

A load of rubbish

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What's wrong with policies on waste, and how to get them right

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AT POPE'S CREEK, on America's Potomac river, there's a pre-Columbian rubbish tip of oyster shells covering 30 acres, to an average depth of ten feet. Humanity has always produced waste in vast quantities; but more people, more consumption and the contribution emissions from rubbish make to climate change mean that disposing of the stuff is an increasingly contentious issue.

People feel that they have a natural right to throw away as much stuff as they like, just as those lucky native Americans chucked the shells from their plentiful oyster piles over their shoulders. They shouldn't. Rubbish damages the environment and is expensive to dispose of. With household waste, just as with toxic chemicals, governments need to persuade people that they should be responsible for the muck they produce.

Trashy regulations

Americans are the champions of trash: on average they jettison over 700kg each a year. But developing nations are catching up fast. By 2030, Indians will be producing twice as much as they are now; Chinese people three times as much.

Waste is also becoming more hazardous. Modern industry produces many things, from coal ash to computers, that are difficult to dispose of properly. The consequences can be grotesque: in the city of Dzerzhinsk, in Russia, decades of slapdash handling of chemical waste has reduced male life expectancy to just 42 years. Rotting waste, meanwhile, produces methane, one of the more potent greenhouse gases, and thus contributes to global warming.

Yet as the [special report](#) on the waste business in this week's issue argues, there are grounds for optimism amid the mounds of rubbish. Environmental concerns have spurred dramatic improvements in the way waste is managed in many countries. Recycling is becoming ever more common. Entrepreneurs are brimming with schemes to turn rubbish into electricity or fuel or fertiliser. Environmentalists dream of a world in which almost nothing is wasted.

But it is governments that have the power to turn such visions into reality, and their policies are all over the place. In America, for example, landfills containing household rubbish are subject to stringent regulation, whereas ones filled with toxic sludge from power plants are less tightly controlled. In Britain landfills are taxed out of all proportion to the damage they do the environment. In poor countries many governments often ignore waste altogether. Only 6% of Madagascar's rubbish is even collected.

To clear up the mess, governments need to hold people and companies responsible for the waste they produce. One way of doing that is to work out the cost of disposal and charge firms and households for rubbish collection based on the volume they produce. That helps discourage people from chucking stuff out, and provides a revenue stream to dispose of it when they do. Another is to oblige manufacturers to take back and dispose of certain goods when consumers have finished with them. That gives firms an incentive to make their wares easy to recycle or re-use.

As consumers, people hate paying for rubbish disposal. But as voters, they claim to worry about the state of the planet. Such measures are the price of cleaning it up.

Talking rubbish

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Environmental worries have transformed the waste industry, says Edward McBride (interviewed [here](#)). But governments' policies remain largely incoherent

Eyevine



THE stretch of the Pacific between Hawaii and California is virtually empty. There are no islands, no shipping lanes, no human presence for thousands of miles—just sea, sky and rubbish. The prevailing currents cause flotsam from around the world to accumulate in a vast becalmed patch of ocean. In places, there are a million pieces of plastic per square kilometre. That can mean as much as 112 times more plastic than plankton, the first link in the marine food chain. All this adds up to perhaps 100m tonnes of floating garbage, and more is arriving every day.

Wherever people have been—and some places where they have not—they have left waste behind. Litter lines the world's roads; dumps dot the landscape; slurry and sewage slosh into rivers and streams. Up above, thousands of fragments of defunct spacecraft careen through space, and occasionally more debris is produced by collisions such as the one that destroyed an American satellite in mid-February. Ken Noguchi, a Japanese mountaineer, estimates that he has collected nine tonnes of rubbish from the slopes of Mount Everest during five clean-up expeditions. There is still plenty left.

The average Westerner produces over 500kg of municipal waste a year—and that is only the most obvious portion of the rich world's discards. In Britain, for example, municipal waste from households and businesses makes up just 24% of the total (see chart 1). In addition, both developed and developing countries generate vast quantities of construction and demolition debris, industrial effluent, mine tailings, sewage residue and agricultural waste. Extracting enough gold to make a typical wedding ring, for example, can generate three tonnes of mining waste.



Out of sight, out of mind

Rubbish may be universal, but it is little studied and poorly understood. Nobody knows how much of it the world generates or what it does with it. In many rich countries, and most poor ones, only the patchiest of records are kept. That may be understandable: by definition, waste is something its owner no longer wants or takes much interest in.

Ignorance spawns scares, such as the fuss surrounding New York's infamous garbage barge, which in 1987 sailed the Atlantic for six months in search of a place to dump its load, giving many Americans the false impression that their country's landfills had run out of space. It also makes it hard to draw up sensible policies: just think of the endless debate about whether recycling is the only way to save the planet—or an expensive waste of time.

Rubbish can cause all sorts of problems. It often stinks, attracts vermin and creates eyesores. More seriously, it can release harmful chemicals into the soil and water when dumped, or into the air when burned. It is the source of almost 4% of the world's greenhouse gases, mostly in the form of methane from rotting food—and that does not include all the methane generated by animal slurry and other farm waste. And then there are some really nasty forms of industrial waste, such as spent nuclear fuel, for which no universally accepted disposal methods have thus far been developed.

Yet many also see waste as an opportunity. Getting rid of it all has become a huge global business. Rich countries spend some \$120 billion a year disposing of their municipal waste alone and another \$150 billion on industrial waste, according to CyclOpe, a French research institute. The amount of waste that countries produce tends to grow in tandem with their economies, and especially with the rate of urbanisation. So waste firms see a rich future in places such as China, India and Brazil, which at present spend only about \$5 billion a year collecting and treating their municipal waste.

Waste also presents an opportunity in a grander sense: as a potential resource. Much of it is already burned to generate energy. Clever new technologies to turn it into fertiliser or chemicals or fuel are being developed all the time. Visionaries see a future in which

things like household rubbish and pig slurry will provide the fuel for cars and homes, doing away with the need for dirty fossil fuels. Others imagine a world without waste, with rubbish being routinely recycled. As Bruce Parker, the head of the National Solid Wastes Management Association (NSWMA), an American industry group, puts it, "Why fish bodies out of the river when you can stop them jumping off the bridge?"

Until last summer such views were spreading quickly. Entrepreneurs were queuing up to scour rubbish for anything that could be recycled. There was even talk of mining old landfills to extract steel and aluminium cans. And waste that could not be recycled should at least be used to generate energy, the evangelists argued. A brave new wasteless world seemed nigh.

But since then plummeting prices for virgin paper, plastic and fuels, and hence also for the waste that substitutes for them, have put an end to such visions. Many of the recycling firms that had argued rubbish was on the way out now say that unless they are given financial help, they themselves will disappear.

Subsidies are a bad idea. Governments have a role to play in the business of waste management, but it is a regulatory and supervisory one. They should oblige people who create waste to clean up after themselves and ideally ensure that the price of any product reflects the cost of disposing of it safely. That would help to signal which items are hardest to get rid of, giving consumers an incentive to buy goods that create less waste in the first place.

That may sound simple enough, but governments seldom get the rules right. In poorer countries they often have no rules at all, or if they have them they fail to enforce them. In rich countries they are often inconsistent: too strict about some sorts of waste and worryingly lax about others. They are also prone to imposing arbitrary targets and taxes. California, for example, wants to recycle all its trash not because it necessarily makes environmental or economic sense but because the goal of "zero waste" sounds politically attractive. Britain, meanwhile, has started taxing landfills so heavily that local officials, desperate to find an alternative, are investing in all manner of unproven waste-processing technologies.

As for recycling, it is useless to urge people to salvage stuff for which there are no buyers. If firms are passing up easy opportunities to reduce greenhouse-gas emissions by re-using waste, then governments have set the price of emissions too low. They would do better to deal with that problem directly than to try to regulate away the repercussions. At the very least, governments should make sure there are markets for the materials they want collected.

This special report will argue that, by and large, waste is being better managed than it was. The industry that deals with it is becoming more efficient, the technologies are getting more effective and the pollution it causes is being controlled more tightly. In some places less waste is being created in the first place. But progress is slow because the politicians who are trying to influence what we discard and what we keep often make a mess of it.

You are what you throw away

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The anthropology of garbage

WASTE can be a revelation. Excavations of old rubbish tips (or middens, as archaeologists call them) provide much of our knowledge of everyday life in the past. Many ancient civilisations piled up mountains of garbage. At a spot in America called Pope's Creek, on the shores of the Potomac river, oyster shells discarded by the pre-Columbian inhabitants cover an area of 30 acres (12 hectares) to an average depth of ten feet. Enormous shell middens can be found all over the world, wherever ancient migrants came across handy oyster and mussel beds.

Archaeologists have found papyrus inscribed with parts of lost plays by Sophocles and Euripides in a Greco-Roman rubbish tip in Egypt. The same site, near the ancient town of Oxyrhynchus, yielded a wealth of 2,000-year-old invoices, receipts, tax returns and other documents.

Modern waste can be equally enlightening. Dustbins generally provide a more honest account of their owners' behaviour than do the owners themselves. A research programme at the University of Arizona conducted several studies comparing the participants' own assessments of their habits with the record provided by their rubbish. It turned out that people wasted much more food than they realised, claimed to cook from scratch more often than they really did and ate more junk food and less virtuous stuff than they admitted. For example, they overestimated their consumption of liver by 200%. A survey on consumption of red meat was particularly telling. Rich households, perhaps wanting to be seen to be eating healthily, claimed to consume less of it than they did, whereas poor ones, possibly indulging in wishful thinking, claimed to eat more.

The project uncovered many other oddities of human behaviour. For example, a well-publicised shortage of a particular product actually causes people to throw more of it away, perhaps because they have bought too much of it. Similarly, a public campaign to get people to take hazardous waste to special collection points makes them put more of it in the bin. Such campaigns seem to prompt them to have a clear-out but they often do not make it to the collection point.

Don't ask, dig

Waste can be used to determine with great accuracy how many people are living in a particular place, how old they are, how much they earn and which ethnic group they come from. America's Census Bureau has toyed with the idea of using data derived from analyses of household rubbish to adjust its survey data. America's Supreme Court has also acknowledged the importance of waste, ruling that police may rummage through trash left out for collection without a warrant.

A better hole

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The charms of modern landfills

LANDFILLS in rich countries have to jump through a lot of hoops to make themselves acceptable these days. For example, the facility at Pitsea in Britain, on the banks of the River Thames near London, accepts only solid municipal and commercial waste, because European law prohibits the mingling of liquid and solid waste, and of hazardous and non-hazardous waste. Its permit allows it to take in a million tonnes of waste a year. The plan requires the parts of the site facing a nearby road and houses to be filled in and rehabilitated first to help hide it from locals' eyes—even though just across the river a massive oil refinery looms.

The landfill sits on a natural foundation of London clay which is more or less impermeable. The owner, Veolia Environnement, one of the giants of the industry, has built an underground wall of similarly waterproof clay around the site which extends deep enough to reach the natural barrier below. The idea is to seal off the landfill from the surrounding marshes and river, preventing any contaminated water—"leachate" in the industry jargon—from leaking out. Landfills without the benefit of a naturally impermeable layer use plastic liners and imported clay.

A system of ditches and drains collects all the leachate, which is pumped through a treatment plant similar to a sewage works. Before it can be released back into the nearby watercourses it has to meet stringent standards, including maximum levels of ammonia, heavy metals and any chemicals that might cause oxygen depletion. Veolia is required to sample water from the surrounding area regularly.

The firm also has to collect the methane emitted by the landfill, which has meant sinking 1,000 wells at regular intervals across the 120-hectare site. The gas fuels ten turbines, each of which generates 14MW of electricity. Air quality, dust, litter, odours and vermin are strictly controlled too. At other sites Veolia has to use falcons, cannons, scarecrows, sonar and other gadgets to scare off the birds that try to scavenge on the rubbish, but not at Pitsea, because the surrounding wetlands are among Britain's few remaining breeding grounds of the black-tailed godwit.

From here to eternity

Veolia must also set aside money to ensure that the leachate continues to be treated, the gas collected, the local environment monitored and any damage remedied after the landfill stops accepting waste, which is meant to happen in 2015. Funding for these financial guarantees makes up 10-15% of the tipping fee of around £25 a tonne (not including the government's landfill tax). The firm's liability lasts as long as the landfill continues to generate leachate or gas. All the data on pollutants are published. Visitors are always amazed, the site manager says, to discover how much more there is to landfilling than tipping waste in a hole.

The appliance of science

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Trash goes high-tech

CAN a landfill ever be too sanitary? Perhaps surprisingly, the answer is yes. Some of them, it turns out, are so dry and airtight that their contents never rot. During its excavations of different landfills, the Garbage Project at the University of Arizona has encountered 15-year-old steak, with fat and meat intact, and 30-year-old newspapers, still quite legible. It concluded that in many landfills only food and garden clippings rot. Other supposedly biodegradable materials, such as paper and wood, often do not decompose at all.

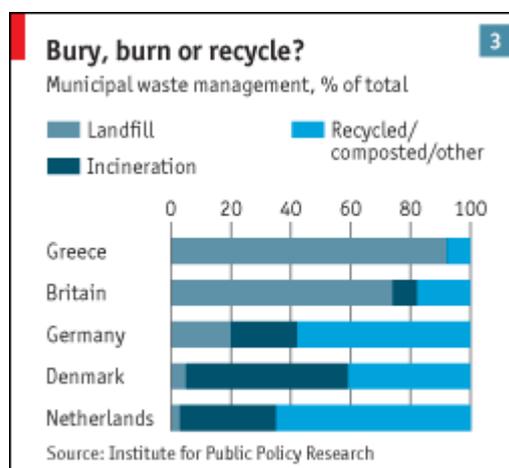
That may sound like a good thing because it reduces methane emissions and leachate. But it also spreads out the risk of pollution over a very long period. And methane is difficult to capture in small volumes at low concentrations. So Waste Management, America's biggest waste firm, has been experimenting with a type of landfill called a "bioreactor", designed to ensure and accelerate the decay of biodegradable waste by injecting a mixture of air, water and recycled leachate. That should increase not just the amount of methane collected but also the capacity of the landfill, since waste shrinks as it rots. It should also reduce the degree of monitoring and treatment needed after closure, and allow the site to be put to another use more quickly.

Waste Management has tried pumping different mixtures through landfills to achieve the desired effect, and found that injections of out-of-date beer and soft drinks work better than water. It has managed to produce gas four times faster than normal and reduce the volume of the waste by up to 35%. The firm has already applied the technique to six landfills and plans to add more this year and next.

Burying is not the only form of waste disposal where new techniques are being tested: burning and recycling, which in some countries account for a large proportion of the total (see chart 3), are also going through great technological upheaval. The next section of this report (see [article](#)) looks at recycling in the traditional sense, of salvaging used metal, plastic and paper. But the sort of recycling where the kit is changing fastest is arguably the humblest: composting. Converting waste into fertiliser saves space in landfills and provides an extra source of revenue. But traditional composting does not save as many greenhouse-gas emissions as it might, since it still involves decomposition.

Hence the recent enthusiasm for a technique called anaerobic digestion, which extracts energy and fertiliser from biodegradable waste while also reducing emissions. Animal slurry, food scraps or garden clippings are placed in vessels that capture the methane as they decompose, leaving nothing but liquid and solid fertiliser—which add to the emissions savings by taking the place of chemical fertilisers made from fossil fuels.

However, even small amounts of stray plastic or glass can cause the whole process to break down. Municipalities that ask residents to separate their biodegradable waste from other rubbish often end up with material that is too contaminated to be of much use. It is only in places with lots of farms generating big quantities of animal slurry, such as Denmark and southern America, that the practice is taking off.



Another nascent treatment for biodegradable waste is enzymatic hydrolysis, which uses enzymes to break down complex molecules into sugars from which ethanol can be fermented. At present this process is uneconomic, but Steen Riisgaard, the boss of Novozymes, one of the firms that make the enzymes, says the cost is falling fast and claims that his American customers will be making money by 2011, with the help of government subsidies.

If Mr Riisgaard is right, there is a wealth of farm waste that could be turned into fuel, from corn cobs to citrus peel to wood chips. By 2030, America aims to produce 5% of its power, 20% of its transport fuel and 25% of its chemicals from biomass—mostly farm, forestry and municipal waste. By the same date the European Union estimates that waste could provide about 6% of all its energy.

It is burning, however, that has attracted the most futuristic technologies. In many countries waste-to-energy technology in its traditional form is being held back by fears about pollution, which make it hard to get licences and permits. Moreover, waste can vary enormously from place to place and day to day, making it hard to calibrate equipment. That can lead to higher maintenance costs and lower energy yields than expected.

One solution is to treat waste before burning it to obtain a more consistent fuel. The simplest technique is to chop it up. That helps a little, but does nothing to separate out the items that do not burn or that would fetch a higher price if recycled.

Sterile solution

Instead, several firms are touting an alternative treatment called autoclaving. In essence, autoclaves are industrial-sized rotating pressure-cookers. They have been used to sterilise things since the 19th century, but steaming municipal waste in them is a new idea. The combination of heat, motion and pressure cleans recyclable items, even washing off labels and glue. It also breaks down food, paper and other combustible material into a fibrous mass that can be used either as fuel or for anaerobic digestion. The fuel is of sufficient quality and consistency to allow it to be used as a substitute for coal in factories and power plants, not just in incinerators.

A British firm called Sterecycle opened the world's first big waste autoclave in north-east England last year and recently announced plans to double its capacity. A rival, Graphite Resources, is building an even bigger plant nearby and there are plans for several more around Britain. But industry veterans question whether the revenue from the recyclables and the fuel will justify the capital and running costs.

Much the same doubt surrounds two other technologies called gasification and pyrolysis. Again, both have been around since the 19th century, but used for other things. They both involve heating, rather than burning, waste until it breaks down into a flammable mixture of carbon monoxide and hydrogen, called syngas, and residual char, ash or slag. The syngas can be converted into a number of different chemicals or even liquid fuel. Waste Management, for example, has started a pilot scheme to turn it into diesel.

A few dozen gasification and pyrolysis plants are up and running in Europe and Japan, and more are planned. Proponents argue that they are cleaner than existing waste-to-energy facilities. But the main advantage of these technologies over incineration, at least in theory, is that syngas can power gas turbines to make electricity. These are more efficient than the steam turbines used in waste-to-energy plants. The hitch is that syngas from waste is full of tarry residue that tends to gum up the turbine. It usually needs to be filtered, a step that raises the cost and reduces the overall efficiency of the process.

Several firms have come up with ways to make cleaner syngas. One method involves a device called a plasma arc gasifier, which generates artificial lightning bolts between two electrodes. The temperature of the arc itself can reach 13,000°C or more. Even a few feet away it can be over 4,000°C, more than enough to vaporise most waste and break down complex molecules. When the gas is cooled, any hazardous elements in the waste end up sealed in a glassy slag that is safe to put into landfill.

What some pilot plants have shown so far, however, is that a lot of the electricity produced is needed to power the arc. Plans for the first full-scale facility, in Saint Lucie, Florida, were recently scaled back.

Ze-Gen, based in Massachusetts, gasifies waste by injecting it into molten steel. The syngas rises through the pool, heavy metals sink to the bottom and other contaminants form a slag on top. Running this kind of furnace, says Bill Davis, the company's boss, consumes only 15% of the energy it produces.

The chief problem Ze-Gen and other firms with whizz-bang waste technologies face, says Mr Davis, is raising money to build full-scale plants. At the moment neither banks nor individual investors have the appetite to take a punt on an unproven idea. In the longer term he worries that so many new waste-processing facilities will spring up that they may actually have to compete for rubbish.

Round and round it goes

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Recycling is good for the environment, but it costs. Is it worth it?

GREG RUIZ and Tara Bai Hiyale live on opposite sides of the world, in utterly different cities: San Francisco and Mumbai. Mr Ruiz has a steady job which brings in almost \$20 an hour, along with a pension, health insurance and even a stake in the company concerned, thanks to an employee share-ownership plan. Mrs Hiyale lives hand to mouth, subsisting in a slum on 100 rupees a day with the help of a local charity. Yet they both do the same job: sorting through the local rubbish, trying to salvage goods that can be re-used. The stark differences in their circumstances say a lot about the global business of recycling.

In India, recycling provides a livelihood for millions. Most urban households do not throw out unwanted paper, plastic and metal. Instead, they save it and sell it to itinerant traders called *kabari-wallahs* who come to call at regular intervals. The remaining waste is picked over by the cleaners and watchmen at the apartment block they live in before being put out in a municipal skip where rag-pickers like Mrs Hiyale search through it again. When trucks deliver the rubbish from these skips to dumps such as Deonar, more rag-pickers comb over it yet again.

Mumbai is thought to be home to hundreds of thousands of rag-pickers. No wonder that until recently Mrs Hiyale could not count on a steady income. What she earned depended on how much she found scouring the streets and rummaging through the skips of the suburb of Ghatkopar, where she lives, and the price her discoveries fetched. Most of the time she took in less than 100 rupees a day. She had become a rag-picker decades ago when a drought struck Mumbai's rural hinterland, forcing her and her husband to abandon the land they farmed and seek work in the city. "Every day was a bad day," she says.

A few years ago Mrs Hiyale came across Stree Mukti Sanghatana, a feminist charity that seeks to provide female rag-pickers (the vast majority) with more stability and security. Now she retrieves the rubbish of apartment blocks that have an arrangement with the charity and sorts the recyclable portion in one of its sheds. She still earns only 100 rupees a day, but at least, she says, she has access to a steady stream of waste. She also has somewhere to store the material she collects, safe from thieves and gouging policemen. And she no longer has to work outdoors all day in the blazing sun and torrential monsoon rain.

The swarming flies and sickly, fetid smell that fill the shed do not seem to put her off her work. She sits on a low, pink plastic stool, behind a mound of unsorted goods which she is gradually dividing into smaller piles. Copper wiring goes in one heap, aluminium foil in another. Iron and steel is divided by thickness; the heftier pieces fetch a higher price. The same goes for plastic bags. Cloth, leather, Tetra Paks—each has its own pile. Coconut shells go into a bag hanging from the rafters.

Another woman comes in, carrying a load of plastic bottles several times her own size on her head. She will sort it by type of plastic and by colour. In another part of the shed a third woman stands knee-deep in waste paper which she is separating into cardboard, newspaper, office paper, glossy paper, coloured paper and envelopes—which, she says proudly, fetch four rupees a kilo, against just one rupee for the newspaper.

Rag-picking de luxe

In San Francisco, Mr Ruiz works for Norcal Waste Systems, which handles most of the city's household rubbish. Some days he stands by a conveyor belt in a huge warehouse, picking wood, cardboard, plasterboard and metal out of demolition debris. The belt moves quite fast, so only the biggest pieces can be retrieved. The rest falls into a skip, to be hauled off to a landfill.

At other times he drives a bulldozer in "the pit", where rubbish trucks dump San Francisco's household waste, to be loaded onto bigger trucks also headed for the landfill. In theory, residents have already separated out anything that is recyclable or biodegradable. In practice, many do not bother. Lots of plastic bottles and paper can be seen through the muddle and grime. A study commissioned by Norcal found that 70% of the material going into the pit could have been recycled.

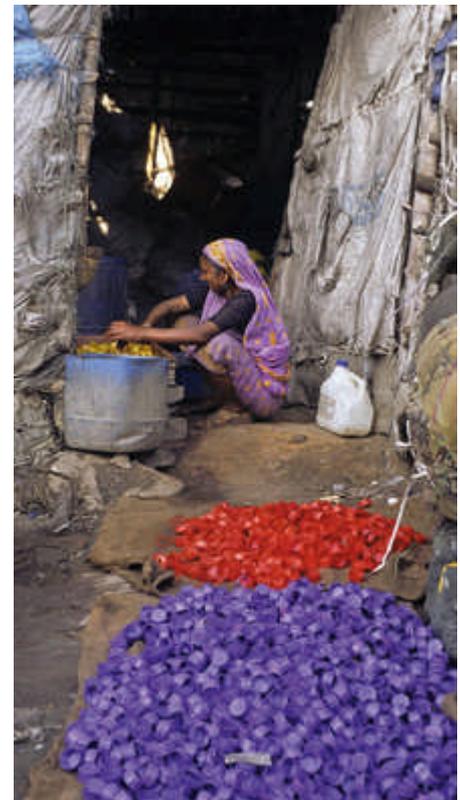
In another cathedral-like warehouse by municipal Pier 96, Norcal sorts the stuff local residents put into their recycling bins. An impossibly complicated network of conveyor belts, chutes and tubes whizzes the trash this way and that. Machines separate out different materials, in much the same way as Mrs Hiyale and her fellow rag-pickers do back in Mumbai. A magnet lifts up any iron and steel. A gadget called an "eddy-current separator" causes other metals, such as aluminium and copper, to jump, literally, off the line into different bins. A series of whirling discs arranged into a steep slope carries the lighter goods—mainly paper—upwards but allows heavier ones to fall. Workers pick off phone books, glass and plastic bottles.

Yet despite all this clever kit, the sorting at Pier 96 is much less elaborate and precise than that performed by Mumbai's rag-pickers. Plastic and paper is separated into fewer colours and categories; indeed, many types of plastic are not accepted at all. The conveyor belts move too fast to catch everything and the workers and machines both make mistakes that they cannot correct.

Norcal is constantly striving to recycle more, and to improve the purity of the processed waste it produces. As it is, the city of San Francisco keeps some 70% of its waste out of landfills—one of the highest rates in the world. That figure is all the more remarkable because almost none of the non-landfill waste is burned. The city council has set a goal of 75% recycling by next year and hopes eventually to achieve "zero waste". It has written Norcal's contract in such a way that the more the firm recycles, the more money it earns.

So Norcal invests in expensive facilities such as the one at Pier 96. It runs vigorous campaigns encouraging its customers to recycle. Its garbage trucks are covered with big pictures contrasting mouldering cardboard with healthy forests and festering table scraps with prospering farms. It inspects its trucks to see which buildings or neighbourhoods are throwing away lots of recyclables and gets its staff to contact the worst offenders to urge them to be more careful. It even has an artist-in-residence programme, designed to show how useful and beautiful junk can be. A recent incumbent made a dress out of used plastic bags; another tried to express "our society's abusive pattern of production and waste" by weaving bits of trash together.

It's a job



No one knows Mumbai's recycling rate, but it seems likely to exceed San Francisco's, for a simple reason. In Mumbai recycling is a profitable pursuit for all involved, whereas in San Francisco it costs most residents money. Indian rag-pickers require no wages, equipment or electricity. By contrast, Norcal has invested \$38m in the materials recovery facility (or MRF, in the industry jargon) at Pier 96 and keeps paying out on running costs.

The revenue from Norcal's MRFs covers roughly half their outgoings. Metal is the only material that is consistently profitable to salvage, says Mike Sangiacomo, Norcal's boss. Cardboard usually is; most of the other goods the firm sends for recycling, including glass, plastic and other types of paper, usually are not.

The shortfall is covered by Norcal's customers, who pay about \$25 a month for waste disposal. Whether that price is worth paying is a complicated question. The answer depends, among other things, on the cost of alternative disposal methods and the value ascribed to the environmental benefits. At the most basic level, recycling competes with landfilling. That is reasonably cheap around San Francisco.

However, Jared Blumenfeld, head of the city's Department of the Environment, explains that even in California, with its strict regulation, landfilling involves environmental costs that the city wants to avoid on principle. Climate change is the biggest concern. California has adopted ambitious targets for reducing emissions, and methane from landfills makes up 18% of the city's emissions.

There has been little detailed cost-benefit analysis of California's emissions targets, Mr Blumenfeld happily concedes, or of San Francisco's aim of zero waste, or of any of the myriad environmental targets set by the city and by the state. Politicians adopt them because they think voters will like the sound of them. And they do: the recycling programme, Mr Blumenfeld says, is even more popular than the mayor, Gavin Newsom, who won 72% of the vote at the most recent election.

But there must be a price that even San Franciscans would balk at paying to reduce their waste. Mr Sangiacomo thinks he could increase the recycling rate by getting the trash in the pit sorted manually, but is not sure the city council would approve the extra expense. In less high-minded places, voters and politicians may well snap their purses shut much sooner.

That is what governments all around the rich world are now grappling with. The economic downturn has cut prices for recyclables by half or more since last summer. The shares of big recycling firms, such as China's Nine Dragons Paper, have plunged over the past year. The American and Canadian arm of Smurfit-Stone, which makes recycled cardboard, has filed for bankruptcy. Some traders have been reduced to stockpiling their wares in the hope that prices will rise. Others are asking governments for support.

There is little doubt that recycling is good for the environment. In 2006 the Technical University of Denmark conducted a review of 272 studies comparing the effects of recycling with those of landfilling or incineration. They came up with 188 scenarios involving different materials and recycling methods. In 83% of these scenarios recycling proved the greener of the available options.

For materials such as aluminium, the case is overwhelming. Recycling it requires only a tiny fraction of the energy consumed when mining bauxite and refining it into the same amount of metal. For other products the benefits are more finely balanced. Glass is heavy, so transporting it uses up a lot of fossil fuel. Collecting it and grinding it up into aggregate to make roads can consume more energy than taking it to landfill. But recycling it to make more bottles generally reaps an energy saving.

The green green glass of home

To recycle glass back into bottles, however, it needs to be sorted by colour. In general, the narrower the categories into which recyclables are sorted and the more meticulous the separation, the easier they are to process and the higher the price they fetch. White office paper is worth more than mixed paper, for example, and bottles made from a single kind of plastic are worth more than an assortment.

That is where the economics start getting tricky. Manual sorting is expensive in the rich world, which is why recyclables are often shipped to places with low labour costs. It helps that there are lots of almost empty container ships sailing back to Asia after unloading consumer goods in Europe and America: they will usually carry secondhand paper and plastic for a song. After preliminary sorting at Pier 96, for example, many of San Francisco's salvaged materials are loaded straight into containers bound for China, where they will be combed over much more thoroughly before being recycled.

The biggest American exporter by volume is a firm called American Chung Nam. In 2007 it sent off 211,300 containers of waste paper for recycling, almost all of them to its sister company in China, Nine Dragons Paper. There were six other recycling firms among the 20 biggest exporters. In 2006 CycloPe estimated the value of the international trade in recyclables at well over \$100 billion.

Sort it yourself

Another way to make recycling cheaper is to get the household or business that generates the waste to sort it free of charge. This is done without demur in much of Europe and Asia, where municipalities often collect paper, plastics, metal and glass separately. (Consumers can be further encouraged to return cans or bottles by including a deposit in their price.) But the Anglo-Saxon world dislikes sorting its own waste and often makes a hash of it. In San Francisco Mr Newsom wants to oblige residents to keep organic waste out of their rubbish bins. Originally he proposed fines of up to \$1,000 for persistent offenders, but this caused such outrage that the figure was reduced to \$100. Even so, says Mr Blumenfeld, the policy is unlikely to be vigorously enforced.



From bottle to bottle

Most cities in America are allowing their citizens to throw anything recyclable into a single bin, to be sorted out at an MRF like the one at Pier 96 in San Francisco. Thanks in part to the spread of such programmes, America's recycling rate doubled between 1995 and 2005, to 32%. Over the same period Europe's, which started at 22%, rose to 41%.

MRFs are getting more sophisticated all the time. At a plant on the outskirts of London a firm called Closed Loop Recycling sorts plastic bottles before recycling them. One machine uses optical scanning to work out what sort of plastic the bottles are made of. Blasts of air from a line of nozzles then direct each one to the appropriate bin. This device can cope with only a few different categories and often makes mistakes. But another machine in the plant, which uses a laser to scan the passing material, can sort plastic by type and colour with great accuracy.

This process, says Chris Dow, Closed Loop's managing director, was "a lab trial" two years ago. The firm is now taking part in a new trial to see whether similar devices can separate mixed plastics of all kinds rather than just bottles. That would dramatically improve the economics of recycling items of marginal value, such as yogurt pots. Thanks to such advances, says Mr Dow, the number of things that can be profitably recycled will keep expanding.

But Closed Loop can afford such fancy kit only because there is a strong market for its product: plastic of sufficient quality to be used to package food. British retailers are keen to increase the amount of recycled material in their packaging, partly because it is slightly cheaper than the virgin sort but mainly because their customers are keen on the idea. Tesco, Britain's biggest retailer, advertises a line of school uniforms made from recycled polyester. One of the ways it has responded to the growing clamour against plastic bags, says Alasdair James, its director of recycling, waste and packaging, is to use recycled ones.

Most of the bottles Closed Loop is currently recycling would otherwise have been shipped to China to be transformed into lower-grade plastic for cheap hard hats, artificial fleeces and the like. But such "downcycling" tends to be much less profitable than genuine recycling, and much more vulnerable to price swings. Closed Loop is still making money. It plans to build a second plant this year, despite the economic gloom.

Closed Loop's success did not come about by chance. The Waste and Resources Action Programme (WRAP), a government-funded agency charged with reducing landfilling, among other worthy goals, helped to pay for the initial trial of the recycled bottles. It also helped to bring together Closed Loop, Veolia (which supplies the used bottles), the retailers that buy the recycled plastic and the banks that financed the plant. It is now providing similar help with the attempt to sort mixed plastics.

WRAP's aim is to harness market forces rather than fight them. By getting municipalities and waste firms together it can ensure big and steady enough streams of different materials to justify investment in new recycling plants. By pooling potential buyers of recycled goods it helps to provide those plants with sufficient customers. And its involvement helps to reassure the investors.

But the most effective policy would be to incorporate the costs of the pollution caused by gathering and processing virgin materials into their prices. That would align environmental goals with business ones, sparing governments the trouble of trying to balance the recyclers' books.

Muck and brass

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The waste business smells of money

RECYCLING aside, waste firms often describe themselves as recession-proof. The logic is simple: their workload is always increasing. As countries get richer and more urban and their populations expand, they throw away ever more stuff. The OECD forecasts that although municipal waste in rich countries will grow only by a fairly sedate average of 1.3% a year up to 2030, or about 38% in all, India's city-dwellers will be generating 130% more rubbish and China's over 200% more over the same period. That increase will come partly from a growing amount of waste generated per person but mainly from a rising urban population. Overall, Nickolas Themelis of Columbia University expects worldwide waste to double by 2030.

Growing wealth generally goes hand in hand with more concern for the local environment. In time, governments in developing countries will make sure that more waste is collected and tighten the rules about disposal. For example, India's Supreme Court has ruled that all cities of 100,000 people or more should provide a waste-collection service. The Indian government, for its part, has set guidelines and targets for treatment and is working on a law on e-waste. At present these rules are observed mainly in the breach, but with time and public pressure compliance should grow.

In rich and poor countries alike the authorities are increasingly inclined to entrust waste management to the private sector. That reflects not just the economic orthodoxy of recent decades but also the rising cost of complying with ever stricter environmental rules. In Britain municipalities have been obliged to hold public tenders for waste management since 1989. In America private firms dispose of roughly 70% of all waste. The more go-ahead cities in China, including Beijing, Shanghai and Guangzhou, have handed some rubbish-disposal contracts to private firms.

Mumbai offers a good example of the way things are going. Its collection rate is already well above the Indian average of 60%. Its environmental standards are also rising. Although almost all its waste currently goes to municipally owned dumps such as Deonar, with almost no pollution controls, the city plans to transform them into sanitary landfills and to build a new, greener facility from scratch. It is also installing equipment to collect methane and leachate at a recently closed dump, Gorai. The role of the private sector is growing: the local government has brought in consultants for the Gorai project and hopes to involve private partners in the landfill schemes. It is already using contractors to take most waste to its dumps.

One big Indian city, Chennai, has contracted out its rubbish collection to Veolia Environnement, one of the giants of the waste industry, which has a number of contracts in developing countries, including Brazil, South Africa and China. Its main rival, Suez Environnement, is active in China, Morocco and elsewhere. Covanta, the world's biggest waste-to-energy firm, already runs one facility in China and has several more in the works.

Waste firms see ample opportunities in the rich world, too, because ever stricter regulations are helping to make up for the slower growth in waste volumes. On the whole, says Henri Proglia, the boss of Veolia Environnement, the more complicated the treatment, the higher the margin.

Between 1985 and 2005, as America's regulations got tighter and small landfills went out of business, average tipping fees rose from less than \$10 per tonne to almost \$35. But the European Union is probably the most zealous regulator: it has separate legally binding "directives" on waste policy in general, hazardous waste, the transportation of waste, pollution control, landfills, incinerators, and a host of specific sorts of waste, from cars to packaging to electronic goods. That has helped to push average tipping fees much higher than America's: €74 a tonne in France, for example, and €50 in Italy, according to Cyclope.

The big waste-industry companies welcome tighter regulation. Unlike the tiddlers, they can afford the investment needed to comply with it. The search for economies of scale has led to dramatic consolidation in recent decades. In Britain, between 1992 and 2001 the market share of the 15 biggest companies rose from 30% to 60%. In America consolidation is still in progress. Last year the third-biggest waste firm, Republic Services, spurned an offer from the biggest, Waste Management, and instead spent \$6 billion buying the second-biggest, Allied Waste Industries. The two remaining firms have a combined market share of 41%, according to Standard & Poor's, a rating agency.



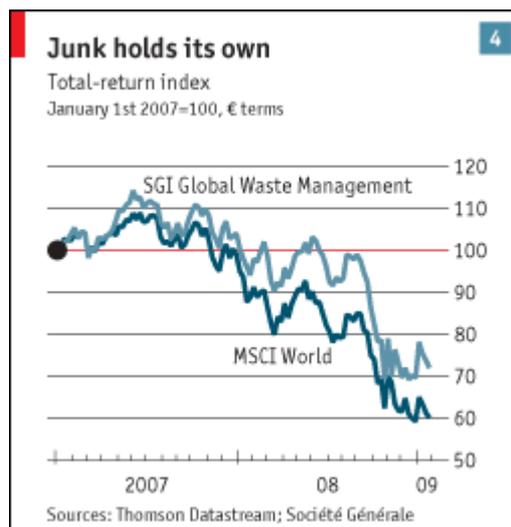
Artful Spittelau

It just keeps coming

For such big, integrated firms, waste is also a very stable business. Although households and businesses produce somewhat less rubbish in tough economic times, the decline in volume is usually only a percentage point or two, says Mr Parker of the National Solid Wastes Management Association. And contracts often run for long periods. Four Winds Capital Management, an investment firm that is setting up a waste-industry fund, reckons that the average length of a collection contract is seven years; of a disposal contract, nine years; and of an integrated contract, 17 years. No wonder that the big firms' earnings are still growing nicely. Shares of listed waste firms have also suffered less than most in the recent downturn (see chart 4).

Waste firms often have multiple revenue streams, which can also help them weather a downturn. A waste-to-energy firm, for example, earns “gate fees” for taking the waste in the first place, as well as payments for the power it generates and any metals it recovers from the ash. Recycling firms are the obvious exception, but even they deal in a variety of goods whose prices do not always move in lockstep.

Concern about global warming should provide a big boost for the waste business in the future. Methane from landfills accounts for only about 4% of greenhouse gases, but it can be dealt with relatively cheaply and easily. Recycling tends to consume less energy than making goods from scratch, which helps to curb emissions.



Cities are particularly keen to tackle landfill gas, says Mr Blumenfeld of San Francisco’s Department of Environment, because it is one of the few sources of emissions over which they have jurisdiction. And in places that do not have much heavy industry it can make quite a large contribution to total emissions: in San Francisco its share is 18%.

In many countries power from landfill gas or waste-to-energy plants (like the one at Spittelau, outside Vienna, illustrated above) attracts subsidies of one kind or another because it saves emissions. In the developing world it can earn UN-backed carbon credits, which can be sold to governments or firms that must reduce their emissions under the Kyoto protocol. Mumbai, for one, plans to sell such credits when its landfill-gas project at Gorai comes on stream.

Firms such as Covanta see worries about climate change as a spur to waste-to-energy projects. Incineration could save up to a gigatonne of emissions if widely adopted, says Covanta’s boss, Anthony Orlando. That is about one-seventh of the current global total. Already, the world’s 700-odd waste-to-energy plants generate more power than all its wind turbines and solar panels put together.

Japan and Singapore burn more than 50% of their municipal waste. Burning is also popular in many European countries. China currently incinerates only 2% of its rubbish, but has set itself a goal of 30% by 2030. That will involve an investment of at least \$6.3 billion, according to New Energy Finance, a research outfit. Even America is thinking again: in 20-odd states that require utilities to generate a proportion of their power from renewable sources, waste-to-energy plants count towards the goal. Mr Themelis reckons it could supply as much as 4% of the country’s electricity.

But it is Britain that currently offers the biggest incentives to waste firms. Trying to meet a target set by one of those European directives, it discourages landfilling by taxing it heavily. The tax rose by £8 per tonne in April last year, to £32 (\$46, €37), and is set to rise by a further £8 both this year and next. In a country that still sends over half its waste to landfill, municipalities and businesses are desperate to find other ways of disposing of their rubbish.

No wonder, then, that so many of them are experimenting with avant-garde technologies. The government estimates that meeting the target will require £10 billion of investment. As one entrepreneur puts it, Britain is “beachfront property” for anyone with a nifty new waste-processing technology to sell.

Less is more

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The ultimate in waste disposal is to tackle the problem at source

SIEBEN LINDEN, a hamlet in former East Germany, half-way between Hamburg and Berlin, looks deceptively normal. There is a cluster of houses, some fields, a few cars parked by the side of the road and a small shop, all set against the backdrop of a looming pine forest.

Closer inspection, however, reveals a few peculiarities. Several of the modern-looking buildings turn out to be made of wood, straw and mud. There are huge quantities of logs, because wood-fired stoves and boilers provide all the heating, and quite a few solar panels, which generate most of the electricity. And there are more young people around than usual in rural Germany. Sieben Linden, a self-proclaimed eco-village, is growing fast, unlike the surrounding towns.

The 120 inhabitants have decided to live in as green a manner as possible. They are trying to wean themselves off fossil fuels, grow their own food and timber, acquire fewer frivolous possessions and produce less waste. Food comes either from their own fields or from wholesalers, so there is no need for much packaging. Any scraps are composted. Urine from the toilets is diverted to a reedbed for natural purification, and the faeces are turned into compost for the community's forest.

The residents live separately but share big appliances such as washing machines and cars. Before buying a new tool, say, they will put a note into the community's logbook to ask if anybody has one they could borrow. If not, they will probably buy one secondhand. They often wear one another's hand-me-downs. Unwanted possessions are left out for others to help themselves.

Carefree consumption is not actually forbidden, though it would raise eyebrows, says Eva Stützel, who helped to found Sieben Linden over a decade ago. But the main reason the inhabitants buy less and waste less is that they have a rich community life which does not revolve around trips to shops, restaurants and cinemas. They go ice-skating on a nearby pond in winter and swimming in summer; they teach one another horse-riding and yoga and tai chi; they put on plays and concerts and seminars.

The idea, explains Kosha Joubert, another resident, is not to adopt a dreary, ascetic lifestyle but to demonstrate that it is possible to live in a green manner without undue sacrifice or disruption. Western urbanites could easily adopt elements of the eco-village lifestyle, she says, by forming car pools, say, or shopping co-operatives.

Tipping point

Until recently most people in the waste industry had assumed that it was impossible to reduce the amount being produced and were concentrating on putting the stuff to better use. But lately that assumption has been challenged. For one thing, the pace at which the rich world churns out rubbish has been slowing.

Between 1980 and 2000 the amount of waste produced by the OECD countries increased by an average of 2.5% a year. Between 2000 to 2005 the average growth rate slowed to 0.9%. That was just ahead of the rate of population growth (0.7%), but well behind the rate of economic growth (2.2%). The OECD describes this as "a rather strong relative decoupling of municipal waste generation from economic growth", although it expresses

some misgivings about the reliability of the data. The European Union has detected a similar trend in several European countries, as has CyclOpe, the research institute.

Reducing the amount of waste being produced makes a great deal of sense, provided it does not cost more, in either environmental or financial terms, than disposing of it in the usual way. Governments hope it might help to trim both greenhouse-gas emissions and waste-management costs. But they are not sure how best to encourage it.

Some are trying to persuade consumers to throw away less. The simplest method is to collect the rubbish less often. In areas of Britain where the dustmen come round only every other week, recycling rates are 10% higher than elsewhere.

Another tactic is to make households pay by volume for the rubbish they generate, rather than through a flat fee or through local taxes. Many places in Europe, America and Asia have adopted “pay-as-you-throw” schemes. (In Taiwan, householders even have to chuck their own rubbish into the truck.) About a quarter of Americans live in communities with such programmes. The EPA reckons that they reduce the volume of rubbish by 14-27% and increase recycling (which usually remains free) by 32-59%.

There are drawbacks. Fly-tipping—the illegal dumping of waste—tends to rise slightly as people try to avoid paying. And householders generally grumble a lot if they have to pay extra to have their rubbish collected. Some communities have responded by offering rebates to those who throw away less—a more palatable way of packaging the same idea. But most local authorities have simply decided against the idea. When the British government offered them money to experiment with pay-as-you-throw schemes earlier this year, not one signed up.

Businesses are generally seen as a softer target than consumers. It can be argued that manufacturers bear some responsibility for the amount of waste rich countries produce. They often have an incentive to reduce waste anyway, since most already pay for disposal by volume. There is even a name for the steady reduction in materials used to make the same goods: “lightweighting”. It is not only electronic gadgets that have become smaller and lighter over the years even as their performance has improved but many other things too, from cars to plastic bags.



A lifestyle choice at Sieben Linden

The average aluminium drink can is now only half as thick as it was in the 1960s, according to Molson Coors, the firm that introduced this type of container in 1959. Its American subsidiary has reduced the weight of its cans by 7% in the past five years

alone. That means savings not only on the metal itself but also on transport and even cooling: thinner cans chill faster.

Officials in the EU, in particular, are keen to hurry lightweighting along. WRAP, the British agency charged with reducing waste, is trying to promote it for various sorts of packaging. It funded trials of a lightweight pull-tab lid for food tins, which it believes could save 15,000 tonnes of steel each year in Britain alone. Heinz, a giant food manufacturer which took part in the trial, hopes that adopting the new lids will save it £400,000 a year. WRAP has conducted similar tests of thinner glass and plastic bottles, with equally promising results.

WRAP also cajoled Britain's biggest supermarkets and food suppliers into signing a voluntary agreement to halt the growth in packaging by last year and start reducing it from 2010. Last July it announced that the initial target had been met, despite a 1.8% rise in sales. Some firms are going much further: in 2007 Tesco pledged to reduce its packaging by a quarter by 2010.

In theory, consumers could steer firms towards waste reduction by buying products that are easy to recycle, say, or have only minimal packaging. To some extent this is happening. Tesco's Alasdair James says British consumers rank the environment as their third priority after price and convenience. But many governments are trying to give greenery an extra push with compulsory waste-reduction schemes. Some levy fees on certain products, akin to bottle deposits, to ensure they are disposed of safely. Thirty-six states in America, for example, charge for the disposal of tyres. The states spend the money on clean-up programmes or pay others to run such programmes. Many of the tyres are blended into road surfaces or burned in cement kilns. Several other states have "advance recovery fees" for computer monitors and televisions. So have Japan, South Korea and Taiwan, among others, and China is working on a scheme.

The problem with fee programmes is that all goods in a category are subject to the same charge, whether they are easy or hard to get rid of. That gives manufacturers no incentive to build easy disposal into the design of a product.

One answer is to ban certain substances outright, thereby eliminating the need to dispose of them later. A number of places, from San Francisco to the tiny Himalayan kingdom of Bhutan, have banned or severely restricted the use of plastic bags. The EU barred the use of several heavy metals and flame retardants in electronic goods in 2006 and recently proposed expanding the scheme. Several American states were so impressed that they have copied the EU's rules.

Return to sender

But the EU has gone further, applying a concept called "extended producer responsibility" to an ever-expanding list of items including cars and computers. At its simplest, this means that manufacturers have to take back their products without charge when consumers have finished with them. The EU's directive on "end-of-life vehicles" not only obliges manufacturers to accept vehicles that are no longer wanted, but also requires them to recycle or re-use 80% of the parts by weight, a proportion that will rise to 85% by 2015. The manufacturers can farm out the job, but only to authorised firms.

Hewlett-Packard (HP), which makes lots of electronic devices that are subject to such rules, says it welcomes them. It has always tried to design its products not just from cradle to grave, a spokesman explains, but from cradle to cradle—meaning with recycling in mind. Its laptops are 90% recyclable and its printers at least 70%. By last year HP had recycled over 450,000 tonnes of used equipment. It aims to double that figure by the end of next year. At its facility in Roseville, California, workers first check discarded computers and printers to see if they can be re-used: it refurbishes 2.5m

devices a year. The rest are taken to bits. First the big, accessible parts are removed, along with anything dangerous, and then heavy-duty shredders grind up the remainder into tiny pieces that can be sorted by standard recycling equipment.

An engineer explains how a decade of such work has taught HP how to make the process simpler and cheaper. It now uses screws instead of glues wherever possible, and has reduced the number of different kinds of plastic in its products from 200 to five. It plans to eliminate one more—polyvinyl chloride—from new computer models this year. It is proud of having closed the loop on ink cartridges for its printers, which it now makes from old cartridges.

But the firm would like to go further, designing computers so that they can be easily upgraded rather than replaced. Ultimately, says Chandrakant Patel, who heads its “sustainable IT ecosystems laboratory”, modern computer systems will allow firms to calculate the precise disposal costs of a product during the design phase and include them in the sale price. More sophisticated products will also warn users when they are about to fail, eliminating the need for spare capacity.

Think before you legislate

Sadly, however, that sort of world is still a long way off. Governments are wildly inconsistent in their approach to extended producer responsibility. They tend to home in on particular products without justification (tyres, after all, are not among the biggest threats to the planet). Their goals seem arbitrary too: how did the EU decide that 85% of car parts had to be recycled, not 84% or 86%? And why should the deadline be 2015, not some other year?

Official thinking about waste in general seems equally confused. Why levy deposits to encourage the recycling of glass bottles but not plastic ones? Why control the disposal of municipal waste in such detail but allow utilities to pile up coal ash unchallenged? Why tax and regulate landfills out of all proportion to the damage they do to the environment? The individual policies do not add up to a grand design.



It doesn't have to be like this

A desire to reduce the amount of waste being produced and to minimise the harm it does is all well and good, but governments must be sure to encourage those ends by the

cheapest and most efficient means. Plugging loopholes in the rules is a good first step. American officials should be much stricter about coal-ash tips, regardless of how much clout utilities have in Congress. Similarly, governments should pay more attention to waste that winds up in the sea, even if it falls outside their formal jurisdiction.

Emissions of greenhouse gases and other noxious chemicals are a worry. But instead of banning or heavily taxing particular waste-disposal technologies to reduce the emissions they produce, governments should tax or limit emissions in general. That would steer investors towards the cleanest technologies, whatever they might be. Thus, instead of clamping down on landfills because of the methane they produce, or incinerators for fear of dioxins, governments should tackle methane and dioxins across the board. If landfills and incinerators can meet the standards they set, they should be welcomed.

Putting a price on greenhouse-gas emissions would also help to promote recycling. At the moment, it is often cheaper to process virgin materials, despite the extra energy required, because collecting and sorting recyclables is so labour-intensive. Recycling produces far fewer greenhouse gases, but recycling firms do not get much benefit out of that because their rivals pay little or nothing for the emissions they produce. In effect, governments are subsidising the use of raw materials by failing to charge big energy users for the emissions they cause. Scrapping that subsidy would provide recycling firms with a big boost.

Above all, regulators should be conscious of the costs of the rules they lay down. Blanket bans, 100% targets and punitive taxes are usually a sign of dogmatism. It cannot be desirable for California to recycle absolutely everything. There must be some waste that is better burnt or buried. Construction and demolition, for example, produce lots of inert waste that can be cheaper to put into landfill than to "downcycle" into lower-value construction materials. And there is nothing wrong with burning wood or even some plastics, provided the right pollution controls are in place. Politicians should prize value for money above political correctness or rhetorical flourish.

Still, in their muddled and heavy-handed way, governments are groping towards the idea of making the polluter pay by internalising the cost of responsible waste disposal. That is surely the right way to go. If governments oblige manufacturers to include the cost of disposal in their prices, firms will pass those costs on to consumers, who will have an incentive to buy the products that are the easiest to dispose of and therefore cheapest. All this should provide a spur to the waste industry and speed the adoption of new technology. Firms like HP have seen the writing on the wall: waste is heading for a redesign.

Sources and acknowledgments

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