinerator, at Edmonton in North London, it was found that highly toxic mixed fly ash and bottom ash was being landfilled in Essex, stored in open heaps in East London, and used for road construction and as housing materials. Tests of the East London heaps found dioxin levels ranging from 241 to 946 nanogrammes (ng) per kg, in line with the 735 ng per kg level established by the incinerator operator in its mixed ash, and well in excess of the 50 ng per kg levels judged acceptable by Germany for ash levels in soil or public places such as children's playgrounds. Even higher levels were found in samples from the 44 allotments on which 2,000 tonnes of ash had been deposited from the Newcastle incinerator at Byker, in one case the level reaching 9,500 ng per kg. The Byker tests also found high lead contamination, with 19 of the allotments tested showing levels above those (331 milligrammes per kg) that led to closure of the nearby City Farm. In the light of the findings from Edmonton and Byker, the Environment Agency launched an investigation into the fate of ash from all 11 municipal incinerators.

[9] Among UK plants that have been shut for reasons of fire and explosion in recent years have been the municipal incinerator in Dundee, and SITA's tyre incinerator in Wolverhampton. On the Wolverhampton plant see the ENDS Report no. 313, February 2001.

[10] The Edmonton incinerator, which was upgraded in 1996, registered nearly 1,800 exceedances with the Environment Agency between 1996 and 2000, exceedances being defined as emissions of 150% over the legal limit for at least an hour. It was only prosecuted once.

[11] The controversy over the operation of the Byker plant and its residues is only one of many waste scandals to have occurred internationally in the 1990s, in spite of modern regulatory structures being in place. In the case of Byker, the problems of ash contamination were first raised by the local allotment holders who funded their own tests, and together with the trade union at the plant, have had to engage in an 18-month dispute over the conduct, results and interpretation of official tests and the action stemming from them. This has culminated in a two-month 'citizen's inquiry', chaired by Andrew Bennett M.P., that has widened the issue into an investigation of Newcastle City Council's waste management strategy and the alternatives. On the centrality of contested science and information in contemporary environmental politics see Ulrich Beck, Ecological Politics in an Age of Risk, Polity Press, 1995.

[12] A survey of 4,000 UK landfill sites in 1993 found that 230 had suffered a major pollution incident, one third of them being modern 'containment' sites, and 10 of them having been started after 1990. 'The Waste Manager', March 20th-22nd 1994, cited in Williams P.T, Waste Treatment and Disposal, Wiley 1998 p.267.

[13] US Environmental Protection Agency 'Greenhouse Gas Emissions from Municipal Waste Management' September 1998 ES-1. This is the final draft which was modified to take on board a number of contested arguments by proponents of incineration: even so the greenhouse gas savings from recycling exceeded those from 'energy from waste' incineration by a factor of four.

[14] D.Gielen and T.Kram, 'The MATTER project on integrated energy/materials strategies for Western Europe', Paper to the ETSAP

workshop, May 1998, Berlin.

[15] USEPA 1998 op.cit.

[16] The model was developed by the Canadian consultancy firm REIC on the basis of waste composition and recycling studies in the UK. The results are reported in R. Murray, 'Creating Wealth from Waste', Demos 1999, p.39.

[17] The link between reducing and recycling waste and global warming has still to be recognised between (and even within) ministries in the UK. The DETR White Paper 'Climate Change: the UK Programme', published in November 2000 contained only three brief references to waste and gave it only marginal importance in the overall Strategy (pp 38, 81 and 184). The same Department's 'Waste Strategy 2000' treats the overall climate change impact as contingent on the specific circumstances of material and place, and suggests (on the basis of a report by the incineration-associated consultancy AEA Technology) that the new Strategy and the impact of the Landfill Directive will have only a marginal impact on carbon emissions (a reduction of 0.1-0.4 million tonnes). See Department of Environment, Transport and the Regions, 'Waste Strategy 2000', HMSO, Vol. 1 p.18.

[18] R.Lal 'Soil conservation and restoration to sequester carbon and mitigate the greenhouse effect', III International Congress, European Society for Soil Conservation, Valencia 2000.

[19] E.Favoino, 'Composting: a backbone of intensive recycling schemes' in: Ecologika, 'The Potential for a Recycling and Composting Led Strategy in Greater Manchester', Technical Papers, Greater Manchester Waste Disposal Authority, December 2001, p.5.

[20] D.J.Gielen, 'The MARKAL systems engineering model for waste management', paper prepared for the workshop 'Systems engineering model for waste management' Gotteborg, 1998.

[21] The arguments on the environmental benefits of recycling as against incineration, in particular with respect to plastics and paper, are more fully discussed in the London recycling plan prepared by Ecologika for the London Planning Advisory Committee and the Environment Agency, 'Re-Inventing Waste: Towards a London Waste Strategy', London 1998, Chapter 4.

[22] P.Hawken, A.B.Lovins, L.H.Lovins, Natural Capitalism, 1999, p. 3.

[23] European Environment Agency, 'Environmental Signals 2000', Copenhagen 2000, p.102.

[24] This is the argument of much footprint research, which calculates the ecological footprint of contemporary modes of production. One example of this work, which looks inter alia at waste in the UK, is a study of the Isle of Wight funded by the waste company Biffa, which showed that the per capita footprint of the islanders was 2.4 times the size of the island, marginally less than the 2.5 ratio for the UK as a whole. See Best Foot Forward and Imperial College, 'Island State: an ecological footprint analysis of the Isle of Wight', Biffaward, 2000.

[25] A.Adriannse, S.Bringezu, A.Hammond, Y.Moriguchi, E.Rodenburg, D.Rogich and H.Schultz, 'Resource Flows: the Material Basis of Industrial Economies', World Resources Institute, Wuppertal Institute, Netherlands Ministry of Housing, Spatial Planning and the Environment, National Institute for Environmental Studies, Tsukuba, Japan, April 1997.

[26] Performance and Innovation Unit, Cabinet Office, 'Resource Productivity: Making More with Less', November 2001.

[27] For accessible versions of the argument see E.von Weizsacker, A.B.Lovins and L.H.Lovins, Factor Four, Earthscan 1997, P.Hawken, A.B.Lovins, L.H.Lovins, Natural Capitalism, op.cit.

[28] G.Gardner and P.Sampat, 'Mind over Matter: Recasting the Role of Materials in Our Lives', World Watch paper 144, December 1998, p.26.

[29] D.Gielen, T.Kram and H.Brezet, 'Integrated Energy and Materials Scenarios for Greenhouse Gas Emission Mitigation', paper for the IEA/DOE/EPA workshop, 'Technologies to Reduce GHG Emissions: engineering-economic analyses of conserved energy and carbon', Washington, May 1999.

[30] On the expression of social identity through things, including the old and the new, see the work of Pierre Bourdieu,and in particular his remarkable book Distinction: a Social Critique of the Judgement of Taste, Routledge, 1984.

[31] This definition came from the Commission's 1992 Report. It is quoted in J.Thornton, 'Pandora's Poison: Chlorine, Health and a New Environmental Strategy', MIT, 2000, pp. 347-8.

[32] Many examples of clean production initiatives are contained in the Journal of Cleaner Production, Elsevier Science. See also Thornton op.cit. Chapter 9.

[33] See E.Favoino, 'Trends in the Treatment of Organic Waste in Europe', in: Ecologika, 'The Potential for a Recycling and Composting Led Strategy in Greater Manchester', part

1, Greater Manchester Waste Disposal Authority, December 2001.

[34] These points echo a number made by two Cranfield design engineers, Chris Sherwin and Tracy Bhamra, in their paper 'Beyond Engineering: Ecodesign as a proactive approach to product innovation' in 'The Proceedings of Ecodesign 99: First International Symposium on Environmentally Conscious Design and Inverse Manufacturing', Tokyo, February 1999, pp 41-6. Their concern was with the product-centred, incremental use to which LCA has been put, rather than its use for designing new products and systems.

[35] M.Braungart and W.McDonough, 'Design for Reincarnation', Resource, April 2000. See also their article 'The Next Industrial Revolution' in Atlantic Monthly, October 1998.

[36] Op.cit.

[37] For North American and UK evidence see R.Murray, 'Creating Wealth from Waste', op.cit. Chapters 4 and 5.

[38] There are reports of some US recycling programmes being cut back for these reasons, losing their momentum, their political support and in the end their budgets. See Institute for Local Self Reliance, 'Wasting and Recycling in the United States', 2000, Grass Roots Recycling Network, Athens GA, 2000.

[39] Flexible specialisation is a term coined by C.Sable and M.Piore in their book, The Second Industrial Divide, Basic Books 1984, which was one of the first to recognise the character of the new paradigm. The new paradigm has also been referred to as Just-in-Time Production, Post-Fordism and Flexible Manufacturing. See also a key early work on the subject, M.Best, The New Competition, Polity 1990.

[40] Two of the most successful recyclers have been the Salvation Army and Oxfam – though neither has yet ventured into multi-material kerbside collection. The 250 members of the Community Recycling Network together are the largest kerbside recycler in the UK.

[41] One example arose when it was discovered that the Audit Commission and the DETR, under pressure from industry, had classified the reuse of toxic incinerator ash for construction as recycling, with the result that the best way of meeting the government's recycling targets would have been to incinerate all combustible waste in order to maximise the residual ash. This ignores (as do many other definitional disputes) the issue of the quality of recyclate discussed earlier.

[42] This is recognised in the EU working document on a future Bio Waste Directive, where separate biowaste collections are proposed for all towns and cities with more than 100,000 population within three years of the Directive coming into force, and all towns and villages with more than 2,000 inhabitants within five years. The collections should be planned for household waste, as well as for biowaste from restaurants, hotels, canteens, schools, public buildings, shops, markets, food businesses and shops. See: European Commission, Working Document, 'Biological Treatment of Biowaste', 2nd draft, Brussels February 12th 2001.

[43] One of the UK's leading recyclers, the community enterprise ECT, uses acorn group marketing data, gathered by postcode, to estimate the composition and quantity of waste from any particular locality – on the basis of which it plans its rounds, forecasts its quantities of captured recyclables and estimates performance.

[44] The UK system of collection and disposal credits provided for such transfers between separated authorities, although collection savings have often been difficult to capture because of the lack of flexibility in contracts. In 1999/2000 Disposal Authorities paid an average of £23.87 for avoided disposal on 1.1 million tonnes of recycled or composted material, but only £0.92 for avoided collection on 32,000 tonnes diverted.

[45] G.Gardner and P.Sampat, 'Mind Over Matter: Recasting the Role of Materials in Our Lives', Worldwatch Paper 144, December 1998, p.15.

[46] L.D.Simone and F.Popoff, 'Eco Efficiency', MIT, 1997, p.3. The authors were at the time Chairman of the Minnesota Mining and Manufacturing Co. and of the Dow Chemical Company respectively, and chaired the WBCSD working group on eco-efficiency. See also N.Nemerow, Zero Pollution for Industry, John Wiley, 1995.

[47] For examples of waste reduction see L.D.Simone and F.Popoff op. cit., and the United Nations University Zeri Project for example of zero emissions.

[48] The problems of extending 'environmental management systems' (EMS) to product design and development is discussed by G.Ries, R.Winkler and R.Zust in 'Barriers to successful integration of environmental aspects in product design', in: 'EcoDesign '99. Proceedings of the First International Symposium on Environmentally Conscious Design and Inverse Manufacturing', Tokyo February 1999 pp 527-532. The discussion relates to experience in Switzerland. Although they highlight the difficulties, it is clear from their paper that the push for effective integration between EMS and product design is

strong, and that increasing numbers of firms are internalising environmental issues in their research and development (60% of 250 firms surveyed were integrating in this way in 1997/8, up from 20% two years earlier).

[49] For a remarkable analysis of the chlorine industry from this perspective, see J.Thornton, 'Pandora's Poison', op. cit. MIT 2000.

[50] See W.R.Stahel, 'The service economy: wealth without resource consumption?', Philosophical Transactions A, Royal Society, London 355, (June) pp 1,309-1,319. See also O.Giarini and W.R.Stahel, The Limits to Certainty, 2nd edition, Kluwer Academic Publishers, 1993.

[51] The auto project is one on which Michael Braungardt has been working as an exemplar of the new low resource economy.

[52] The Product Life Institute, 'The Shift from Manufacturing to a Service Economy 1998-2010', Geneva, p.165 (the report is available for US$/Euro 5,000 from the PFI, PO Box 3632, CH 12ll Geneva 3).

[53] See David Morris 'Building a new carbohydrate economy', Renewable Energy World, Vol 4 no 5, September-October 2001.

[54] Franklin Associates estimates that the new material 'Ecolean' has between 30% and 70% less environmental impact than the glass, laminated cardboard and aluminium it is designed to replace.

[55] Henry Ford made some trenchant observations in his autobiography on the old engineering order who dismissed his initiatives as unworkable, see My Life and Work, Heinemann, 1924.

[56] On the early development of the opposition to incineration in the US see B.Commoner, Making Peace with the Planet, Gollancz, 1990, Chapter 6.

[57] Sweden in 1990 relied on landfill and incineration in broadly equal proportions (44% and 41%) with recycling and composting accounting for 16%. In that year they amended their Solid Waste Act to set out the principles of Producer Responsibility and encourage dry recycling. Producer Responsibility legislation and subsequent ordinances were introduced in 1992-4, covering packaging, tyres and waste paper. By 1997 recycling and composting had reached 33% and they are presently in line to rise much higher when the ban on organics to landfills comes into force in 2005. In France, recycling was overshadowed by incineration until 1999, when the Environment Minister ordered the closure of 20 high polluting incinerators (with a further 40 on probation) and ordered waste plans to be redrawn to given greater emphasis to recycling.

[58] The Dutch programme was in part a response to dioxin scares in the late 1980s, when high dioxin levels in cows' milk and dairy products were traced to incinerator emissions. It was found that none of the incinerators were complying with the required standards. After the rebuilding programme, there have been regular surveys which are still finding that not all the new generation of incinerators comply with the strict standards the Dutch have introduced.

[59] The Bio-Waste Directive was planned as a compliment to the Landfill Directive (for details see footnote 42 above).

[60] See the Commission's proposals for the sixth EC Environment Action Programme, published in February 2001 (ENDS Report 313, pp 46-48) and the speech to the European Waste Forum on June 21st 2001 by the Environment Commissioner Margot Wallström, which hinted at a possible shift away from product-based EC producer responsibility initiatives to a broader, materials-based policy.

[61] The Italian Decree no 22, which implemented a number of EU Directives, included a provision that all non-hazardous waste must be disposed in the region where it is produced.

[62] See Roger Crowe, 'Green finds a primary role in the boardroom', Financial Times April 12th 2001.

[63] The nuclear industry, for example, found itself beached in the 1970s as the result of concern about emissions, the disposal of nuclear waste and the cost of decommissioning. The phaseout of PCBs, CFCs and asbestos threatened firms dependent on these materials. Pesticide producers have found themselves attacked from four directions – the impact of pesticides (particularly those based on organochlorines) on workers in pesticide factories, on the farmers applying them, on water quality and on consumers of food with pesticide residues. In some instances the compensation claims for pollution incidents made on manufacturers (notably Union Carbide at its Indian Bhopal plant) have been so large that they have led to the rapid collapse of firms internationally.

[64] The pressure on major companies in the UK to incorporate environmental considerations into their decision making has been increased by the recent conclusions of the Turnbull Committee on corporate governance, which establishes guidelines for the management of environmental risk.

[65] R.Slater, 'State of Composting in the UK', Materials Recycling Handbook, Emap, 2001.

[66] John Gummer, for example, overrode the advice of his civil servants in allocating £12 million Capital Challenge funds to London boroughs because the Boroughs had produced detailed plans that promised a significant expansion of recycling in London. There are many similar examples from the period of office of Michael Meacher.

[67] Merrill Lynch, 'Pollution Control', September 1998 p.7

68 The system of recycling credits applied a parallel principle within the public sector, with provisions for arms length inter-authority transfers (according to disposal costs saved) that served as a price supplement.

[69] See the controversy surrounding the report by the Environment Agency Board member Paul Dalton on the inadequacy of the EA's regulatory practices on the ground, 'Just Who Does the Environment Agency Protect?', August 2001. A summary of the controversy appeared in an article by Paul Brown in the Guardian, September 12th 2001.

[70] John Turner in evidence to the House of Commons Select Committee on 'Delivering Sustainable Waste Management', op, cit. 'Minutes of Evidence' p.89.

[71] There are 15 compliance schemes, the largest of which, VALPAK, represents 3,000 of the obligated parties and accounts for 60% of the compliance 'market'.

[72] The Environment Agency estimates are contained in their nine regional strategies published in 2001. The results of the waste strategy model and a summary of the Landfill Directive RIA model results are contained in Annex B of 'A Way with Waste', DETR, 1999, Volume 2 pp 148-160.

[73] Manchester Waste Limited and the Manchester Waste Disposal Authority have been in dispute with the Environment Agency over the classification of the organic output from their mechanical treatment plants, which at the moment is classed as non-inert waste and subject to the landfill tax. See the House of Commons Select Committee Report, Environment, Transport and Regional Affairs Committee, 'Delivering Sustainable Waste Management, Minutes of Evidence', March 14th 2001, p.62.

[74] The collection authorities are bound to deliver their waste to such facilities under the terms of the Environmental Protection Act 1990 which gives disposal authorities first claim on any waste or recyclate in their area for which contractual provision has been made.

[75] PFI contracts have sought to introduce some sharing of these risks with the contractor, recognising that this will lead to higher gate fees. A study for the DTI reported that gate fees in the initial PFI waste contracts, all of which were centred round incinerators, were 19%-26% above those of cost-plus contracts. See Impax Capital Corporation Ltd, 'The Influence of the PFI on Waste Management Pricing', Report for the New and Renewable Energy Programme, ETSU B/WM/00549/REP, 2000.

[76] That this conflict is a real one is shown not just by the low recycling rates of UK authorities served by incinerators but also by the recycling programmes in countries like Holland and Denmark which have had to fit in with the volumes and priority materials required by each country's stock of incinerators.

[77] There has been a recent shift in view in some parts of the waste industry. A recent document from Biffa commented that 'most in the industry agree that that at least 60% is a realistic target for diversion from landfill into biodegradation and recycling.' See Biffa, 'PFI Update', July 2001. Biffa has been an exception within the mainstream waste industry in re-assessing the role of waste management in the light of the need to re-establish biological and technical cycles.

[78] For a statement of this position see J.Rifkin, The Age of Access, Penguin 2000.

[79] The DTI consultation paper on renewable energy strategy emphasised EfW as a significant potential contributor to the renewables programme ('New and Renewable Energy for the 21st Century', DTI March 1999) and the 1999 Waste Consultation Paper took this up, concluding that 'the Government will continue to encourage the recovery of energy from waste, where this is the BPEO, as part of its renewable energy strategy.' 'A Way with Waste', DETR, 1999 vol 1, p.21. Nevertheless, in terms of climate change strategy, waste was given only marginal importance chiefly because the AEA report estimating the CO2 savings from recycling omitted all energy saved from avoided virgin production (see footnote 13 above).

[80] 'Making Waste Work', DETR, 1995, p.53

There have also been controversies over toxic ash from the Sheffield plant and pollution in Dundee. In Sheffield tests of bottom ash showed dioxin levels at 150 ng/kg. In Dundee, a Friends of the Earth survey found high levels of contamination around the incinerator, which led to calls for medical screening of those living in the area. See Sunday Times, July 15th 2001.

[81] There were substantial delays in delivering WISARD, caused, it was said, because its designers had found it difficult to get it to produce results

supportive of the 'integrated option'. This was eventually solved, but after less than a year, the Scottish Environmental Protection Agency decided to end its compulsory use on the grounds that it always produced results favouring incineration.

[82] In the first half of the 1990s there was a small Supplementary Credit Approval programme to assist local authority recycling; and later individual awards were made under Capital Challenge and Single Regeneration Budget (SRB) programmes. The total was probably less than a tenth of the amount by which the UK remaining incinerators were subsidised.

[83] In a Parliamentary answer the Minister Michael Meacher said that this was not necessarily the case, but the Guidance continues to carry weight nonetheless.

[84] Op.cit p.58

[85] 'A Way with Waste', op.cit. vol 1 p.25 The wording was kept in 'Waste Strategy 2000', vol 2 p.77

[86] Op.cit. vol 2, p.19 'Waste Strategy 2000' in re-affirming this point said that EfW plants should be 'appropriately sized' and not crowd out recycling, but no geographical limits were set for the catchment areas so that EfW applications are being considered for areas where their capacity equals the whole MSW stream. See Vol 1, p.23 para 2.23.

[87] In September 2000, after Ministerial intervention, it was announced that priority in the allocation of PFI funds should be given to recycling, but the PFI terms and process still favour capital intensive projects and promote wholly inappropriate long-term contracts. As for the £140 million for recycling, none was earmarked for 2001/2.

[88] Proceedings of the Welsh Assembly, May 10th 2001, Cardiff.

[89] The data is for dry dustbin recyclables and is derived from DEFRA, Municipal Waste Management 1999/2000, July 2001, Tables 8 and 9, and from estimates made for UK waste composition by the Canadian waste analysts REIC. Target capture rates are from best practice programmes in the UK and Canada.

[90] The levels of organics found in residuals in the integrated food waste collection systems operated in Italy average 15%-20%. In the best schemes they fall to 10%. In Austria and Germany the levels average 40% and in the Netherlands 50%, partly because of the high diversion levels in dry recyclables in all these countries, and partly because of the widespread use of wheeled bins for residuals, which attracts a higher levels of organics than the Italian system (see inset 2).

[91] The Environment Agency issued a Consultation Paper 'Guidance on the Waste Treatment Requirements of Article 6(a) of the Landfill Directive' in late 2001. It defines 'treatment' narrowly, so that all residuals after source-separation for recycling would be considered as 'treated' in spite of the fact that their fermentability would be in no way reduced. This is another example of the UK's environmental minimalism, and is in line with British opposition to the EU's Bio Waste Directive.

[92] MBT has been largely ignored in the UK. Two plants are currently at the planning stage, but MBT has been scarcely considered in the waste plans of disposal authorities or the RTABs. Waste Strategy 2000 mentions MBT only briefly, noting its widespread use in Austria and Germany, and highlighting issues of pollution control found in some of the plants there. It is not included as an option in the models that informed Waste Strategy 2000, nor in the proposed 'integrated' option, in which incineration with energy recovery is put forward as playing 'a full and integrated part in local and regional solutions'. See Waste Strategy 2000, vol. 2, pp 78-85.

[93] A recent report by AEA Technology for the EU Commission 'Waste Management Options and Climate Change', ED 21158, 2001, estimated that MBT produced the lowest GHG flux (a negative flux of 340 kg CO2e/per tonne of MSW) of the various options for treating mixed waste prior to landfill. The principal reason is the sequestration of carbon through the landfilling of the stabilised organics following the MBT process.

[94] See Peter Jones of Biffa in his evidence to the Select Committee in October 2000, Environment, Transport and Regional Affairs Committee, Fifth Report, 'Delivering Sustainable Waste Management, Minutes of Evidence', March 2001 pp.7-8. There has been growing pressure from industry to increase the landfill tax in ranges from £25-£40 a tonne, but this is in part driven by the high cost of methods of residual treatment rather than the cost of recycling. The lower range estimate is based on the extra cost of moving to intensive recycling in all sectors of the economy, with the financing of recycling increasingly shifting to the market through producer responsibility legislation.

[95] In Italy three-stream systems have been introduced close to (or below) the costs of traditional collection. This has been in part due to the low cost methods of food waste collection and in part because of the scope for savings from the large number of regular collections (three or four per week in many Mediterranean countries) once food waste is separated out (see inset 2). An application of the Italian food waste model to Greater Manchester forecast that waste system costs would fall for

all nine boroughs. See M. Ricci, 'Guidelines and Costs for the Management of Food Waste in Greater Manchester' in Ecologika, 'The Potential for a Recycling and Composting-led Strategy for Greater Manchester', Greater Manchester Waste Development Authority, December 2001.

[96] The Essex High Diversion Programme, 'Prospectus', Chelmsford, June 2000. The local authority share of new fixed investment is estimated at £35.5 million. If this was publicly financed, it would lower the revenue support to £18 million, and require an overall sum of £53.5 million to fund the transition.

[97] The estimate does not include the recycling credits provided by Essex County Council (reflecting the costs of disposal and the landfill tax) nor of any increase in the costs of CA sites. Including recycling credits in funding requirements would add a further £3 million p.a., giving a total of £18 per household p.a.

[98] The transitional costs depend in part on the level of disposal costs. In a study for Greater Manchester similar to that undertaken for Essex, capital costs were £4.5 million and transition costs £25 million for a population 50% greater than that of Essex. The main reasons for the lower costs were the higher level of disposal costs (a saving of £36 for each tonne diverted from disposal was assumed for the nine Greater Manchester boroughs) and the use of the low-cost Italian food waste collection systems. By comparison, in Toronto, where disposal costs are high because of the need to export waste to landfills in Michigan, the Council recently announced its plans to achieve a 60% diversion target by 2006, with an incremental cost of only £5 a tonne.

[99] It might well be less in the event that a shift to four-stream systems would produce more packaging waste from the estimated 4.6 million tonnes in the domestic waste stream than the 1.2 million tonnes forecast as required for the 60% target. Supply would exceed demand and put downward pressure on PRN prices in the process.

[100] If the 50% target for the recovery of packaging waste in 2001 is met, it will have cost the 'obligated parties' some £100 million, little of which has gone to the municipal sector. The £100 million figure is given in the government's September 2001 consultation paper on 'Recovery and Recycling Targets for Packaging Waste'.

[101] The government is currently undertaking a five-year review of the performance of the Environment Agency. The draft report of this Review was summarised in ENDS no 320, September 2001. The report does not address the main issue that has emerged in the conduct of the Environment Agency, which is the problem of getting a rule-based organisation to take a proactive role in environmental protection, coupled with the issue of regulatory capture.

[102] The New Opportunities Fund has developed fruitful methods of managing the bidding process, including joint seminars for applicants and individual specialist advice.

[103] The OECD has made waste minimisation, extended producer responsibility and changes in the mode of consumption the prime focus of its work on waste since 1994.

[104] Gielen,Kram and Brezet op.cit. (see footnote 29).

[105] USEPA, September 1998 op.cit (see footnote 13).

[106] G.A.Davis, 'Principles of Application of Extended Producer Responsibility' Proceedings of the OECD Joint Workshop on Extended Producer Responsibility and Waste Minimisation Policy, Paris March 2000, Part 1, pp.102-8. Gary Davis is from the Center for Clean Products and Clean Technologies, University of Tennessee.

[107] For other products and substances the EU has used bans – as in the case of the landfilling of tyres and the phasing out of CFCs in fridges and air conditioners, and of halons in fire protection systems.

[108] This was notably the case in the electric and electronic goods sector, where UK firms showed a marked reluctance to expand recycling in spite of the forthcoming EU Directive and the advances made in electronics recycling on the continent.

[109] Report of the Task Force of the Advisory Group on Packaging, DEFRA, November 2001.

[110] For a more detailed discussion see ECOTEC, 'Effects of Landfill Tax – Reduced Disposal of Inert Waste to Landfill', January 2000.

[111] See E.Darier (ed) Discourses of the Environment, Blackwell 1999, particularly the introduction by Darrier, and the chapter by T.W.Luke, 'Environmentality as Green Governmentality', pp 121-150.

[112] This is the position of Ulrich Beck in a succession of books on risk and modernity. Beck is a professor of sociology in Munich, one of the international centres of the re-insurance industry. See particularly his book Environmental Politics in an Age of Risk, Polity Press 1995.

[113] For a review of the problems surrounding scientific knowledge and its treatment within conventional risk assessment see M.O'Brien, Making Better Environmental Decisions, MIT

Press, 2000. The book also outlines a different approach termed 'alternative assessment'.

[114] A recent study that highlights the issue of information, hazards and governance is by the European Environment Agency, 'Late lessons from early warnings: the precautionary principle 1896-2000' which was published in January 2002. In light of the historical experience of hazards such as asbestos and BSE, the study considers how more accessible, science-based information and stakeholder governance in economic activity could minimise environmental harm and maximise innovation. The proposals have particular relevance to the issue of information and governance in relation to Zero Waste.

[115] Performance and Innovation Unit, Cabinet Office, 'Resource Productivity: Making More with Less', November 2001, op.cit.

[116] The former DETR has produced guidelines for business on reporting waste, which were aimed at helping companies measure the waste they produce, how waste management could be improved and achieve savings. These need to be extended to the materials productivity strategies outlined here.

[117] On alternative experiences of quasi-public institutions to provide technical support and advice to industry, see H.Rush et al, Technology Institutes: Strategies for Best Practice, International Thompson Business Press, 1996

[118] The Advisory Committee on Business and the Environment, 'Resource Productivity, Waste Minimisation and the Landfill Tax' August 2001. Another of its recommendations was to raise landfill costs and to use the extra tax revenues to fund resource productivity initiatives in the business sector.

[119] Lord Marshall, 'Economic Instruments and the Business Use of Energy', Treasury, November 1998.

[120] For a description of the programme see P.Hermens and T.van Roemburg, 'Dutch Perspective on Waste Prevention Target Setting', OECD Joint Workshop on Extended Producer Responsibility, op.cit. Part 2, pp 41-49, March 2000.

Proceedings of the OECD Joint Workshop on Extended Producer Responsibility and Waste Minimisation Policy, op.cit. March 2000, Part 1, Introductory speech.

[121] On reuse and the ways in which consumers and local authorities can influence its expansion see N. and D. Goldbeck, Choose to Re-use, Ceres Press, New York, 1995.

[122] Proceedings of the OECD Joint Workshop on Extended Producer Responsibility op. cit.Part 1, Introductorary speech, March 2000.

[123] OECD, 'Environmental Strategy for the First Decade of the 21st Century', adopted by OECD Environment Ministers May 16th 2001, and the accompanying 'Environmental Outlook'.

[124] M.Braungart, 'Waste Must Equal Food' Green Punkt Scheme Annual Report 2000, 'Recycling as a Source of Raw Materials', p.78. He continues 'natural processes are not eco-efficient but rather eco-effective. Nature does not save, it "wastes" – however with suitable resources (just look at a cherry tree in spring – what a "waste" of energy and raw materials.)'

[125] J.Waller-Hunter,op.cit.

126 For a good recent summary of his ideas see W.R.Stahel, 'From Design for Environment to Designing Sustainable Solutions', in: UNESCO, Our Fragile World: Challenges and Opportunities for Sustainable Development, EOLSS Publishers, 2001, pp 1553-1568.

[127] A summary of the industrial metabolism approach, based on ex post material flows, is given in R.U.Ayres, 'Industrial metabolism: theory and policy' in: R.U.Ayres and U.E.Simonis (eds), Industrial Metabolism: Restructuring for Sustainable Development, United Nations University Press, 1994.

[128] On the shift in environmental policy from centralist regulation to market instruments and the issues arising see M.R.Chertow and D.Esty (eds), Thinking Ecologically: the next generation of environmental policy, Yale 1997.

Robin Murray is an industrial economist. He is a Visiting Research Associate at the Centre for the Study of Global Governance at the London School of Economics and author of Creating Wealth from Waste.

How to comply with the landfill directive without incineration: A Greenpeace blueprint

Publication date: 9 November, 2001

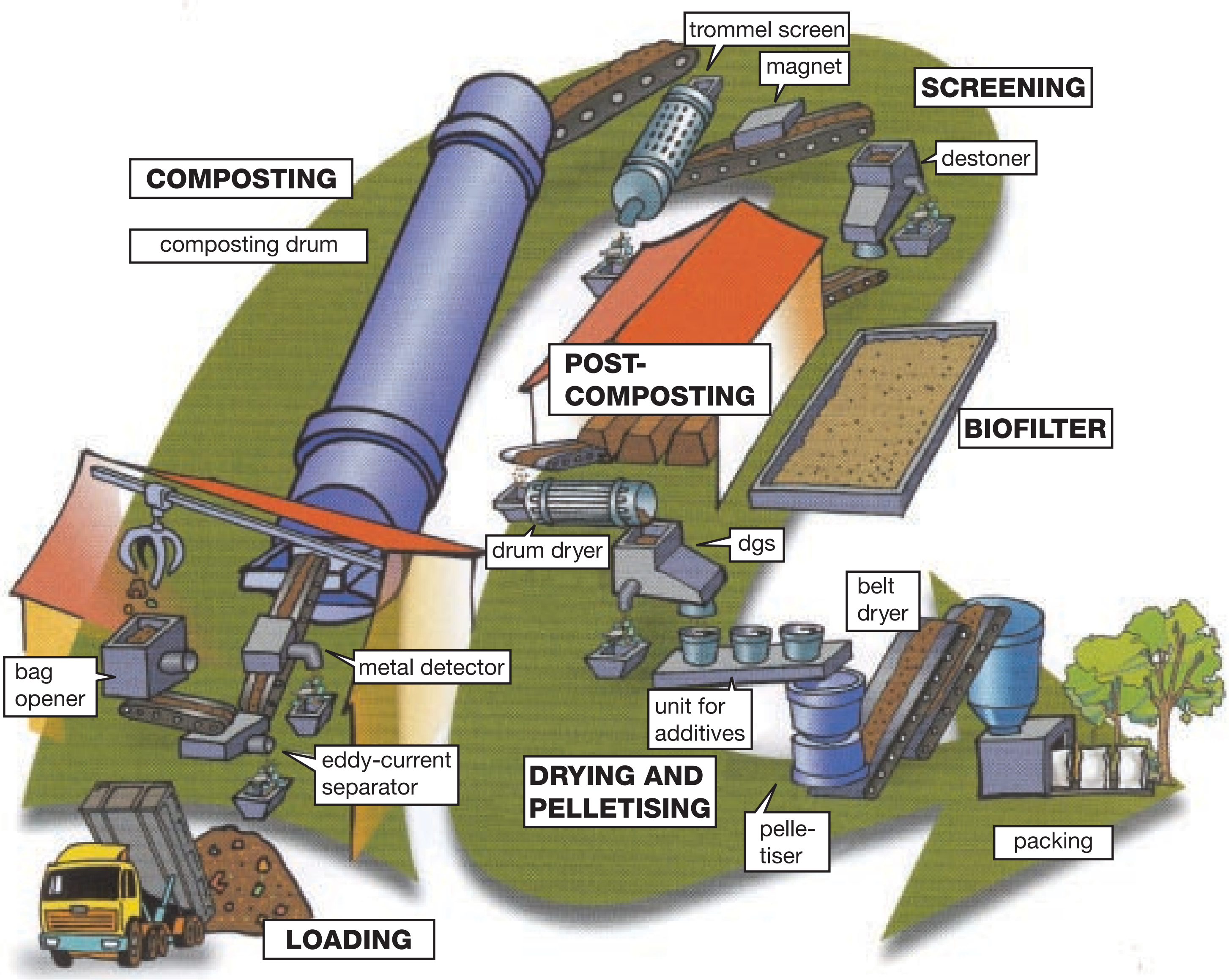
This report details a practical strategy which local authorities can use to achieve maximum recycling rates and safely deal with residual waste. Reviewed and endorsed as practical and entirely achievable by Biffa Waste, the report illustrates possible options with examples of techniques and technology from around the world as well as in the UK.

Landfilling of municipal waste has to be reduced for a variety of reasons. The current practice of landfilling mixed municipal waste is highly polluting, as well as unpopular and ultimately unsustainable. Now the European Landfill Directive, which came into effect on 16 July 2001, demands significant reductions in the quantity of biodegradable waste disposed of in this way. As part of the drive to comply with the Landfill Directive, the Government has set mandatory recycling targets for local authorities.

Some local authorities are arguing that incineration is necessary to meet the UK's commitments under the Directive, or to deal with residual waste left after maximum practical recycling levels have been achieved. Neither of these arguments is tenable.

How to comply with the Landfill Directive without incineration: a Greenpeace blueprint

GREENPEACE



Energy from waste = a waste of energy. Plastics and paper are the main source of calorific value in an incinerator. Burning plastics, which are oil based, is effectively burning fossil fuels – the main factor behind global warming. Paper is produced from wood by an energy intensive process. Burning it wastes energy and resources as well as generating pollution.

Contents

List of information Boxes

Executive Summary

Landfilling of municipal waste has to be reduced for a variety of reasons. The current practice of landfilling mixed municipal waste is highly polluting, as well as unpopular and ultimately unsustainable. Now the European Landfill Directive, which came into effect on 16 July 2001, demands significant reductions in the quantity of biodegradable waste disposed of in this way. As part of the drive to comply with the Landfill Directive, the Government has set mandatory recycling targets for local authorities.

Some local authorities are arguing that incineration is necessary to meet the UK's commitments under the Directive, or to deal with residual waste left after maximum practical recycling levels have been achieved. Neither of these arguments is tenable.

If the UK does nothing more than recycle or compost 30% of newspaper, card and organic waste, we will have met the 2010 target in the Directive of reducing biodegradable waste going to landfill by 25% of 1995 levels. This target and the 2013 target of 50% can easily be exceeded with technology currently available and in use. The 2020 target of 65% may be more demanding, but we can learn from cities and regions around the world that have already achieved more than this. The Directive gives the UK almost two decades to put in place the necessary systems.

The techniques and technology needed to meet the Landfill Directive targets should also enable local authorities to meet the UK Government's mandatory recycling targets. Once implemented, the strategy set out below will ensure recycling is maximised, and provide the means to go beyond currently perceived limits to recycling.

Organising efficient kerbside collection and composting of kitchen and garden waste is the single most significant step authorities can take towards meeting the Landfill Directive and recycling targets. Getting this stream right is the key – taking us from waste management to waste utilisation.

The basic infrastructure for managing source separated domestic stream materials can also be used for recyclable and organic material from trade and other non-dustbin streams.

Residual Waste

When the types of collection, composting and recycling systems described below are in place, residual waste can be reduced to a very small fraction of the municipal waste stream. Eventually, these residuals can be dealt with by a combination of regulatory, fiscal and consumer driven mechanisms such as producer responsibility legislation (e.g. the Waste Electrical and Electronic Equipment Directive), disposal taxes (e.g. the Landfill Tax and an incineration tax) and design efficiency. In the meantime, material that cannot be re-used, recycled or composted, should be cleaned and stabilised, then landfilled.

Mechanical Biological Treatment (MBT) systems, which stabilise and reduce the volume of residual waste still further, can be used to achieve this cleaning and stabilising function at the 'back end' of kerbside collection, composting and recycling schemes. They can also provide the 'failsafe' that some managers are currently seeking – a way to guarantee mandatory targets are met.

There are several reasons why using landfill for cleaned residual waste is better than building incinerators, the most important of which are:

- Unlike incineration, landfill does not perpetuate the need for waste. Source separation schemes like those outlined here mean that residual municipal waste will be less toxic and much reduced in volume compared to current levels. Continuing improvements in recycling, product design and buying habits mean landfill can be reduced incrementally and eventually phased out. Incinerators on the other hand must operate at near capacity throughout their 25-30 year lifetime if capital investments are to secure a return. Once built, they are a structural impediment to significantly reduced levels of waste disposal.

Organising efficient kerbside collection and composting of kitchen and garden waste is the single most significant step authorities can take towards meeting the Landfill Directive and recycling targets. Getting this stream right is the key – taking us from waste management to waste utilisation.

- Incinerators do not eliminate the need for landfill. They produce contaminated ashes that have to be landfilled, as well as air pollutants. Highly toxic pollution control residues often have to be transported many miles for burial. Incinerators do not solve the problems of landfill and create new ones.

When considering options for the disposal of materials that cannot be recycled, it is important to be aware that incinerators can achieve a maximum 70% reduction in the mass of waste incinerated (30% is left as ash). Reduction in volume compared to landfill, where waste is normally compacted prior to burial, is even less – around 45%.[1] The actual reductions of municipal solid waste achieved by mass burn incineration is around 55% by weight as non-combustible material (so called by-pass) has to be sorted and removed from the stream before burning.

Current state-of-the-art mechanical screening and composting systems exceed the reductions in mass and volume achieved by incinerators. At the same time they eliminate the pollution problems associated with incinerators. When carefully planned and managed, they can provide a useful, marketable product that can return nutrients to the soil and rebuild soil quality. They also provide a method of recovering valuable resources such as aluminium.

Examples from around the world show that using current technology, councils can achieve diversion rates that smash the 60% 'barrier'. The inhibiting risk aversion that pervades waste management in the UK needs to be replaced with a culture of imaginative problem solving and a new 'waste utilisation' approach. The quest for convenient 'magic box' solutions that deal with mixed municipal waste must be replaced with an energetic and forward-looking search for flexible solutions that eliminate dependence on polluting and unpopular 'burn it or bury it' technologies altogether.

How to meet the landfill directive without using incineration

Municipal Waste

Separate at source
(household and business)

Collect at kerbside
Refurbish Re-use (new business opportunities)

Compost
Fertilisers mulch soil improver

Recycle
New goods & Raw materials

M.B.T
(Mechanical Biological Treatment)
Low grade Compost (Roadside, landfill cover)
More raw materials

Landfill
Residuals stabilised & reduced in quantity

Meeting the Landfill Directive targets

'It is entirely possible to achieve the Landfill Directive without using incineration, using a flexible 'pick and mix' option. Such an option would utilise source separation, kerbside collection, composting, recycling and mechanical screening to deal with municipal waste in a way that actively contributes to the economic, social and environmental goals of sustainable development.'
– Peter Jones, Director, Biffa Waste Services

The European Landfill Directive sets mandatory targets for a three step reduction in biodegradable waste going to landfill. Set against a 1995 baseline, it requires a reduction of 25% by 2010, 50% by 2013 and 65% by 2020.

The targets apply only to untreated biodegradable municipal waste. They are intended to reduce the role of landfill in producing methane, a potent greenhouse gas, as well as reducing the quantity and toxicity of leachate produced by landfill sites and the volume of waste landfilled. According to Government estimates, 60% of the current municipal waste stream is thought to be biodegradable.[2] The real figure may be higher than this.

One way of meeting the first target of a 25% reduction would be to recycle or compost just 30% of newspaper, card and putrescible waste. We have until 2010 to do that. Any local authority that cannot meet that target without resorting to incineration deserves to have serious questions asked about its policy and management. In fact, much greater recycling rates than this can be achieved. Once the initial investment is made in effective systems, the cost per tonne for waste management begins to decline significantly.[3]

It is necessary to reduce the amount of all types of waste going to landfill. But it is not desirable, or necessary, to do this by increasing reliance on incineration. Incineration is hugely unpopular and highly polluting. And it does not solve the landfill problem. 30% by mass of the waste burnt remains as ash and 15% of municipal waste by-passes incinerators as large non-combustible items.

Cities and regions in Canada, the USA, Australia and New Zealand have achieved significantly larger reductions in landfilling – up to 70% – without using any incineration. Moreover they have done this relatively quickly, generally in a period of five years or less. In the UK, there are several examples of communities that have achieved recycling rates of over 50%.

Many waste professionals in the UK see a dramatic increase in recycling and composting as severely constrained by logistical, cultural, technical and economic factors. Some put a limit of around 50% on what they believe can be diverted. Any strategy has to be shaped with respect for the experience of waste managers, but the experience of municipalities and regions in other countries also provides valuable insights. Leading waste authorities elsewhere have reached 60% diversion and are now planning strategies to reach 85%. Edmonton in Canada has already attained a 70% diversion of residential waste from landfill without any incineration. In the UK, Essex has been the first county to adopt a 60% target by 2007, and its first pilot scheme is already approaching this target. According to Peter Jones of waste management company Biffa, 'Most in the industry agree that at least 60% is a realistic target for diversion from landfill into biodegradation and recycling.'[4]

Mersea Island, Essex
Mersea Island has achieved a recycling rate of 57% and a participation rate approaching 90% in the 4,500 households covered by its recycling scheme.

Contact Chris Dowsing, Waste Policy Officer,
Colchester Borough Council,
Tel 01206 282736.
chris.dowsing@colchester.gov.uk

It is necessary to reduce the amount of all types of waste going to landfill. But it is not desirable, or necessary, to do this by increasing reliance on incineration.

There is no doubt that there are challenges to reaching high diversion rates: setting up new collection methods, ensuring public participation, finding markets for collected materials. Others have faced the same challenges and solved them. In the UK, we are currently at the very bottom of the league when it comes to 'waste utilisation'. But that gives us one advantage. We can look at others to see what is possible and get some ideas on how to achieve it.

This briefing is intended to map out the general features of a sustainable waste management (or waste utilisation) system, by highlighting technologies and best case examples from around the world. The principles, techniques and technologies outlined in this report represent the best environmental options, and are applicable to metropolitan and rural areas alike. The details and implementation need some imaginative thinking from decision makers and waste managers!

Wye, Kent
The WyeCycle community composting and recycling scheme has enabled the local authority to reduce mixed waste collections to once a fortnight for 1000 households in Wye and Brook. Weighings of residual waste put out for collection show average waste production to be down to 250kg per household per year. (UK average is approx 1 tonne)

- Glass, paper, metals and textiles are collected weekly in a black recycling box
- Kitchen waste, including vegetable, fish and meat waste is collected weekly & composted.
- Garden waste is collected separately
- All compost produced is sold as a soil conditioner and mulch

Contact Richard Boden,
Managing Director, WyeCycle.
Tel 01233 813298

Source Separation – as easy as 1-2-3

The first principle of any waste management scheme that hopes to achieve high diversion rates and good quality recyclables is source separation of waste. This means kerbside collection of three streams:[5]

- dry recyclables
- compostable material
- residuals

Additionally, hazardous materials (paint, oil, pesticides, fluorescent light bulbs etc) should be kept out of the municipal waste stream, either by separate collection or by utilising "bring" points at civic amenity sites, or a combination of both.

Stream 1 – wet organics

After source separation, composting is the most important step towards sustainable waste management.

Composting quickly reduces the volume of waste landfilled. All waste authorities achieving 50% plus recycling levels have paid close attention to the collection of the organic stream.

Separation of the organic stream reduces the toxicity of residual waste because it removes organic acids, which dissolve heavy metals in the waste and cause them to leach. In fact, it is the organic material in landfill that causes many of the environmental problems associated with this form of disposal.

Profiting from waste – Isle of Wight
Demand for compost produced from household waste on the Isle of Wight far outstrips supply – the source separated green and organic waste produces high quality compost used by local tomato growers. Compost mechanically sorted from residual mixed waste is used as a landfill cover material that would otherwise have to be imported onto the island.

Contact Sarah Humphries, Island Waste Services,
Tel 01983 821234

Instead of being a disposal problem, organic household waste can be used to generate useful end products that have both a market value and an environmental value.

Organic waste often makes up over 40% of the household waste stream. Diverting the full range of organic materials combines with dry recycling to dramatically reduce the volume, weight and odour causing potential of the residual stream. The organic and dry-recyclable stream can potentially take 70%-80% of total household waste.

Diverting food waste is the step that crosses the threshold from ‘add-on’ recycling/composting services to a true three stream system. It brings high diversion levels within councils’ reach and is a useful source of nitrogen where high quality, high value, compost is the objective.

Garden (green) waste can be diverted rapidly and at low cost. Its diversion enables waste managers to make major cost savings. It is relatively easy to handle through home composting, at Civic Amenity (CA) sites, through wheeled bin or paper sack kerbside collections, and at central composting sites.

Experience has shown that it is generally best to treat the green garden waste and kitchen waste as two separate streams. Food waste has a high density, hence can be collected in small buckets and does not need compacting. It will need composting at enclosed facilities due to the presence of meat and fish. Green waste is low density and best compacted when collected. Separate collection also allows green and kitchen waste to mixed in the correct proportions for the required end products.

Garden waste Home Composting.
Home composters cost £10-£15 per unit and divert an average of 120kg per household per year, and in some cases up to 250 kg. Over ten years, this means the Council pays a maximum of £15/tonne to divert this material – with savings including disposal costs (£20-£35/tonne), refuse collection costs and gate fees at central composting sites.

After source separation, composting is the most important step towards sustainable waste management.

Home composting is the best option for garden waste, but it will also be necessary to offer a collection service.

Collection of garden waste

Current resources can be used in new ways to minimise the infrastructural costs of increasing the quantity of material collected and recycled.

One possibility is the weekend collection of green waste in refuse collection vehicles (RCVs), which are often unused on these days. This low cost way to begin diverting organics provides large quantities of clean green materials for central composting sites. Further savings are available by running the service only during the 8-9 peak green waste months.

Green waste collections can cut costs and generate income through two additional methods:

- Local authorities already have the power to require that households separate green waste from refuse – thus increasing participation
- Many already charge for special green waste sacks (10p-£1/each)

Weekend collections + charges for sacks + a nearby composting site + gate fees £15-£20/tonne + disposal credits (in some counties) = a smart, cost-effective step in the diversion of the organic stream.

Kitchen waste – getting all the organics

Programmes across Britain (e.g. Daventry, Rochford, Wye) and elsewhere show that collecting food waste can reduce the volume of residual waste tonnages, and permit fortnightly rather than weekly collections, saving up to £100,000 per refuse round. Food waste also improves the texture, moisture and nutrient content of compost when mixed with green waste.

To date there is little data on kerbside collection costs for compostable waste, however a figure of about £10 per household per year has been suggested.[6]

Wealden, East Sussex, has increased its recycling rate from 4% to 53% in two years in areas where it has introduced kerbside recycling. It uses a wheeled bin collection of garden, uncooked kitchen waste and cardboard, a kerbside box for mixed paper, cans and foil and a wheeled bin for residual waste. The kerbside box and green waste bin are emptied one week and the residual refuse bin is emptied the next using the same vehicles and crew.

The initial approach of giving households a single recycling box had little effect on recycling rates. Change came when the council began to collect green compostable waste. Two further innovations increased capture rates – a restricted capacity of the mixed waste bin (through fortnightly collections), and a firm line with people who persisted in mixing their rubbish: their bins were not collected. The result was almost total compliance.

When new areas are included in the scheme collections are carefully monitored for the first six weeks and specific advice given to householders on an individual basis.

The Government strongly supports the composting of waste, this is a vital component of meeting Waste Strategy targets for recycling and composting and targets under the Landfill Directive to reduce the landfilling of biodegradable municipal waste

Collection of kitchen waste

There are two main methods of collecting food waste at the kerbside:

- Mixed with green waste and potentially cardboard in wheeled bins @£12-£18/unit, or in reinforced paper sacks @20p
- Separately in a small bucket or other compost container @£2-£8/unit

The two principal practices used to accomplishing cost efficient collection of organic waste are to introduce alternating fortnightly collections of refuse and organics; or fortnightly residual refuse collections with weekly organics. Weekly collection of kitchen waste should be given preference where possible as this minimises potential odour problems and is therefore more readily accepted by the public.

Richard Boden of WyeCycle offers the following advice for achieving maximum collection rates:

- Treat kitchen and garden waste as two separate streams
- Collect all kitchen waste
- Ban garden waste from the mixed waste bin
- Make a charge for collection of garden waste (so smaller properties which produce little of this waste are not subsidising householders in larger properties which produce a lot).
- Don’t provide a wheelie bin for garden waste
- Do not collect mixed (residual) waste weekly
- Do collect kitchen waste weekly

‘Organise your organics’ – Isle of Wight

On the Isle of Wight over 15,000 small buckets for collecting organic waste have been distributed to households that have requested them. The service began in December 1998, about 30% of households on the island participate and this figure continues to rise. Most island schools also separate their waste.

Contact Sarah Humphries, Island Waste Services, **Tel** 01983 821234

The Animal By-Products Order

Organic waste, including kitchen and catering waste that may contain meat, will be subject to new EU regulations due to come into force in Spring 2002. These regulations are intended to control the transport, handling and disposal of animal derived products in order to increase food safety. They will stipulate that such waste must be composted in an enclosed environment and must reach a specified temperature (likely to be 70°C for 60 minutes). The EU Animal By-Products Regulation will allow composted kitchen waste to be used on all land except pasture land, used for grazing animals.

This means there will be a huge potential market for properly composted household kitchen and garden waste; agricultural and horticultural uses, greenhouse growing, retail for the domestic market, turf growing, landscaping, roadside soil improvement, mulching applications etc.

DEFRA sees composting as vital to the future of waste management:

"The Government strongly supports the composting of waste, this is a vital component of meeting Waste Strategy targets for recycling and composting and targets under the Landfill Directive to reduce the landfilling of biodegradable municipal waste…Where catering or household waste contains meat or other products derived from animals then, although it may be composted, it may not, currently, be used on land…where animals (including wild birds) may have access. However this position is set to change. The draft EU Regulation on Animal By-Products will allow the use of properly composted mixed waste on all land except pasture land. We expect this regulation to come into force in the Spring of 2002."
DEFRA Briefing note on composting 21 June 2001

There will be no restrictions on the composting or use of green waste (garden waste).

In-vessel composting systems ensure the absence of odours, that pathogenic organisms are killed and a high quality compost.

Utilising the collected material – composting technology

When choosing the best compost system it is important to consider the operational aims and whether the chief objective is to manage the waste stream as cheaply as possible, to reduce the organic content of the residual waste stream or to produce quality compost. The priority given to each of these will influence the type of system needed.

Windrow systems

Areas which contain or border on farms, rural spaces or landfills can often compost their organics centrally at an open, windrow site. This is the traditional method of composting in elongated heaps that are periodically turned. Climatic conditions and feedstock properties are important considerations in determining the suitability of windrow composting. Oxygen content, temperature and moisture content should all be monitored and controlled. Cost of windrow composting is normally around £15-£20/tonne of waste. Before investing in windrow composting systems local authorities need to be sure that they will be able to meet future regulations in terms of pathogen kill, quality of the final product and odour and dust emissions. In this respect, in-vessel systems have distinct advantages.

In-vessel composting

In vessel composting systems allow greater control of the process and of its outputs. For dense, urban areas, a range of enclosed, in-vessel systems also ensure the absence of odours and cut transport and land costs. A high temperature can be obtained across the whole composting mass to ensure pathogenic organisms are killed. Composting is also quicker under these more controlled conditions. Operating costs tend to be higher than for windrow systems, but in terms of quality control, pathogen kill, land use and public acceptability, in-vessel systems will generally pay dividends. Some land, indoors or out, will normally also need to be set aside in which the compost can mature. Capital costs are typically between £3 million and £4 million per 20,000 tonne throughput.

A Vertical Composting Unit. VCU sites in Australia and New Zealand process a wide range of organic materials – including green waste, food processing wastes, paper and sewage sludge.

Vertical Composting Units – odourless, small footprint, low cost

By raising the composting process into 6 to 12 metre high vertical compartments, Vertical Composting Units's (VCUs) greatly reduce the land area required. A single VCU will process up to 1500 tonnes annually, on a area of 11m^2 – while a 10 unit placement will process 10-15,000 tonnes on under 200 m^2 of concrete. The critical advantage for urban waste managers is that VCUs can be easily placed at CA sites, waste depots, within some Materials Reclamation Facilities (MRFs) or directly attached to organic-waste generating firms or facilities.

The VCU process was designed by microbiologists to break down and eliminate odours within the chamber. The enclosed chambers make it impervious to pests and vermin. Gravity draws the organic material down through the system, reducing the number of moving parts and operational costs. Naturally generated temperatures reach over 75°C, ensuring a pasteurised and odour stabilised end product. The system requires as little as 11kWh energy to process a tonne of waste.

VCUs have a capital cost of around £70,000 for one unit. One operative is able to feed up to 5 units. CA sites generally offer the lowest cost composting through VCUs. Capital, equipment, running and maintenance costs are £15-£20/tonne if every component must be purchased – but at CA sites these costs fall to the £10/tonne range.

Anaerobic digestion

Anaerobic digestion is an alternative form of composting, which takes place in an oxygen-free environment. It produces two streams of useable products. The first is biogas (consisting primarily of methane and carbon dioxide with small amounts of hydrogen sulphide and other gases) which can be burnt to generate electricity or heat or used as a vehicle fuel. The second is a 'digestate' – a thick slurry or near solid residue. Assuming contaminated waste has not been used as the feedstock, this can be used as a nutrient rich soil conditioner or liquid fertiliser.

There are about 70 plants operating around the world that use MSW (Municipal Solid Waste) as a feedstock. Anaerobic digesters currently have higher capital and operating costs than composting systems, and there will be emissions from burning gases for energy. The best results from this technology have so far been achieved in conjunction with sewage sludge handling systems. However, contaminated feedstocks will result in contaminated residues.

Multi-story blocks

Experience in North American cities and pilot schemes in the UK have shown that high capture rates from high rise and multi-story blocks are possible and can have significant benefits. Convenience is the key. Modification of waste chutes has proved successful but costly. Door to door (or floor to floor) collection schemes can offer a greatly improved waste disposal system for high rise tenants. The convenience of putting out waste for recycling rather than taking it to a paladin or chute provides a major incentive for recycling beyond any householder commitment to the principle of recycling.[7] Costs of door to door collection systems are partly offset by recycling credits, avoided disposal costs and reduced cleaning time from blocked chutes and overspilling paladins. The key to success seems to be in getting residents to see the benefits in terms of an improved service. Pilot schemes in London have shown that the improved service to residents, together with appropriate educational measures can achieve 58% set out rates and 75% participation.

Stream 2 – Dry Recyclables

Building a successful basic recycling programme.

'Core' dry recyclables are 30%-40% of household waste (paper, metal cans, glass bottles and textiles.) They can usually be collected through a simple box and vehicle and bulking system. On their own, they enable a 15%-20% recycling rate to be achieved. It is vital that these systems not only maximise their performance – and minimise their costs – but lay a sound basis for adding the 'expanded' range of recyclables as a next step. A comparative study of the alternative collection methods available, which includes transport, labour and capital packages, is important with regard to individual circumstances, but recent experience in the UK has identified three key factors and innovations which can ensure that performance is maximised:

A – Education is the #1 factor in recycling success

The financial value of investing in education is easy to calculate. If a recycling system presently has 40% participation, and if those participants are separating out 40% of their recyclables – then just 16% of available recyclables will be set out for collection. It requires a solid educational campaign to increase those rates. If participation and separation rates are increased to just 60% and 60% (= 36%), this will more than double the materials set out. An 80% x 80% performance (=64%) will quadruple materials collected. It is a far better financial decision to spend 50p or £1 per household to get more materials set out in the first place, than it is to add another vehicle or piece of materials reclamation equipment.

Resources currently discarded have been described as urban mines because of the untapped resources they represent.

‘Core’ dry recyclables are 30%-40% of household waste (paper, metal cans, glass bottles and textiles.)

Successful recycling programmes provide some key insights in ‘how to do’ recycling education.

- Keep It Simple
- Always Use Graphics
- Make It Personal
- Target Feedback
- Repeat, repeat, repeat

Sending someone to the door to deliver the box and answer any questions is much better than just dropping a box with a brochure in it on a doorstep. Successful programmes have used local residents or the new kerbside collection staff to make the delivery personal, answer residents questions and encourage participation. Feedback cards are also useful. Waste composition studies will reveal which materials households don’t know they can recycle, enabling managers to target the ‘missing’ materials for follow-up promotions. These often focus on high-value aluminium cans and textiles, and can rapidly boost overall programme sales revenues.

After (but not instead of) education, there is no doubt that some gentle coercion can increase quantities collected dramatically and rapidly. Some European cities return bins unemptied, with an explanatory sticker, if organic waste has not been separated. Some impose a fine for non-separated waste, others charge for waste collection by weight or volume. Rebates or cash incentives for households that do source separate may also increase participation rates.

Halifax, Nova Scotia, Canada.

Severe environmental problems resulting from an existing landfill, together with opposition to the introduction of incineration resulted in a system based on three stream kerbside collection which has enabled Halifax to reach a 65% diversion from landfill rate.

Halifax Regional Municipality (HRM) has a population base of approximately 350,000, comprised of some 133,000 households. It has an annual waste generation of 260,000 tonnes. For years, the municipalities - Halifax, Dartmouth, Bedford and the more rural Halifax County - relied on landfill as the primary waste management method. One of the criteria established by the Community Stakeholders Committee, who participated in the waste strategy planning process, was that no raw organics, could be sent to landfill. The group concluded that rather than have to spend time and money maintaining waste degrading at its own rate in a land-fill, it made more sense to force it to degrade in a controlled environment, accelerated as much as possible, and landfill a stable waste.

Stakeholders felt that basing the collection and management programme on source separation was the best route to take. They believed that if the system only relied upon mixed waste processing at a centralised plant, there would be no incentive for people to learn about waste management and to make proper purchasing decisions. Ensuring the programme was based on source separation meant source reduction and reuse would also take place.

The CSC strategy specified that waste be separated into three streams: recyclables, compostables and refuse. (Household hazardous waste is also collected). The plan also called for construction of a household hazardous waste facility, a state-of-the-art landfill, a front-end mixed waste processing and back-end stabilisation facility, and composting plants.

The programme

The system includes:

- Source separation of organics, recyclables and residual waste fortnightly collection of organics and residual waste
- weekly collection of recyclables (biweekly in the rural areas of the county)
- use of aerated carts for organics collection
- a site that includes a mixed waste processing facility designed to handle 119,000 tonnes/year of MSW, a thirteen channel agitated bed composting system to process the mixed waste after recyclables are removed
- landfill for stabilised waste.

The total solid waste stream is roughly 55% residential and 45% commercial. The institutional, commercial and industrial sector is responsible for its own collection. Tipping fees are designed to encourage IC&I source separation. They are set at $68 (Canadian) per tonne for separated organics and $100 per tonne for mixed waste.

Contact: Tab A Borden, Nova Scotia Department of the Environment.
E-mail: bordenta@gov.ns.ca

B – New collection technologies.

The success of kerbside schemes depends heavily on the collection method employed. It determines the participation rate and levels of contamination of collected material. Getting the collection right is crucial. Participation rates are closely linked to the convenience of the systems. At the same time the collection method must be compatible with the treatment technology. Collection and disposal authorities must work together on this.

High-productivity, low cost recycling vehicles.

Most recycling vehicles developed in the 1980s had multiple fixed compartments, often with hydraulic lifting equipment, cost £70-£120,000, and have a long wide profile. Such vehicles simply do not work in many parts of the UK. This has resulted in a number of collection vehicle innovations:

Pedestrian Controlled Vehicles (PCVs).

PCVs are small, electrically-powered, recycling vehicles currently used to collect recyclables from 100,000 households in Haringey, Islington and other parts of the UK. Manufactured in the UK, PCVs are designed to be light, no wider than a street sweepers barrow, and to travel at walking speed. Because PCVs operate on pavements, they cut the time taken to carry boxes to the vehicle.

The materials collected are sorted into variously sized, labelled, builders bags on the platform of the PCV. The bags are rolled off into empty parking spaces or other collection points once full. The operative then unfolds a new set of bags and continues collecting, while a single, larger, crane equipped vehicle (@£35,000-£40,000) collects the sacks from 6 to 8 PCVs. The fact that one crane-vehicle driver can serve

A PCV and operative at work in Islington between six and eight collection staff (as opposed to a 1:2 ratio on most recycling vehicles) dramatically cuts costs. PCV-based recycling systems offer additional cost savings and benefits:

- Very high productivity at 500-1000 households per operative-day
- Capital costs of £8,000 (lease @ £2,500), recharging costs of 20p/night
- Widespread popularity with local residents as they are quiet and emissions free – Staff are on foot and thus easily accessible to respond to the public's questions
- They do not block traffic in narrow streets or inaccessible areas
- Flexibility is maximised as programmes can add materials simply by adding new builders bags – or a second trailing cart
- They can be stored 'remotely' in local depots/buildings, thus cutting time to/from the round.
- The use of crane vehicles means the elimination of the usual congestion at the MRF during peak hours; builders bags on the crane vehicle do not 'cube out' as cages/compartments do; and the bags can be handled easily.
- Both PCVs and crane vehicles can be used for other evening or weekend duties (e.g. collecting in city centres, markets, parks, or from bring banks.)
- PCVs can also collect kitchen organic waste.

Stillage vehicles:

are low cost (@£35,000-£40,000), flexible, and have been widely proven in their use – e.g. the community sector uses stillage vehicles to collect from hundreds of thousands of households in London, Bath and elsewhere.

Co-collection vehicles:

can be inexpensively made out of RCVs (@£15,000-£35,000 per retrofit) and can collect two of the three main streams in one pass – an approach well-suited to remote areas, offering substantial cost savings and reduced traffic.

These three methods enable communities to add a recycling vehicle for £8,000-£40,000 in capital costs – compared with £100-£120,000 for RCVs – and mean that the capital constraints holding back recycling are often much less than imagined.

C – Bulking and sorting for next to nothing.

The high capital cost and operational complexity of running a full-scale Materials Reclamation Facility (MRF) is unnecessary in the first stages of a recycling programme. For instance, both the stillage and PCV-based systems operating in London rely almost entirely on bulking materials into large Roll-on-Roll-off facilities (RORO's) using forklifts with rotating heads. In Islington, where PCVs collect from 40,000 households, the builders bags are simply bulked in an outdoor area which formerly held some recycling banks. There is thus no reason for kerbside recycling to be delayed until a full-scale MRF is built.

Expanded recycling.

There is a further 10%-15% of additional dry recyclable materials (corrugated card and card packaging, aluminium foil and aerosols, engine oil and various plastics) which, once collected, will enable a step change in recycling.

Collecting the full, expanded set of recyclables requires two basic systems changes:

- Corrugated card and plastic bottles have large volumes and low weights, so sufficient handling capacity must be provided throughout the system – especially in household storage containers and on the collection vehicles
- More types of materials means further sorting either at the kerbside or, more likely, at a MRF. If a basic MRF facility is available, recycling managers can reduce the number of sorts done on the kerbside trucks, thus generating savings on collection costs. Some schemes have found it beneficial to collect and compost card with green waste. Card can aid the composting process and provide a useful source of nitrogen.

Add cardboard and plastics… get MORE newspapers and cans. Adding the expanded recyclables has the surprising side-benefit of ALSO boosting the capture rates for the core recyclables. This seems to occur because households now find it easier to separate out ALL paper and board for recycling than they did to pick out specific grades – and because every material that is added furthers the practices and culture of recycling.

Toronto's waste plan – 60% diversion by 2006, 100% by 2010

'We are proposing transformational change, but the net result will be a simple and convenient system that will be easy for the resident to understand and take part in.'

Key assumptions to achieving its targets:

- organics will be collected each week
- anaerobic digestion will be the main treatment method for organic materials
- recyclables will be collected every two weeks
- residual resources will be collected every two weeks
- costs are based on a four-day 10-hour working week using existing staff

The practical plans:

- Just one collection truck will go down the resident's street on the same day each week; it will be a modern truck with two compartments.
- On one week the truck will collect organics from a hard, animal-proof container placed at the kerb, and also pick up recyclables which will be placed kerbside in one or more containers or bags; all dry recyclables can be 'co-mingled.' No need anymore to have a separate Grey Box for papers and Blue Box for bottles and cans.
- On the second week the organics will be picked up again, this time along with the residuals (anything that can't be recycled or composted).

'We will begin the four-year implementation of the new programme in 2002, starting with 170,000 residences. We will expand the number aggressively in the ensuing years.

When fully implemented, the net operating costs of the new system will be about $157 million per year (2006) or $160 per household per year. We asked ourselves how this would compare with other, more modest approaches to resource diversion. We were delighted to discover that it compares almost equally to keeping the status quo ($155 million or $158 per household in 2006) or just adding weekly recycling to the status quo ($158 million or $161 per household). The costs per household are the base costs and do not include debt service and indirect corporate charges. Meanwhile the big payoff is in a programme that is simpler to understand, easier to participate in, and much better for the environment that we live in.'

Waste Diversion 2010 Report, City of Toronto

Nova Scotia, Canada

A 50% reduction of solid waste going to landfill in five years has been achieved. Important elements of this model are:

- Deposit/refund on all drinks containers. (Achieved over 80% return rate).
- 100% access to kerbside recycling
- two bag collection system (green bag, blue bag)
- DoE ban on compostable organic material in landfills. (72% of residents have kerbside collection of all organic material)

Details: www.gov.ns.ca/envi/wasteman/

Glass bottles are ideal for re-use

Stream 3 – Residual Waste

The Last Resort – MBT systems

The three stream system outlined above points to a new way of thinking about the handling of residuals. Best known in Europe as Mechanical-Biological Treatment (MBT), these systems are built on the three stream logic. This moves us from a time when we could simply landfill or incinerate mixed, unsorted waste into an era of 'streaming' materials into their highest economic and environmental value.

The objective of MBT systems is to avoid putting toxics, recyclables and organics together into any final disposal option where they can interact and contaminate each other. Instead, MBT systems combine a series of treatment steps to remove as much recyclable, organic and toxic material from the residual as is possible – thereby producing an inert, 'stabilised' final product. MBT systems generally reduce the weight of the residuals they receive by a further 50%.

MBT systems enables cities and regions on both sides of the Atlantic to increase greatly their waste diversion rates – e.g. Halifax, Nova Scotia's 350,000 people boosted their diversion rate to 61% when launching their full 3-stream + MBT system; Edmonton, Alberta's 900,000 citizens reached 70% last year; and there are now dozens of such 3-stream + MBT systems across Europe, in Germany, Austria, Italy, Flanders and other regions.

The 'Bedminster' System

This modular system can be used for source separated or mixed waste. Mixed waste can be sorted manually or mechanically. Mechanical pre-sorting may include bag openers, eddy-current separators, metal detectors etc. The main component of the system is a sealed unit, rotating drum, designed to mix, aerate and homogenise the material. After the drum, raw compost is passed through a trommel for screening, and cleaned again to remove small items such as screws, paperclips and pieces of plastic. The compost can be left to mature for three to seven weeks either outdoors or indoors. Turning, aerating and sprinkling can be manual or via computer controlled automation. Sophisticated monitoring of the process and analysis of the product assure quality.

How MBT systems work:

1. **Source separate first.** MBTs should receive the residuals left after the maximum front-end source separation has been achieved – thus maximising the economic and environmental benefits from source-separation and minimising the size, cost and complexity of the MBT plant required.

2. **The mechanical stage.** Residuals are fed into a highly-mechanised front-end (to remove metals, plastics and other materials). This maximises the diversion of recyclable materials, separates of the compostable element and ensures the cleanest feedstock possible for the next stage.

3. **The biological stage** is usually an enclosed, in-vessel composting system which is intended not primarily to produce a saleable compost product, but rather to reduce the weight, and render inert any biologically active organic materials (that is, to 'stabilise' the residue.) The materials broken down and composted at this stage include paper and board, green/kitchen organics, and the organic content contained within nappies, packaging, textiles etc.

4. **The residue** is both greatly reduced in weight, and is stabilised. It can be landfilled, greatly reducing the risk of methane production, leachate difficulties and landfill fires, used as landfill cover or if contamination is low enough, as low grade compost.

Perhaps the greatest advantage of MBT plants is their flexibility – they can be built on a modular basis, and as source separated tonnages rise, the equipment and space can be shifted into high quality composting or clean MRF processing.

Perhaps the greatest advantage of MBT plants is their flexibility – they can be built on a modular basis, and as source separated tonnages, rise, the equipment and space can be shifted into high quality composting or clean MRF processing. MBT plants can be sited and constructed more quickly than a similarly sized incinerator, at a fraction of the cost. They can also be cost effectively built on a smaller scale.

Why landfill of separated, stabilised waste is better than incineration

Until we can achieve zero waste (see p.25), material that cannot be re-used, recycled or composted will have to be stabilised, then landfilled. There are several reasons why this is better than building incinerators:

- Incinerators do not eliminate the need for landfill. They produce contaminated ashes that have to be landfilled and by-pass 15% of municipal waste that is non combustible. Many incinerator operators now also reject large batches of PVC plastic because of its high chlorine content.
- Landfill does not perpetuate the need for waste creation as incinerators do (because landfill is more flexible, has a lower capital cost, shorter lead times, can operate with shorter contracts and can be designed to cope with decreasing quantities of waste). Source separation schemes like those outlined here mean that the quantity of residual waste will be much reduced and decreasing. Landfill can therefore be reduced by orders of magnitude, and phased out as we approach zero waste. Incinerators on the other hand must operate at near capacity for their 25-30 year lifetime in order to make sure capital investments secure a return. Once built they are a structural impediment to significantly reduced levels of waste disposal.
- With organic materials removed from landfill, leachate will be reduced in terms of quantity and toxicity.
- Source separation of waste means that hazardous materials will be easier to identify and keep out of the waste steam. Again toxicity of materials entering landfill will be reduced. Many toxic materials entering a mass burn incinerator are impossible to identify.
- With organic and hazardous materials (including products containing hazardous substances) removed from the waste stream the residuals will be much closer to inert. It would be acceptable to bury the small amounts of this type of inert residual waste generated after intensiv composting and recycling programmes. Incinerators on the other hand always generate highly toxic waste from thermal and chemical reactions that take place during combustion of mixed materials.
- Those that argue incineration with energy recovery is better than landfilling maintain that the energy recovered from burning waste makes it a greener option. This is not true. The two materials that supply a significant calorific value in municipal waste are plastics and paper/card. Plastics consist mostly of oil. In terms of climate impact, burning them is equivalent to burning fossil fuels. In terms of resource and energy use, it is far more efficient to recycle paper than to burn it as fuel.

When landfilling residuals, waste authorities should be sure that material that is landfilled a) has been reduced to the smallest quantity possible, and b) is as inert as possible. The way to do this is to mechanically treat residual waste befor composting using MBT systems. Landfills must be constructed using the best available technology and incorporate feedstock control to prevent the disposal of hazardous materials. Approval for landfill developments must be strictly limited to prevent over supply of disposal capacity.

The objective of MBT systems is to avoid putting toxics, recyclables and organics together into any final disposal option where they can interact and contaminate each other.

Edmonton, Canada, (population 636,000) has already diverted 70% of household waste from landfill, without using incineration. This is a recent achievement made possible by:

- Separate doorstep collection of dry recyclables, from all households (recycling rate achieved 15 – 18%)
- Mechanical separation and composting of the remainder
- "Take" collection points for household hazardous waste.

The only sorting Edmonton residents are required to do is for recyclables and household hazardous waste (2 bin system). The remainder is sent to a state of the art screening and composting facility, which produces a compost product in four weeks.

30 – 35% of material entering the composting process is landfilled. This is comparable to the solid waste volume reductions obtained by incineration, where 30% of material is left as ash and 10 – 15% is rejected as oversized non-combustible.

Edmonton residents have 2 containers. A blue bag for dry recyclables, (glass, paper, card, metals, plastic) and a bin for everything else.

1. Dry recyclables are processed at a materials recovery facility.

2. Householders are not allowed to put hazardous materials into the waste stream. Instead they must be taken to "Eco-Stations", which keeps dangerous waste out of the landfill. It can then be directed to facilities for reuse or recycling.

3. The household waste in the "everything else" bin is taken to the composting facility. There it is:

- Tipped. Oversize and unacceptable items are removed
- Screened. The material is transported by conveyor belt to a screen which removes non-biodegradable materials
- Composted. The conveyor moves the screened material to three aeration bays, where the material is regularly turned and air is drawn through it. After 4 weeks the compost is finely screened and the product is ready for marketing.

Details of the Edmonton system can be found at: http://www.gov.edmonton.ab.ca/am_pw/waste_management/

The MBT facility in Edmonton, Alberta

Thermal treatment – gasification and pyrolysis

Some local authorities are looking into the possibilities of 'thermal treatment' technologies to deal with residual municipal waste. There are several variations to gasification and pyrolysis systems. Pyrolysis heats waste in an oxygen free environment to produce gases and liquids which can be used as fuels, and a solid residue. Gasification involves the partial combustion of materials in the presence of air, steam or pure oxygen. The product is a mixture of combustible gases, tar compounds and particulates. Some systems use a combination of both techniques. The claim is that these technologies can achieve higher thermal efficiencies for power generation than mass burn incinerators and that less pollution will be generated. Neither of these claims have been substantiated by operating plant. Although they have met with some success for homogenous feedstocks, such as coal or sewage sludge, results with municipal waste are not encouraging. There is currently very little data available for plants of the type or scale applicable to UK municipal waste. However it is clear that gasification and pyrolysis have many of the same problems as conventional incineration – i.e. the production of hazardous pollutants from chemical reactions, and the discharge of these pollutants in solid and gaseous emissions. Test data and Environment Agency licences for the pilot projects in the UK, and data from plants in other parts of the world, reveal the same pollutants released as in conventional incineration and in quantities of the same order of magnitude.

Gasification and pyrolysis are not solutions to the fundamentally dirty and flawed practice of mixing municipal waste and then trying to dispose of it. They offer no more than a possibility of reducing some of the impacts. As such they are an end-of-pipe pollution management tool rather than a solution to the problem.

Re-use

Local authorities should do what they can to encourage producer responsibility. They can also take a variety of measures themselves to increase re-use. Central to every waste strategy is a serious waste reduction programme. Refurbish and re-use schemes not only reduce waste, but also provide good quality employment and encourage small scale businesses which generate money for the local economy. Local 'swap days' reduce waste at minimal cost.

There are many imaginative schemes in the UK and around the world in which waste reduction schemes play a significant part in waste strategies. Local authorities also have a considerable amount of buying power. Buying large quantities of refurbished and recycled products, particularly through supply-and-buy-back agreements can help stabilise markets for recyclates and recycled products.

Aluminium moulding machine

Zero Waste (or damn close!)

Waste is not inevitable. It is the result of a series of decisions such as what a product is made of, how it is made, how it is designed, the thought put into what will happen at the end of its life etc. In this respect, a great deal of waste is the result of bad design.

Economic imperatives are sometimes the cause of this sort of bad design. A product that is cheaper than a competitor's because it can be thrown away without regard for the environment is in fact receiving a subsidy through public money spent on costs associated with its disposal. One way of internalising these costs into the cost of the product is through individual producer responsibility. Put simply, this means that if a product (and its packaging) cannot be re-used, recycled or composted then the individual producer must be responsible for collecting and safely dealing with the product at the end of its life. The financial imperatives inherent in individual producer responsibility will tend to lead to products designed to eliminate waste. European Legislation is emerging to address this issue. For example the Waste Electrical and Electronic Equipment and End of Life Vehicles Directives.

Individual producer responsibility is the final piece of the jigsaw that makes Zero Waste an achievable target. It is one mechanism by which reductions in the production of waste can be implemented. In conjunction with the source separation of waste for all households, intensive composting and recycling programmes and effective refurbish and re-use schemes, residual waste can be considered a temporary phenomenon. Whether or not we can achieve zero waste or can only get close, Zero Waste as a policy is proving to be the most effective driver in achieving waste diversion beyond what used to be imagined as maximum limits. Those implementing Zero Waste policies are showing that the only real limits are those imposed by lack of imagination and lack of political will.

Canberra, Australia, has gone from 22% to 66% recovery of waste in six years (93/94 – 99/2000), with no incineration. The success is part of a drive to achieve 'zero waste' by the year 2010 utilising systems designed to separate waste into streams to maximise recycling.

Details:
www.act.gov.au/nowaste/wastestrategy/index.htm

Finances – cutting costs, raising revenues and new external funds

Dramatic improvements in the financial costs/benefits of recycling and composting have been made in the past three years: the net costs of recycling have continued to fall; new external funds have been announced (below); rising landfill taxes have increased the value of recycling credits; and Materials Marketing Consortia have been successfully developed.

External Funds

There is a range of funding coming on-stream that provides a new opportunity for local authorities to invest in recycling:

- £50 million through the New Opportunities Fund
- £140 million through a ring-fenced recycling/composting fund
- £1.127 billion in new Standard Spending Assessment (SSA) funding
- PFI funding in Sept/2000 revised its criteria to prioritise recycling/composting
- Landfill credits (£100 million annually) now target recycling more directly
- SRB (Single Regeneration Budget) -related funding
- The Neighbourhood Renewal Fund (£900 million for 88 Boroughs)
- Social Exclusion Funding
- Market development funds (e.g. the £40 million WRAP programme)
- An annually rising set of PRN targets

These funds offer the UK's local authorities access to a major share in £2 billion to £3 billion over the next three years. By contrast, landfill and incineration face ever rising costs through rising landfill taxes; Parliamentary support for a proposed incineration tax; the end of renewable energy funding, and the tightening of PFI limits on incineration.

The opportunities for local authorities to act now and accelerate their shift toward high recycling and composting systems are clearer than ever before.

Other benefits

When costing changes in waste systems – market sales, recycling credits, external funding and waste systems savings are usually included. However, there are additional important benefits that waste managers should include when making the case within the local authority for investment in new systems:

- Increased recycling employment generates additional financial benefits for the local economy – e.g. adding 50 new collection jobs injects £750,000 into the local community, often more than any increased waste management costs.[8]
- Tangible, visible progress in recycling helps to constructively engage neighbourhoods, estates and businesses – with consequent savings in Council decision-making time by reducing damaging 'Council vs. The Public' battles.
- Quality of life gains include reduced street litter, cleaner neighbourhoods, and, most significantly, the improvement in quality of life on estates.
- Finally, the environmental gains from reducing waste going to landfill and incineration – in energy use, in improved air and water quality, reduced CO2 emissions and in global resource conservation – may provide the greatest benefits of all.

Further information

The Composting Association:
2001 Large Scale Composting: a practical manual for the UK.
1998 A Guide to In-vessel Composting – Plus a Directory of Systems
www.compost.org.uk

Progressive Farming Trust (2000).
Kerbside collection of source separated compostable household waste – a review of methods of encouraging the establishment and expansion of such schemes. Bulson, H.A.J and Purbrick E.A.
ISBN 1-1872064-31-0

Greenpeace UK 2001:
Achieving Zero Waste
www.greenpeace.org.uk

Waste reduction Programs
www.city.toronto.on.ca/taskforce2000
www.targetzerocanada.org
www.gov.edmonton.ab.ca

Manufacturers/distributors of in-vessel and other composting systems

Alpheco Ltd. Ipswich
tel 01473 730259 fax 01473 730295
alpheco@anglianet.co.uk
www.alpheco.co.uk

Bedminster AB, Sweden
tel +46 8 52 03 59 00.
bedminster@bedminster.se www.bedminster.se

EcoSci Ltd. Exeter.
tel 01392 424846 fax 01392 425302.
Ecosci@mail.zynet.co.uk

Farrington Environmental Ltd. Wells, Somerset.
tel 01749 676969 fax 01749 679915

Plus Grow Environmental Ltd. Manchester.
tel 0161 872 3022 fax 0161 972 9756

Wilkie Recycling Systems, Berks,
tel 0118 981 6588/6330
info@wilkiwrecycling.com

Wright Environmental Management UK Ltd. Belfast.
tel 01232 640972 fax 01232 640976
www.wrightenvironmental.com

Notes

[1]DoE 1995, Making Waste Work.

[2]DETR 2000 'Waste Strategy 2000' part 2, p.191.

[3]See for example EA/LPAC/Ecologica 1998, Re-Inventing Waste: towards a London Waste Strategy, and Robin Murray 1999, Creating Wealth from Waste, Published by Demos.

[4]Biffa, July 2001, PFI Update.

[5]In some circumstances where it is felt that a three bin system is not workable a two bin system can be used. (Dry recycleables in one bin the rest in the second stream, or compostable material in one bin and the rest in the second), followed by mechanical separation before recycling. Edmonton, Canada has reached 70% diversion using two bins. However organic waste collected without source separation is likely to be contaminated to some degree and will have restricted end use applications and a lower market value.

[6]The Composting Association, 2001. Large Scale Composting. A Practical Manual for the UK. p 27.

[7]Re-inventing Waste: Towards a London Waste Strategy. Robin Murray/Ecologica 1998.

[8]See for example Robin Murry "Creating Wealth from Waste" DEMOS (1999).


CLEANSING
INCINERATOR
TOXIC CRIME

‘There is no question that the Landfill Directive can be met by local authorities without mass burn incineration’

Philip Cozens, Major Projects Development Officer, Shanks.

‘It is entirely possible to achieve the Landfill Directive targets without using incineration’

Peter Jones, Director, Biffa Waste Services

Printed on recycled paper made from 100% post-consumer waste

October 2001

GREENPEACE

Canonbury Villas London N1 2PN Tel: 020 7865 8100 www.greenpeace.org.uk