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Maximising the Value of Recycled Materials

The waste and recycling sector in the UK was valued at £11 billion in 2011 and is forecast to grow by 3-4% a year in this decade. This POSTnote provides an overview of the way materials are recycled in England and how their economic value can be better exploited.

Overview

- Recycling is an increasingly important source of materials, largely because the prices of many primary materials are becoming more volatile.
- Many products are not designed with recycling in mind. This and other factors, such as contamination, make recycling economically challenging.
- New technologies, for example for labelling and better separating of recycled materials, could increase the materials' economic value.
- There is increasing interest in moving towards a 'closed loop economy', where all materials can be used again and no waste is generated.

Background

Until recently, recycling was mainly seen as a way to reduce the amount of waste sent to landfill as well as reducing emissions. There is now widespread recognition that materials from recycling also have an economic value. This POSTnote looks at:

- the rationale for using recycled materials (also known as secondary materials)
- policies affecting recycling in England[1]
- the recycling process and the challenges faced in making it economical
- the prospects for implementing a 'closed loop' economy in the UK, where all materials are recovered and reused.

Other methods of extracting value from waste are not discussed in this note. Processes for generating energy from waste are discussed in POSTnotes 353, 387 and 410. Reuse of whole components from end-of-life products is discussed in POSTnote 420.

The Rationale for Recycling

'Primary' materials are those obtained from their original source, such as mineral deposits. Secondary materials are obtained from recyclate (waste collected for recycling). There are several reasons why recyclate is an attractive source of secondary materials for new products.

- It is becoming harder to extract primary materials: the energy requirements and emissions associated with extraction are rising, with implications for cost. Extraction is predicted to account for 40% of the world's energy use by 2050.[2]
- Increasing global demand, caused by the global rise in population and prosperity, is making primary materials more costly.
- The prices of many primary materials (such as rare earth metals – POSTnote 368) are becoming more volatile. This is caused primarily by increasing global demand and geopolitical issues in countries with the largest reserves.[3]

Materials Security

A survey by the UK Engineering Employers Federation found that 80% of its members thought raw materials shortage would be a risk to their business in 2012.[4] The supply of recyclate is more secure than that of primary materials, as recylcate is largely a domestic resource. In many cases secondary materials cost less to obtain, both in monetary and environmental terms. For example, processing aluminium from recycled cans uses up to 95% less energy than is required to extract it from bauxite ore.[5]

Transition to a Zero Waste Economy

The revised EU Waste Framework Directive (2008) sets targets for 50% recycling of household waste and 70% recovery of construction and demolition waste by 2020. The Department for Environment, Food and Rural Affairs (Defra) aims to use these as a stepping stone to a 'zero waste economy', by setting targets to reduce the amount of waste created, and to recover the rest, for reuse, recycling or energy generation.[6] Separate EU policies exist for specific products, for example waste electronics (WEEE). These policies are transposed into UK law as outlined in Box 1.

There is increasing interest amongst businesses and government in moving towards a 'closed loop economy' (Box 2). This is a hypothetical scenario, where every waste material is used again, and nothing is wasted. 'Closed loop' is a different concept to the 'zero waste' economy, although no waste is generated in either case. The zero waste economy focuses on reducing waste through many strategies, including reusing and recycling materials, but unlike the closed loop economy it is not focused on making best use of the resources available.[7]

Recycling rates have quadrupled in England over the past decade. It is increasingly economical to produce secondary materials from bulk recyclates such as paper and plastic. However, only a small proportion of valuable materials used in low volumes, are recycled. Of 60 metals examined in a global study by the United Nations Environment Programme, only a third had recycling rates above 25%. In the case of gold, which has a relatively high recycling rate, around $34 billion per year is lost in waste.[3]

How Are Materials Recycled?

There are numerous steps involved in recycling, from collection through to the recycled material being used again. There are many different recycling schemes in England, but they broadly break down into six stages:

- Collection/Deposit: Household waste (including recycling) is collected by local authorities (LAs) and waste management companies. Materials that are not collected can be deposited at recycling centres. LAs must also offer a collection service to businesses, but can set their own prices.
- Sorting/Baling: Materials that have been segregated at source are sent to a transfer site to be baled and despatched to UK and overseas reprocessors. Any materials not source-segregated are sent to a **Materials Recovery Facility (MRF)** to be sorted. MRFs use a range of sorting technology as well as manual sorting to separate materials based on size, weight, magnetism or chemical make-up.
- Sale of Sorted Materials: After being sorted in the MRF, the materials are prepared for transport and sold to reprocessors (materials recyclers). Any remaining material that is unrecyclable (for reasons outlined on page 3) is sent to landfill or used to generate energy.
- Reprocessing: At the reprocessor the bales are broken down and often have to undergo further sorting to remove contaminants. The level of contamination of incoming material varies greatly depending on the material and the supplying MRF: from 2.5% for aluminium cans to 18.2% for mixed plastics.[8] With the contamination removed it is ready to be used in the manufacturing of new products.
- Sale of Secondary Materials: Reprocessors sell the secondary materials they generate to manufacturers. They usually sell for a percentage of the primary material price, depending on the quality (grade) of the material. Price can vary greatly depending on market conditions. Box 3 gives an example of how plastic is reprocessed.
- Manufacturing: The secondary materials can be used in new products, usually in combination with primary materials. For example, HDPE (plastic) milk bottles in the UK are made up of at least 15% recycled HDPE.

Box 1. Recycling Policy in the UK

The EU revised Waste Framework Directive 2008, implemented in England as the Waste (England and Wales) Regulations 2011, is the main policy instrument covering recycling and diversion from landfill. There are also several policies covering the recycling of specific products:

- Electrical goods: the Waste Electrical and Electronic Equipment Regulations 2006 (as amended) require producers of EEE to pay for the collection, treatment and recycling of WEEE. The regulations also require distributors of EEE to operate take-back schemes for customers.
- Packaging: the Producer Responsibility Obligations (Packaging Waste) Regulations 2007 (as amended) require certain businesses that handle packaging to ensure that a proportion of it is recycled. To show they have discharged this legal obligation, these businesses must obtain evidence that packaging waste has been recovered in the form of Packaging Waste Recovery Notes (PRNs) and Packaging Waste Export Recovery Notes (PERNs). These evidence notes are issued by accredited reprocessors/exporters on each tonne of packaging waste they reprocess/export.
- Vehicles: the End of Life Vehicle (ELV) Regulations issued in 2003 and 2005 require vehicle manufacturers to pay for most of the cost of ELV take-back schemes and set a recycling target of 85%.

Defra is responsible for waste and recycling in England. The Environment Agency is responsible for licensing waste management and recycling facilities in England and Wales. It also monitors exports of recycling and enforces transfrontier shipment regulations. WRAP (Waste and Resources Action Programme) is a not-for-profit organisation funded by each of the devolved governments, with a budget of £65m in 2011/12. WRAP and its partners aim to improve the UK's resource efficiency by tackling market failures and promoting the waste hierarchy. It carries out research and development, co-ordinates voluntary agreements and drives innovation.

Box 2. The Closed Loop Economy

In a closed loop economy, materials are divided into two categories depending on their origin: biological or non-biological. Non-biological materials (e.g. plastics and metals) continuously circulate through the economy in various products, and are fully recovered and used again at the end of a product's life. Biological materials may also be recovered and used again, but where this is not possible (i.e. in the case of food) they are converted to compost or digestate (POSTnote 387).[7]

Used products are returned to manufacturers so the materials in them can be used again. One possible business model supporting this is where products are leased and companies retain ownership of them, selling *use* of them to customers rather than selling the product itself. Few firms have implemented closed loop in their businesses to date, although some examples exist. The carpet tile manufacturers Desso and InterfaceFLOR have switched to a closed-loop model, leasing use of their carpets and remanufacturing the used tiles into new carpet at the end of their functional life. The plant machine manufacturer CAT has also moved towards closed loop, taking its old vehicles in and stripping them down for functional parts to reuse in its 'Reman' vehicles. To improve customer confidence in the products, CAT offers the same warranty on the Reman models as it does for every other line. As a result, this is now its fastest-growing area of business.

Challenges in Extracting Value from Waste

There are a number of reasons why the full potential of secondary materials is not exploited.

- The quality of recyclate can pose challenges, though there have been many improvements in recent years.

- Products are not usually designed with recycling in mind.
- A lack of data throughout the recycling chain can limit the ability of the recycling and waste management industries to plan ahead.
- There is a need for more recycling infrastructure in the UK, but there is currently limited incentive for investors to finance it.

Quality of Recyclate

'Downcycling'

In most cases the quality of the secondary material is as high as the primary material – for example in the case of recycled aluminium or plastics. In some cases the economics of recovering high-quality secondary materials is prohibitive, which can be due to the low value of the material, product design or contamination. Because of this, materials are sometimes 'downcycled', i.e. used in a less valuable application. For example, mixed colours of glass bottles are difficult to separate once the bottles are smashed, and so cannot be used to make new bottles. Instead, they are usually made into building aggregate. Concrete, bricks and ballast recovered from demolition are also converted into aggregate as it would be uneconomical to separate them for reuse. Unlike the closed loop model, where materials can be reused in any product, downcycling reduces the number of options for reuse of a material, and the number of times it can be recycled.

The value of a recycled material depends on what it can be used for. Clear PET, which can be used in drinks bottles, traded at £250-350/tonne in June 2012. In the same month coloured PET, which consists of a mixture of different coloured flakes and is generally used in strapping, traded at £70-80/tonne. The difference in price arises because the mixture of coloured flakes cannot be used to make new bottles, since they don't meet customer preferences. They must therefore be reused in lower grade applications.

Contamination

The value of secondary materials is also affected by the level of contamination in recyclate. The quality of recyclate being supplied to reprocessors depends on the materials collected for recycling, the collection method and the sorting efficiency in MRFs. The quality of household recyclate in particular has dropped in recent years, partly because of the different collection systems operated in each local authority and the drive to increase the range of materials accepted. There is confusion for residents as to which materials are collected in their area. As a result up to 30% of material entering MRFs may not be recycled, either because it is not recyclable or the MRF is not designed to process it. Some of this material is passed on to reprocessors, which drives up the operating costs for both MRFs and reprocessors, and has a particular impact on the profit margins of the latter.[9]

Judicial Review proceedings have been brought against Defra and Welsh Ministers challenging their transposition of the revised EU Waste Framework Directive in the Waste (England and Wales) Regulations 2011 (as amended), specifically relating to separated collections of recyclate.

Box 3. Reprocessing of Plastic Bottles

In Dagenham a company called 'Closed Loop Recycling' operate a plant, which reprocesses HDPE (high density polyethylene, used in milk bottles) and PET (polyethylene terephthalate, used in bottles for drinks or cleaning products). The plant, developed with support from WRAP, produces clear HDPE and PET for reuse in milk and drinks bottles, as well as mixed colour HDPE and PET, in the following stages:

- Bales of plastic bottles are shipped in from MRFs. The bales may be solely HDPE, solely PET or a mix including other plastics.
- Mixed bales are broken and fed into a machine which identifies the type of plastic each bottle is composed of by its absorption of infra-red light, separating them into clear HDPE, clear PET and coloured PET, using air jets to push them off the conveyor. The separate material streams are fed through a 'picking line', where any plastics in the wrong stream are removed manually.
- The plastics are ground into flakes and any labels or other contaminants are separated out by density and weight in flotation tanks and air separators. The flakes are washed in a hot caustic bath to remove any contaminating chemicals.
- HDPE flakes are melted and the liquid plastic is passed through a filter to remove any small contaminants that remain. It is then extruded into a solid filament and cut into pellets, ready to be sold. The PET flakes, separated into clear and coloured streams, are sorted on the basis of infra-red laser light scattering. This identifies any remaining contaminant material and removes it using air jets. The PET flake is sold for reuse in this form, without remelting.

These proceedings are currently before the Court. The amendments, which will be implemented in 2015, aim to ensure that collected recycling meets "appropriate quality standards". Separated collections of materials can be used to achieve this, but only where this is "technically, environmentally and economically practicable". There could be confusion over how to interpret the amendments. Defra and the Welsh Ministers will be developing proposals for further guidance to clarify this. Mixed collections will still be acceptable as long as the recyclate quality is sufficient.

New Processes

New processes are being developed to extract materials from previously uneconomical sources. The WEEE reprocessor Sweeep-Kuusakoski operates a process that extracts lead from the leaded glass used in cathode ray tube televisions, producing around 1 kilogram per TV. This lead can then be used in other applications, rather than being downcycled and diluted to an unrecoverable level for use in building materials. Reprocessors are also interested in the idea of 'machine vision,' referring to computer and camera systems that can be 'taught' to recognise images. A machine vision sorting system could recognise and remove specific contaminants that might be difficult to differentiate by conventional means, developers say.

Product Design

Composites and assemblies of multiple materials can be costly or difficult to recycle. In many cases where the individual materials are low value, or high value but present in small volumes, the return on the materials does not justify the cost of separating them. Examples include used packaging containing 'barrier films' to keep food fresh and waste electronics which can contain a variety of plastics and metals. Addressing this problem will require changes in

design practices, which will in turn require greater collaboration between the recycling industry and those involved in product design.

One way these issues are being addressed is through the EU Ecodesign Directive. Some of the main aims of the Directive are to reduce materials use and emissions in product design, as well as improve the recyclability of products. A number of organisations are also working to improve communication between designers, engineers and reprocessors, through schemes like The Great Recovery Project run by The Royal Society for the Encouragement of Arts, Manufactures and Commerce and the Technology Strategy Board. WRAP (see Box 1) provides funds for research and pilot projects aimed at recovering problematic materials, such as composite plastic films on ready meals.

New designs, particularly related to product assembly, could improve the value generated from recyclate. These can be simple, such as the use of clear plastic milk bottle tops with coloured tamper seals underneath, replacing coloured tops which can contaminate recyclate. In the case of more complex assemblies, such as WEEE, 'active disassembly' could be used. These are fastenings that release at specific temperatures, allowing products to be disassembled in a controlled sequence simply by heating them. However, these modifications require adoption by both the product design community and manufacturers to be effective.

New technologies aimed at improving the automated separation of recycled materials are also in development. A European Commission 7th Framework Programme project is investigating the use of advanced labels to help sorting machines identify materials. This might involve the addition of a dye that emits a particular frequency of light under infra-red, or the inclusion of a texture on the material surface that isn't visible to the naked eye but reflects laser light in a very specific pattern. Miniature Radio Frequency ID tags (see POSTnote 255) have also been suggested for this purpose.

Availability of Data

Data is required at each stage of the recycling process so that groups involved can plan effectively for the future. There is a lack of data available in several areas, including:

- Imports: the volume of imported materials, particularly in complete products, or components of products isn't well known. This limits reprocessors' ability to identify and plan for new sources of material. The Environmental Sustainability Knowledge Transfer Network is setting up a pilot 'Resource Dashboard.' When launched in 2013 it will provide businesses with data on flows of critical materials into the UK, along with prices and alternatives that could be used to increase resource security.
- Contamination: The levels of contamination in produced by MRFs are not widely reported. This can make it difficult for reprocessors to ensure the recyclate they receive from MRFs is usable. Defra is consulting over a statutory MRF code of practice, which would establish guidelines for sampling sorted materials, building on the voluntary code of practice developed by the Environmental Services Association. This is regarded as a positive step by reprocessors, but there are concerns that the proposed sampling rate is too low to give an accurate idea of the output quality.
- Destination of recyclate: The location in which materials are reprocessed is often not reported. The 'End Destinations of Recycling Charter' (developed by the Resource Association) attempts to encourage wider reporting of detailed recycling data to improve recycling practices in industry and households.

Recycling Infrastructure

Recycling requires upfront investment in equipment. Some of this comes from local authorities but the rest must be privately sourced. To date the ability of MRFs and reprocessors to attract investment has been limited by various factors. First, they face problems in ensuring a consistent supply and quality of recyclate, because of variation in recycling systems across England and the volumes of recyclate being exported. Secondly, there is a 'chicken and egg' problem: for a consistent supply to develop there must be a demand, but demand will not develop without a consistent supply. WRAP and the UK Green Investment Bank provide funding to help start up new recycling processes. Voluntary agreements between manufacturers and reprocessors, such as the Courtauld Commitment (developed by WRAP), can link up the stages of the recycling chain and help provide security for investors. The Courtauld Commitment helps manufacturers to increase recycling of their packaging as well as using more recycled material in new packaging. Corporate social responsibility commitments made by individual companies can have the same effect.

Prospects for a Closed Loop Economy

The closed loop economy has been projected to save the UK economy up to $1.1 billion (£0.7 billion) and enable a 1.4% reduction in emissions.[3] It could improve security of materials supply for UK companies, by allowing them to access a guaranteed stock of high-quality materials in the form of their own end-of-life products. However, there are very few businesses implementing it. The issues already highlighted in this note currently act as a barrier. Moreover in order to make the transition to a closed loop economy, businesses and consumers would need to understand the benefits. Decisions also need to be made on who should fund schemes to recover products after use and how such schemes should operate.

Endnotes

[1] Approaches to recycling in devolved nations vary widely, it is not possible to cover them in this briefing
[2] Green Alliance (2011) *Reinventing the Wheel: A circular economy for resource security*
[3] Ellen MacArthur Foundation (2012) *Towards the Circular Economy*
[4] Defra (2012) *Resource Security Action Plan: Making the most of valuable materials*
[5] BIR (2008) *Report on the Environmental Benefits of Recycling*
[6] Defra (2011) *Government Review of Waste Policy in England*
[7] M. Braungart W. McDonough & A. Bollinger (2007) *Cradle-to-cradle design*
[8] WRAP (2009) *MRF Quality Assessment Study*
[9] Resource Association (2012) *Costs of Contamination Report*

POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of policy issues that have a basis in science and technology. POST is grateful to James Lawrence for researching this briefing, to the Institution of Chemical Engineers and the Northeast of England Process Industry Cluster for funding his parliamentary fellowship, and to all contributors and reviewers. For further information on this subject, please contact the co-author, Dr. Chandrika Nath. Parliamentary Copyright 2013. Image copyright iStockPhoto.com.