GLOBAL WATCH MISSION REPORT

Waste electrical and electronic equipment (WEEE): innovating novel recovery and recycling technologies in Japan

SEPTEMBER 2005

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Waste electrical and electronic equipment (WEEE):

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REPORT OF A DTI GLOBAL WATCH MISSION
SEPTEMBER 2005

dti

Mini-Waste
industrial waste minimisation

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EXECUTIVE SUMMARY

Background

According to Japanese government sources[1], as much as 450 million tonnes (t) of waste is generated every year, of which 50 million t is municipal solid waste (MSW), and the number of final disposal sites is rapidly dwindling. A commonly quoted figure from various sources is that general waste landfill sites will be full within 10 years and that industrial landfill will be full by 2007/8.

There is also a recognised problem of increasing environmental damage being caused through waste disposal such as increasing global warming, decreasing air quality and long-term environmental effects of hazardous substances.

In addition forecasted resource constraints are beginning to impact on manufacturing costs in Japan, not least due to the close proximity of materials-hungry neighbours such as China and Korea.

Consequently the Japanese government instigated a formal programme of sustainable development based on the 3Rs (reduce, reuse, recycle) in the 1990s[2] and a framework of recycling laws was established during 2000 to 2003, ranging from packaging, home appliances, food, construction and end-of-life (EoL) vehicles.

The mission

The substance of this report is based on the effect and application of the Japanese Home Appliance Recycling Law (HARL, 2001) with 44 million domestic households disposing of 18 million appliances each year.

The mission team were representatives of the Mini-Waste Faraday Partnership, which is one of 24 Faraday Partnerships funded by UK government and the research councils. The Partnership is developing improved contacts between industry and academia within the UK in the field of resource productivity and waste minimisation in the five key sectors of food, construction, mining and minerals, metals and electronics.

The team represented a cross-section of the industry both in size (large UK nationals and small to medium enterprises – SMEs) and sectors (waste collection and logistics, eco-design, plastics recovery, WEEE and mobile phone recycling).

Six of the mission team are part of a small core team forming a network of industrial members set up, under the auspices of the DTI Global Watch Service and the new Resources Efficiency Knowledge Transfer Network, to promote post-consumer plastic recovery and reuse. A secondary objective of the mission was to consolidate the strategy and objectives of this group.

The UK delegation visited leading Japanese companies (Mitsubishi Electric – Hyper Cycle, Toshiba, Hitachi, Panasonic – METEC, Sharp – Kansai Recycling, Sony – Green Cycle and Tokyo Eco Recycle) as well as meeting government officials at the Ministry of Economy, Trade and Industry (METI).

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1 *Towards a 3R-Orientated, Sustainable Society: Legislation and Trends* (Ministry of Economy, Trade and Industry, Japan)

2 *Law for Promotion of Utilisation of Recycled Resources*

Several mission participants also had a half-day visit to the International Plastic Fair 2005 at Makuhari Messe. The mission members delivered a seminar on *Application of the WEEE directive in the UK and Europe* at the British Embassy in Tokyo to an audience of over 80 delegates.

Many of the companies visited are market leaders in the electronics sector and have advanced manufacturing/de-manufacturing processes. For example, Sharp has in production one of the first electronic devices featuring active disassembly using smart materials (ADSM) for shape-memory polymer components. The main thrust of the mission was to visit as many recycling facilities as possible to look at technology and understand any major differences in philosophy.

As previously mentioned the main driver for recycling is legislative as enshrined in HARL. This law was formulated in the late '90s and had a wide consultative process within the industry. Hence when the law was finally enacted in 2001 most of the major manufacturers had already instigated the policy within their organisations, and in at least one instance visited by the mission had started to build recycling facilities, although these would be better described as disassembly factories.

The major original equipment manufacturers (OEMs) split into two groups – imaginatively called Group A and Group B – to build recycling capabilities. Group A consists of Panasonic, Toshiba and Matsushita; Group B of Sony, Sharp, Sanyo, Hitachi, Mitsubishi and Fujitsu. These groups set up joint ventures (JVs) with each other, with one partner being responsible for – and running – the facility as the major shareholder and the other

Exhibit S.1 Japanese environmental laws partners being involved as lesser shareholders. They also invite the minor producers to join their consortia depending on the location of the particular facility.

Regulation and control

Overall responsibility for legislation in the WEEE arena lies with METI. Broadly speaking, Japanese society and its legislature are very 'environmentally friendly'. They commissioned a study and then enacted a 'Basic law for a Recycling-Based Society' (June 2000) which acted as an umbrella for a number of related laws.

Exhibit S.1 details their relationship but the ones most relevant to the mission were the Law for Promotion of Effective Utilisation of Resources (LPEUR) and HARL, both enacted in 2001. Of these, LPEUR is the more broadly based and similar to what the EU proposes for the WEEE directive. However, HARL is the most concise and universally applied as it currently covers Japan's four major home appliances: air conditioning units, fridges, washing machines and televisions (TVs) – defined as cathode ray tubes (CRTs), not liquid crystal displays (LCDs) which were only just coming onto the market at that time.

The cost of financing HARL is borne by the consumer, directly and transparently, through a system of unified, government-set charges (Exhibit S.2).

Appliance type	Charge	
Refrigerator	¥4,600	(~£23.00)
Air Conditioner (A/C)	¥3,500	(~£17.50)
Television (CRT)	¥2,700	(~£13.50)
Washing Machine (W/M)	¥2,400	(~£12.00)

Exhibit S.2 Charges for recycling of home appliances under the HARL system

In the case of replacement equipment the shop is required to take back the replaced appliance. The retailer will arrange for the appliance to be collected and delivered to a local central stockyard (190 of them around the country) and from here they are separated by type of appliance and make, then sent to the local Group A or Group B recycling centre depending on the make.

The key strength of the system is that the recycling centres get a very clean segregated waste stream and have very detailed information regarding the appliance composition and manufacturing method because they have the assembly blueprints from the original build (in many cases they can scan in the model ID or serial number to have a precise design specification). There will be a major difficulty in applying a similar system in the UK where this kind of information may not be available.

In the case of redundant or scrapped appliances the system is similar except in a few minor details. If consumers have details of where the appliance was originally purchased they can require the store to take the appliance back. If the store is not known, no longer trading or too far away, they can contact a dedicated collection unit to come and pick the item up. For example, in the case of TVs this service is provided by the Post Office.

As mentioned, the system is financed by consumers, who buy a multipart docket or manifest from the Post Office. The consumer keeps the top copy and sticks the remaining docket package on the appliance; when it is collected another copy is filed; at the stockyard another copy is removed; likewise at the recycling centre; and finally the last copy is sent to a central data collection authority. At any point in the proceeding any of the participants can check where the appliance is. This proves to be a very concise and simple audit trail and there is evidence that consumers do check with the data recording body that their particular appliance has been disposed of responsibly. A flow sheet is shown in Exhibit S.3.

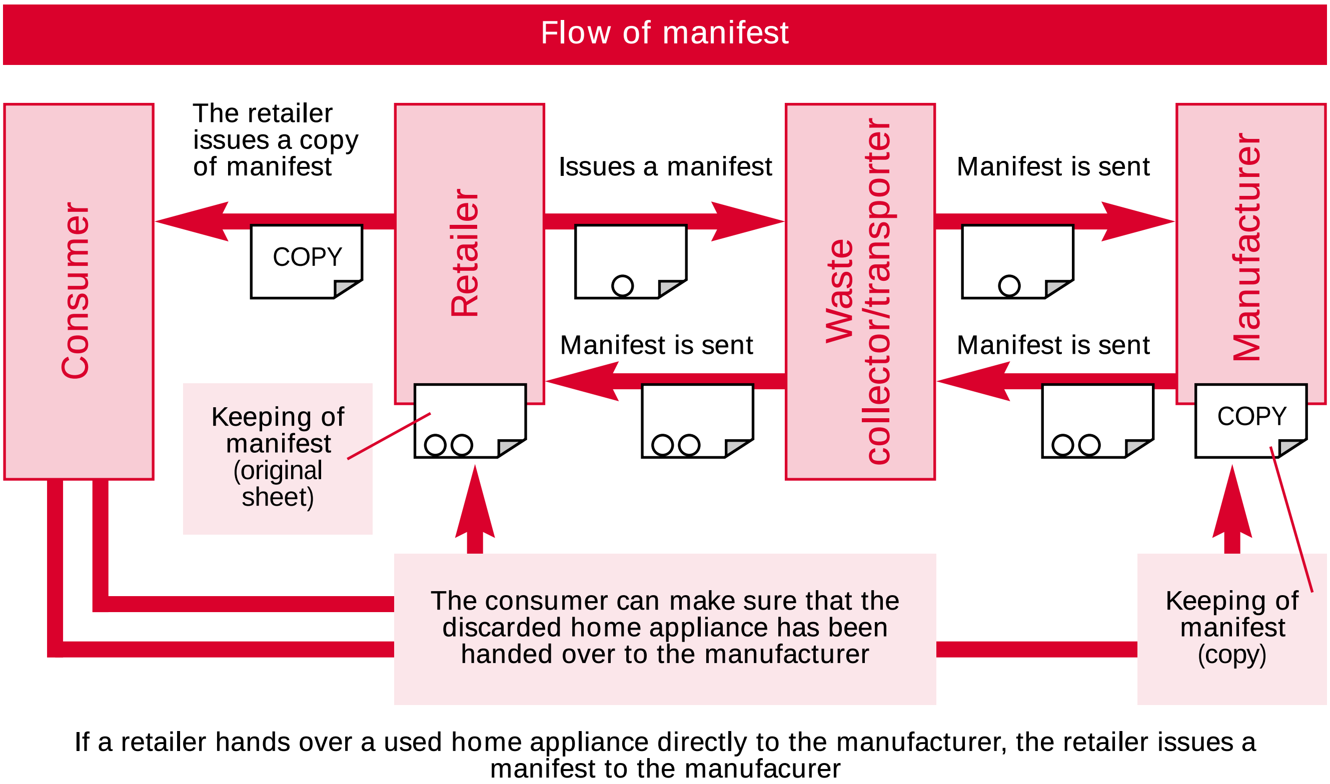

Exhibit S.3 Flow of recycling manifest

Appliance type	Recycling target	Actual recycling rate			
		2001	2002	2003	2004
Air conditioner	60%	78%	78%	81%	82%
Television	55%	73%	75%	78%	81%
Refrigerator	50%	59%	61%	63%	64%
Washing machine	50%	56%	60%	65%	68%
Total number of units recycled		8,538	10,147	10,460	11,214

Exhibit S.4 HARL recycling targets and actual rates, 2001-2004

Appliance type	Component percentage by weight					
	Plastics	Aluminium	Copper	Steel	Glass	Other
Air conditioner	11	7	17	55	0	10
Television	23	2	3	10	57	5
Refrigerator	40	3	4	50	<1	3
Washing machine	36	3	4	53	<1	4

Exhibit S.5 Typical percentage weight of material components of home appliances

Surprisingly, METI – which has overall responsibility – insists that fly-tipping to avoid paying the disposal charge is virtually unheard of.

Within the legislation the government has set strict targets for the amount of material recovered for each group of appliances (Exhibit S.4) and all recycling centres have to report their figures regularly.

These targets have a tight definition of what counts as 'recovered', with the fraction of any appliance being 'reused' (due to refurbishment, social reuse, sold on to third parties) as being disallowed. 'Recycling' is defined as the total weight of waste sold for recycling or reuse divided by the total input.

The targets were set following consultation with industry, obviously based on industry knowledge of the average material weights of components in each type of appliance (Exhibit S.5).

There is no requirement for the recycling centre to achieve better figures but all routinely do, prompting speculation that the government may increase the targets in the future in light of significant year-on-year improvements from the recycling centres. When METI was directly asked if this was likely, it replied that it was very pleased with the results and, as self regulation was clearly still delivering improvements, it didn't want to punish recyclers by imposing stricter targets in the near future. Again this could be seen as a crucial difference between Japan and the UK.

Due to having a well-defined collection system and only looking at four groups of appliances, segregation and cleanliness of operation was impressive. A standard stillage cage appears to be used to deliver appliances to site and obviously makes transportation and storage 'modular' and compact. Crucially it delivers appliances to recycling centres in 'good condition' (for example the mission saw very few examples of TVs with broken screens or fridges with the gas pipework broken or leaking).

Industrial investment

The regulations were broadly created in consultation with industry and widely disseminated with a guaranteed implementation date. Consequently the major players such as the large electronic manufacturers had plenty of time to put measures in place. Indeed some facilities were already constructed and in operation before the laws were enacted. The system of payment by the consumer guaranteed a revenue stream for the recycling centres. Finally, by close cooperation the major suppliers set up JV companies thereby limiting their exposure to financial risk and reducing their capital expenditure.

Vertical integration with the parent organisation also made recycling easier – ie cheaper and quicker – and gave a ready market for recovered materials. For example, virtually all the plastic recycled at Kansai Recycling Systems Corp (KRSC) is reused by Sharp – some 150 tonnes per year (t/y) from HARL appliances, 15 t/y from photocopiers and 10 t/y from personal computers (PCs).

This closed-loop system is seen as a 'virtuous cycle' by Japanese companies and features prominently in their annual 'corporate responsibility reports' of which they are all justifiably proud. That said, the industry has still invested heavily in the 46 or so recycling centres throughout the country, as can be seen by the capital investment numbers mentioned in individual visit reports later in this document.

Essentially, the Group A and Group B consortia operate similarly designed plants using similar basic technologies. The appliances are treated on dedicated lines with combined treatment only happening on the residual elements at the end of lines or where similar components had clearly been identified, such as common plastic casings or printed circuit boards (PCBs).

The amount of manual handling and disassembly was surprisingly high but obviously very efficient. Some typical examples quoted were nine minutes for a TV, 12 minutes for a fridge and 24 minutes for an air conditioner.

The use of sophisticated data logging systems (for what are essentially waste handling sites) was in evidence with many able to provide real-time information such as units per hour and weight of each material recovered.

The residual technologies to separate the various materials were generally tried and trusted – such as shredding, magnetic and eddy-current separation, plastic air and density flotation – but were applied to very clean, concentrated feedstock, hence delivered impressive separation results. There was evidence of some innovative technology in the area of plastic separation but this is available and understood in Europe.

Disassembly was mainly manual as mentioned with the only ‘robot’ technology seen being a hot-wire separator to divide funnel glass from tube glass on some of the TV lines. Obviously mechanically assisted manual handling was common with the favoured equipment being ‘intelligent’ sensor-controlled motorised conveyors and vacuum lift devices.

Gas recovery equipment from fridges and air conditioners was the common vacuum extraction system but rigorously applied using loss-in-weight detection to make the process semiautomatic. The companies were at great pains to point out this technology at each facility as they are clearly very sensitive to any climate change gas issue (this is possibly part of the Japanese culture – an island nation being significantly at risk from sea-level change, and the Kyoto Protocol being a national emblem).

Conversely, incineration of any finally unrecoverable waste stream was generally seen as acceptable and ‘good practice’. Energy-from-waste (EfW) plants were cited as a good means of disposing of unrecoverable mixed plastics, and mixed plastic/metal fractions ‘recycled’ to non-ferrous smelters was generally acceptable.

Due to the almost non-existence of CRT manufacture in Japan – now that LCD TVs are the dominant equipment manufactured – disposal of leaded glass from TVs is starting to prove difficult, with most being considered for export to China and some starting to be used as a silica slagging agent in lead smelters or other pyrometallurgical processes.

One of the advantages of only treating appliances of known composition was that many fractions were being recycled directly back to the parent companies for 100% reuse, giving a completely closed-loop recycling route for certain constituents like plastics. Also the use of JV companies with no intellectual property right (IPR) concerns allowed ‘design for disassembly’ to be explored. Already the number of separate parts in appliances was falling allowing easier recycling. Some companies were putting brand-new appliances through the recycling centres to determine how they could be ‘designed for disassembly’, using time-and-motion type studies to determine choke points in the process. As yet there was little evidence of ‘active disassembly’ components being used to reduce the manual dismantling operation but clearly some companies such as Sharp had development programmes in place.

None of the processes observed to recycle appliances was ‘revolutionary’ (bearing in mind we were only seeing a snapshot of well-established showcase sites) and could easily be applied in the UK. The key difference is that there is very close vertical integration between the legislators, consumers, manufacturers, recyclers and the supply chain and logistics. With only a few appliances being legislated for in Japan this is clearly easier than the European WEEE directive philosophy.

Conclusions

Japanese companies and stakeholders covered by and involved in implementing HARL are developing advanced knowledge of how to run 'recycling systems' – the legal system, infrastructure, plants and logistics: the HARL system has been running since 2001 and many of the recycling plants since 1999. This has been done through a strategic approach that involved government (METI), investors and industry. This knowledge and the learning curves developed on how to run 'recycling systems' will enable the Japanese to:

- Set up plants in other countries for their own companies and/or sell turnkey solutions
- Establish 'recycling systems' for other electronic products based on the learning from HARL
- Develop international standards based on Japanese experience

Most of the focus of the mission presentations was on responses to HARL but it is clear that LPEUR has an important role in stimulating recycling and eco-design in other electrical and electronics product categories, eg computers, mobile phones, small electrical items and photocopiers. In addition it was reinforced that eco-design – and particularly 'design for disassembly' – is being implemented by a number of the companies visited (see also the eco-design report[3]).

3 *The 'state of the art' in eco-design in the Japanese electronics sector,* final report, 1 November 2002, published for DTI by the Centre for Sustainable Design (CfSD) at Surrey Institute of Art & Design, University College

KEY FINDINGS AND RECOMMENDATIONS

The mission team found many examples of 'best practice', some of which – but not all (due to cultural and economic differences) – are applicable to the UK. These are briefly set out below.

Centre of excellence

- Complete a study of the 'state of the art' in electronics recycling in the UK to map against emerging opportunities
- Develop some form of strategic cooperation between UK and Japan focused on the transfer of recycling and eco-design knowledge and technologies
- Develop a UK network of electronics recycling technology companies
- Consider the educational element of any such centre of excellence as a forum for teaching future generations

Investing in industry

- Develop a UK demonstration recycling plant based on Japanese knowledge and experience
- Develop an Anglo-Japanese research project to classify the recycling plants seeking to explore inward investment from Japan

Legislation

- Consider carefully the difference between LPEUR and HARL on companies as a model for implementation of the WEEE directive

Overall policy recommendations for the UK

- The government should consider setting up a national WEEE recycling R&D facility or 'centre of excellence' (similar to METEC) to encourage innovative R&D.

- DTI funding should be strategically focused and, in this arena, made available to 'kick start' integrated demonstrator facilities. National demonstrator funding is vital and, where appropriate, covering 100% of feasibility costs would be key to this sector.

- The current policy of longer-term funding programmes should be encouraged and structured to persist over a decade if required. The current government Technology Programme 'Towards Zero Emissions' call should be extended to emphasise this area.

- Government support should not stop with R&D but should continue down through product development and field trials to market, with a suitable emphasis on 'new product' manufacturing development. Again the 'Sustainable Products' call in the Technology Programme is to be encouraged.

- DTI should bring in simple regulations in the key sectors as soon as possible, with a longer-term view to amending and extending these measures as experience is gained. An agreed and published schedule of reviews would be helpful for future industry planning. This would bring stability to the 'recycling' market and encourage longer-term investment.

- The government should be encouraged to 'brand' recycling technologies as a means of reducing energy consumption, towards meeting Kyoto global warming targets. They should also be seen as a method of securing a long-term supply based on recovered materials.

- Education is seen as a key area both to enlighten the younger generation about fundamental recycling and the older generation towards the use of recovered materials as sustainable products. This should be funded and based in a centre of excellence similar to Japan.

1 INTRODUCTION

Japan has a population of 127 million living on a landmass of 378,000 km^2 whereas the UK has a population of 60 million on a landmass of 295,000 km^2. Population density in Japan is further exacerbated by available land being mainly concentrated in coastal areas.

Gross domestic product (GDP) is £2,844 billion with a growth of 1.1% giving a *per capita* wealth of £22,500 (equivalent figures for the UK are £935 billion, 1.9% and £15,500 respectively). Unemployment is 4.4% and the average wage is £42,000 for men and £20,000 for women. With comparison figures in the UK of 4.7% and £24,000 it can be seen that with near zero interest rates in Japan the disposable income is higher than in the UK.

In terms of carbon dioxide (CO_2) emissions Japan is ranked fourth in the world, only surpassed by the USA, China and Russia. However, being a nation particularly vulnerable to sea level change and having the Kyoto Protocol to their name, the Japanese have a heightened awareness of the implications of inaction. Many times during mission visits the subject of doing things to reduce global warming came up, not only in the context of the driver for material reuse to reduce emissions but also in altering manufacturing facility management (eg Matsushita Eco Technology Centre – METEC – had a policy of reduced air conditioning in its office environment as well as its de-manufacturing facility).

Japan has the world's second largest economy; however, the massive growth seen during the 1980s peaked in the early 1990s and has been replaced by periods of recession interspersed with slow growth. Recently there has been evidence of another growth spurt but it is still seen as very fragile, and with Japanese exposure to global markets the recovery is patchy (eg during our visit Sony announced worldwide job reductions of 10,000 with analysts predicting larger cuts to come[4]).

Exhibit 1.1 Japan in silhouette

The Japanese government continues to take steps to stimulate the economy through massive spending programmes, including heavy investment in R&D. The total science and technology (S&T) budget for 2003 is ¥3.59 trillion (£19.4 billion), an increase of 1.2% on 2002, indicating a continued commitment to this sector.

4 *Financial Times – East Asia Issue, Week 39*

Private sector R&D investment is also massive, and increasing, accounting for 78% of total national spend, including a significant amount on basic research. The top 10 Japanese companies invest more in R&D than the whole of the UK (public and private sector). Much of this is invested outside Japan, with around 160 Japanese companies having R&D or design centres in the UK (46% of Japanese investment in the EU), and over 250 Japanese companies manufacturing in the UK.

Paradoxically the large number of SMEs seen in the UK is not so evident in Japan as this role in the economy seems to be serviced by focused divisions within the larger companies.

Recycling is addressed by the major manufacturers supporting JV enterprises where one of them, dependent on location, holds a controlling share but treats redundant equipment arising from the other partners as well as its own.

The Japanese economy is heavily dependent on raw material imports, having few natural resources of its own. Increasingly resource-hungry neighbours such as China are also having a supply and demand effect. Recent increasing oil and metal commodity prices have been particularly significant as a driver to assist WEEE recycling. Japan's electronics sector is a major consumer of plastics, which are heavily dependent on oil prices.

Meanwhile, contrary to the trend in desktop computing where precious metals content is dropping, the component-rich new electronic devices such as personal digital assistants (PDAs) and mobile telephones are using an increasing amount.

Another key market is TV technology, with there being very few CRT manufacturers in Japan now as production moves to plasma and LCD screens. Moves to this new technology are generating large numbers of CRTs being recycled but limiting the closed-loop philosophy as recovered materials such as lead glass are not being recycled to new CRTs.

2 AIMS AND OBJECTIVES

High-level aims

The high-level aims are to identify:

- The mechanisms put in place by the Japanese government to achieve its targets for electronic recycling
- The approach taken by industry to match this aspiration
- Integration of academia with industry to transfer R&D expertise into industrial processes
- Multidisciplinary collaboration to bring about step changes in technology
- Training capabilities and method of implementation for the overall recycling targets
- Integration of novel technologies with traditional recycling technology both in industry and academia
- Complementary strengths of the Japanese and UK manufacturing base to identify potential new alliances

Japan represents 23% of total EU imports of electronic equipment, with a trade deficit of €14 million. The information gathered from this mission will be exploited in several ways.

First, comparisons will be made with the approach adopted within Japan to introduce new technologies, specifically in the field of plastics and metals recovery, and more generally in recycling technologies. Examples of best practice will be translated to potential adoption within the UK context to act as the EU clearing house.

Secondly, particular technologies will be investigated to identify the strengths within the UK and those in Japan to improve collaboration to develop improved manufacturing principles. For example the advantages of active disassembly are not well understood in the UK and the Japanese perspective would be important.

Finally, actual manufacturing capability will be assessed to determine if improved cooperation will result in advantages for both markets.

Mini-Waste Faraday is already operating to identify R&D needs for industry already familiar with this technology, and hence improve productivity within those companies. In addition it is assisting companies that have not already looked at exploiting this technology by introducing them to world experts in the field. By translating the experience and expertise in Japan, this process can only be improved and therefore both the rate of advance of the technology and the rate of uptake is likely to increase.

Specific objectives

Following release of the WEEE directive in Europe, Japanese manufacturers are keen to see recycling sites established in Europe to address the producer responsibilities obligation. In Japan there is a national collection system for the four major appliances with two industrial consortia (Group A and Group B) established to treat them. The two groups operate 41 sites across the four major islands.

This solution is similar to the National Clearing House system being considered in the UK. However, areas of particular weakness were identified within the EU economy around the collection and segregation of these wastes.

Another significant gap is the area of plastics recycling and recovery. This technology gap is seen to influence the shredding and subsequent separation technologies, these being a particular strength in Japan.

The areas of interdisciplinary research have not previously been investigated, and therefore no conclusions can be drawn on the current state of development.

Several specific areas are thus of major interest to the mission team:

- Best practice for collection and segregation of WEEE
- Perceived needs for improved separation techniques, including depollution processes
- Advanced shredding and mechanical separation
- Performing of novel leaching and electrochemical reactions to recover metals
- Improvement of metal revalorisation efficiencies
- Performing of novel processes to recover plastics
- Level of plastic revalorisation efficiencies (if any)
- Recycling capability (particularly from small-scale collection sites to large processing units)
- Uptake of technology by the uncontrolled sector of electronic goods, comparing this with the ‘big’ four proscribed by HARL
- Tools available to audit the logistics of the collection system and recovery routes

3 MISSION PARTICIPANTS

Participants from the UK

The participants in this mission were representatives of the key areas of UK expertise in recycling technology:

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Mini-Waste Faraday Partnership

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Peter Murphy BSc, PhD
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Stuart Randall
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DARP Environmental Ltd

Keith Freegard MIChemE, MBA
Director
Axion Recycling Ltd

David Scott BSc, PhD
International Technology Promoter
DTI Global Watch Service

Brief biographies and contact details for the UK participants may be found in Appendix B.

Participants from Japan

Visits were organised to meet representatives of different components of the Japanese recycling community:

METI (Ministry of Economy, Trade and Industry)

Eiji Yokose
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Takeshi Tokita
Business Promotion Section
Sony Recycle-Business Administration

Green Cycle Corporation

Toshimi Saito
President and Representative Director

Takeshi Tokita
Business Promotion Section. Sony

Nobuhiro Hori
General Manager

Visit reports relating to the above organisations are in Appendix D.

4 LEGISLATION

Introduction

Sustainable waste management has been a high priority for the Japanese government for the last 20 years with their enormous manufacturing base and limited natural disposal options. Existing landfill space is due to run out in 2008 and the government has been following a planned strategy since the early '90s under the basic 3Rs – reduce, reuse, recycle.

WEEE legislation was clearly the key focus of the mission visit but WEEE is just part of a coordinated range of legislation formulated by government in close cooperation with industry. With an annual 450 million t of waste arising from industrial production and consumption, the country has been seeking to reduce dependency on both natural resources and end disposal, and sees sustainable environmental development as an essential part of economic progress.
This mindset seems to be carried through to Japanese industry which, with its cultural commitment to R&D, appears to view the challenge as an opportunity to improve manufacturing and design processes.

The Japanese government has therefore built an environmental strategy around the 3Rs – reduction of waste generation, reuse of parts, and recycling of used products as raw materials – with the aim of reducing dependence on natural resources and mitigating society's environmental impact.

This strategy is underpinned by the Fundamental Law for Establishing a Sound Material-Cycle Society[5] that was put into force in January 2001 and establishes the basic principles under which other environmental legislation should operate. This imposes the obligations of different sectors and the

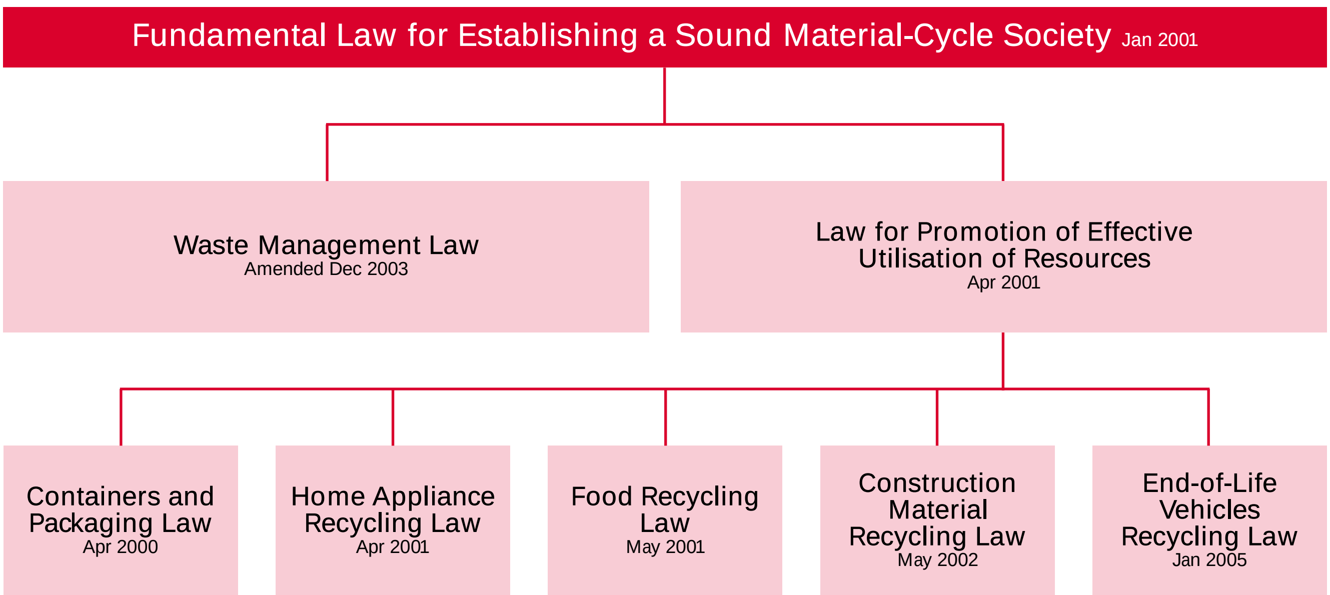

Exhibit 4.1 Japanese environmental legislation

5 www.env.go.jp/en/lar/wastelaw/SMCSlaw.pdf

measures to be taken by national government and comes under the responsibilities of METI. Under this come the two key laws that then govern the application of detailed regulation 'on the ground'. The Waste Management Law basically deals with disposal whilst the Law for Promotion of Effective Utilisation of Resources (LPEUR) deals with the 3Rs through product-related law.

This sequence of waste and recycling law is also then supported by a Green Purchasing Law, creating legislative circularity for the production process and a complementary range of strategic goals.

Additional supporting waste-related legislation has also been applied such as the Soil Contamination Countermeasures Law, the

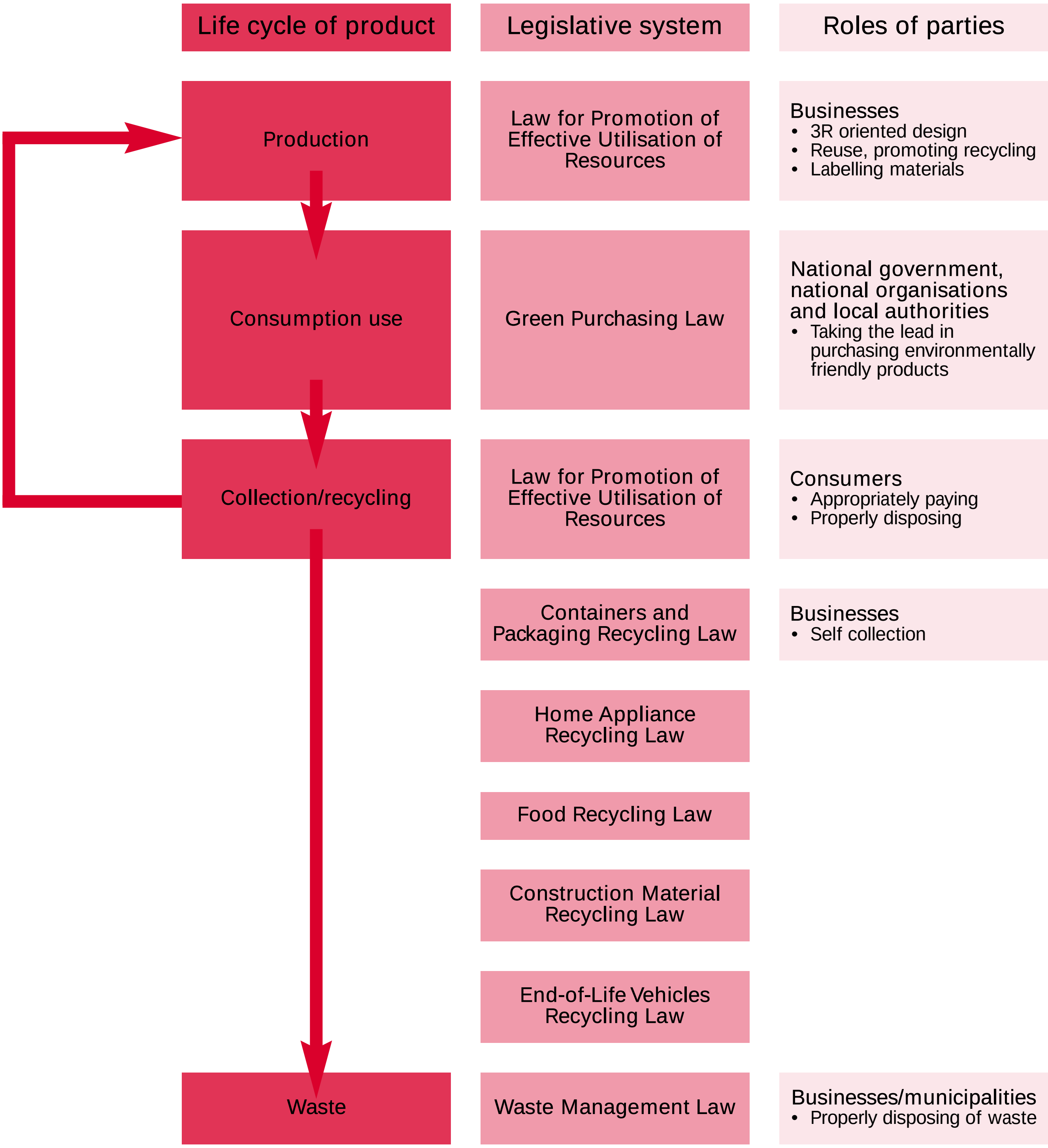

Exhibit 4.2 Legislative circularity in Japanese waste management

Animal Excrement Management Law for agricultural waste and the Law for Promoting Management of Release of Chemical Substances. Thus there is a full range of legislation applied across both the municipal and industrial/commercial waste streams.

The key driving legislation for the Home Appliance Recycling Law (HARL) is LPEUR. This was applied in April 2001 and provides for 3R measures to be taken by business in the production stage – Producer Responsibility. This includes design, labelling for separate collection and the development of an end-of-life (EoL) take-back system.

It applies responsibilities to each party in the supply and consumption trail:

Businesses

- Rationalising the use of raw materials with the aim of minimising
- Using recyclable materials and reusable parts
- Promoting their use at EoL

Consumers

- Using products for as long as possible
- Using products with high recycled content
- Cooperating in separate collection

National and local government

- Taking financial measures
- Promoting green procurement
- Promoting S&T development

Ten designated industry areas and 69 product items were identified to be addressed by LPEUR, covering around 50% of municipal and industrial wastes (Exhibit 4.3).

This all-encompassing law therefore requires that even those products not directly covered by specific producer responsibility are under pressure and scrutiny to be encouraged towards improved environmental performance. It has also led to the development of additional take-back schemes for household PCs and portable batteries.

For some years, consumers have had the ability to return EoL computers through a national take-back scheme where the computer could be packaged, taken to a local Post Office and returned to the manufacturer at consumers' expense. In October 2003, manufacturers voluntarily started to include a recycling mark on computers entitling consumers to return them free of charge at EoL but with an additional recycling fee incorporated in the sale of the product.

For compact rechargeable batteries, a national returns system has been set up at manufacturers' cost with collection points in shops and a national recycling centre.

Home Appliance Recycling Law (HARL)

The main purpose of the mission was to investigate HARL and the facilities being used for the recycling process.

This law is an excellent example of the Japanese approach to environmental sustainability in applying the following process:

- It appears to have been developed jointly – and in a coordinated and collaborative spirit – by industry and the relevant Japanese ministries
- It set down clear responsibilities, a clear timetable and clear environmental objectives
- It limited application to gain what was considered to be the optimum achievable benefit
- It gave industry a risk-free framework in which to invest

HARL was passed in 1998 giving the producers – manufacturers and importers – of four domestic appliance types the responsibility of providing a national take-back scheme and achieve recycling targets. Air conditioners, washing machines,

Industry	Requirement	Sector
Resource saving industry	Reduction in generation of by-products	Pulp and paper Organic and inorganic chemical manufacture Steel/iron making and rolling Primary copper making/refining Car/motorbike manufacture
Resource reutilisation industry	Required to use recyclable resources and reusable parts	Paper making Glass container manufacture Construction Rigid PVC pipe manufacture Copier manufacture
Specified by-products	Required to promote the reuse of by-products as recyclable resource	Electricity industry Construction industry

Purpose	Requirement	Products
Resource saving products	Ensure rational use of raw materials, prolong product life and reduce generation of new products	Cars Electrical home appliances Personal computers Pinball machines Metal furniture Gas and oil appliances
Resource reutilised products	Ensure use of recyclable materials or reusable parts	Cars Electrical home appliances Personal computers Pinball machines Metal furniture Gas and oil appliances Bathroom and kitchen systems Copying machines Devices using compact rechargeable batteries (power tools, cordless phone, electric bicycle, etc)
Specified labelled products	Labelled to facilitate separate collection	Aluminium and steel beverage cans PET beverage bottles PVC construction materials Paper packaging Plastic packaging Compact rechargeable batteries
Resource recycled products	Promote self-collection and recycling	Compact rechargeable batteries Personal computers 29 specified products using compact rechargeable batteries (power tools, mobile phones, video cameras, shavers, etc)
By-products	Promote reuse of by-products as recyclable resources	Coal ash from electricity generation Construction waste

Exhibit 4.3 Key sectors affected by LPEUR

televisions and fridges/freezers were targeted as the items where the greatest environmental net benefit could be achieved.

Japan has ~44 million households disposing of ~18 million of these units each year, equating to ~1 million t. Before HARL, 71% of these items were disposed of through untargeted disposal, mostly as waste, although there would have been a significant quantity entering the scrap metal industry. The remainder were exported (24%) or sold as second-hand goods (5%).

Since HARL, it would appear that ~62% are entering the take-back process and achieving an average 72% recycling rate. History does not currently relate what happened to the 38% that do not enter, but it is assumed that they get resold or exported although there is acceptance that 1-2% are ‘illegally’ disposed of which would suggest fly-tipping. If this is the case, this equates to around 100,000+ units a year, a not inconsiderable problem.

Requirement

The regulations lay down specific recycling targets for the four types of appliance and only relate to household waste equipment. Business WEEE is not covered by HARL, although under LPEUR businesses have a duty to maximise recycling.

The recycling levels are as follows:

- Air conditioners 60%
- Televisions 55%
- Fridges/freezers 50%
- Washing machines 50%

‘Recycling’ is defined as the total weight of waste sold for recycling or reuse divided by the total input.

There are no targets for collection, but items collected must be recycled through the system.

The system had to be in place for commencement in April 2001, at which point manufacturers took responsibility for the collection and recycling of these items.

5 LOGISTICS AND COLLECTION

The regulations required manufacturers and importers to set up a national collection and recycling infrastructure. Manufacturers split themselves into two groups which then set about building the recycling plants on the basis of shareholdings:

- Group A – 40% of the market with Matsushita (Panasonic) and Toshiba as the two largest members: 25 recycling plants
- Group B – 60% of the market with Hitachi, Mitsubishi, Sharp, Sanyo, Sony and Fujitsu as key members: 15 recycling plants

Group A has effectively contracted out the operation of the plants to waste management companies whilst Group B has built the plants itself.

Plants are built on the basis of prime

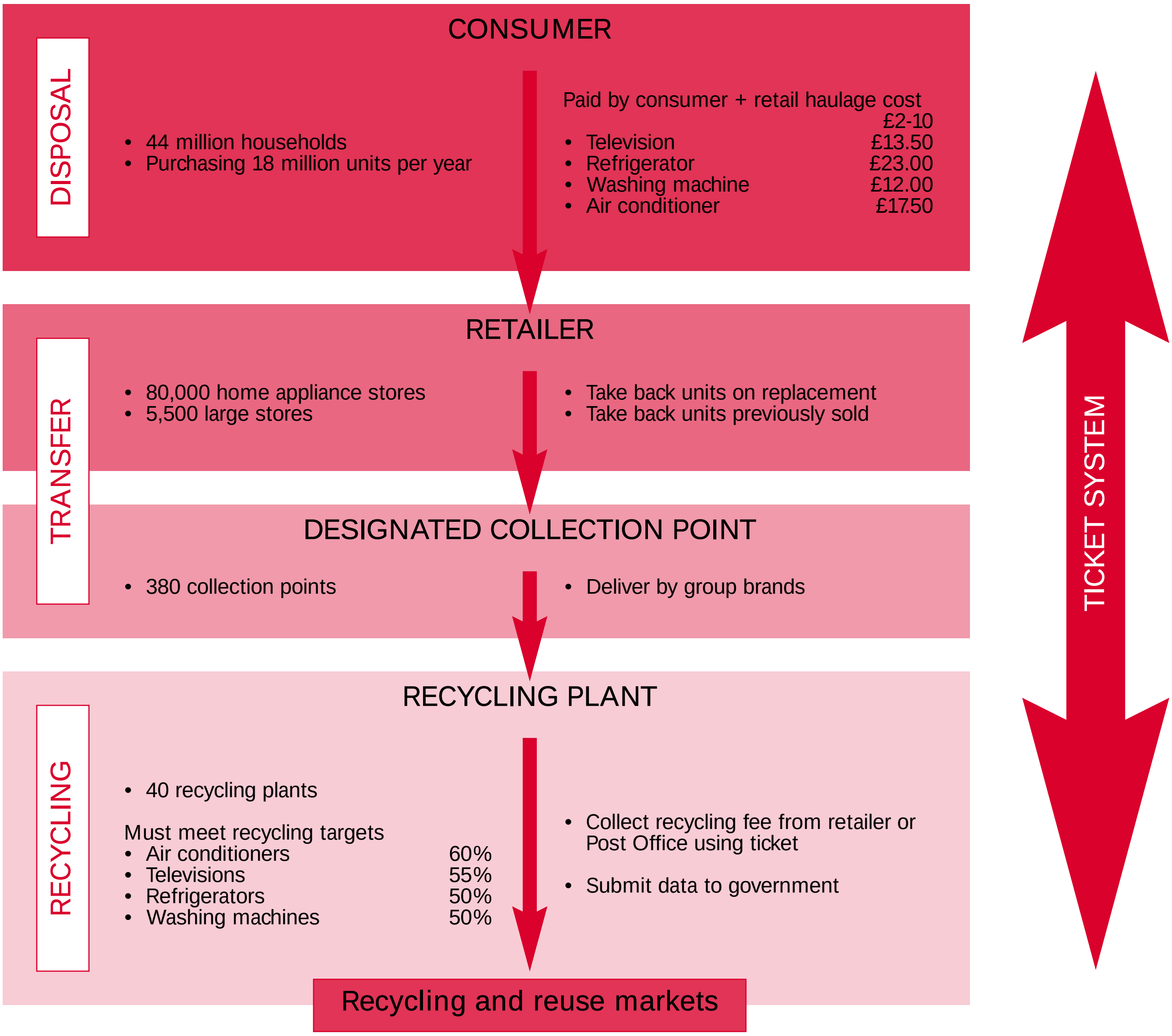

Exhibit 5.1 HARL system for disposal, transfer and recycling of home appliances

manufacturers having the main shareholding whilst the other manufacturers and importers take a small shareholding.

These plants are fed by a national collection system operating through 380 designated collection points that act as bulking and transfer facilities. The plants will only take back product brands related to their Group companies.

Collection is carried out primarily through electrical retailers who are required to take back used products from consumers either when they purchase a new product or if a consumer delivers the old product back to where it was bought from with proof of purchase. On delivery to the retailer, the consumer will pay a national recycling fee plus an additional amount (£2.50 – £10) put on by the retailer to cover transport costs to the collection point.

The national recycling fees are currently:

- Television (CRT) ¥2,700 yen (~£13.50)
- Fridge/freezer ¥4,600 (~£23)
- Washing machine ¥2,400 (~£12)
- Air conditioning unit ¥3,500 (~£17.50)

A fridge/freezer unit could therefore end up costing the consumer over £30 on disposal.

A voucher system is used to track all items and enable the recycling centre to claim back the recycling fee from the retailer (explained later). These vouchers can also be purchased from the Post Office and consumers can take products direct to the designated collection points although only about 10% do. In this instance the recycling plant would claim the recycling fee back from the Post Office (as municipalities also can).

The regulations apply strict monitoring requirements: all recycling plants are required to submit monthly returns showing the number of units received and the level of recycling achieved.

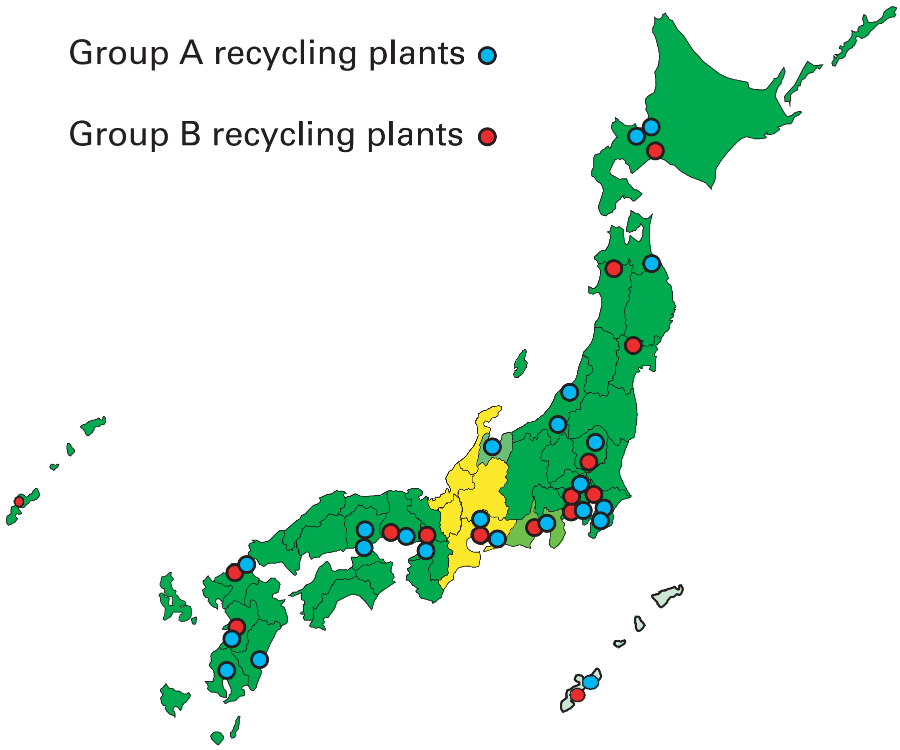

Exhibit 5.2 Location of Group A and Group B recycling plants

6 PROGRESS AND CURRENT POSITION

The regulations have provided the manufacturers with a clear basis for investment, ensuring guaranteed supply and certainty of revenue. The results have therefore been extremely encouraging and have led to long-term development towards improving both recycling rates and environmental design.

The Group A/B system provides some degree of individual producer responsibility thereby encouraging improvements in design for dismantlability. Indeed, it was evident throughout the mission visit that the companies operating the plants saw them as very much part of their R&D structure, and a number of manufacturers test their equipment through the plants before it is released.

The level of recycling achieved is impressive, with year-on-year increases for both quantities of units collected and appliance recycling rates (Exhibits 6.1 and 6.2), but this is achieved at relatively high cost compared to expectations in Europe and especially in the UK.

The main reason for the high costs is the extremely high level of manual disassembly that is applied; but if consumers are prepared to accept the high costs, there is little incentive to reduce them. However, it was indicated that the level of consumer dissatisfaction with the recycling fees has grown to such an extent that municipalities are complaining of significant increases in illegal disposal – fly-tipping.

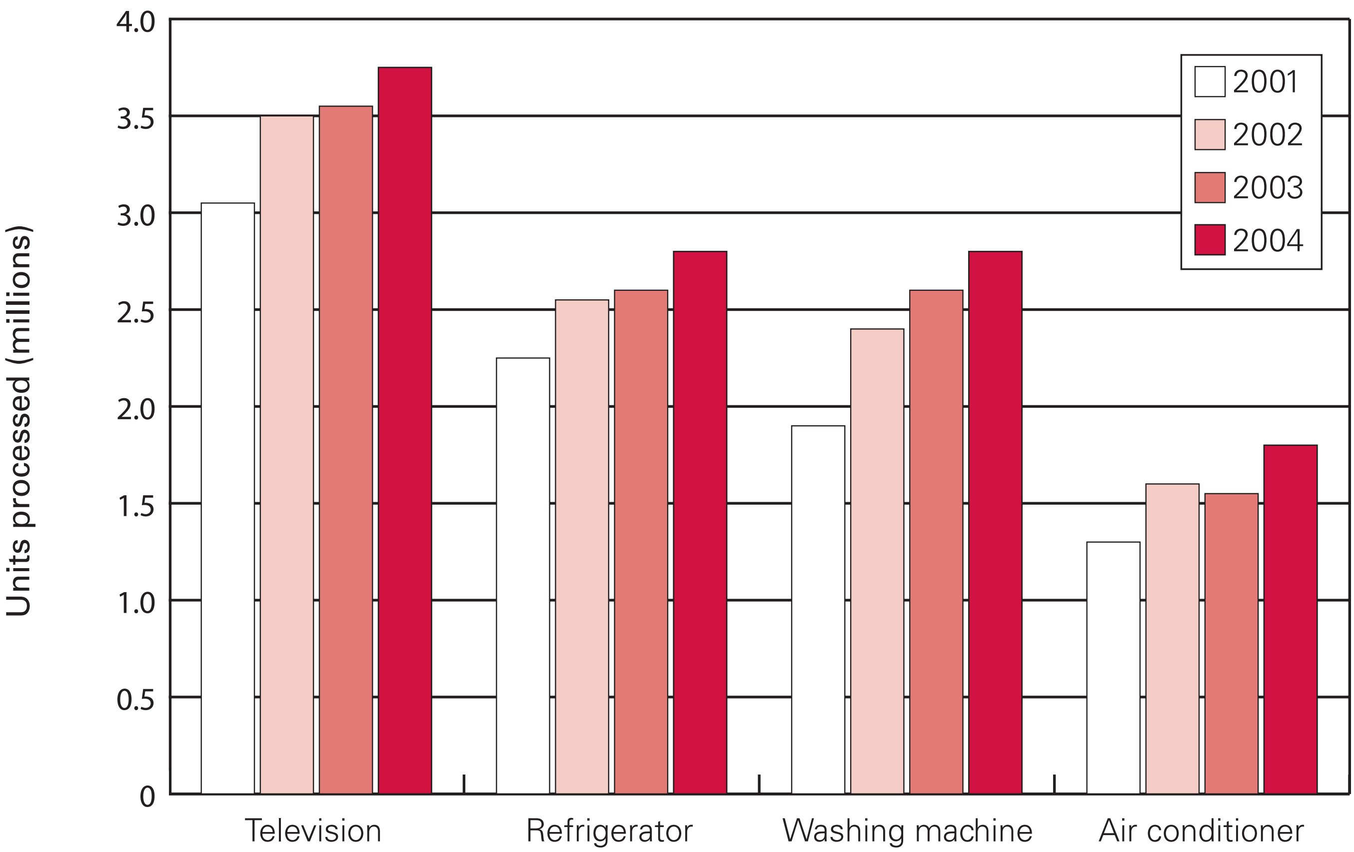

Exhibit 6.1 HARL: number of home appliances processed, 2001-2004

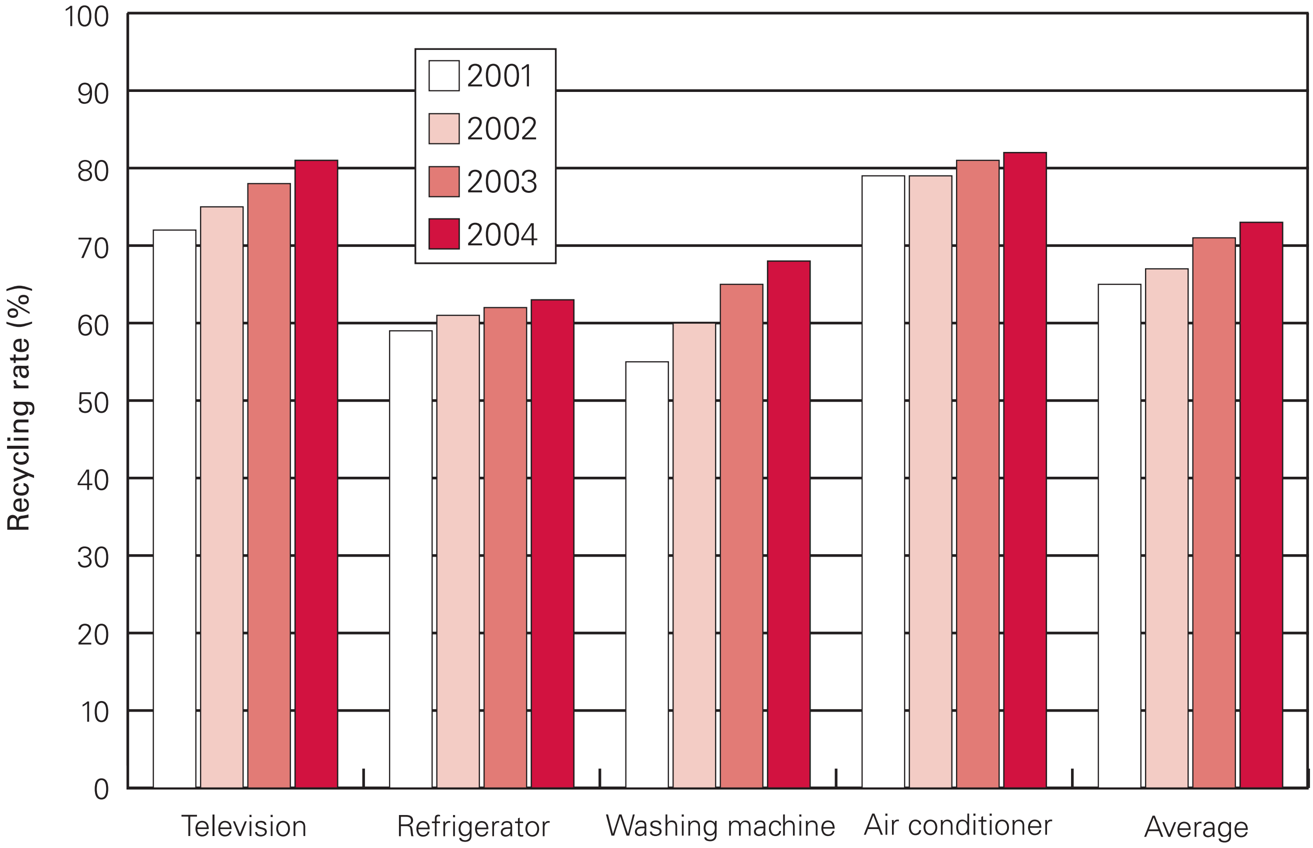

Exhibit 6.2 HARL: recycling rates, 2001-2004

The government is therefore said to be considering a review of the regulations that would require manufacturers to apply a visible fee to the sale of new products. This would be likely to lead to pressure to bring down the costs of recycling to avoid manufacturers being uncompetitive in the market, especially against imports, and could in turn adversely affect recycling rates as recycling plants looked for savings in their recycling costs. However, it was claimed by some plant operators that they believed that their current methods were as cost effective as could be achieved because of the relative value of recyclables compared to disposal costs if they weren't recycled.

It is also interesting to review the technical data relating to materials recovered through the recycling process for 2004/5 (Exhibit 6.3).

In addition, 995 t of chlorofluorocarbon (CFC) coolants were extracted from air conditioners, plus 311 t of coolant CFC and 625 t of insulator CFC from fridges and freezers.

Material	Air conditioner	Television	Fridge/freezer	Washing machine
Iron	25,878	8,167	71,608	37,668
Copper	4,137	3,835	1,267	789
Aluminium	1,340	123	380	455
Iron/nonferrous composite	30,396	1,100	19,401	10,893
CRT glass	-	60,818	-	-
Other value materials	3,185	9,823	10,888	8,903
TOTAL	64,939	83,868	103,546	58,710

Exhibit 6.3 HARL: tonnes of material recovered, 2004/5

7 DATA RECORDING AND REPORTING

HARL ticketing system

One key element in the successful implementation of HARL is the use of a ticketing or voucher system that ensures the traceability of an EoL appliance on its journey from the consumer to the recycler. Introduced about two years ago, the system has been found to be a very useful way of monitoring and tracking EoL appliances. The system is administered by an organisation known as the Home Appliance Recycling Law Ticket Centre, a public foundation owned by the Japanese government. (The ticket centre is regulated by HAPA, a trade association of appliance manufacturers, but it is ultimately under government control.)

The basic process employs five tickets per item to be recycled and these are used to track the progress of the appliance through the recycling system. Each 'ticket' consists of a book of five copies each printed with an individual number and, in total, costs the equivalent of approximately £15, although this amount varies from appliance to appliance. The tickets contain details of the appliance, the name of the retailer and manufacturer and, from the information and reference number on the ticket, consumers are able to check the status of their appliance, eg to find out whether it has been returned to the manufacturer or sent on to a third-party recycler. Consumers thus have full traceability of their appliance via this relatively simple system. (They are able to find the status of an electrical appliance which they submitted for recycling by accessing the web page of the Association for Electric Home Appliances (AEHA) and using a checking system that tracks the status of all collected electric appliances.)

The ticketing scheme places a number of obligations on people and organisations in order to ensure that the process works efficiently. For example, consumers are obliged to both cooperate in appropriately transferring used appliances to retailers in order to ensure recycling and to agree to pay the necessary fees for the transfer and recycling of those appliances. Similarly, retailers have an obligation to take back used home appliances both when the appliances are those which retailers themselves previously sold to consumers and when retailers sell the same kind of home appliances to consumers. They also have an obligation to transfer them to the relevant manufacturers or importers. Manufacturers and importers are then obligated to receive appliances for recycling at designated take-back sites and to recycle them according to the recycling standards set by the Japanese government. To date, 46 dismantling factories have been established in Japan.

Retailers and manufacturers have an obligation to keep the tickets for three years. The scheme works as follows. One voucher is given to the consumer when an item is delivered to the shop for recycling. This voucher provides evidence of delivery of the appliance for recycling and payment of the appropriate fee. This fee is determined by the particular type of equipment to be recycled and also includes an additional amount to cover the cost to the shops of transporting the item to a take-back site. One copy is retained by the shop and the other three travel with the item to a designated input site. At this point one copy stays at the site and the final two go with the appliance to the recycling plant. The recycling plant then sends one voucher back to the shop in order to initiate payment of the recycling fee and it retains the final one for its own records. If consumers take items directly to a designated collection point, they can obtain books of tickets from the Post Office. A schematic of the process is shown in Exhibit 7.1 and some actual vouchers in Exhibit 7.2.

Exhibit 7.1 HARL ticketing process

Exhibit 7.2 HARL vouchers

Role of the Post Office

The Japanese Post Office is used to administer the ticketing system because it is both convenient for the consumer and because it is also seen as an independent body with the required infrastructure to cope with such a large undertaking. It also gains revenue from sales of tickets. This relatively simple approach is in significant contrast to the UK, where the possibility of establishing a clearing house was originally proposed but was eventually shelved due to the predicted high costs. In contrast, the Japanese have merely utilised an asset which they already have in place.

Role of the consumer

One of the fundamental reasons why HARL appears to work so well is because the Japanese public seems extremely willing to participate in the scheme even though there is actually a substantial cost incurred. This highlights the significant differences in both national culture and individual ways of thinking between the UK and Japan.

It is difficult to conceive of the average British consumer being willing to pay £15 or so to have old appliances removed and recycled. Even before the new European WEEE legislation comes into force, it is frequently possible to find EoL electrical and electronic appliances abandoned at the roadside. The imposition of a fee such as is used in Japan would surely cause this type of illegal activity to escalate further. In Japan, although the consumer is obligated to ensure that redundant equipment is disposed of in the correct manner, there actually appear to be cultural reasons that encourage individuals to participate in recycling.

It has also been suggested that in the near future consumers may be required to prove that they have recycled their old equipment when buying new equipment. This goes to the take-back ethos where, if an appliance has not been returned or if it has been dumped illegally, a penalty would be payable. In this case, by acting correctly, there would be a built-in incentive.

Benefits to manufacturers

The ticketing scheme offers a number of benefits to manufacturers. For example, they get market research information on sales of their appliances. They can also trace their appliances to ensure that they have been

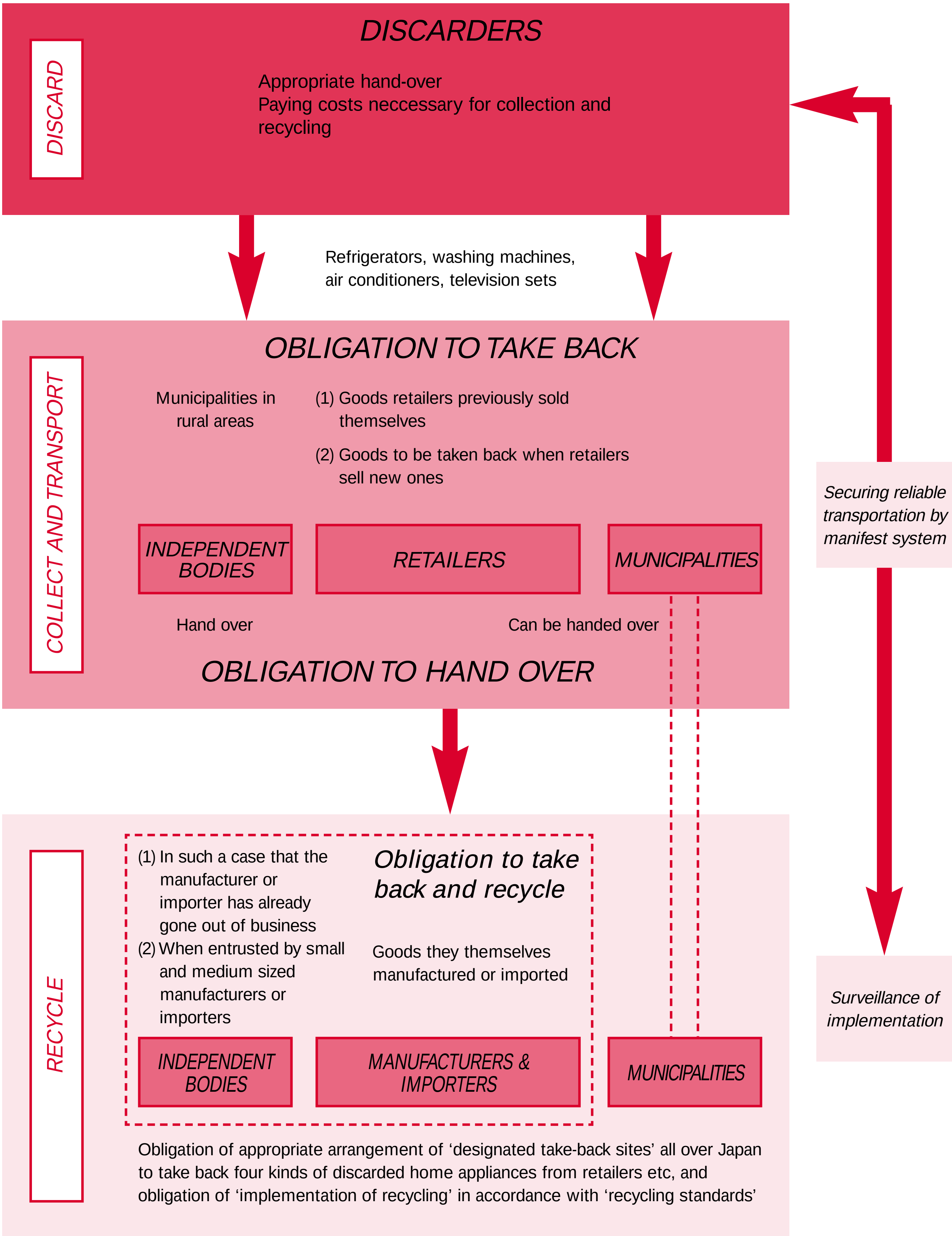

Exhibit 7.3 HARL system obligations

disposed of correctly. This of course is very important to manufacturers as it can enable them to adjust their supply chain accordingly. It also enables them to monitor their environmental reports. This is something which is deemed to be very important to Japanese companies as can be seen from the annual reports produced by all of the major large companies.

Benefits to the retailer

Retailers, as with manufacturers, are able to exercise stock control, to gain market assessments and an insight into new trends. The ticketing system gives retailers full compliance with HARL, something which both they and the manufacturers have signed agreements to uphold. Participation and support for the system can also give a company the ability to extol its green credentials.

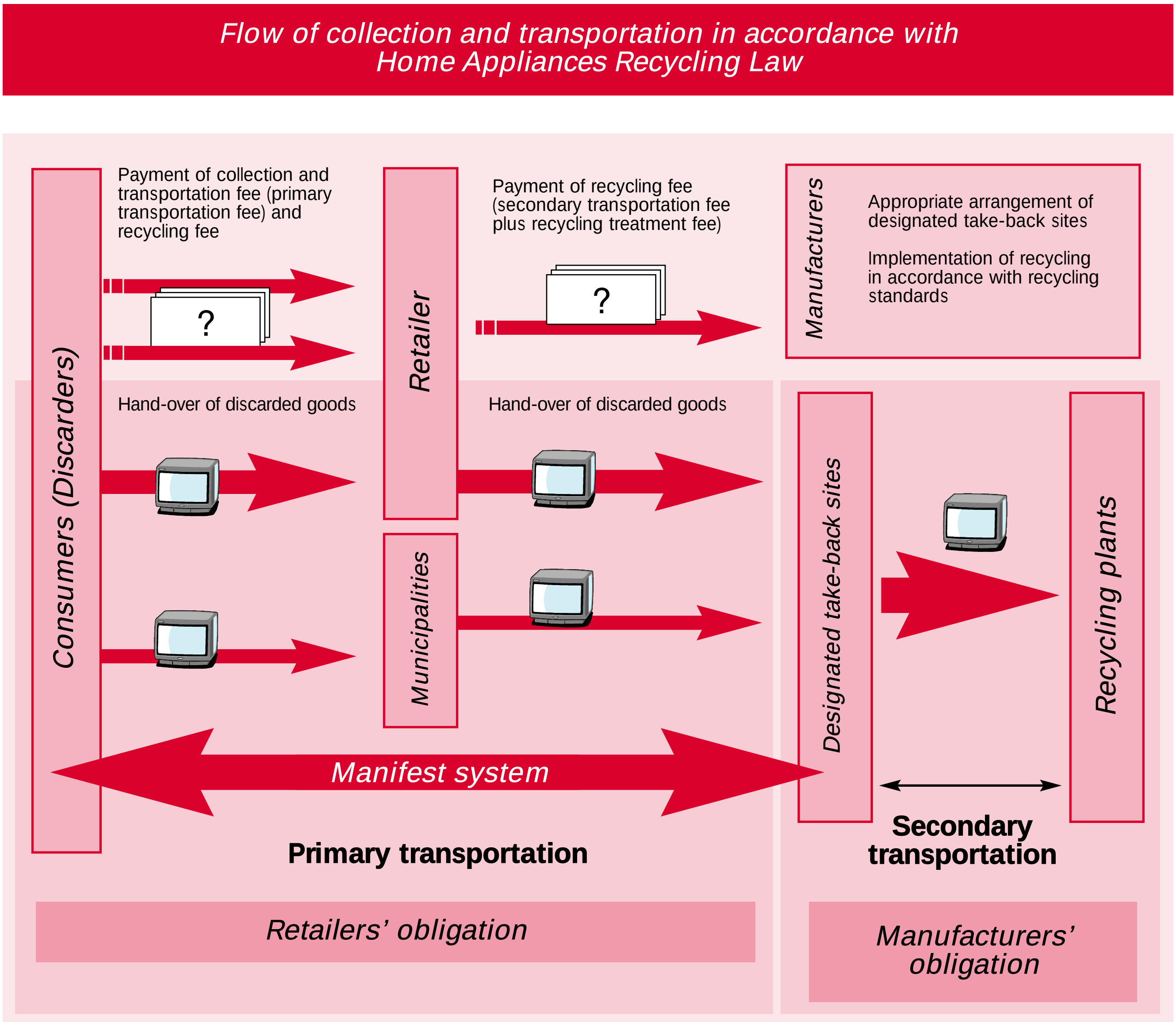

Exhibit 7.4 Flow of collection and transportation in accordance with HARL

Benefits to the government

The ticketing system enables the government to gain in several ways, as it is able to collect data on imported electronic goods and also to understand how the electronics sector is performing. It also has control over recycling and can monitor the efficiency and impact of its home appliance recycling legislation.

In summary, the Japanese government has put in place the ticketing system to ensure that there is a completely transparent audit trail which can be audited at any level and which has the agreement and support of all the manufacturers.

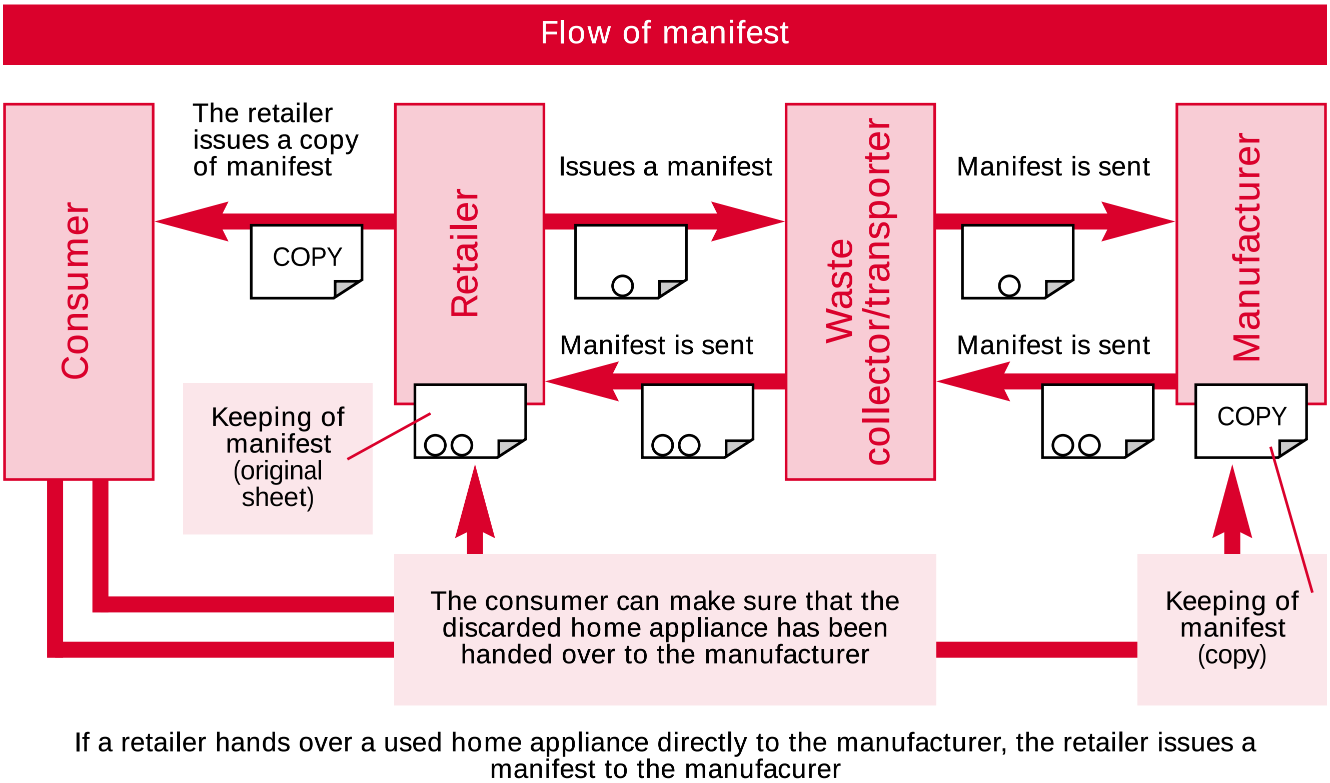

Exhibit 7.5 Flow of recycling manifest

8 PROCESSING

Introduction

On 5 June 1998 Japan published the Law for the Recycling of Specified Kinds of Home Appliances after consultation with major stakeholders. The enforcement was to coincide with that of the Basic Law for Establishing the Recycling-Based Society on 1 April 2001.

Eighty percent (by weight) of discarded products consisted of air conditioners, washing machines, CRT televisions and refrigeration equipment. These products also contained substances of concern such as leaded glass and ozone depleting gases.

With the assurance of the Japanese government regarding costing, the major Japanese manufacturers joined in groups (Group A and Group B – see Exhibits 8.1 and 8.2) and began researching the most efficient methodology for processing these product lines.

An advanced disassembly and sorting system known as the 'HEART System' (High Efficient Applicable Recycle Technology) was

Cleanup	LG Denshi Japan	Techno Matsuo
CORONA	Matsushita Electric Industrial	Toho Gas
Daikin Industries	Morita Denko	Tokyo Gas
Distribution Japan	Orion Electric	Toshiba Carrier
Electrolux Japan	Osaka Gas	Toshiba Corporation
Engin Service	Samsung Japan	Toshiba Video Products Japan
GE Quartz Japan	Takagi Industrial	Victor Co of Japan

Exhibit 8.1 Group A companies

Ace International Japan	Hitachi Living Supply	Pioneer Electronic
Aiwa	INTERCONP	Rinnai
Amway Japan	Iwatani International	Ryohin Keikaku
ASCO Japan	Koizumi Seiki	Sanyo Electric
BALS Corporation	Kyushu Takemura Electronic	Sanyo Electric Air Conditioning
Best Denki	Meikoh Enterprise	Sawafuji
Chofu Seisakusho	Miele Japan	Seiwa Electric
Creative Yoko	Mitsubishi Electric	Senju
Daewoo Electronics Japan	Mitsubishi Electric Engineering	Sharp
Designated Corporation, NEC	Mitsubishi Heavy Industries	SOKO
Eco 21	Mitsubishi Trading	Sony
Fujitsu General	National Federation of	Toyotomi
Funai Electric	University Co-operative	Tsann Kuen International
GEAEC	Associations	Tsunashima
Haier Japan	Nissho Iwai Mechatronics	Tsunashima House Ware
Hitachi Home & Life	Nitto Reinetsu	Twinbird
Solutions	Noritz	Yoshii Denki
Hitachi Joei Tech	ONKYO LIV	

Exhibit 8.2 Group B companies

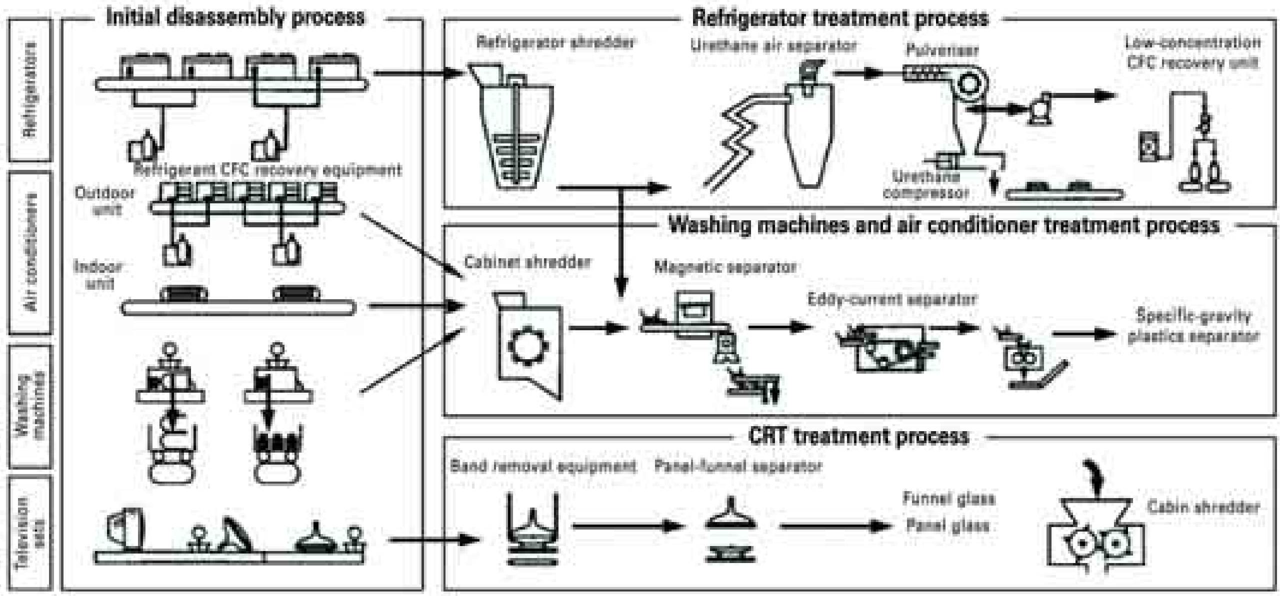

Exhibit 8.3 An early Japanese basic processing concept

developed following experimentation with whole product shredding and manual removal of materials from conveyor lines and cryogenic immersion of products in liquid nitrogen (-120ºC) and crushing technologies. Although some cryogenic process continues, it is considered impractical with desired throughputs. Shredding and picking lines contaminate materials with hazardous substances, prevent reuse of certain components and it is considered a health and safety risk to the workforce.

Eventually a basic concept was developed which can still be seen today at the majority of processing plants, combining manual depollution or pretreatment with shredding and separation technologies. The system developed (Exhibit 8.3) considered the possible future inclusion of other product lines such as office equipment, vending machines and gas instruments.

Processing systems

The processing plants visited by the mission team in 2005 still appeared to follow the original concept (Exhibit 8.4).

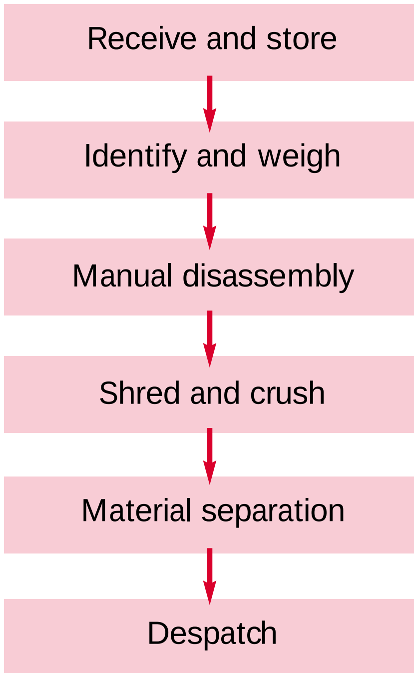

Exhibit 8.4 Process flow

EoL products arrive at processing plants in ‘group’ containers. These containers have been designed by each group, dependent on differing requirements. They are colour coded – Blue = Group A, Yellow = Group B – and manufactured in China.

The containers are product specific on arrival so some form of sorting has already taken place, presumably at the manufacturer's collection facility, of which each group manages 190 facilities. Eighty percent of products are Japanese.

Products also arrive group specific: Group A plants only process Group A products, a convenient system that is unique to Japanese culture, and a benefit unlikely to work outside Japan. Also each individual product carries the fifth sheet of the HARL manifest including bar code; these are read by bar code readers and the information contained uploaded to the management software system and to the AEHA website where consumers can monitor the movements of their discarded appliances: www.rkc.aeha.or.jp (only available in Japanese).

Manual depollution or pretreatment

The four product types are sorted into lines, before any manual disassembly; the product is identified by its bar code and weighed. Each product type then follows a prescribed disassembly procedure.

- Refrigerators

Any single type polymers such as salad crispers or vegetable drawers are removed and granulated with others of the same polymer type. Plastic coated steel shelves are removed along with the magnetic door seals. Refrigeration units are then aligned to aid refrigerant gas removal, using a mechanical lifting device. The gas is vacuumed into a container which is located on a scale system, allowing the monitoring of the refrigerant gas removed and determining the contents of the container, to allow replacement when full. The compressor is then removed, punctured and drained of oil. The remaining carcass is then positioned ready for shredding.

Exhibit 8.5 Refrigerant degassing line and mechanical handling at Hyper Cycle Systems

- CRT televisions

The casings are unscrewed and identified by material type; cabling, speakers, PCBs, copper rich components, steel banding and electron guns are all removed and separately containerised for further processing. Some of the plants visited went on to separate the different glass types using the 'hot wire' method; at METEC this procedure has been automated using an optical system for the positioning of the hot wire. Others send the remainder to other plants for separation. Sealing with tape or adding water contained the phosphorus coating on the panel glass.

Exhibit 8.6 Removed TV speakers at Tokyo Eco Recycle

Exhibit 8.7 Automated glass separation at METEC

- Washing machines

The major differences noted between Japanese and European washing machines were that Japanese units were upright twin tubs with salt water counterweights whereas European units tend to be front loaders with concrete counterweights. The usual manual disassembly of cabling, PCBs and single type material was observed; in addition a purpose-built press was used for separating motor drives from PP tubs and extracting salt water from the counterweights.

Exhibit 8.8 Washing machine handling at METEC

Exhibit 8.9 Washing machine disassembly at Tokyo Eco Recycle

- Air conditioners

The major task in the processing of air conditioning units is the removal of refrigerant gases – ozone depleting substances such as CFCs, or hydrocarbon greenhouse gases. The remainder of the unit is becoming more and more single type material and copper-rich heat exchangers, all of which is separated. The remaining carcasses of these appliances then go through a shredding and separation process.

Exhibit 8.10 Air conditioner line at Hyper Cycle Systems

Processing technologies

The five processing plants visited by the mission all had noise, odour and dust abatement systems, and all seemed to have similar primary shredders – a vertical design combining shredder and hammer mill properties. All investigations indicated these primary shredders all came from one of two makers: Kubota and Kinki kogyo.

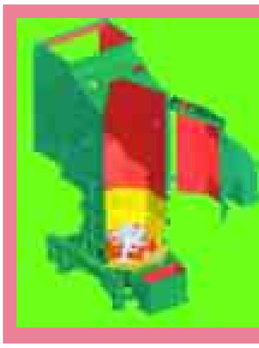

Exhibit 8.11 Kinki shredder (source: ww.kinkikogyo.co.jp/tategata.html)

At least one processing plant had requested modifications to be made to their Kinki kogyo unit and now their parent company holds the patent for this design.

Exhibit 8.12 Shredder outputs at Tokyo Eco Recycle

Only one twin-shaft wheel shredder was seen at METEC for processing refrigeration units.

Exhibit 8.13 Twin-shaft shredder (German system)

The next standard processing observed was a magnetic separation device such as a rotating band magnet for removing ferrous materials. All processing plants claimed between 99.5% and 99.8% purity rates for ferrous outputs. Then a combination of eddy current and specific gravity separation units was used to separate aluminium, copper and polymers, with all plants claiming between 97% and 99% purity rates.

Refrigeration systems were processed through a polyurethane air separator and the foam was heated to extract the maximum amount of blowing agent from the foam matrix. The foam was processed through a large diameter outlet briquetter.

Exhibit 8.14 Briquetted polyurethane foam (Japan)

Television glass types were processed through a crusher and despatched as cullet.

Some plants were further developing plastic separation by type, predominantly by specific gravity or flotation, or a combination of both. Polymer separation by type appeared to be the next important issue to the processing companies, if not in-house by other processing plants.

Summary

A great deal can be learnt from the systems used in Japan, although much of the workings are dependent on Japanese culture and would not transplant to the UK or Europe. The many experiences and developments made by such a well-organised culture and people would transfer into the UK as genuine cost savings in logistics and processing and – particularly so – to the value added to the material due to manual disassembly. Markets for these materials require quality and quantity; the 'Japanese system' seems to increase quality without affecting quantity.

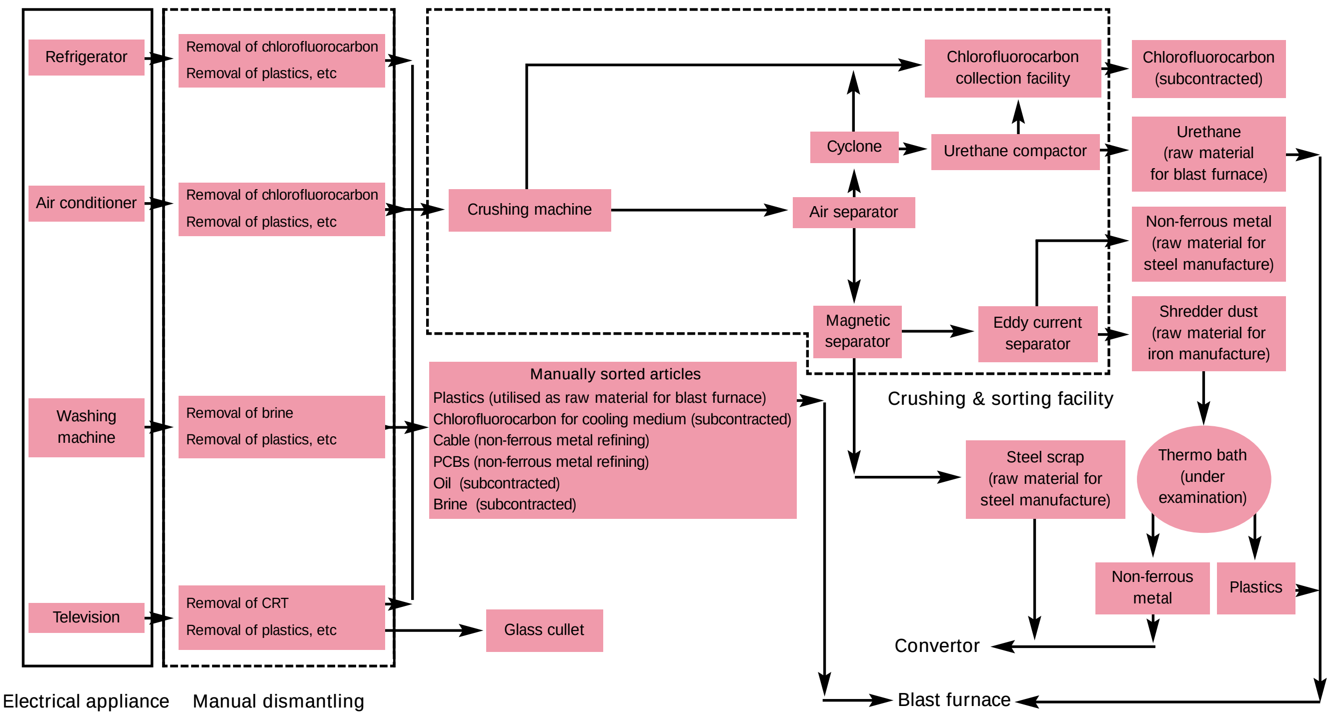

Exhibit 8.15 A précis of 'The Japanese System' (source: www.jfe-steel.co.jp/archives/en/nkk_giho/ 85/pdf/85_09.pdf)

9 PRODUCT DISASSEMBLY

The mission to Japan was to take an overview of electronics recycling technologies and report back on any new or developing technologies that may be of any interest to UK companies. Of particular interest was the plastics recycling and reuse element.

Despite preconception before the mission, the level of product disassembly found in Japan is similar to that seem in the UK at places such as the Hampshire Trust recycling site in Portsmouth. The difference is in scale and efficiency. The majority of disassembly is manual on a production line basis, looking much like an assembly plant in reverse. Dedicated lines for each major HARL item are standard, and segregation of the incoming 'product' by both type and manufacturer is obviously a very significant advantage.

In general the 'good quality' of the returned goods was apparent, with no evidence of the UK policy of 'compacting' WEEE goods into skips. There was no evidence of post-consumer damage that is common in the UK waste stream. This is patently a product of the manufacturer 'take-back' system previously mentioned, reinforced by cultural attitudes towards cleanliness, recycling and protecting the environment. Whether this attitude is extended to post-consumer goods not falling under the HARL legislation was difficult to gauge as the mission did not see any, other than small quantities of PCs being recycled.

The main 'novel' investment in the recycling centres seemed to be in avoiding manual handling by the use of air lifts and motorised conveyors but this was by no means universal and the whole process still involved a very high degree of manual labour.

Unlike the assembly plants for these goods there was no evidence of robotic dismantling, the nearest to it being the near universal hot-wire machine to separate funnel and tube glass of televisions.

Easy-release technology – smart disassembly

The mission team were also looking at emerging technologies and development of current and newly implemented technologies such as active disassembly (AD). This is a method of disassembling products into their separate components, and is a significant step towards meeting of WEEE requirements by manufacturers. Any singular or combined use of specifically engineered and smart materials, adhesives, layers and parts, integral or discrete, plays a key role within AD. It allows for a cleaner, nondestructive, quicker and more efficient method of component separation. The term ADSM (active disassembly using smart materials) is therefore synonymous with AD. Robotics can also be used within AD and is referred to as 'automatic disassembly'.

The mission visited all major manufacturers in the electronics industry such as Panasonic, Sony, Hitachi and Sharp, and asked whether AD technology was being considered for implementation within their product range. All except Sharp said that they had no interest in the technology. Although this may be true it also may be because the topic is commercially sensitive. Sharp's development – 'easy-release technology' – is being implemented in one of its products.

A video was shown of a shape-memory alloy washer being used on a screw fixing for a battery casing. Immersion in boiling water caused the split c-washer to expand and release the screw fixing. This has great potential for the rapid dismantling of appliances using heat instead of manual labour and shredding machinery. However, it was apparent that this was not in common usage and was not seen in the post-consumer goods being recycled. Subsequent intelligence in the UK has indicated that the technique is also being used by Sharp in some of its LCD screen manufacturing, but again probably only in high-value items.

The product they revealed to us that was in trial mass production was a mains charger for a mobile phone; the units were being produced in Poland. However, having seen the presentation they gave to us it is evident that they may well be using this technology in LCD flat panels for televisions.

The AD technology used was in the form of 'shape-memory washers'. Shape-memory materials can be polymers or metal alloys. Such a material is manufactured to hold a set shape until it is taken to a trigger temperature, at which point it adopts a second set shape. When the product needs to be disassembled it can usually be heated or cooled. At this point the snap-fit will automatically transform to allow release. Trigger temperatures can be set to a fairly accurate range of values. However, in the literature other means of triggering the disassembly through microwave, infrared, pressure, sound, electric current or magnetic fields have also been studied.

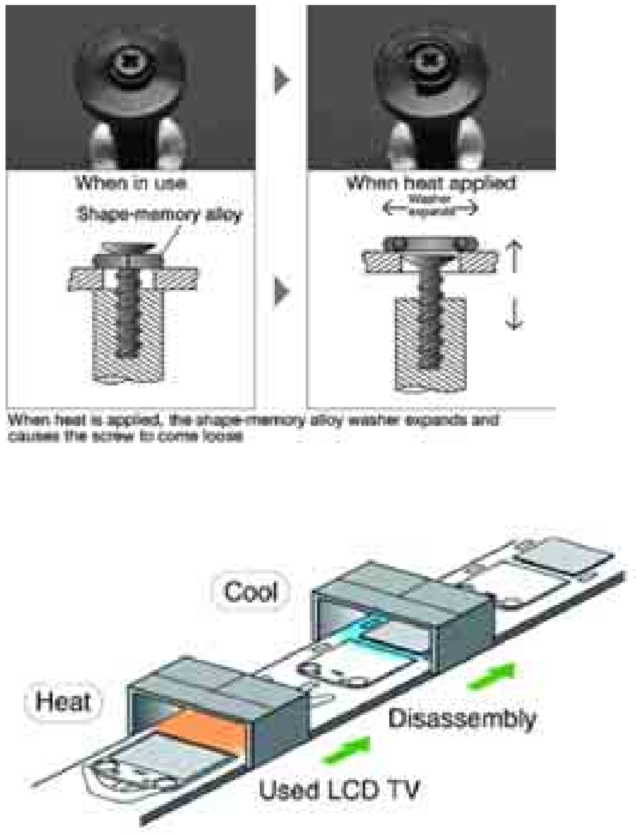

Exhibit 9.1 Shape-memory washer and example of disassembly system (courtesy Sharp)

Exhibit 9.1 is an example of the shape-memory washer being used by Sharp and an example of the system that the EoL product will pass though to be disassembled, this illustration showing a temperature model which triggers the disassembly process. It will be interesting to see how EoL products that have this technology built in are dealt with. The recycling market will have to evolve to deal with this new challenge.

10 MATERIALS RECOVERY AND MARKETS

10.1 Plastics recycling

The majority of plastics recycling information came from a presentation by Mr Kamaguchi of Sharp who was extremely knowledgeable and helpful.

Plastics account for 20-40% of the mass processed but over 50% of the volume. Japan estimates that the disposal volume of electrical waste will increase 1.4 times by 2010, and landfill space will be exhausted by 2008.

Quantities of plastics arising from electrical and electronic (E&E) waste appliances in Japan are estimated as:

- HARL appliances 150,000 t/y
- Photocopiers 15,000 t/y
- PCs >10,000 t/y

Sharp presented a summary of available recycling routes for plastics (Exhibit 10.1).

In order to build a sustainable, reuse society, it is necessary to promote self-recycling materials as much as possible – using the closed material recycling (CMR) route.

Open material recycling often leads to only one reuse cycle before eventual disposal to landfill.

An explanation was given of the many factors that could lead to degradation of material properties during the lifetime of a plastic component (Exhibit 10.2).

Sharp has developed a way to analyse the antioxidant level in the recovered material, and conjectures that antioxidant is ‘consumed’ during the lifetime of a plastic component. When the level drops below a threshold level (~100 ppm) then the material properties begin to tail off rapidly as molecular degradation occurs. It is possible to revitalise the lifetime of polymers by adding more antioxidant to the resin before re-extruding (Exhibit 10.3).

The inclusion of foreign bodies in the polymer matrix also leads to a reduction in material strength due to stress concentration effects (as measured by the Izod impact strength test). This problem was being overcome by improved washing methods and the use of melt filtration to minimise the level of foreign parts.

Closed material recycling (CMR)	Reuse as plastic parts in E&E goods
Open material recycling	Reuse for other plastic goods
Chemical recycling	Pyrolysis, or breakdown to monomer
Thermal	Incineration and combustion

Exhibit 10.1 Classification of plastics recycling (courtesy Sharp)

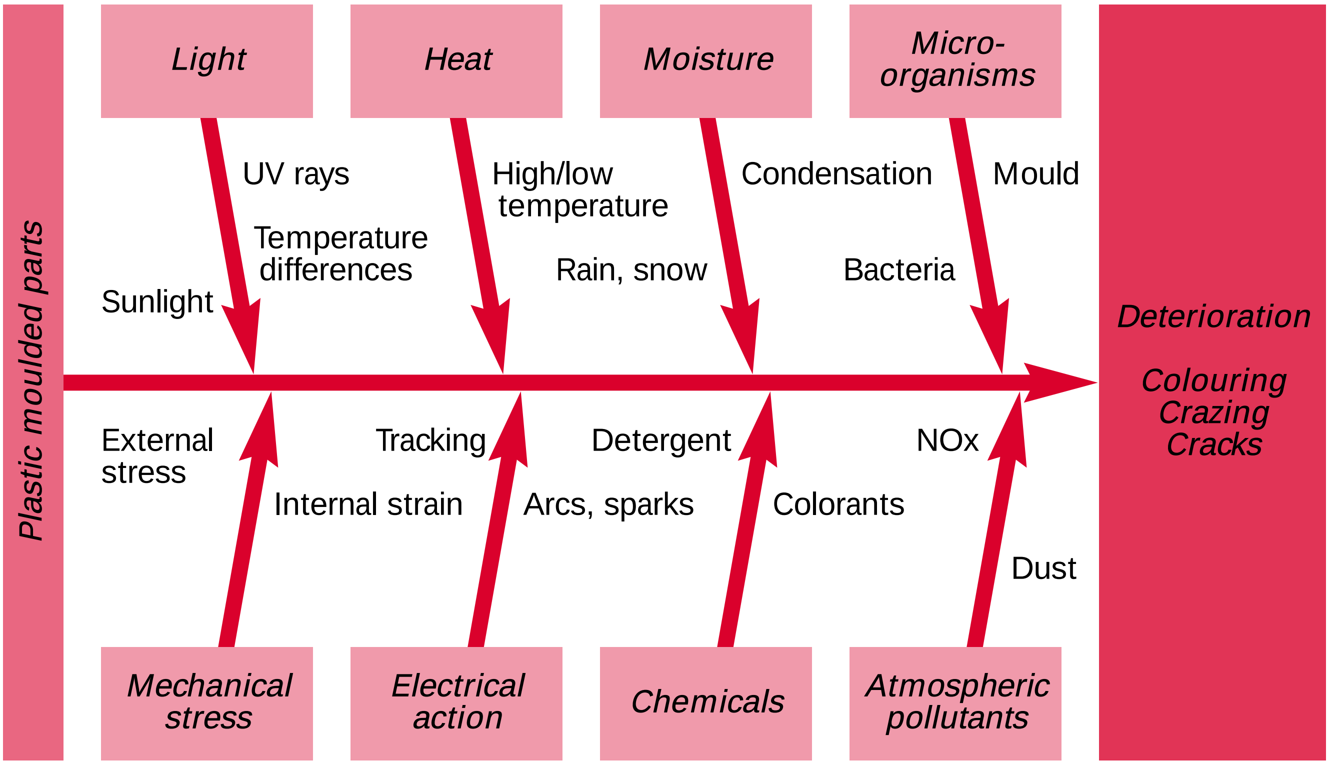

Exhibit 10.2 Factors leading to degradation of plastics (courtesy Sharp)

Deterioration characteristics

1 When the antioxidant concentration drops below the threshold value (~100 ppm or ‘C’), the properties of the plastics decline abruptly

2 The remaining life of plastics in the wasted products ranges from B to C

3 To use the plastics as raw material for new products, their life must be improved up to point A

4 It is crucial to develop technology for evaluating remaining life and improving life

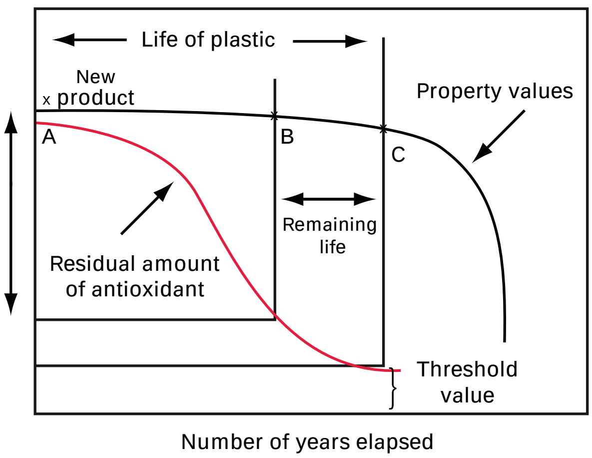

Exhibit 10.3 Plastic deterioration characteristics (courtesy Sharp)

An example was given of the CMR route for the polypropylene (PP) material from recovered washing machine drums. The part to be recycled is first carefully separated from the machine and other parts (eg a hydraulic hub-puller was used for drive-motor removal). Sharp showed a video clip of the closed-loop recycling process for this material, illustrating:

- Drum disassembly method
- Initial cleaning of adhered dirt/residues/labels
- Shredding on site – down to ~10 mm chips
- Water washing in vertical rotary friction washer
- Drying with rotary dryer unit
- Analysis to determine the degree of antioxidant in the recyclate chips – as the basis to evaluate remaining lifetime of the polymer
- Mixing with antioxidant additive (in tumble mixer)
- Melt filtration in extruder
- Pellet forming in water bath system

Finished plastic pellets are reused to make large parts for Sharp products (eg condenser cover plate for rear of A/C unit, or fridge back cover tray). Product moulding examples shown were 100% recycled resin. Sharp has utilised 420 t of recovered plastic in closed-loop applications in the four HARL product types in 2004. It has set a target of 500 t in 2005 (estimated at around 7-10% of plant annual tonnage, if all from the Osaka plant).

Plastic recycling rates

The data collected centrally by METI for the overall recycling rate in Japan show the level of plastics found in disposed items in comparison to the target recycling rates for each HARL product. The estimated fraction of plastic by mass in the four product streams compared with the recycling target is shown in Exhibit 10.4.

A set of pie charts by METI analysing the material types actually recycled for each product group has very small sections dedicated to 'other valuable materials' (estimated at 2-10% by mass). This material grouping is stated to include *'printed circuit boards and other plastics'*.

At several of the sites visited by the mission the companies were claiming much higher levels of actual recycling (eg 80-95%) than the target figures. These higher levels can only be claimed if a high proportion of the plastics content is being recycled (or recovered).

For example, at Sony's Green Cycle centre the quoted recycling rates for 2004 were:

- Air conditioner 91.4%
- Television 92.9%
- Refrigerator 81.5%
- Washing machine 89.5%

Product	Plastic fraction in each item	Recycling target	Recycling rate reported 2003
Air conditioner	17.5%	60%	81%
Television	16.2%	55%	78%
Refrigerator	43.4% (inc foam)	50%	63%
Washing machine	34.7%	50%	65%

Exhibit 10.4 Estimated plastic fraction by mass in HARL product streams (courtesy METI)

At Hitachi's Tokyo Eco Recycle, Dr Kenji Baba quoted a recycling rate of 98% (although the average was stated as 70% elsewhere in the presentation).

The measurement of the recycling rate must be analysed to understand this information. It is clear that the individual companies are including thermal recycling of mixed waste plastics – and also urethane foam used as refuse-derived fuel (RDF) – in their in-house figures. This would not count towards recycling in the UK.

The sites visited by the mission were also likely to be the 'showcase' establishments for each company. As the larger firms operate several recycling centres, there is likely to be a reduced recycling rate at the sites where less advanced technology is being applied.

Recycling techniques

All the sites visited were employing manual dismantling to remove hazardous materials (mostly CFC refrigerants; CRTs) and any large components such as drive motors or washing machine drums. These large components were being separately collected for recycling with an emphasis being placed upon good quality of strip-down to give a high purity of the recycled material.

The type of plastic components seen to be removed were:

- Washing machine drums – PP
- Large moulded bases and covers for washing machines – acrylonitrile-butadiene-styrene (ABS)
- Fridge trays and vegetable boxes – polystyrene (PS) or PP
- TV casings and back covers – PS or PP
- Air conditioners – covers and fans

In most instances there was an emphasis on collection of clean components, with effort being seen to remove labels and adhered dirt. Similar plastic types were collected together and then diverted to dedicated shredding machines to reduce the polymer to ~10 mm chips. This material was then sent off-site for further processing.

TV casings were being removed at all sites, but there was no visual evidence of at-line analysis of polymer type or any attempt to stream the casings by brominated flame-retardant content. It was stated at two companies that up to 60% of the TV casings *do* contain brominated additives. This means that the shredded plastic from this particular stream is finding its way into lower-grade applications in non-E&E goods.

Of particular note was the use of brominated plastic generated from the Hitachi plant. An example of using the brominated content to provide flame-retardant benefits was seen in the production of a cable-tray conduit used for the laying of power cables alongside railway lines. This is a durable product application where the flame-retardant properties are of continued lifelong benefit.

However, in most cases the quantity of plastic being manually removed from the four product types was observed to be fairly low in relation to the total plastic content of the items. This means that a large proportion of the plastic is only released for recycling in the downstream bulk shredding process.

Most sites were using a similar format of vertical shredder to size-reduce the stripped bodies or casings. It was judged that heavy, dense components such as drive motors were being manually removed prior to shredding in order to reduce wear on the equipment.

All plants were operating some form of air classifier or dust blower to remove the urethane foam and other dirt post-shredding. This was then followed by metal recovery using magnetic and eddy-current equipment. In the majority of plants the residual stream was a mixed plastic material in the form of 5-10 mm shredded chips (Exhibit 10.5). When questioned it was clear that this polymer mix was being sent for thermal recovery via incineration or as reducing agent at blast furnaces.

There were only two sites where some effort was being made to separate the polymer types from the bulk stream:

- METEC – the fridge plastic was fed into a density separation line that included a high-g spinning disc water cyclone to generate a good split between the PP and PS materials. It was stated that PVC was also being removed, possibly using a high density solution method.
- Sony – some form of sink float facility was in operation to wash and remove PP material (although the final product appeared visually of low quality).

METEC also had a screened-off section of the plant where further plastics separation technology was under development. In the development laboratory the mission team were shown samples of high-purity plastic which were stated to have positive value for reuse applications.

In all cases it was difficult to make an accurate assessment of the continuous processing systems because they were mostly enclosed in soundproof rooms or only able to be viewed from remote galleries.

10.2 Glass recycling

Simple, manual CRT removal was being applied at most of the sites. Effort was made to scrape off labels and excess dirt. The X-ray tube was being manually removed from the CRT cone either with a disc grinder or by using a file and breaker tube. Minimal concern was given to the release of phosphor powders, with one site pouring some water into the open hole of the CRT and another applying some sticky tape.

Exhibit 10.5 Residual mixed plastic chips

Stripped down CRTs were being stacked in cages with blankets to prevent breakage at most sites. These cages were then shipped to another site for glass recovery.

Only at METEC did the mission observe a system for CRT splitting. This utilised an in-house design of hot-wire cutter as follows:

- The CRT (less X-ray tube) was fitted onto the cutting jig
- A camera device raised the tube up to the level of the frit (weld) between the cone and the face glass
- A glass cutter arm made a score mark on the tube as it was rotated, at a level 10 mm from the frit join
- A hot-wire band about 3 mm thick was wound around the tube and heat applied to cause a break on the score line
- After lifting off the cone section and metal shield, a manual vacuum brush was used to remove the phosphor coating

This type of technology has been further developed and is now available commercially across Europe from a range of equipment suppliers.

Sony mentioned a process to clean the CRT glass which was able to grind off the graphite coating from the cone glass, but this was at a remote site.

It was commonly stated that CRT glass was being used to manufacture new CRTs, although with the TV market becoming dominated by LCDs and flat screens this may not be sustainable.

LCD recycling

No LCD TV equipment was seen coming into the recycling plants, which is strange because there must be some broken units entering the waste stream. It can only be assumed that as they do not strictly conform as a HARL product no legal recycling is required.

We saw a large plasma screen stripped down for assessment in the METEC development laboratory, and Sharp mentioned some work on LCD recycling and indium recovery.

Some laptop LCD displays were separately stored at both Sony and Hitachi, with some care being taken to remove the halogen back lights. On questioning we were told they were destined for incineration. Clearly the mercury content was a problem.

10.3 Metal recycling

No novel metal recovery technologies were seen at any location, with the usual separation techniques of magnetic, Foucault and eddy-current separation being used. Clearly density separation used to upgrade the plastic fraction produced a metal-rich contaminated plastic stream.

As some of the major manufacturers in each Group have metal production facilities (eg Mitsubishi), the bulk of novel separation may be done elsewhere. Thermal recoveries of the various fractions were mentioned at various sites. These included secondary aluminium smelter, primary iron and steel with a recycled element and copper refineries used to recover the precious metal group (PMG) from the associated copper fraction.

As with the plastics fractions, CMR of the various metals was considered desirable, and clearly this is in fact easier with metals than plastics in any case. As many of the companies involved have interests in other consumer goods, in the transport sector and other manufacturing, finding a friendly partner willing to reuse ‘recycled waste material’ is obviously easier than in the UK and Europe.

On a less obvious note, culturally there seems to be no particular barrier to reusing materials from waste in manufacturing new products, unlike the UK and continental Europe. Recycling appears ingrained in the Japanese psyche and consequently there is a natural expectation that products will have a high proportion of recycled material. The debate about ‘when is a waste not a waste’ does not seem to arise in Japan.

The four HARL items contain a number of differing metals that can be recovered; however, the metals need to be separated taking into account the depollution concerns and the economic element as well during the disassembly phase.

The mission was shown how differing metals were physically separated from plastics as far as economically possible. However, there are occasions where a particular component of plastic is bonded to the metal and it would not make economic sense to separate these parts. An example is a washing machine circuit board which is encased, or ‘potted’, in clear plastic so as to eliminate short circuits.

The main parts of all four machines are separated prior to crushing or shredding, the main metals recovered from each machine being as follows:

- Washing machine: steel, aluminium, copper
- Television: steel, copper
- Air conditioner: steel, copper, aluminium, cast iron
- Fridge: steel, copper, aluminium

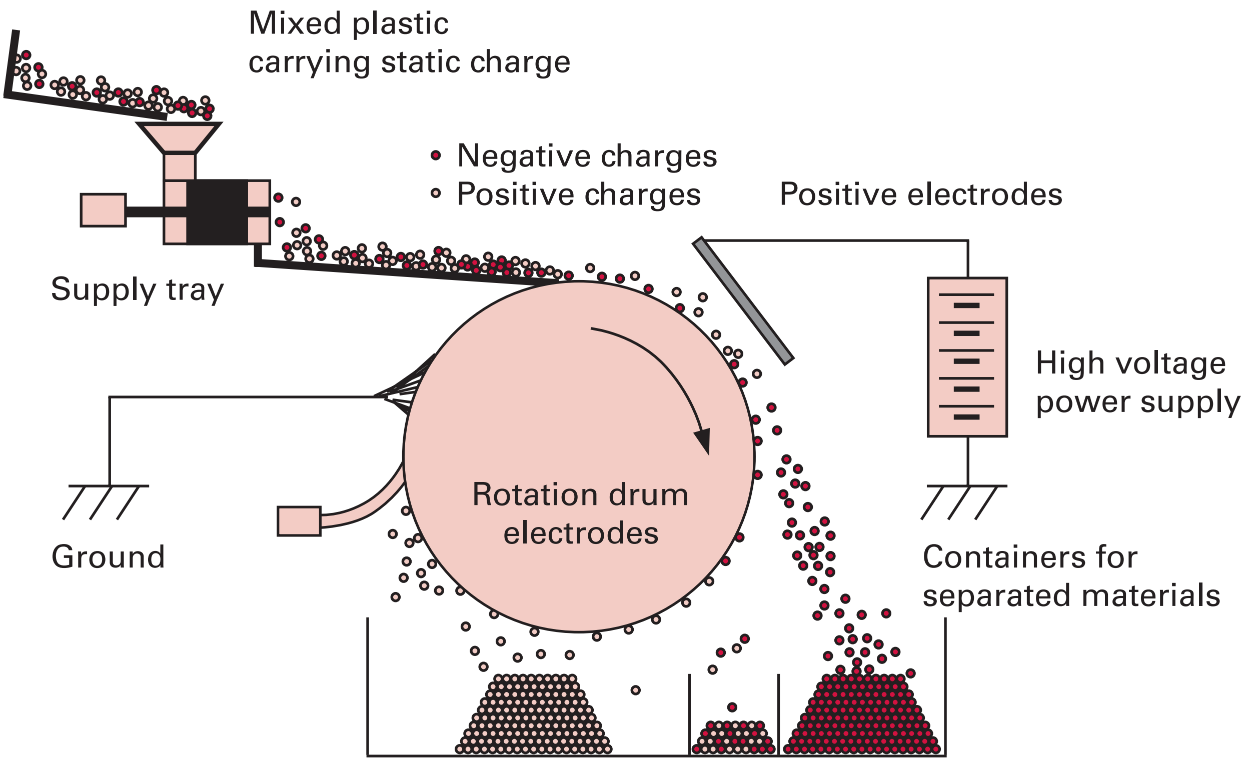

Exhibit 10.6 Rotating drum (eddy current) metal separator

The above metals are separated as they emerge from the crushing/shredding process and are separated further by varying means as described above.

Exhibit 10.6 is an illustration of eddy-current separation for ferrous and nonferrous metals; this ensures that the material collected is of a uniform standard.

Only one company visited dealt with EoL PCBs and that was the Green Cycle Corporation (Sony). All other sites visited sent the PCBs directly to smelters for metal recovery. It can only be assumed that Green Cycle has as one of its stakeholders a smelter which can absorb the cost as it is kept in 'the family'.

Tokyo Eco Recycle even went as far as using specialised equipment (Exhibit 10.7) to pulverise and reduce the amount of plastic covering, delivering a higher-grade metal waste.

Ferrous wastes from casings of washing machines and air conditioner units along with straps from televisions were reduced to ~30 mm pieces and then sent to steel producers for processing into new material.

Compressors from fridges are normally kept separate as they are drained of oil, sent for shredding, and then collected with all the other ferrous metals.

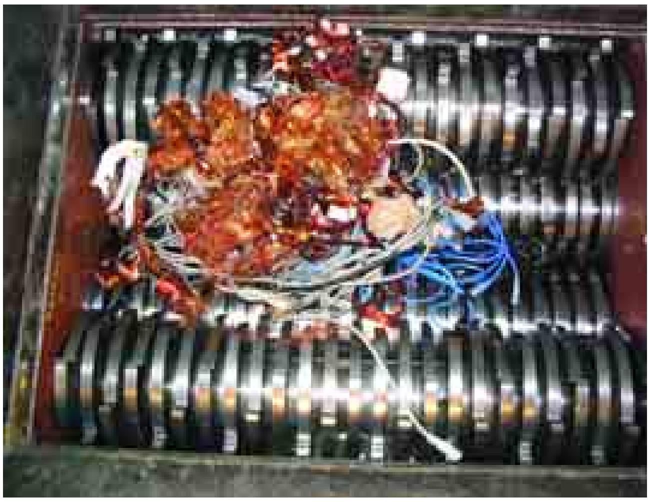

Exhibit 10.7 Shredder (courtesy Tokyo Eco Recycle)

11 FUTURE TRENDS

LCD recycling

A brief summary was given of Sharp's work in the recycling technology for LCD screens. They have developed guidelines for the safe removal of mercury backlights and removal of the liquid crystal material. They appear to be working on a method to remove indium from LCD glass by acid dissolution, but details were limited. The future goal is to reach 100% recycling of LCD TV sets.

Plant-based plastics mixing with PP recyclates

Use of plant-based polymers is increasing in Japan; examples were shown of a Walkman casing made from polylactide (PLA).

Sharp has worked on recycling of plant-based plastics mixed with PP. This gave a problem due to the noncompatible nature of the two materials (one plant-based, one mineral-based). Sharp has developed a compatibliser chemical (a copolymer chain molecule of polyester-PLA-polyester) that made the 'particles' of PLA disperse into the PP matrix. This caused a large improvement in the strength of the polymer.

Sharp predicts a large increase in the use of plant-based materials, and these will need to be compatible with mineral-based polymers for ease of future recycling.

12 MISSION FINDINGS

Overview of government, academic and legislative drivers

There is a clear goal to progress home appliance and other electronics recycling within Japan. One of the key reasons is that Japan will run out of landfill in the near future – however, this needs further investigation due to conflicting information (eg some companies quoting the year 2008 and some giving 13.1 years of landfill from 2002). Municipal solid waste (MSW) treatment methods are heavily skewed to incineration (78.4%) with recycling (17.3%) and landfill (4.3%) coming in second and third place[6] and with home appliances representing only 2% of MSW[7]. Other motivations for accelerating recycling of home appliance and other electronics include advanced knowledge development relative to Europe and North America and ultimately medium/longer-term competitive advantage.

'The Japanese System' gave Japanese companies the confidence and certainty in the late nineties to make investment decisions to build recycling plants and infrastructure, eg on the basis that the Home Appliance Recycling Law (HARL) was implemented as planned in 2001. In addition, the requirement that consumers must pay a primary logistics fee and a recycling fee has meant that there is a guaranteed and predictable income for the corporate owners of the recycling plants. However, the actual economics of the recycling plants are not entirely clear, eg some recycling plants seem to have received capital and other grants from government. It appears that most of the recycling plants were set up as pilots from 1999 and came on stream from 2001, therefore allowing problems to be sorted out before coming into full operation.

There seems to be between 42 and 50 recycling plants focused on HARL requirements (depending on company definition) – and these are split between the A and B Groups (quoted as 30 in Group A, 16 in Group B and three jointly owned). The exact number, geographical distribution and types of recycling plants are slightly unclear as they appear to depend on definition. There also appears to be 380 take-back sites, 190 controlled by Group A and 190 controlled by Group B[6].

Ministry of Economy, Trade and Industry (METI) statistics indicate that the recycling rates for the four product categories covered by HARL

Appliance type	Recycling target (HARL)	Actual recycling rate (2004)
Air conditioner	60%	82%
Television	55%	81%
Refrigerator	50%	64%
Washing machine	50%	68%

Exhibit 12.1 HARL recycling targets and actual rates, 2004 (source: Mitsubishi presentation, 2005)

6 Ministry of Environment (2002) in British Embassy presentation (2005)

7 Ministry of Economy, Trade & Industry (METI) (undated) in British Embassy presentation (2005)

(televisions, washing machines, air conditioners and refrigerators) are being overachieved as a result of the 'buy-in' from all key stakeholders in Japan, ie consumers, industry and government. It should be noted that the Japanese define the recycling rate as 'weight of materials recycled' divided by 'weight of unit treated'[6].

In the five recycling plants visited (Matsushita Eco Technology Centre – METEC (Matsushita), Hyper Cycle Systems Corporation (Mitsubishi Electric), Kansai Recycle Systems (Sharp), Green Cycle Corporation (Sony) and Tokyo Eco Recycle (Hitachi)) much of the technology used seems to be low tech, similar and with a high labour content, eg manual disassembly. Many of the recycling plants seem to be using their own technologies with several stating that they had patented particular processes.

Green Cycle Corporation (Sony) and Tokyo Eco Recycle (Hitachi) seem to be at arm's length from their mother companies, ie they are contractors, with their own profit and loss and balance sheet responsibilities, whereas METEC (Matsushita) gave the impression of being more closely linked to the corporate body.

The ownership of each recycling plant seems to be dominated by one key shareholder with financial contributions from other members of either Group A or B, dependent on which Group the recycling plant belongs to.

The Law for Promotion of Effective Utilisation of Resources (LPEUR) was also passed in 2001 and seems to have much broader remit by product category and coverage, eg it covers both eco-design and recycling. For example, since April 2001 computer manufacturers have been required to design products that consider the 3Rs (reduce, reuse, recycle) and are also obliged to collect and recycle end-of-life (EoL) computers from business. Manufacturers have also been required to collect and recycle computers discharged from households since October 2003. The details and obligations of LPEUR were not highlighted by any of the companies visited and this is an area that needs further investigation especially in relation to computers and mobile phone recycling (British Embassy presentation (2005)).

A key learning is that – in effect – the owners of the recycling plants have had approximately six years' experience of running the 'recycling systems' for televisions, air conditioners, washing machines and fridges. This 'recycling system' includes, for example, the collection, logistics, storage, sorting and recycling involving a range of different stakeholders, eg consumers, retailers, the Post Office, manufacturers, logistics companies and recyclers. Therefore the key lead that the Japanese have is the *knowledge* and information on how to design, develop and run recycling systems, infrastructure and plants focused on these product categories. They would interpret this as their 'intellectual property' (IP) which they could offer to UK alliances and joint ventures (JVs).

There was evidence of advances of eco-design, eg 'design for disassembly' (Hitachi) and use of 'automated disassembly used smart materials' (ADSM) for a battery charger (Sharp). Subsequent research would also indicate that Sharp is using similar techniques in the latest flat-panel TVs. Hitachi mentioned that Toshiba was also developing similar software, although this was not covered in the Toshiba visit. Hitachi also highlighted the problem that mainstream design engineers are not always *au fait* with environmental considerations and the challenge of producing tools for non-specialists, eg design engineers generally do not have the time or primary motivation to be environmental experts, therefore they need simple tools and rules to help with decision-making. For further information see the eco-design mission report[8].

8 *The 'state of the art' in eco-design in the Japanese electronics sector*, final report, 1 November 2002, published for DTI by the Centre for Sustainable Design (CfSD) at Surrey Institute of Art & Design, University College

There was evidence at Tokyo Eco Recycle that some waste products were being converted into *green* products to sell to government in relation to the requirements of the Green Purchasing Law (also passed in 2001).

It appeared that only METEC is systematically passing new products through a test recycling system. Green Cycle and Tokyo Eco Recycle both implied that they would be keen to do such testing for a fee, but it was not happening on a continuous basis.

It appears that the METEC facility is a demonstration plant with a very strong emphasis on education and communications. In a similar vein, Tokyo Eco Recycle seems to be developing a model with a strong focus on producing high quality, real-time management information possibly as a focus for the development of a software simulation program.

13 CONCLUSIONS

Japan's household appliance recycling regulations and the framework in which they operate sit in stark contrast to the UK's dysfunctional approach to the application of waste-related legislation. The Japanese have the advantage of being able to set their own timetable and structure without the constraints of Europe that the UK has to operate within; nevertheless, there would seem to be clear lessons that the UK could learn from the Japanese approach:

1. **Coordinate government departments.** There appears to be an acceptance amongst government departments of their own roles within legislative development with strong support appearing to be given to lead departments.
2. **Industry input.** There appears to be a much closer working relationship between government departments and the relevant industries when it comes to creating legislation.
3. **Timetables.** The government would seem to be able to set a clear timetable for implementation that gives industry the knowledge and certainty to invest in the necessary infrastructure.
4. **Clear strategic aims.** There appears to be a well coordinated long-term strategic plan in place that avoids reactive knee-jerk policies and gives all stakeholders an overarching understanding of their roles.

It was clear that Japanese society is not so cost driven as the UK and that they seem prepared to overinvest in order to get it right, a culture that seems to extend throughout Japanese society. Whether that can continue, of course, remains to be seen but it was certainly refreshing to see a system that seemed more concerned about where it was going than about how cheaply it could get there.

Plastics technology

In general, the level of plastics recycling technology being employed was not thought to be of a particularly novel or innovative standard. The exceptions to this were the excellent re-compounding work seen at Sharp and the mechanical hydrocyclone displayed at METEC.

Manual dismantling to recover large components of a single, easily identified polymer type was being applied in all plants, although with varying degrees of diligence. The plastic parts seen being removed manually will probably account for less than 10% of the total item mass.

The four products included under HARL are relatively low in plastic content compared with smaller household goods that fall under the UK legislation. Application of well-proven metal recovery methods and CRT glass recycling is able to deliver the majority of the recycling rate needed to achieve the Japanese targets on these four appliances. In addition, inclusion of thermal recovery (incineration) as part of the in-house recycling rate calculation makes it possible for individual sites to state very high material recovery rates.

Appendix A

ACKNOWLEDGMENTS

The mission team would like to express their sincere thanks to the many individuals and bodies that made this mission possible:

- The Mini-Waste Faraday Partnership, now the Resource Efficiency Knowledge Transfer Network, which acted as the principal coordinating body
- The DTI Global Watch Service, particularly David Thompson, for providing financial support and advice
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- Mr Kakuchi our translator, guide and 'minder' who kept us to our schedule, ensured we were always at the right place at the right time, and advised on matters of protocol in addition to faultless translation when required
- The DTI International Technology Promoter (ITP) network, particularly the ITP for Environmental and Sustainable Energy Technologies in Japan, David Scott
- All the individuals and companies the team visited who were extremely open and helpful in making themselves available to answer our questions and show us round their facilities

Exhibit A.1 Mr Kakuchi – translator, guide and 'minder'

Appendix B

MISSION TEAM DETAILS

Exhibit B.1 The mission team at Tokyo Eco Recycle; L to R: Mr Kakuchi (translator), Martin Charter, Martin Goosey, Keith Freegard, Peter Murphy, Arnold Black, Stuart Randall, David Scott, Ryozo Tanaka (Senior S&T Officer, British Embassy Tokyo) (Phil Conran is missing from the picture because he was taking the photo!)

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Arnold is a project manager with 20 years' experience in the heavy industrial sectors of mining, chemical and waste treatment with multinational manufacturing and UK contracting companies. He has worked overseas on world-scale industrial plants and with UK manufacturing sites with hazardous chemicals and effluent treatment.

Arnold is Deputy Director and Technology Translator of the Mini-Waste Faraday Partnership and has extensive experience of technology auditing and knowledge transfer from academia into industry. From proof-of-concept to installation and commissioning with long-term operation experience, Arnold is a multidiscipline team manager with good commercial and technical skills.

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Martin is the Director and Visiting Professor in Sustainable Product Design at the Centre for Sustainable Design. Since 1988 he has worked at director level in 'business and environment' issues in consultancy, leisure, publishing, training, events and research. Martin has an MBA from Aston Business School, and has interests in sustainable product design, green(er) marketing, and creativity and innovation.

Martin presently directs a regional network on 'producer responsibility' issues related to the electronics sector and he is Editor of the Journal of Sustainable Product Design. He is a member of the advisory board of the CARE electronics network, and judges on the ACCA's sustainability reporting awards and SEEDA's Environmental Technology Taskforce. He is the author, editor and joint editor of various books and publications including *Managing Eco-design* (1997), *Sustainable Solutions* (2001) and *Sustainable Value* (2004).

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Dr Goosey is Chief Scientist and Technology Fellow at Rohm and Haas Electronic Materials Group's (formerly Shipley) European headquarters in Coventry where he has responsibility for environmental R&D activities.

A chemist by training with a PhD in microelectronics reliability, Martin has over 30 years' experience in the electronics industry. Prior to joining Shipley in 1992, he worked at Plessey's Caswell Research Laboratories. Martin also worked at the Morton Chemical Research Centre in Woodstock, Illinois, and immediately before joining Shipley was a Senior Manager with the Technology Marketing Division of the Welsh Development Agency.

Martin is a Chartered Scientist, a Chartered Chemist, a Fellow of the Royal Society of Chemistry, a Fellow of the Institute of Materials and a Fellow of the Institute of Circuit Technology. He is Vice Chairman of the European Institute of Printed Circuits and Chairman of Intellect's Environmental Working Group as well as being a member of several key organisations representing the interests of the UK printed circuit board industry.

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Peter has 30 years' experience in manufacturing. He joined the firm aged 19 and worked on the shop floor learning the trade which was a mixture of material components supply for the cutlery, agriculture and horticulture trades. Peter went on to set up a division of the company which made and sold a range of handmade knives and he was invited to some of the premier shows in the UK to exhibit and sell.

After trying to dispose of some personal mobile phones in an environmentally friendly way the idea of mobile phone recycling was conceived. Peter undertook research assisted by Environmental Business Network (Sheffield University) and found that the WEEE directive offered an excellent business opportunity and a chance to help the environment. Active Recycling was formed in July 2000 with the express intention of being a recycling company that could completely recycle a mobile phone with zero landfill.

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Phil Conran
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Phil began his professional life in the British Army and served for nearly 10 years before moving to a sales role at Marconi. He then became self-employed, setting up a security destruction and clinical waste business. In 1991 he joined Biffa Waste where he is responsible for the practical, cost-effective introduction of recycling into a number of municipal and commercial contracts, together with development of environmental initiatives.

It is expected that Biffa will be providing compliance services under the WEEE regulations including both administration of the compliance scheme and the collection and treatment of obligated WEEE. Phil is working on the development of the WEEE compliance scheme, and is currently a member of the government's Advisory Committee on Packaging.

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Stuart is a technical engineer with 27 years' experience in the industrial sectors of gas distribution, electrical and electronic equipment repair, refurbishment, recovery and recycling. He started his career aged 16 as an apprentice with British Gas, rising to Senior Technician for nonroutine operations.

Stuart changed direction in 1994 into R&D management and has subsequently designed and developed refrigeration-recycling processes and developed a novel closed-loop WEEE regulation plant. He acts as CEO for the WEEE Recycling Network.

Stuart is currently the Technical Director and Chairman of DARP Group, an international consultancy specialising in recycling technologies, and has extensive contacts in the UK, Japan and Germany in the recycling and waste management sectors.

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Keith trained with Unilever and has an MBA from Cranfield University. He has held operational and general management positions in two start-up companies and has led the development of a novel process for production of biodegradable packaging chips as a replacement for expanded polystyrene.

Keith founded Axion Recycling in 2001 to develop new projects in the waste recycling sector. Since then, Axion has delivered a SMART-funded practical study into the pyrolysis of mixed waste plastics to produce a hydrocarbon liquid fuel – 'plasoil' – and a great deal of self-funded R&D of novel plastic separation techniques. During this period the company has also carried out consultancy work in related systems.

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David is the DTI International Technology Promoter (ITP) for Japan covering Chemicals, Materials, Energy and Environment. His experience includes 10 years with the Osaka Gas Group in Japan and Europe covering R&D, business development and market analysis. He has also worked for British Gas and on university-based R&D projects funded by British Coal and BP. His other experience includes working in export management in manufacturing and consultancy in marketing and innovation.

DTI's global network of 22 ITPs covers a range of sectors:

- Environmental and sustainable energy technologies
- Information technology, electronics and communications
- Life sciences
- Performance engineering and materials

Appendix C

MISSION KEY QUESTIONS

General background

1. How many official recycling facilities are there in each group? Is the Matsushita Electric METEC a 'showcase facility' or are others being developed? How does it differ from the other waste facilities?

2. What is required to get facilities approved through the planning and land use laws?

3. How profitable are these recycling factories and what plans are there to commercialise, develop and export recycling technologies? What successes have there been in waste market development? For example, how many real products and businesses have been created?

4. How much DE-manufacturing, recycling and then RE-manufacturing is being carried out?

5. Is design for active disassembly (ADSM) starting to have an impact?

6. How are you building a 'recycling content' criterion in the general public perception and the public procurement programme? To what extent are you building recycled materials into products?

7. What plans does Japan have to start influencing other countries to move towards a 'closed loop' approach, eg China? If so, how are they going to do it?

Legislative issues

8. Is there a high-level, cross-ministerial group coordinating strategy?

9. How are the recycling systems associated with HARL working?

10. What are the longer-term plans on green procurement, driven by the Green Purchasing Law (GPL)?

11. Under the GPL how is Japan defining 'recycling'?

12. What monitoring techniques/technologies are being used to detect pollutants pre/post-processing and maintain compliance?

13. Are there any 'standards' for recycling? Is there a standard definition for WEEE? When is waste a waste and when does it become a 'raw material' again?

14. What funding opportunities are there in Japan to support this activity, either corporate, private venture capital or government schemes?

15. Do any of the recycling companies have any input into the design stage of the process?

16. Are any of the recycling companies accredited by manufacturers or undergo any training from them?

17. What is the view on the export of specific electronic goods to Third-World countries? Do you refurbish specific electronic goods like mobile phones for resale, or strip to reuse components?

18. What schemes are in place to handle the collection and logistics of transporting WEEE to reprocessing plants?

Specific materials questions

19 What advances have been made in shredder technologies?

20 What advances have been made in physical separations of batteries (and other toxic materials), metals (ferrous and nonferrous) and nonmetallics (plastics, ceramics, glass, rubber, etc)?

21 What activity is there in plastic and polymer recycling? What plastic recycling technology is currently being used? What technology is under development?

22 What activity is there in CRT glass recycling? What CRT glass recycling technology is currently being used? What technology is under development?

23 What activity is there in LCD recycling? What LCD recycling technology is currently being used? What technology is under development?

24 What activity is there in precious metal recycling? What precious metal recycling technology is currently being used? What technology is under development?

25 What activity is there in smart material recycling? What smart material recycling technology is currently being used? What technology is under development?

26 What activity is there in lead-free solder recycling? What lead-free solder recycling technology is currently being used? What technology is under development?

Appendix D

VISIT REPORTS

Contents

D.1 International Plastic Fair (IPF)

25 September 2005

On the Sunday preceding the mission some team members visited Japan IPF 2005. This was held at the Makuhari Messe Exhibition Centre (Tokyo) across eight halls during 24-28 September. In total some 396 exhibitors across 2,717 booths were listed and they were sectioned by halls into specific areas of technology and manufacturing.

The mission members were interested in some key questions which were broadly categorised as follows:

- How many companies are producing and/or supplying recycled plastics?
- Where is the recovered material coming from and in what form?
- Which materials and which markets are they supplying?
- What equipment and/or technologies are being used and where is it being supplied from?
- How many companies are trading partners within Japan and across Asia?
- To what extent are multinational organisations represented?

In the time available these were challenging questions to answer, and information was naturally limited to those companies the mission members were able to contact. Generally speaking the replies were of an unsatisfactory nature and therefore these issues merit more detailed investigation.

It was rapidly apparent that very few companies were actually supplying recycled or recovered plastics and even fewer were producing them. Some companies claimed to be in this market but actually were just offering a ‘compounding’ service, mainly to supply plastics of a uniform colour and quality. These companies were gaining most of their materials from virgin redundant feedstock such as offcuts. Off-spec materials were also being modified (mainly in product form and colour) and offered as low-grade raw materials for other products.

Exhibit D.1 The mission team visit the International Plastic Fair

The team failed to find anybody offering true recovered plastic materials from any kind of EoL recycling operations. After the visits of the following week it is clear that this material, limited though it is, is finding its way into the supply chain via a closed-loop route with the original manufacturers, *not* the open market.

Where recycled material was being supplied it was into similar areas as in the UK and Europe. Material substitution was the key market such as addition to virgin plastics and use in low-specification ‘green products’ such as plastic wood articles.

A vast array of equipment for plastic manufacture was available from many vendors, this being the bulk of the exhibitors. Broadly speaking, in the mission’s area of interest, the equipment comprised conventional compounding machines, extruders and shredders. There was evidence of the better known European machines being available through Japanese and other Asian franchises.

China was seen as a key market, and a number of Japanese companies either had JVs with Chinese companies and/or agency agreements. It was clear from the exhibition, and the formal visits during the following week, that Japan views China as an opportunity rather than a threat. The Japanese use China as a cheap manufacturing facility, compared to Japan, and a market for recycled materials. After a two-year embargo on exporting waste plastics to China (which had been seen as a dumping ground to allow Japanese companies to claim ‘recycling’ targets) the market has been opened up again. Now China is increasingly being used as a plastic recycling centre, labour being the main cost in recovering plastic materials from EoL products. Paradoxically China’s economic growth is also providing an indigenous Chinese market for recovered materials and driving material costs in Japan up.

A number of multinational companies were exhibiting at the exhibition, the majority of these being based in the USA or Germany. No UK companies were found in the listing although some UK agency suppliers were present on the biggest multinational stands.

More details about the exhibition are available on www.a-tex.co.jp/plastics

D.2 METI (Ministry of Economy, Trade & Industry)

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26 September 2005

The meeting opened with a presentation of a brochure *Towards a 3R Oriented Sustainable Society: Legislation and Trends*. This brochure was widely mentioned during the various mission meetings and forms most of the backbone of this mission report. Hard copies were kindly couriered to the UK for distribution at the mission dissemination event. An electronic version can be found on the METI website as a PDF in English.

Subsequent discussions with the group of METI officials all from the Department of Information and Communication Electronics established the following information.

The Ministry for the Environment is responsible for enforcing the HARL and LPEUR regulations and the results are monitored independently by another quasi-government organisation. These results and statistics are published annually by METI.

Despite the self-evident success of the HARL legislation, METI currently has no plans to extend the requirements to other appliances. These other appliances are covered by LPEUR (which does not appear to have any targets associated with it) and are handled by local prefectures much the same as in the UK; some charge for disposal, some don't. These recycling technologies are the standard crush, shred and bulk separation of metallics.

By common consent the next items that would be included in HARL would be PCs, with a focus being on B2B. Like the UK, mobile phones seem to be a special case and are recycled by the manufacturers to recover the PMG content.

It is essentially illegal to export non-working electronic appliances to China but some 'illegal activity' goes on. METI estimated that two million TVs and several million VCRs were illegally exported to China via middlemen in Singapore in 2004. Spot checks are carried out on suspicious consignments to discourage this trade.

General public awareness of HARL and other recycling activity is very high, around 80%, and the government does not consider it necessary to advertise to raise awareness. The level of recycling activity has significantly increased since HARL came into force, including increased recycling of non-HARL appliances. The next huge hurdle is analogue TVs when digital is enforced in 2011.

Local opposition to recycling plants is low as they tend to be located in remote locations. (When the mission later visited various sites, they did not appear to be in 'remote locations' – but that may just be down to the definition of rural/remote in Japan!)

Incineration of final recyclate is well accepted and there seems less opposition in Japan than in Europe, possibly as incinerators are seem as energy-from-waste (EfW) plants and Japan is very energy dependent.

PC recycling marking is in force as part of LPEUR and those with markings are collected for free by the Post Office and delivered to the manufacturers' recycling plants. In the case of unmarked products the consumer pays a fee. The idea is for a highly visible fee on new machines.

The HARL ticketing system is controlled by a quasi not-for-profit organisation called HAPA, which acts like a manufacturing trade association but seems to be under the ultimate control of the government. Disposal of old products in the absence of buying a new one is through the original vendor if known, otherwise through the ticketing system described in Chapter 7.

METI appears to be consulting with Japan's near neighbours on common strategy for the Pacific Rim but to date this has not really been on an official basis. Likewise, dialogue with the UK and EU has just started. This is being driven to some extent by EU legislation like RoHS which is having a very big impact on Japanese manufacturers.

Further information

More details can be found at the links:

www.meti.go.jp/policy/recycle

www.env.go.jp

D.3 Mitsubishi Electric Corporation – Hyper Cycle Systems

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Kazuyuki Iimura
Manager, Home Appliance Recycling Group
Business Development Group

Katsumi Fujisaki
Manager, Recycling
Business Development Group

26 September 2005

Headline information as presented by Takashi Hishi – President:

- Start of operation – 12 May 1999
- Capital build cost – £26 million equivalent
- Total site area – ~16,276 m^2
- Total floor area – ~13,447 m^2
- Transformer substation capacity – 1,550 kWh
- Treatment capacity – 1,050,000 units/y of electric home appliances (including Kyoto branch) + 400,000 units/y of office automation equipment
- No treatment by water or incineration
- Recycle of refrigerator insulation CFC
- ISO 14001 certification – April 2001

Mitsubishi Electric supports two JVs in Japan, this one in Higashihama and one in Kyoto.

The Higashihama plant does all HARL products except TVs plus some photocopiers and PCs. The Kyoto plant processes TVs as well. This is due to logistics as Mitsubishi originally manufactured TVs in the Kyoto region and could reuse the recycled glass.

Mitsubishi is particularly proud that the plant was built and commissioned *before* the HARL legislation came into force. It is also keen to promote its two new brand leaders, the 'Uni' and 'Eco' manufactured units using the 3R principles. The Uni (Universal) units have the minimum of 3R principles embedded in them while the Eco units are 'super green' – using 3R principles in the entire supply chain, manufacturing and delivery system – and are sold at a considerable premium because of this.

Mitsubishi analyses the take-back figures on a monthly basis; there are peaks in July and August for fridges and air conditioning units (unsurprisingly), while TVs peak in December. Both phenomena are driven by matched peaks in sales of new units. This ability to analyse take-back figures against new sales is clearly a marketing advantage for the OEM suppliers in Japan that would be impossible to emulate in the UK model. This analysis also allows them to predict labour requirements and move operators around at peak times as the different appliance inputs are out of phase.

Mitsubishi uses a horizontal self-recycling system as detailed in Exhibit D.2. As can be seen, disposal to landfill is clearly a very small fraction. It also claims to not incinerate any residuals. However, this is rather disingenuous as energy from waste is not classed as incineration nor when metal is recovered from ash! In addition, plastics used as a reluctant additive to the company's in-house smelting group Mitsubishi Steel also don't count.

However, Hyper Cycle Systems at Higashihama claims to recycle 99% pure PP and reuse all of it in new Mitsubishi products, which is significant. The high-precision plastic

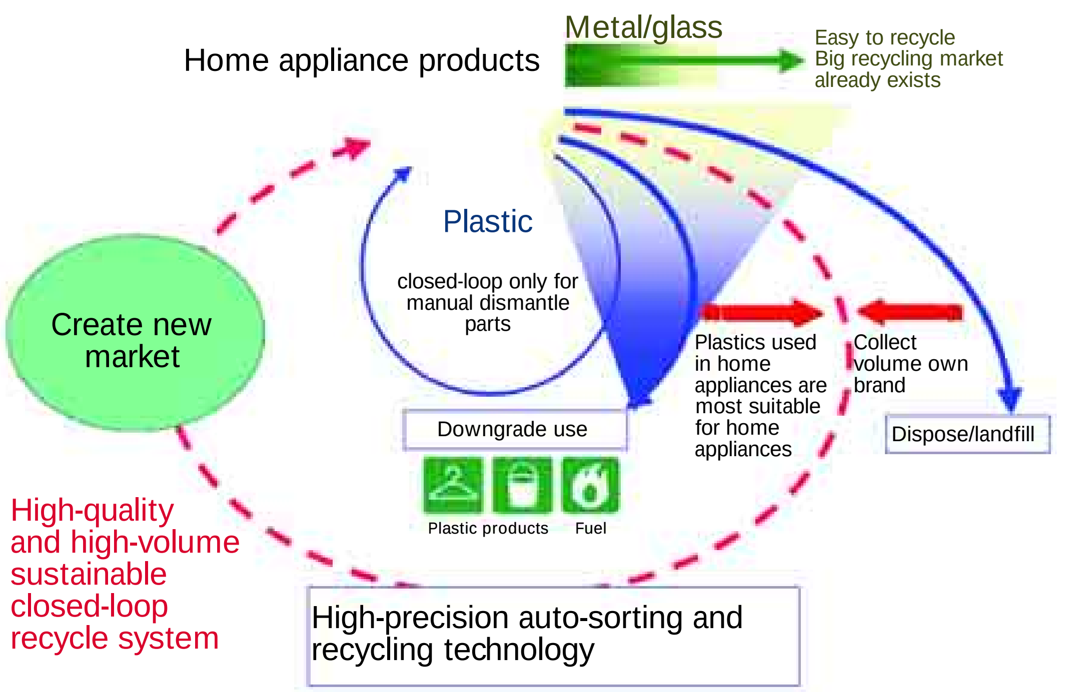

Exhibit D.2 Mitsubishi Electric's 'horizontal self-recycling' concept (courtesy Mitsubishi Electric)

recycling loop (Exhibit D.3) uses primary and secondary shredding followed by dry specific gravity and electrostatic induction charging to remove metals. The final two-stage process of electrostatic friction charging removes the PVC component.

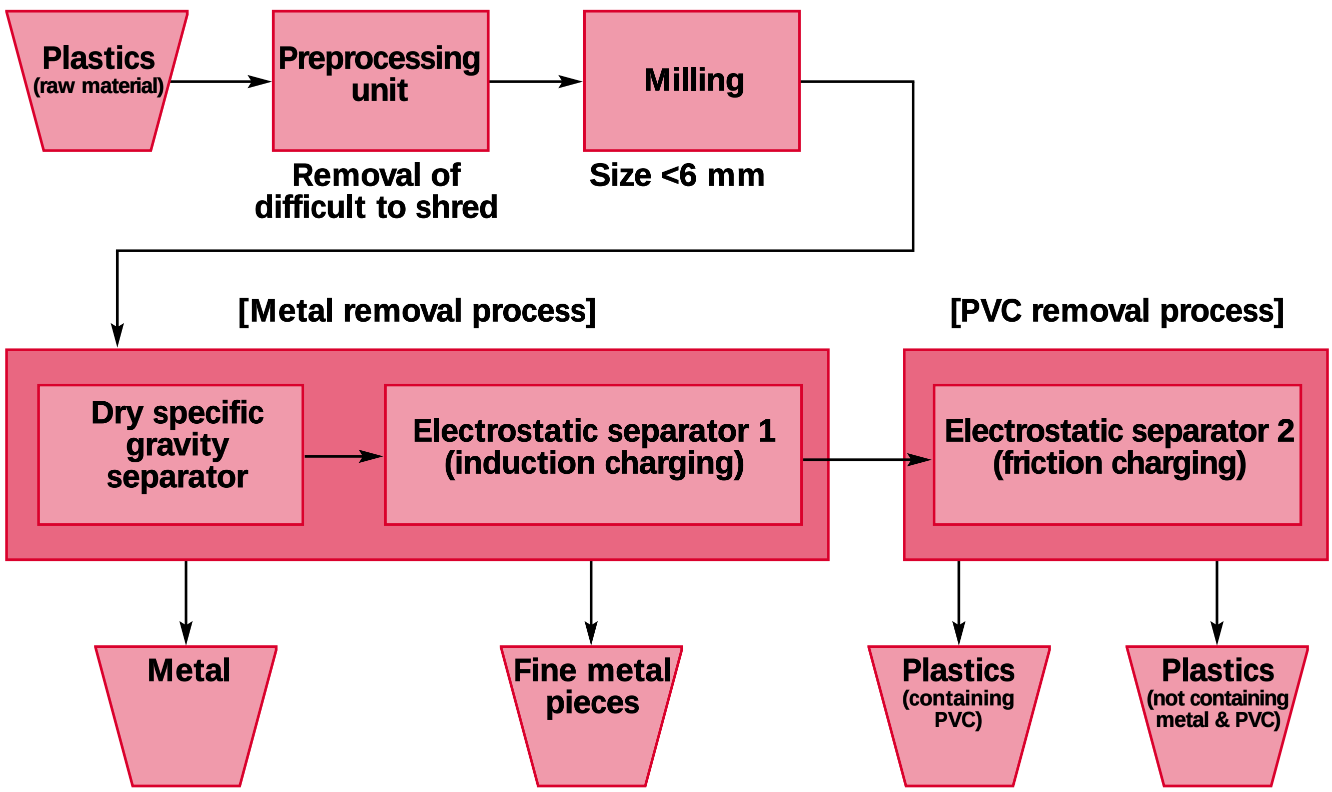

Exhibit D.3 High-precision separation of plastics at Higashihama plant (courtesy Mitsubishi Electric)

Exhibit D.4 Recovered plastics at Higashihama plant

Another area of interest was the Freon recovery unit to reclaim uncontaminated R22 as shown in Exhibit D.5.

One of the collaborators, Asahi Glass, has further refined the process to recycle the recovered gas into a cleaned product that can be used in a plastics synthesis plant as shown in Exhibit D.6.

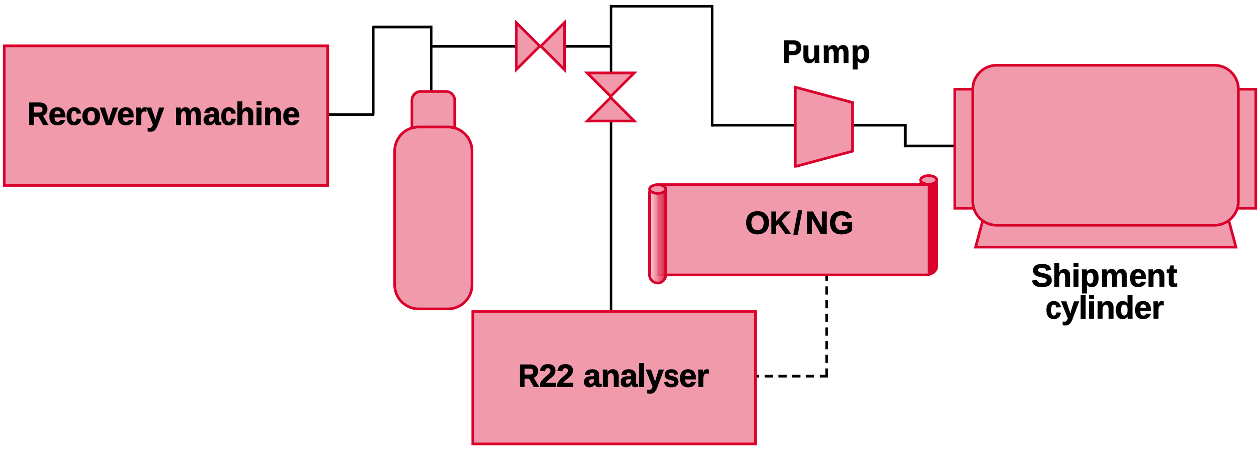

Exhibit D.5 Freon recovery process at Higashihama plant (courtesy Mitsubishi Electric)

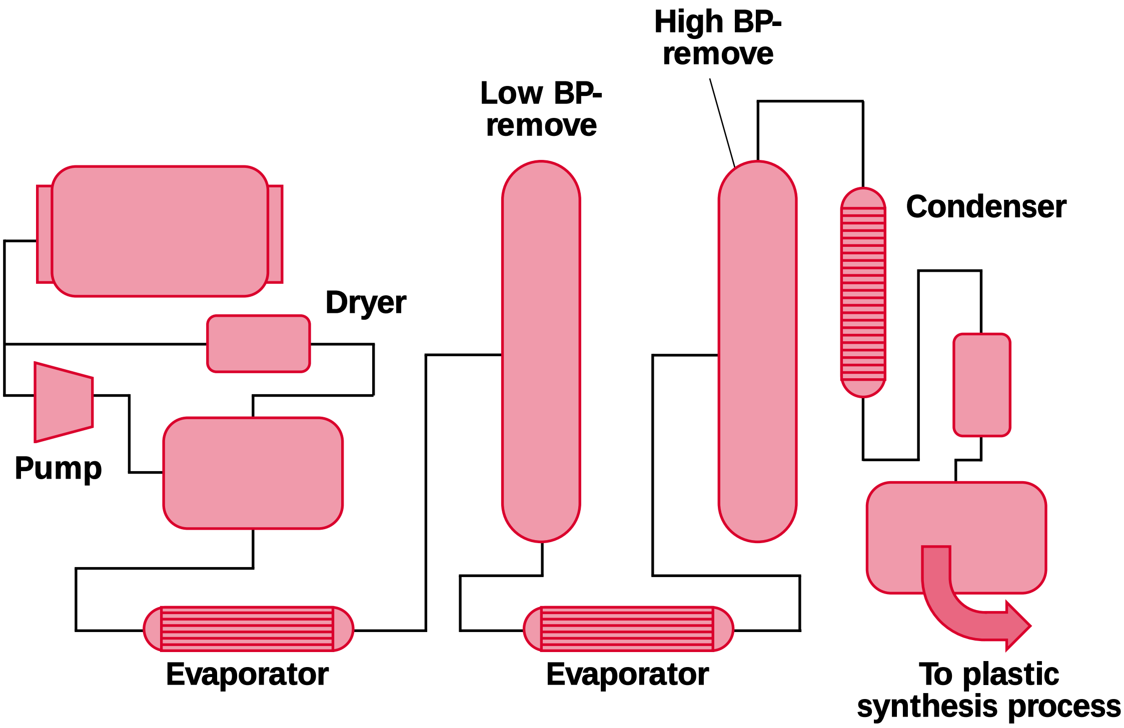

Exhibit D.6 Processing of recovered refrigerant gas into cleaned product (courtesy Mitsubishi Electric)

Exhibit D.7 Fluorinated plastics made from recovered R22 (courtesy Mitsubishi Electric)

These plastics plants produce Teflon type materials that are used to coat Mitsubishi products such as non-stick electric fish grills and domestic infrared ovens (Exhibit D.7).

During the plant tour it was apparent that Hyper Cycle Systems has a very integrated process with preliminary upstream separation being merged into common downstream unit processes, which is demonstrated by the flow sheet model in Exhibit D.8. This would become a common feature of all the site visits.

The company's representatives were very keen to point out that the recycling philosophy is deeply embedded within Mitsubishi which has a significant ongoing commitment to 'design for the environment' principles in its new product design. An example of this policy was the fact that the reprocessing unit has a photovoltaic (PV) solar roof which generates a significant amount of the energy the unit uses!

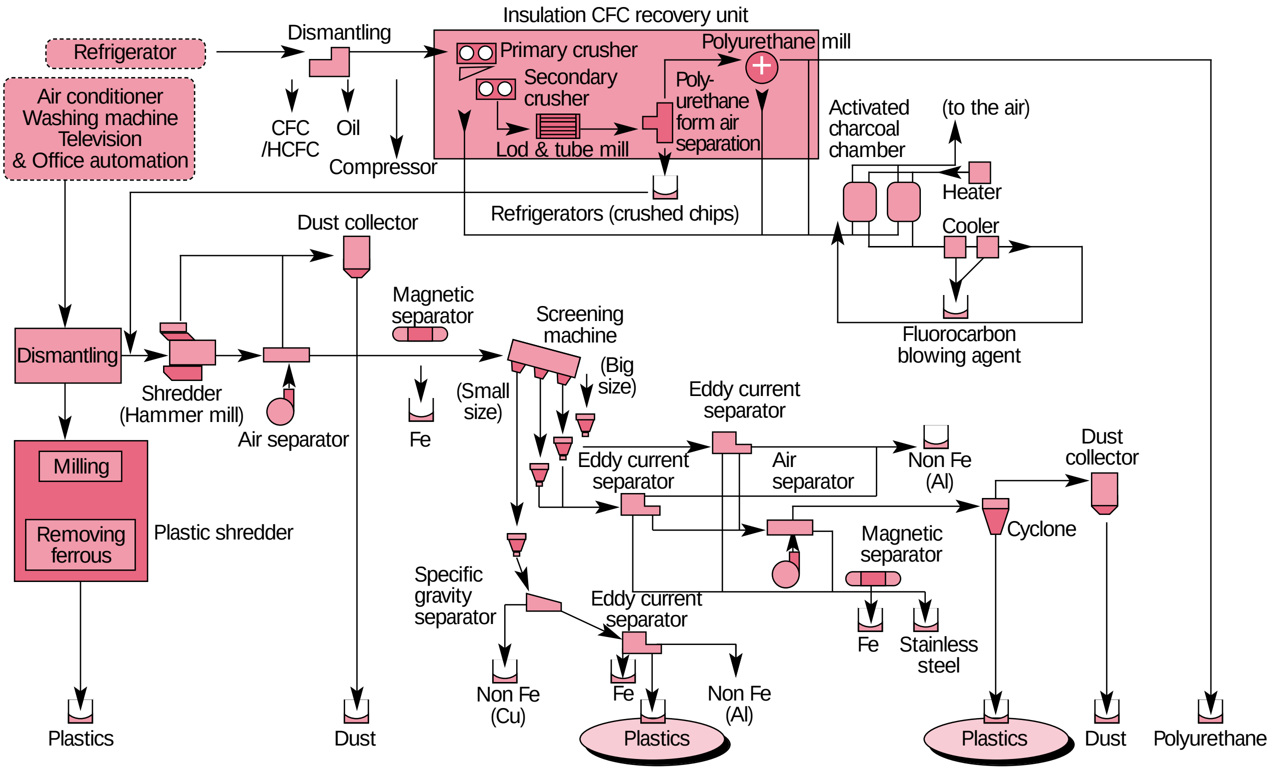

Exhibit D.8 Flow sheet of Higashihama plant (courtesy Mitsubishi Electric)

D.4 Toshiba Corporate Manufacturing Engineering Centre

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27 September 2005

Toshiba's Corporate Manufacturing Engineering Centre is not a recyling facility and was clearly more involved in product development R&D, albeit with a knowledge of manufacturing for EoL recycling. The facility has 543 employees, 332 researchers and 81 technicians and has been running since 1970.

Core technologies are semiconductors, mechanical components, manufacturing innovation, quality control procedures, mechatronics, motor/inverter technology, and electronic components assembly (such as 'flip chip' and SMT liquid crystals). The facility also does rapid prototyping with a PCB modelling centre, soldering school and value engineering unit.

Due to the training element it has a strong educational focus both for its own employees and the general public (this seemed a strong theme in all the sites visited by the mission).

The Centre focuses on technological solutions for Toshiba's manufacturing units. Most of the rest of the visit centred around one aspect of this which was its approach to the lead-free solder problem. While of specific commercial interest to a number of the mission delegates it is not particularly relevant to the objectives of the mission. Consequently these highly technical details have been left out of this report.

Most queries on HARL and recycling were referred to their published literature and suggestions that we contact their partners in Group B for more precise details. On the specific topic of LCD recycling the host engineers were aware that some research had been done in this area but most LCD materials were recycled to secondary aggregate and road surfacing applications.

Clearly Toshiba is active in the area of recycling but not at this site, and the assembled people from the Environmental Management Division were only involved peripherally. Pre-mission intelligence from UK delegates indicates that Toshiba is already doing very sensitive confidential R&D into active disassembly and possibly did not want to speak about it in an open forum.

D.5 Hitachi – Production Engineering Research Laboratory (PERL)

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27 September 2005

Following introductions and exchanges of business cards, the mission team was given a short presentation by Dr Itoh on the overview of Hitachi Corporation and the breakdown of Hitachi R&D in Japan and overseas (see www.hitachi.com/about/corporate/organization and www.hqrd.hitachi.co.jp/global/ organization.cfm).

The Production Engineering Research Laboratory (PERL) was established in 1971 in Totsuka-ku in Yokohama and employs 314 staff. Milestones for PERL include a fully automated assembly line for tape recorders, producing 100,000 sets per month in 1980, and winning the Ohkouchi prize – recognised as the most prestigious award for production engineering and technology in Japan. PERL has also won other awards: 1990-1995 for the development of large-scale computers, and 2001 for manufacturing innovation in the PC industry.

Developments now concentrate on the collaboration between design and manufacture. The mission was shown evidence of EoL now being factored into these equations, all part of the Japanese 'Monozukuri' (the art of making things). The basic philosophy is based on the Hitachi Ltd *Standards of Corporate Conduct* (established in June 1983). These are intended to set Hitachi's action guidelines for addressing environmental conservation in relation to its business activities, and are a major influence at PERL which is responsible for evaluating chemical substances used in products and the total management system for a 'recycling based society'.

Lead-free soldering technology

The mission was given an insight into PERL's work on lead-free soldering by Mr Masahide Okamoto. He explained the Hitachi timeframe for the application of lead-free solder:

- 1983 – Hitachi started research into lead-free soldering
- 1999 – lead-free soldering introduced into Hitachi laptops and phased in throughout their product lines
- 2002 – all industrial equipment and products of all affiliated companies were lead-free

Lead-free solder paste has a higher melting point (260 °C) than conventional Sn-Pb solder paste (240 °C). Problems occurring during the wave soldering process, such as fillet lifting and cavities caused by shrinkage, were overcome by rapidly cooling the underside of the PCB.

Mr Okamoto explained the IMS (Intelligent Manufacturing Systems) project EFSOT (Environment-Friendly SOldering Technology) – a joint project between Japan, Europe and Korea (Exhibit D.9) – and the timeframes involved (Exhibit D.10).

JAPAN	EUROPE	KOREA
Hitachi	TU Berlin (RCP), Germany	LG Electronics (RCP)
Fuijstu	AB Mikroelektronik, Austria	ECOJOIN
NEC	Gaiker, Spain	Jaeneung College
OKI Electric Industry	Indumetal Recycling, Spain	KITECH
AIST RC for LCA	Philips, Netherlands	
Hokkaido IRI	Pre Consultants, Netherlands	
Hokkaido University	Avantec (Promosol), France	
Juntendo University	Thomson, France	
NIES		
Osaka University – Department of Manufacturing Science		
Osaka University – CRCAST		
Shizuoka University		
Tohoku University		
University of Tokyo		

Exhibit D.9 Participants in the EFSOT project

The objective of the EFSOT project was to develop a set of new technologies and a database that would enable selection of an optimum solution for a given application and product by identifying such characteristics as solderability, joint reliability, toxicity and – most importantly – the environmental impact of possible combinations of lead-free solders including those used to metallise the parts to be soldered prior to actual soldering.

EFSOT was funded (€10 million) by the EC within the FP5 Growth Programme under the contract number G1RD-CT-2002-00838.

EFSOT – SCHEDULE

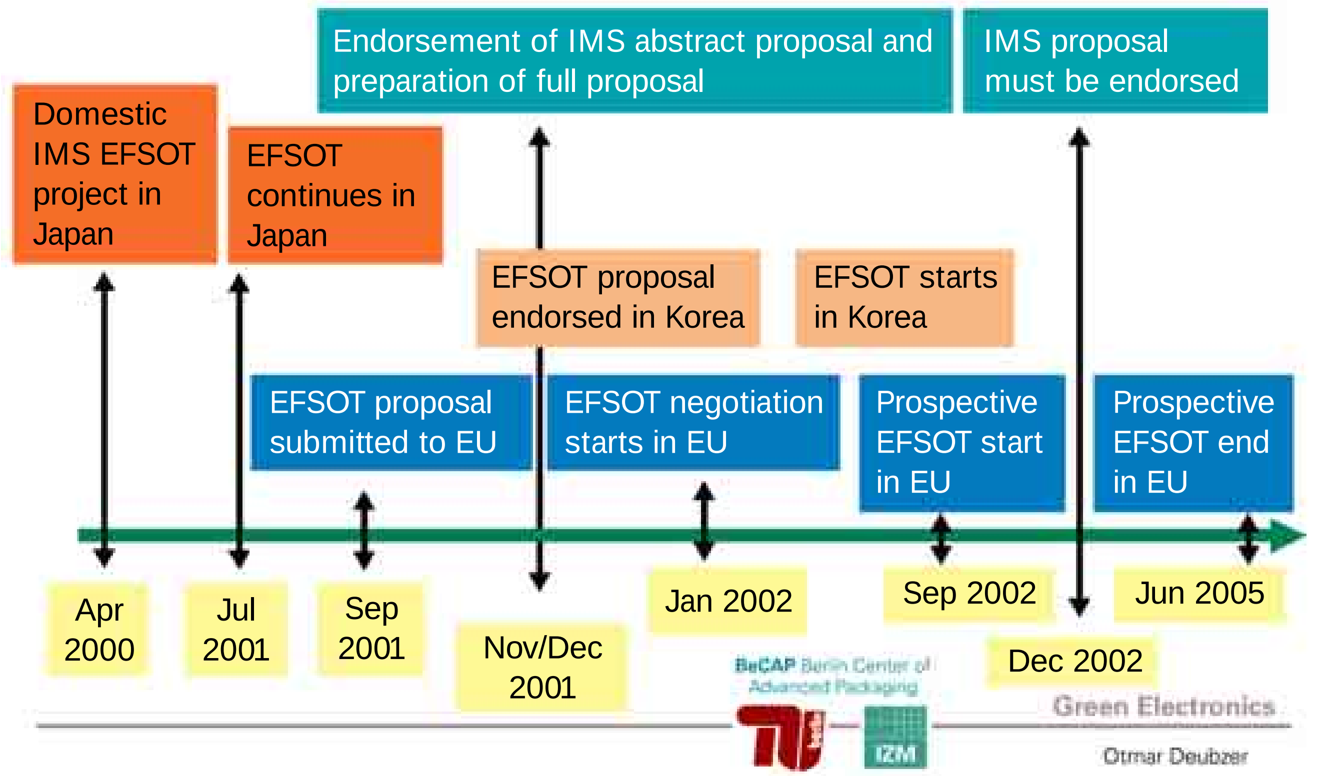

Exhibit D.10 EFSOT project schedule (source: www.pb.izm.fhg.de/ee/addon/EFSOT_Presentation.pdf)

Environmentally benign manufacturing

To promote environmental initiatives, Hitachi Group has built an environmental management system for consolidated reporting. Hitachi's Senior Executive Committee for Environmental Policy, a managerial level committee chaired by the President, assesses and determines the environmental policies and strategies for the entire Hitachi Group.

The environmental policies adopted are delegated to the Environmental Management Operations Committee to be implemented and communicated throughout the organisation. The Environmental Committee (and subcommittees) works to attain environmental goals and tasks by conducting investigations and developing useful evaluation methodologies and techniques.

It also establishes the organisations required for implementing environmental activities in each business, and designates environmental operations officers within Hitachi's business groups, subsidiaries and affiliated companies who are responsible for managing environmental matters within each organisation.

Both within Japan and overseas the Hitachi Group shares information about laws, regulations, market trends, and reports on relevant topics. From 2005 it has also been working to upgrade its environmental management system in its facilities in Europe and China to promote the sharing of information and enhancement of environmental activities within the Group in each location, and plans to implement the same measures in the USA and other locations.

For its part in this, PERL was responsible for designing environmental tools and systems as part of Hitachi's ECP (Environmentally Conscious Product) objective. Other responsibilities included developing lead-free soldering technologies and chemical substances management systems, in part due to EU RoHS legislation, and a management system for 'circulating materials' in preparation for Japanese and European reuse and recycling laws.

Recyclability Evaluation Method and its application

In 1999 Hitachi introduced a system of labelling products with environmental impact information. Under this system, products sold in Japan had an environmental rating as well as pertinent environmental data. The new system first appeared on PCs launched in December of that year.

In 1994 Hitachi drew up a set of standards for assessing products in terms of decreased use of resources, recyclability and ease of disassembly. In the same year, the company developed and implemented Life Cycle Assessment (LCA), Disassemblability Evaluation Method (DEM) and Recyclability Evaluation Method (REM). As of April 1999, these design tools had been used to develop a total of 62 'green' products.

For the new system, products will be evaluated based on a set of criteria for assessing product design in terms of environmental compatibility. A product that receives a high assessment score will carry a special mark and relevant environmental data.

The mission was given a short explanation of REM by Dr Toshijiro Ohashi, who said the quantitative attributes of REM are recycle expense index, estimated value, estimated recyclability rate, recyclability/disassemblability evaluation score, etc. The goal is to provide designers with a tool to compare recyclability of various design options. The user inputs part name, material and mass, and symbols which indicate the required disassembly operation. There are some 20 types of disassembly operation elements, categorised by movement, tool operations, etc.

Examples include upward movement, screw rotation and cutting. Model output includes estimated disassembly time and total recycling expense. The system has now been incorporated with CAD software, so giving a schematic view for disassembly lines.

It appeared that REM was of little use to processing plants in Japan as the plants were processing only limited product lines made by the parent manufacturer.

REM is offered to contracted users at http://ecoassist.omika.hitachi.co.jp.

Summary

Hitachi has worked in several different areas of environmentally benign manufacturing, including lead-free soldering, evaluation methods for recycling, inverse manufacturing, and recycling information exchange systems. It has clearly articulated a policy to pursue environmentally conscious design and manufacturing in a variety of areas, and quantified specific goals and target dates.

D.6 Matsushita Eco Technology Centre Co Ltd (METEC)

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Yutaka Horinouchi
Director
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28 September 2005

After an introduction and welcome by Ko Fukuda, a DVD presentation was given about Matsushita's commitment to the environment and the METEC facility itself. The facility opened in April 2001 on a site already owned by Matsushita and its cost was given as ¥5 billion (~£25 million). It had the capability to process one million units per year. The area in which it was built was famous for growing rice used in saki production.

Matsushita was committed to the development of green products, as well as to recycling research and technology. It was fully aligned with the need to reduce, reuse and recycle (the 3Rs) and to coexist within the global environment.

The plant had been commissioned to coincide with the implementation of HARL and Matsushita had established specific product recovery points throughout Japan. The plant was processing the four types of electrical goods specified in HARL – air conditioners, washing machines, televisions and refrigerators.

In addition to the actual disassembly lines in the plant, there was also an education centre where the public – particularly school children – had the opportunity to visit the facility to learn more about Matsushita's recycling activities and the need to recycle more EoL products. For example, the education facility showed and contrasted the material and component content of a TV made 20 years ago with one made today: the reduction in the number of individual components and materials was significant.

The plant had been built in such a way that it did not look like a recycling plant from the outside. Special attention had also been paid to the design in order to reduce noise emission from the plant: it had been soundproofed and anti-vibration mountings had been used on the equipment. Dust and dirt was collected and cleaned or incinerated.

The aim was to make the plant as open to the community and general public as possible. METEC also participated in an Environmental Council meeting with local residents every three months.

The recycling processes used in the facility were basically the same as might be encountered in other plants but the cleanliness of the whole facility clearly distinguished it as a showcase recycling centre, especially when compared to the other plants visited during the mission.

There appeared to be a large amount of manual work undertaken in the plant and there were a large number of staff working on the dismantling lines.

The overall process flow in the plant was as shown in Exhibit D.11.

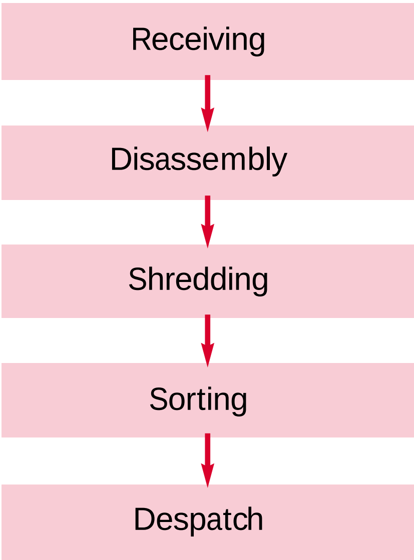

Exhibit D.11 Process flow at METEC

The key part of the whole process was the shredding operation and it appeared that some considerable thought had been given to the design and type of shredder used for each specific product. The shredders were surrounded by noise barriers and air was filtered before leaving the enclosures.

Following the introduction and DVD presentation the mission team visited the training centre, where more details were given regarding the recycling of the four types of products handled by the plant. The education centre had examples of the types of materials that were recycled at the plant, and the approximate material compositions for each type of product are shown in Exhibit D.12.

The recycling rates achieved by METEC were given – they are well in excess of the amounts required by HARL (Exhibit D.13).

Details were then given of the recycling of the four different products defined by the law.

The first one discussed was televisions and, as can be seen from Exhibit D.12, by far the biggest proportion of material in a TV is glass. It was stated that CRT glass could be recovered with 99.7% purity and that the recovered glass was used to make new CRTs. The quantity of glass in a typical CRT was said to be equivalent to the quantity needed to make 68 drinking glasses.

	Television	Washing machine	Air conditioner	Refrigerator
Glass	57	-	-	-
Plastic	23	36	11	40
Iron	10	53	55	50
Copper	3	4	17	4
Aluminium	2	3	7	3
Other	5	4	10	3

Exhibit D.12 Approximate percentage by weight of material found in the four products defined by HARL

	Television	Washing machine	Air conditioner	Refrigerator
Required by HARL	55	50	60	50
Achieved by METEC	70-80	65-70	75-85	65-75

Exhibit D.13 Percentage by weight of recycling required by HARL and actually achieved by METEC

Because the glass in a CRT varies in composition between the panel and the funnel (the funnel glass containing lead for example), it was critical that the CRT be split into two parts at exactly the right place for recycling. Matsushita had developed a special cutting machine that used an optical system to ensure that the CRT was divided at the desired place. In this process the CRT initially had a groove ground around its circumference at the point where it was to be split. A heated wire tape was than wrapped around the CRT and a current was applied which caused the tape and thus the CRT to heat up locally in the region of the groove. On cooling, the differential contraction of the two types of glass on either side of the groove caused the CRT to crack into two, giving the panel and funnel portions. After cleaning, the glass was sent for recycling. However, it was interesting to note that the CRT phosphors were simply removed by suction and then destroyed by pyrolysis.

The material composition given (Exhibit D.12) for a typical washing machine showed that it was more than 50% iron and 36% plastic. The polymer was mainly PP and this could be obtained in a relatively pure form, via density separation, to give a polymer with good enough quality for use in washing machine base panel mouldings. It was stated that salt water was used as ballast rather than concrete in many Japanese washing machines, the majority being top loading machines.

Refrigerators were also typically more than 50% iron and 40% plastic. One of the key challenges with refrigerators (and with air conditioners) was the presence of CFCs which had to be removed and collected so that they could subsequently be destroyed or converted into materials suitable for use in the manufacture of fluoropolymers. In addition to the removal of CFCs from the cooling system, they were also removed from the polyurethane foam insulation. The oil in the compressors contained dissolved CFCs and these were removed by bubbling gas through the oil. METEC had also been working in a project with the University of Osaka to develop new methods for removing CFCs from various materials.

Plastic from refrigerators was recycled into new fridge components such as bottom insect covers and the compressor oil was sent to an oil recycling company where it was converted into new lower-grade oil. Compressors were mechanically split to enable aluminium, copper and iron to be recovered. It was also stated that fridge compressors were treated differently to air conditioning compressors. METEC had developed (with Japanese government funding) a new shredder technology in 1998 specifically for compressors and this operated at room temperature. Recovered metals were pressed into compacted blocks that were sent to a refiner. CFCs were also removed from air conditioner units and each individual type of CFC was separately collected. The most common refrigerant gas was R22; the quantities of R502 and R134 encountered were small and decreasing. METEC is shredding 80,000 fridges each year.

A water-based centrifugal separation technology was being used to separate individual components in a mixed plastic waste stream. Specifically, PS with its higher density could be separated from PP. The unit used at METEC had a 500 kg/h capacity.

Different types of shredders were used for specific items, for example a vertical spinning shredder was used for refrigerators while a two axis, twin-shaft wheel shredder was used for washing machines. The washing machine shredder was supplied by Kubota and the fridge shredder by Kinki (www.kinkikogyo.co.jp).

The facility also had a development area that was used for company internal R&D and training work. Examples of a range of recovered materials were shown and these were given red or green labels depending on whether or not they could be sold. Work was carried out on materials that couldn't be sold to upgrade them. The Japanese government had funded a project to add value to CRT glass. This project had been successful and the technology had subsequently been deployed around Japan.

Design engineers are trained at the development facility to make sure that they understand dismantling and recycling. The facility used formal training tools and it also had small compact shredders that were used for evaluations on new products. There was a lot of information in the facility about lead-free assembly and soldering. METEC had also produced a book called *Hazardous Substances Non-use Techno School Book* and it was printed in both Japanese and English.

METEC is increasingly thinking about future products and gave the example of a new fridge design which they would dismantle now, so that they would already understand how to handle it at EoL.

Work was also being carried out in the experimental laboratory on the treatment of oxidised solder (solder dross). Sesame seeds were being used to reduce the oxidised solder back to metals.

A presentation was given on HARL. This law, which came into force in 2001, established a socially acceptable recycling scheme that aimed to minimise recycling costs and which had convenient logistics. The system that had evolved was characterised by cooperation between local recyclers using their existing infrastructure and a decentralised recycling network. Although the law covered TVs, there was no obligation to process CRT-based monitors from PCs; they were very occasionally processed at the plant but they were typically handled elsewhere.

Exhibit D.14 Storage and stillage at METEC

It was asked if HARL covered non-CRT based TVs, ie LCD. These were not currently included in the law, but it was likely that they would be added in the future.

Overall this was a very interesting visit to what was clearly a showcase demonstration facility. The actual equipment used in the processing of the four types of EoL products was not particularly novel and was similar to that seen at other plants visited. Some work had clearly been done to optimise shredder performance for the most appropriate type of design to be applied to each product. The main feature of this plant was not so much the technology but the fact that it was running efficiently as part of an effective integrated process that began with the consumer and ended with the recycler. The whole mechanism had been initiated by HARL and it was clear that, despite the charging of fees for recycling EoL appliances, the Japanese public were willing to play their part in making the process work. It is difficult to imagine a similar process being so successful in the UK for numerous reasons including cultural ones.

Exhibit D.15 Disassembly at METEC

Exhibit D.16 Air conditioner disassembly at METEC

D.7 Sharp – Kansai Recycling Systems Corporation (KRSC)

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Mr Yoshinori Tatsumi
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Mr Yohei Kawaguchi
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From KRSC:

Mr Koji Yoshino
President, Kansai Recycling Plant
(plant manager for the recycling operation)

29 September 2005

The KRSC plant is located in the Osaka region. It was established in December 1999 and began operation in April 2001. It is a JV between Sharp Corporation and Mitsubishi Materials Corporation. The plant handles the four products covered by HARL for the regions of Osaka, Kyoto, Nara and Wakayama. Key facts about the site are:

- Capacity – 790,000 units/y
- Visitors – 1,200/y
- Capital investment – ¥300 million (~£1.5 million)
- Site area – 8,680 m^2
- Building – 2,850 m^2 (total floor area – 5,310 m^2)
- Labour – 150 people

The Company President gave an initial talk outlining Sharp's commitment to the environment.

This was followed by two presentations – one from the Plant Manager (Mr Yoshino) and one from the Plastics Technologist (Mr Kawaguchi).

Sharp's environmental policy focuses on:

- Resources reuse and recycling
- Global warming – CO_2 emissions etc
- Control of hazardous materials – RoHS

Readers seeking more detail on the 'company corporate responsibility' story are referred to Sharp's annual *Environmental and Social Report*[9]. This has sections on: green logistics; developing green technologies; super green products, both in-use and material content; super green factories with zero waste and near-zero emissions; reducing use of hazardous chemicals; etc.

9 www.sharp-world.com/corporate/eco/report/index.html

The following summary of the operation is based upon the presentations and the observations of the mission team during the factory tour.

In the limited time available, the Plant Manager concentrated upon the following:

1 Freon gas removal and monitoring system – A semiautomated system has been implemented to ensure that all refrigerant gases collected from air conditioning and fridge equipment is correctly recorded and stored in separate transport containers. Each individual unit is bar-coded into the gas-removal section and the model and serial number used to ascertain the type of Freon gas used (often this is also clearly marked on the compressor/gas system).

   During gas removal the weight of the unit is monitored and gas extraction can only be stopped once there is no further detected drop in mass. A system of warning/signal lamps is used to inform the process operator when it is safe to unhook the gas extract clamp from each item. Much effort was given to separate storage of the different gas types – which was explained as being needed to satisfy ‘gas storage’ laws, but this seems unnecessary if all hydrochlorofluorocarbon (HCFC) gases are being sent for thermal destruction.

2 Plant inventory and material flow control system – Explanation was given of the information technology (IT) system that records the data from each unit entering the plant and links this to the mass flows of material leaving the factory. Real-time stock control and work-in-process (WIP) monitoring was included. There appeared to be nothing novel here, other than all incoming units were seen to be clearly marked with the consumer’s shipping ticket which formed the key to the whole system, even allowing individual trace-back by item for the original disposer.

3 Plastic recycling – There was brief mention of the plastic from washing machine tubs being recycled since 2001 back into new parts for Sharp washing machines. TV cases and fridge base plates etc are being sent for recycling into other low-grade goods; this is thought to be due to the high incidence of brominated flame-retardant additives (see following visit report on Green Cycle Corporation).

4 Plant flow sheet – A block flow diagram of the main unit operations carried out in the plant (Exhibit D.17) shows the initial manual disassembly operation on four lines dedicated to each product, with removal of large items (eg CRTs, motors, big plastic parts) and Freon gas extraction. CRTs are sent for processing at a remote site after removal of copper yoke and X-ray gun. Sticky tape is used to prevent escape of phosphor powders.

   After the manual strip-down of the units is complete, the material is sent for shredding in a soundproof, enclosed room. The fridge and washing machine housings are sent to two similar shredders (vertical shaft design, made by Kyboto). These units incorporate two shredding regions: the first gives a hammer-mill effect using breaker bars and stators; smaller pieces then fall into an annulus gap between the rotor and the shredder wall to undergo further size reduction down to about 10-25 mm. This design has the advantage of allowing continuous operation, with gravity infeed and output of materials. Sharp provided technical data on this unit together with information on the lifetime of the primary wear parts (330,000 units processed in eight months between replacement of breaker-bar and stator plates).

The fridge-body shredder feeds the metal, plastic and urethane-foam mixture to an air blower that removes the lighter insulation foam waste. This material is sent for thermal destruction following compression in an extruder to form pellets.

Magnetic and eddy-current separators are then used to reclaim the metal fractions, and the remaining mixed plastic waste is sent for external recycling. The mixed plastic has been sent for thermal recovery at incineration plants, but this may be linked to mention of a law banning export of waste to China for the last 18 months.

During questioning Mr Yoshino quoted the following figures for dismantling labour across each of the appliances:

The plant handles 3,600 units daily with a staff of 85 people on a 12-hour shift pattern. The average time to dismantle each unit is as follows:

- Television – 9 minutes
- Fridge – 12 minutes
- Air conditioner – 24 minutes (more Freon to extract)

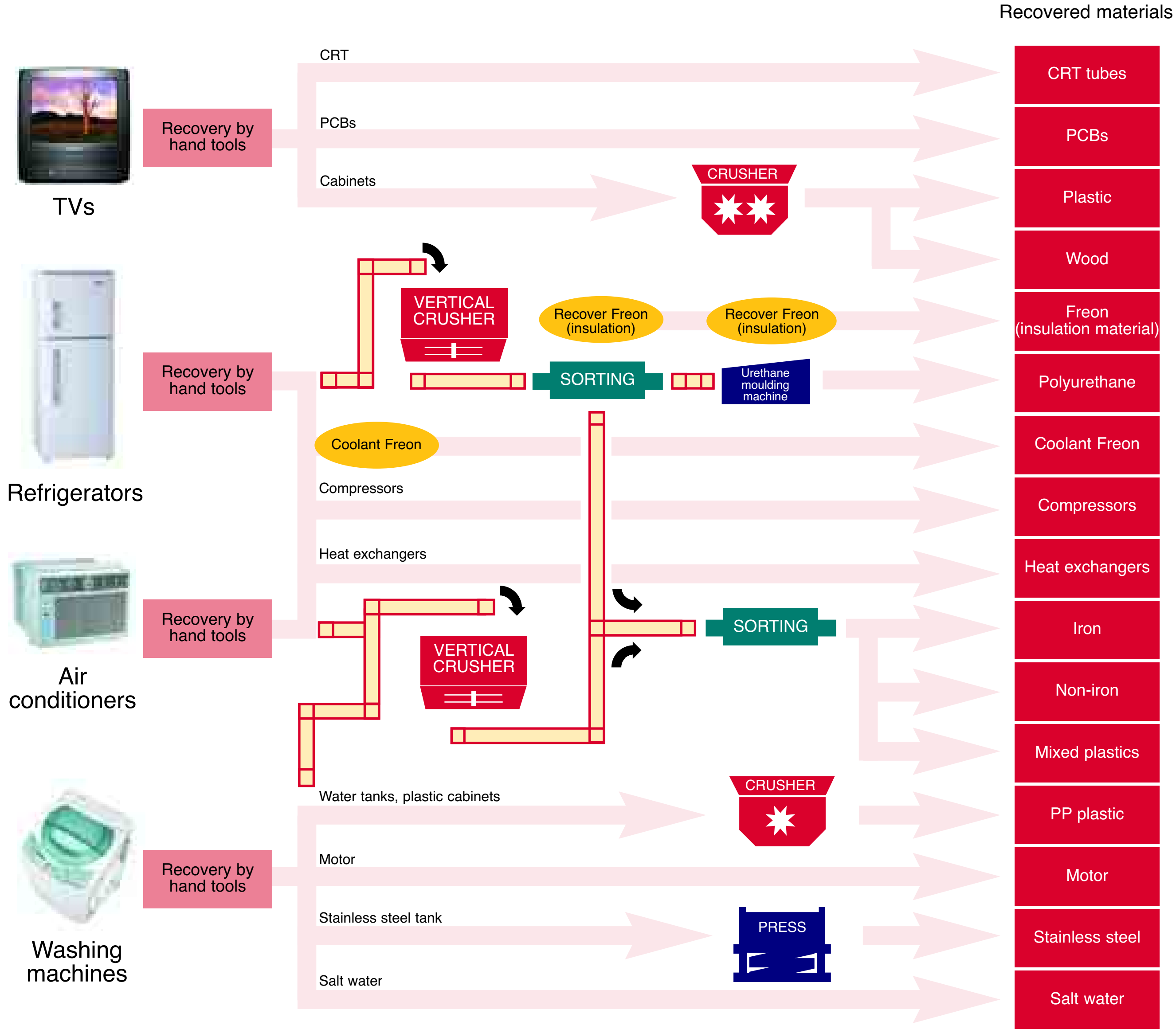

Exhibit D.17 Processing flow of KRSC appliance recycling plant (courtesy KRSC)

D.8 Green Cycle Corporation

29 September 2005

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General Manager

Green Cycle Corporation is a subsidiary of Sony Electronics and is known as a Sony family company. It is located approximately two hours from Tokyo in Nagoya city (Exhibit D.18).

There are sixteen shareholders in the plant ranging from Sharp, Fujitsu and Sanyo through to companies which are relatively unfamiliar in the UK such as Sekisui Chemical Co Ltd and Nihon Cullet Co Ltd.

Exhibit D.18 Location of Green Cycle Corporation

Exhibit D.19 Green Cycle Corporation (Sony) facility

Key facts about the site are:

- Established – 28 July 1998 (operation started 24 October 2000)
- Capacity – 850,000 units/y
- Capital investment – ¥350 million (£17 million) as of November 2002
- Employees – 130 (as of November 2002)
- Site area – 23,185 m^2
- Facility area – 4,689 m^2

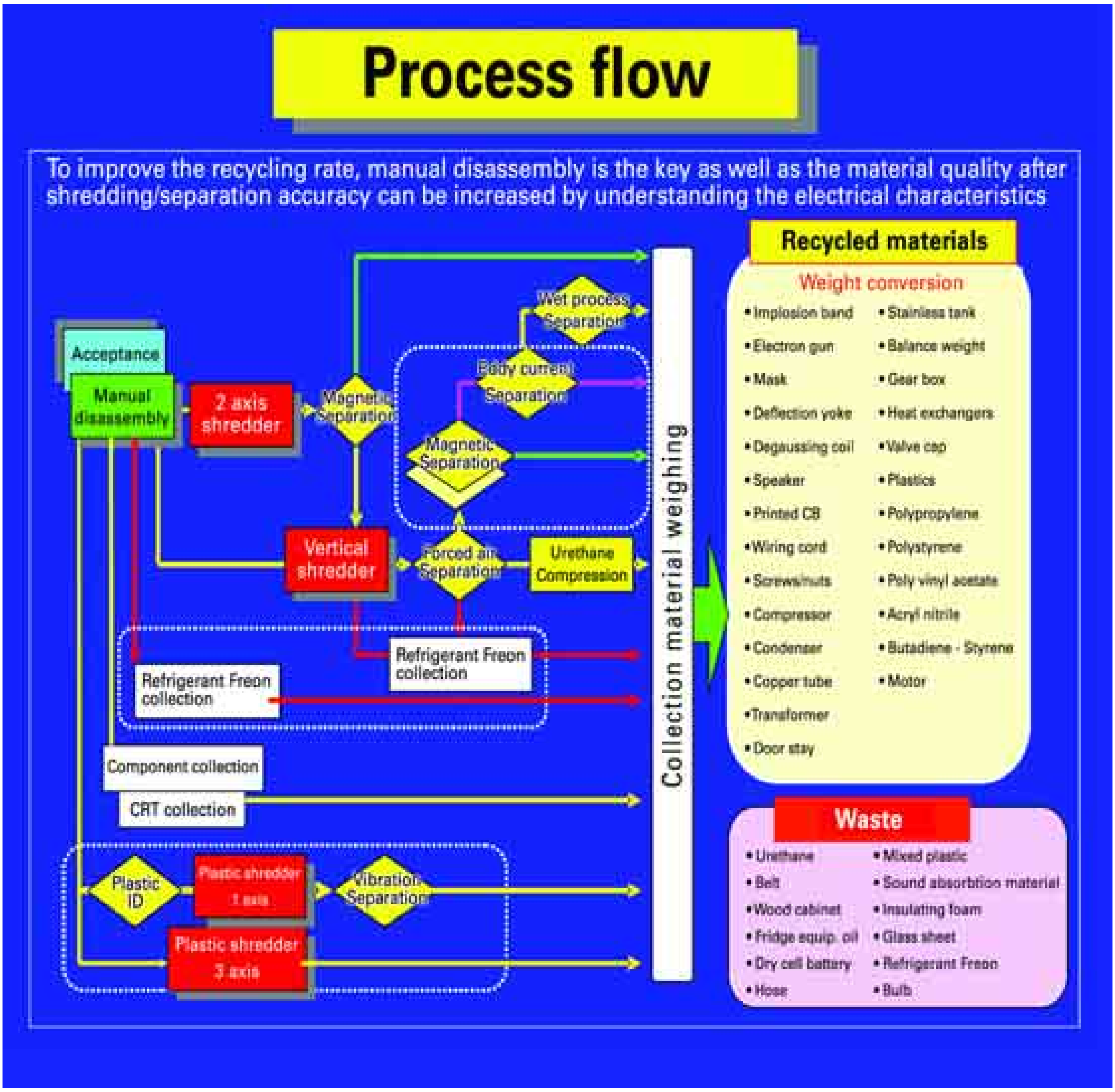

Exhibit D.20 Process flow at Green Cycle plant (courtesy Green Cycle Corp)

The mission arrived at the plant to be met by Mr Saito, Mr Hori and Mr Tokita and shown to a conference area to be given a short presentation on the ethos of Sony and the Green Cycle Corporation which may be summarised as follows:

- Efficient plant with the simplest layout
- High recycling ratio of 98% or more of CRT glass
- High recovery of 93% or more for adiabatic CFC and cyclopentane
- Aiming at high plastics recycling ratio by the introduction of a plastics separator
- High recycling ratio of 80% or more by using wet-type separator plant with noise and dust proofing

The visitors were shown round by Mr Tokita and taken to a viewing platform where they were able to see television and air conditioner disassembly lines.

They were also told of the recording of data collected from the redundant units that are sent to the plant. These data were evident on all equipment that was entering the plant as a sticker (ticket) was attached to every item collected (see Chapter 7 for details of this system).

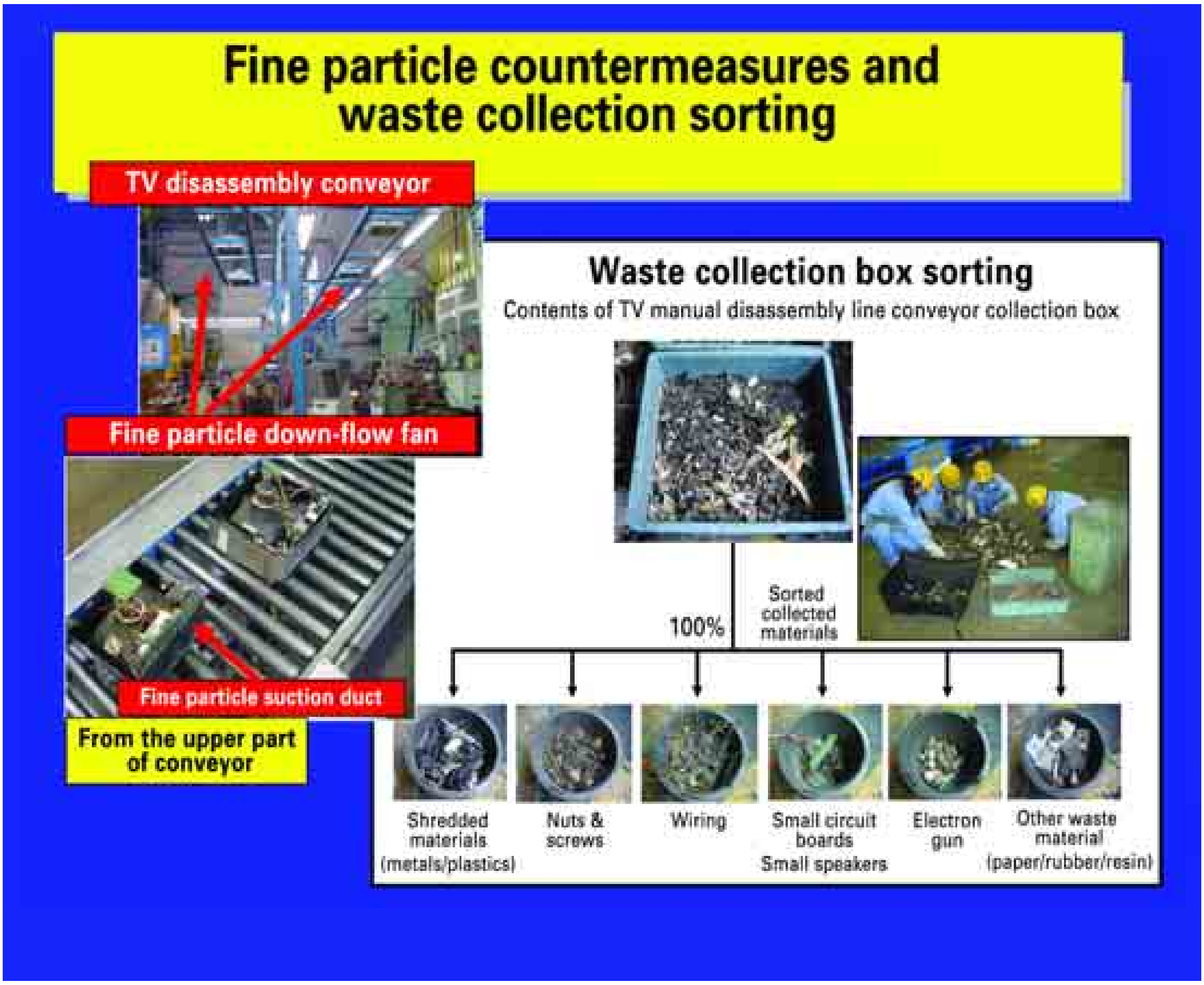

Exhibit D.21 TV disassembly at Green Cycle plant: fine particle countermeasures and waste collection sorting (courtesy Green Cycle Corp)

Television recycling

This semiautomated plant is fed by fork-lift trucks depositing units onto a roller conveyor feeding differing work stations. The various stages of disassembly are:

1. The units are checked into the system by scanning in the bar code on the return ticket attached to the unit.
2. Differing components are manually stripped from the unit: first the external power supply and then the deflection yoke, speaker, degaussing coil, PCB and cabinet. All are separated into discrete bins.

Exhibit D.22 Laptop disassembly at Green Cycle plant

Exhibit D.23 Television disassembly at Green Cycle plant

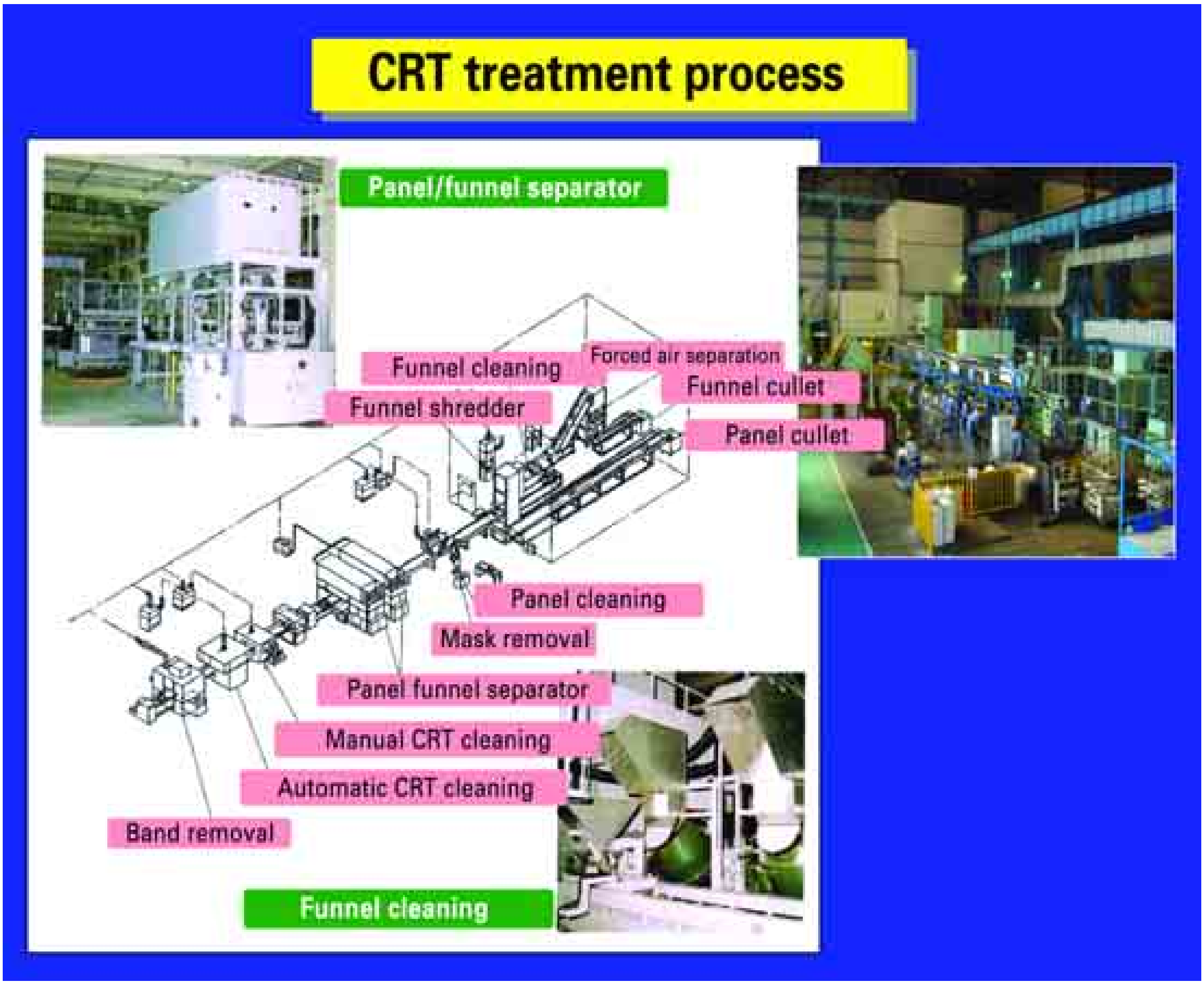

Exhibit D.24 CRT treatment process at Green Cycle plant (courtesy Green Cycle Corp)

Exhibit D.25 TV/computer screens undergoing treatment at Green Cycle plant

3 There does not appear to be any check on whether the plastic is flame retardant or not and so it is assumed that it is mixed, as it is put in for shredding with all other plastics.

4 The neck of the CRT to which the gun is attached is removed by angle grinder; there was no evidence of water being added to the inside of the tube at this point as had been seen at the Hitachi plant visited earlier in the week. Here tape was put over the opening to stop the phosphor escaping.

Exhibit D.26 Conveyor system with air conditioners ready for processing at Green Cycle plant (arrow indicates rollers necessitating manual intervention to enable movement of units)

5 The CRT is then sent down the line and cleaned of most of the carbon grime it has accumulated over its lifetime in use. This is accomplished by use of a small hand-held angle grinder fitted with an abrasive mop.

6 After thorough cleaning the whole CRT is placed (not thrown!) into a cage and each layer covered by thick sheeting.

This was the first time the mission team had seen such care being taken with CRTs. By timing the process it was found that each operator took a full three minutes to clean one unit.

Air conditioner recycling

The largest volume of any of the recycled items was the air conditioner units. With the climate in Japan these are used in virtually every home and so tend to be more in evidence than other equipment.

The units arrive from the extensive stockyards where they are stored and are deposited by fork-lift truck onto a powered conveyor system. Then they are dealt with manually as the self-propelled conveyor system gives way to a roller system as illustrated in Exhibit D.26.

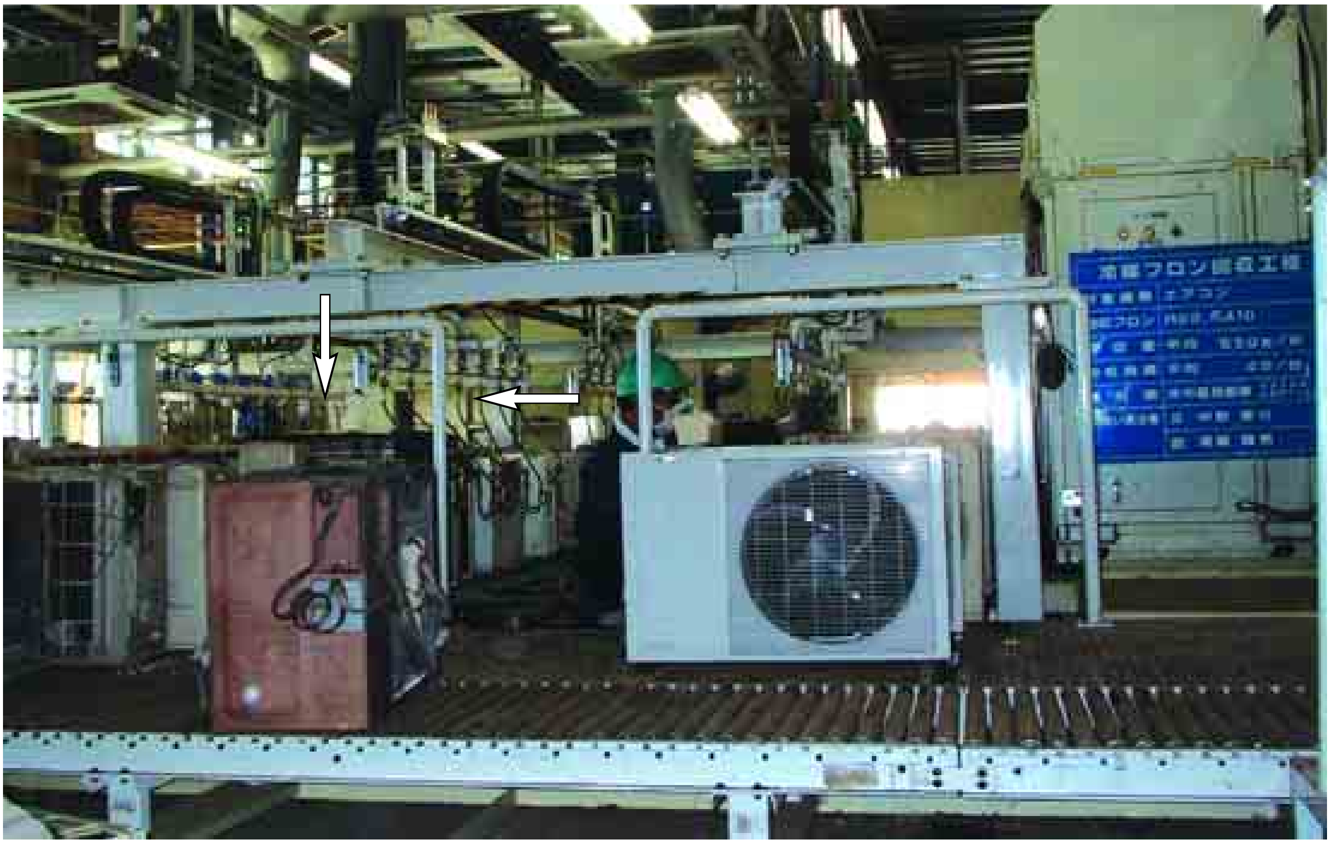

Exhibit D.27 Processing of air conditioners at Green Cycle plant (arrows indicate removal of Freon gas)

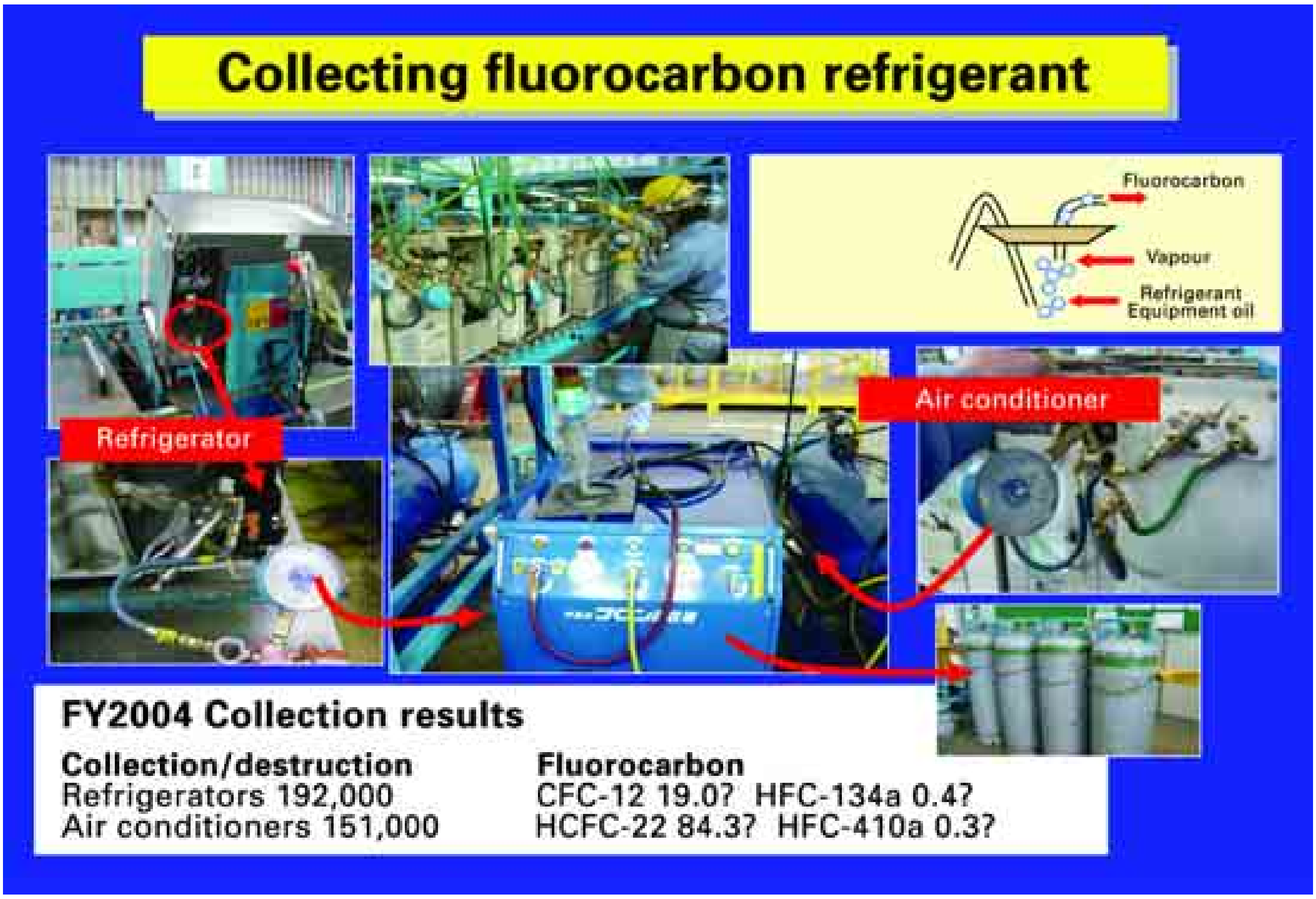

Exhibit D.28 Collecting fluorocarbon refrigerant at Green Cycle plant (courtesy Green Cycle Corp)

The process is as follows:

1 First, as with all recycled equipment, the bar code is scanned on the return ticket so the particular unit is recorded as having been received for recycling.

2 The units then undergo depollution as illustrated in Exhibit D.27 to remove all CFCs, namely Freon gas which is stored in containers. This is regulated by an operative who monitors the amount taken from each unit and ensures that each unit is empty before disconnection. The gas is then sent for incineration as it cannot be used for any other purpose.

3 The power cord is severed and placed in a bin.

4 The outer case is detached using air-powered screwdrivers.

5 At the same station the outer case is separated into metal and plastic grill. This is normally achieved by prising the two apart with a large hand-held screwdriver! The components are then placed into differing bins appropriate to their composition (metal/plastic). This was the norm at all plants visited.

6 Once the unit is exposed, the piping, heat exchanger, condenser and compressor are removed and placed into their respective bins, being sent off site for further treatment.

7 Other plastic components, such as the plastic drum, are separated on site.

All of the metal components (other than heat exchanger, condenser and compressor) are taken directly to bins to be processed off site.

The remaining material is dealt with on site in the two spindle horizontal crushers, the plastics being sent to the dedicated crusher on site.

Washing machine recycling

The next line shown to the mission was the washing machine disassembly process. This was by far the dirtiest recycling process of all and was similar at all facilities visited.

In Japan most washing machines are top loading not front loading as in the UK (Exhibit D.29). Also it would seem that the majority of drums are plastic instead of stainless steel.

Exhibit D.29 Comparison of typical UK and Japanese washing machines: (a) UK model – front loading; (b) Japanese models – top loading

The disassembly process is as follows:

1 The units arrive as all recycled units previously described and have the plastic lids removed from the top of the unit.

2 Then the waste pipe is removed and any external fixings from the bottom of the unit.

3 The unit is then turned over manually and the washing drum is detached by using an air chisel.

4 The drum is then separated from the motor. At Green Cycle this is done in either of two ways. One method is by air chisel to sever the fixing bolts but we were also shown a 'separating booth' in which the drum could be placed into a jig and a saw blade used to cut though the fixings automatically. This was not in use at the time but was obviously used in 'campaign style'. The problem with this particular recycling method is waste water but we were told that all waste water is treated before release.

5 The drum and motor plus any fixings being removed, the drum is then sent to the dedicated plastics crusher if it is plastic (in most cases it is) or, if metal, the normal procedure is to crush it under a hydraulic press to reduce the volume for further processing.

Fridge recycling

The next line was the fridge section. The process is as follows:

1 The fridges arrive, as with all other equipment, but with the difference that special air suction lifting equipment is employed to lift and orientate the units.

2 The unit's bar code is recorded from the return ticket.

3 The unit is stripped internally of all loose drawers and shelves.

4 The outside magnetic strip surrounding the door is removed.

5 The compressor is removed and drained of oil (the oil is apparently commonly of vegetable origin and is sent for separate recovery).

6 This unit is then sent directly to a vertical shredder.

7 Certain fridges/freezers have a heat shield on the back which is aluminium and has to be manually removed. This is undertaken by using a large bar (Exhibit D.30) before being sent to the vertical shredder.

Exhibit D.30 Manual removal of aluminium heat shield from back of fridge/freezer at Green Cycle plant

Conclusions

- Plastics

Plastics were seen to be fractionated and subjected to a washing process although they did not appear to be of any greater value visually than those seen at other plants as can be seen from Exhibit D.31. This fractionated plastic is roughly 10 mm in size.

Exhibit D.31 Fractionated plastic at Green Cycle plant

- Facility

The facility itself was obviously not purpose built and was probably an old fabrication shop as the area around it was of old 'heavy industry' origin. The stockyard was very large and appeared to be very pleasant to work in with plants and shrubs in evidence. This was a common feature of site visits and goes to show how the workers are not forgotten but made to feel fortunate to work in such an environment.

- Shredder/crusher technology

The equipment seen at the Green Cycle facility was two spindle crushers which dealt with all metal waste. After being roughly crushed in the two spindle crushers it is finely crushed in a vertical crusher. Although fridges are fed directly into the vertical crusher there is a dedicated plastics crusher.

- CRTs

The form of recycling for this type of item varied from plant to plant but it was noted that Green Cycle went to greater lengths to achieve a much cleaner end product. They claim to have had the 'World's First TV Cathode Tube Recycling System'. From looking at the information in a brochure this system would seem to be fully automated but unfortunately it was not located on the site visited. One of the Green Cycle stakeholders is Nihon Cullet Co Ltd so it follows that they would need to maximise the facility to receive good quality glass for recycling.

One point they were happy to tell the mission was that they did export in the region of 10,000 old television units to China each year.

- Air conditioners

The air conditioner units the mission saw at this plant seemed to be treated in much the same way as elsewhere and the same disassembly systems were used.

- Washing machines

The difference in how Green Cycle and other recyclers treat washing machines is the manner in which the motor and fixings are removed: Green Cycle uses a semiautomatic cutter while others use semiautomatic pullers.

- Fridges

All of the facilities visited were treating the fridge in much the same way and seemed to be very proficient at doing so; the one major problem component for recycling was the magnetic sealing strip on the door.

- Workforce

It has to be said that the workforce in every company visited was very well organised and extremely well motivated; Green Cycle was however the only company to hire in its workforce on a short-term basis, meaning that they were presumably all on temporary contracts.

- PCBs

The Green Cycle plant was the only facility visited by the mission to actually shred circuit boards on site. This may be due to the fact that they have shareholders in the facility to deal with the recovery of precious metals within the group.

Further information

For a more detailed overview of the company's environmental policies please refer to the following links:

www.sony.net/SonyInfo/Environment/environment/management/vision/index.html

www.sony.net/SonyInfo/Environment/environment/communication/report/1997/qfhh7c000000dub5-att/e_1997_03.pdf

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Department of Environmental Business and Technology

30 September 2005

Tokyo Eco Recycle Co Ltd was established in 1999 as a corporate response to HARL. In 2004 its rate of recycling for four consumer electronic goods of commercial value (televisions, refrigerators, washing machines and air conditioners) exceeded the government standards by a wide margin, and the company achieved zero emissions to landfill for the third consecutive year.

In 2005 the company won the ninth Honda Prize for Recycling Technology Development, for achieving zero emissions in the household electrical appliance recycling division.

Exhibit D.32 Tokyo Eco Recycle site

HARL was enacted with the goal of encouraging the efficient use of resources. Tokyo Eco Recycle handles about one-quarter of the volume of the four categories of items covered under the Law. The company handles about 300,000 items per year in Tokyo, and in 2003 sent only 0.1% of the total to landfill, meaning that in effect it achieved 'zero emissions' of waste.

The site is located at nearby Wakasu Park and campsite, popular with Tokyo residents, and was therefore subject to strict noise, vibration, odour and dust emission controls. Takenaka (the corporation responsible for design and construction) was responsible for negotiations with various government agencies and advisory councils with regard to specific laws and regulations.

The Hitachi process was applied to five plants in Japan. Hitachi founded three new companies for recycling home electric appliances in Hokkaido, Tokyo and Tochigi based on this process.

President and CEO Dr Kenji Baba introduced the mission to Tokyo Eco Recycle. He started by explaining the origins of HARL and LPEUR, stemming from the 1994 Basic Environmental Law, and the development to the Basic Law for Promoting the Creation of a Recycle-Oriented Society of 2001. He went on to explain how the fees and the manifest system worked, and how consumers could follow (via the website) appliances through this system to the point where the appliance was recycled.

The definition of the recycling rate, which is determined by the law, was given as:

$$\text{Recycling rate} = \frac{\text{Recycled valuables (t)}}{\text{Initial weight (t)}}$$

Each product has its own target recycling rate:

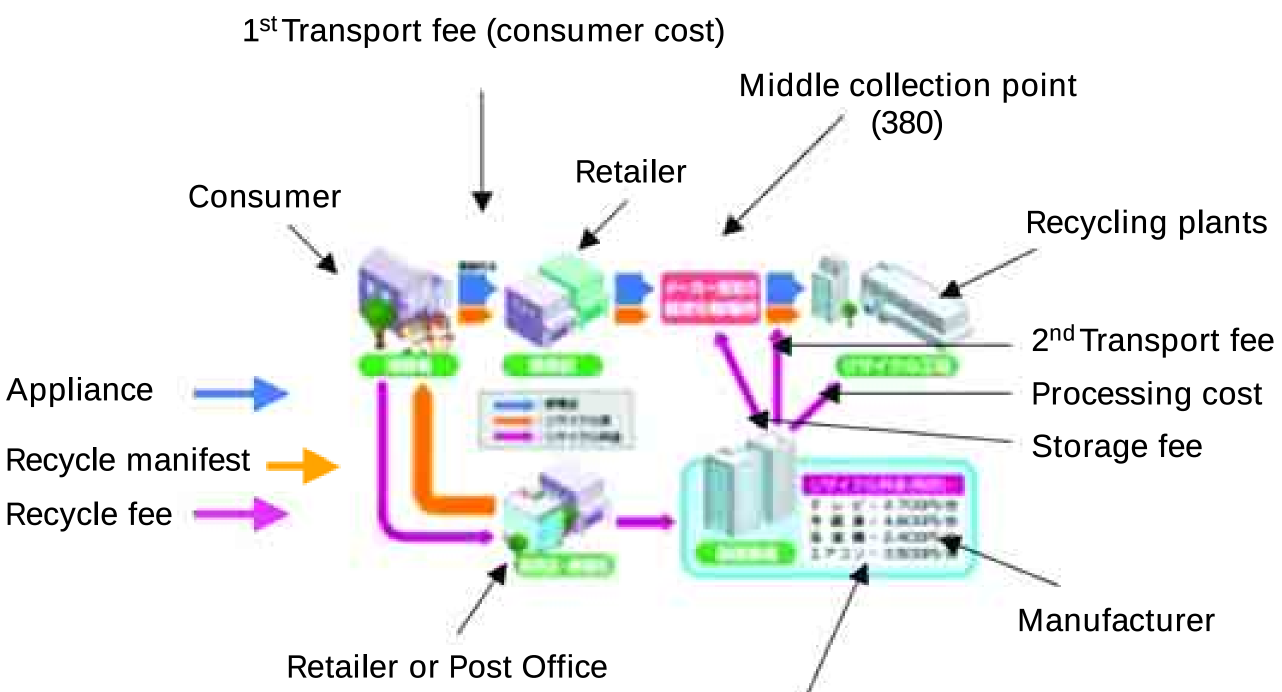
- Television – 55%
- Refrigerator – 50%
- Washing machine – 50%
- Air conditioner – 60%

Tokyo Eco Recycle achieves 70% recycling rate as an average on all product lines.

There are monthly fluctuations in the number of home appliances recovered for recycling in Japan, the hotter months seeing an increase in refrigeration and air conditioning units, for obvious reasons. Also, the Japanese workforce purchasing new products with bonuses earned at work causes peaks in December and January (Exhibit D.34).

Key facts about the site at Wakasu are:

- Established – 22 November 1999
- Capital investment – ¥300 million (~£15 million)
- Shareholders – Hitachi 48%, Ariake Kogyo 34%, Hitachi Home & Life 3%, Mitsubishi 3%, Sharp 3%, Sanyo 3%, Sony 3%, Fujitsu General 3%
- Site area – 7,609 m^2
- Building area – 2,892 m^2
- Total floor space – 3,319 m^2
- Structure – Steel
- Number of floors – 2
- Project period – 1999-2001
- Handling capacity – 400,000 units/y (8 h), 600,000 units/y (12 h)
- Project owner – Tokyo Eco Recycle Co Ltd



Television	¥2,700 (£13.50)
Refrigerator	¥4,600 (£23.00)
Washing machine	¥2,400 (£12.00)
Air conditioner	¥3,500 (£17.50)

Exhibit D.33 Japanese manifest system

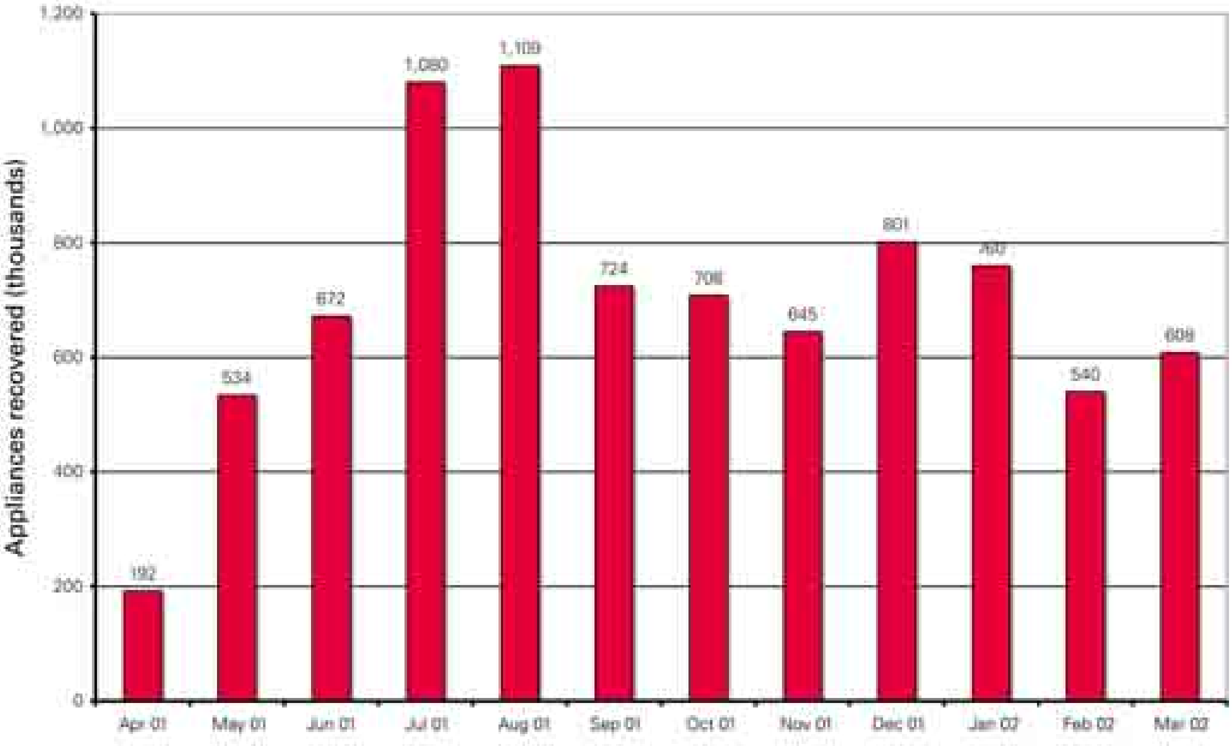


Exhibit D.34 Number of home appliances recycled in Japan, 2001/2

Recycling process

Processing at Tokyo Eco Recycle starts with product identification by utilising the bar code on the manifest attached to the appliance. The appliance is then weighed.

Products are then dismantled by hand, valuable resources are reclaimed and hazardous materials separated out. The remainder is processed using technology similar to that seen in all the plants visited; however, the vertical shredder used, made by Kinki, has undergone modifications. These modifications were requested by Hitachi, which now holds the patent on the modified shredder. The whole system is monitored by an ‘operation and management support information system’ which integrates the multiple databases used.

Planning and status reports of goods arriving, treatment and remaining stock are updated every 30 minutes. A full flow report is produced the following day. With information collected regarding container stock, daily work efficiency and daily CFC recovery monitoring combined, this produces sufficient information for policymaking and operational planning on an hourly, daily and monthly basis.

Single type polymer reclamation is becoming more important. Single type polymers used in salad crispers from refrigeration units and washing machine components are set aside and processed through a separate shredding system and washed, to produce single type polymers for remoulding into new component parts for products such as washing machine bases and air conditioning covers.

99.8% of materials such as ferrous, stainless steel, copper and aluminium are recycled, and refrigerant gas is incinerated; less than 0.1% is landfilled at Tokyo Eco Recycle.

Polymers not separated for reuse can also be incinerated; this material is then used for roadbed, or incinerated ash becomes raw material for cement based products.

Foam from refrigeration units is now sold to the Japanese government for insulation materials on low-cost housing projects and to assist in complying with Green Procurement legislation.

The next issue for the company is the recycling of resources. In Japan the 20th century was the time of 'incineration and landfill'; the 21st century is 'recycling of resources,' not only from waste recycling but the overall impact on the environment, packaging, transport, etc.

After a short video presentation on the workings at Tokyo Eco Recycle, the mission team were shown the process from a viewing gallery where they were allowed to take pictures.

In a secure room, accessed by fingerprint identification system, they were shown PC and gaming machine processing. It was policy to destroy information recording devices such as hard drives; removed hard drives were placed in a container which punctured the device in four places, giving reassurance to end users with regard to data destruction (Exhibit D.36).

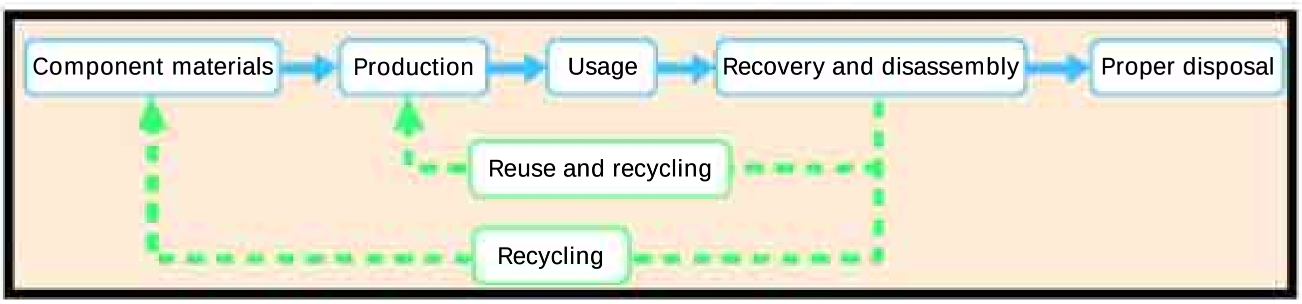


Exhibit D.35 Resource recycling in Japan

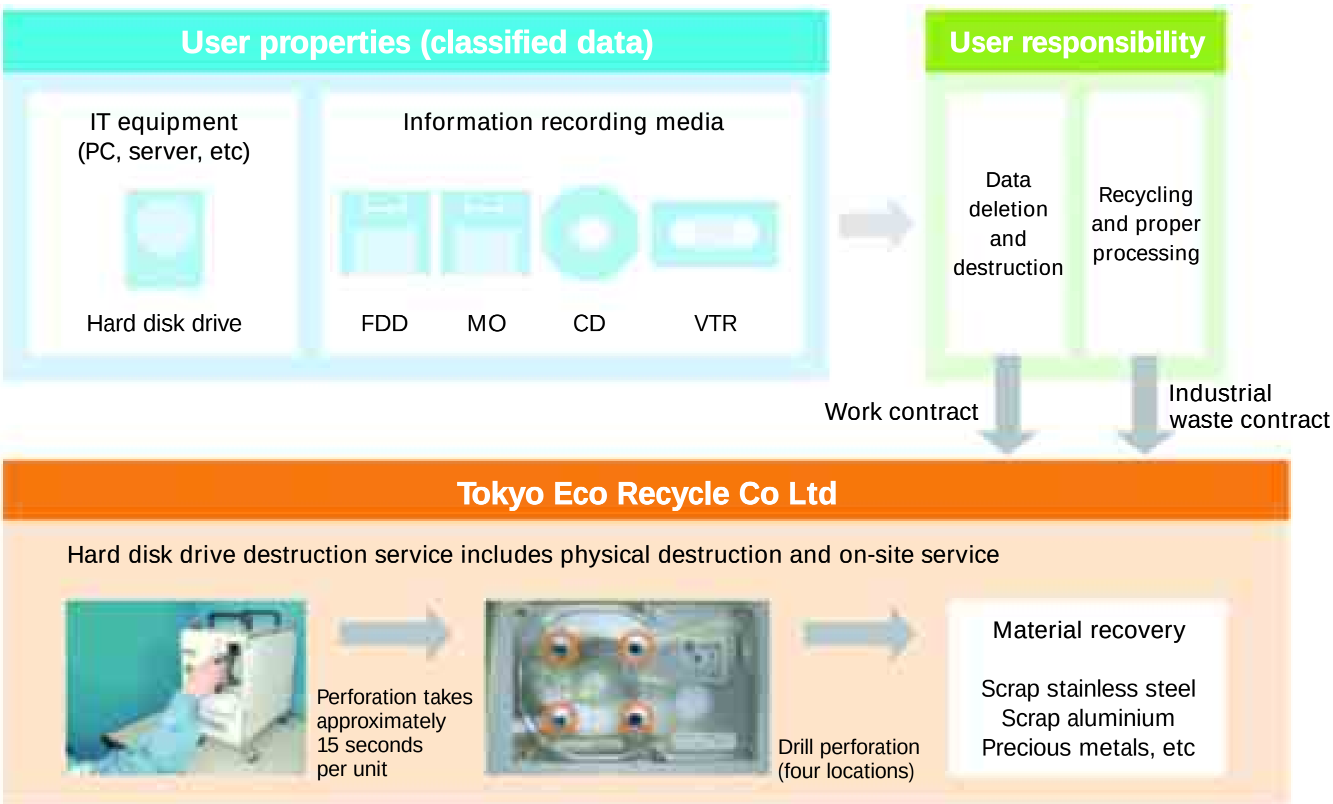


Exhibit D.36 Processing and recycling of devices containing confidential information (source: http://greenweb.hitachi.co.jp/en/sustainable/resources.html)

Summary

Tokyo Eco Recycle was set up as a demonstration plant between 1995 and 1998, part-funded by METI and the AEHA. The system was established in collaboration with government, investors (from Group B companies) and local waste management companies.

The knowledge and experience of the company will be a great benefit to government and industry in Europe to obtain compliance under the WEEE directive and other environmental and sustainability policies.

All indications were that Tokyo Eco Recycle and other processing plants were investigating the possibilities and economic drivers associated with polymer type separation from a mixed plastic waste associated with EoL electrical products.

Great emphasis was attached to manual pretreatment of products to add value to material arisings, more effective material separation, and the protection of the workforce and Japanese society generally.

Appendix E

EDUCATION, EDUCATION, EDUCATION!

Recycling is not a dirty word in Japan

Much has been made over recent years of how clean and tidy Japan is compared to Europe and the UK in particular. Japan is a very forward looking nation, identifying the problem of resource productivity early and then embarking on a national programme of educating people into recycling of waste.

Clearly there is a cultural difference that pervades all aspects of Japanese society. More difficult is to understand how this has been handed on to the younger generation. The area of recycling electronic scrap gives a clear insight into one powerful mechanism: long-term education.

All of the sites visited had education facilities which were used to tell people about the benefits and positive impact that recycling have on everyday life. Clearly this is not entirely philanthropic; there is a publicity aspect to this as they are manufacturers as well as recyclers. Also, by law, any profit generated from the recycling fees has to be reinvested in the HARL process. However, it is also clear that most companies are passionate about getting the 3R principles across.

Matsushita Electric, best known for its Panasonic brand, has led the way through its advanced recycling plant in the western Japanese town of Yashiro. The Matsushita Eco Technology Centre (METEC) came into being after the Japanese government passed tough recycling measures that came into effect in 2001.

Exhibit E.1 METEC facility

Focusing on METEC shows what one plant alone can achieve and what we should aspire to in the UK.

Exhibit E.2 shows a particular demonstration unit at METEC aimed at children. The machine, as can be seen from the photograph, demonstrates the separation of differing materials by weight. In the high-volume airflow, the light balls are sent directly across while the heavier ones fall to the bottom. The subject is treated as a fun activity rather than a straight teaching method. The machine that is used is clearly not expensive to build and the simple design can very easily be explained to an audience of young children. The clever part in the demonstration is that the children are invited to interact with the equipment for themselves.

All the balls have differing symbols in Japanese representing the different materials, mainly plastics. This simple unit adds interest and meaning for the children who have previously been given a factory tour. It allows the children to be able to understand in their own way how the plastic recycling machinery they have just been shown in the factory actually works.

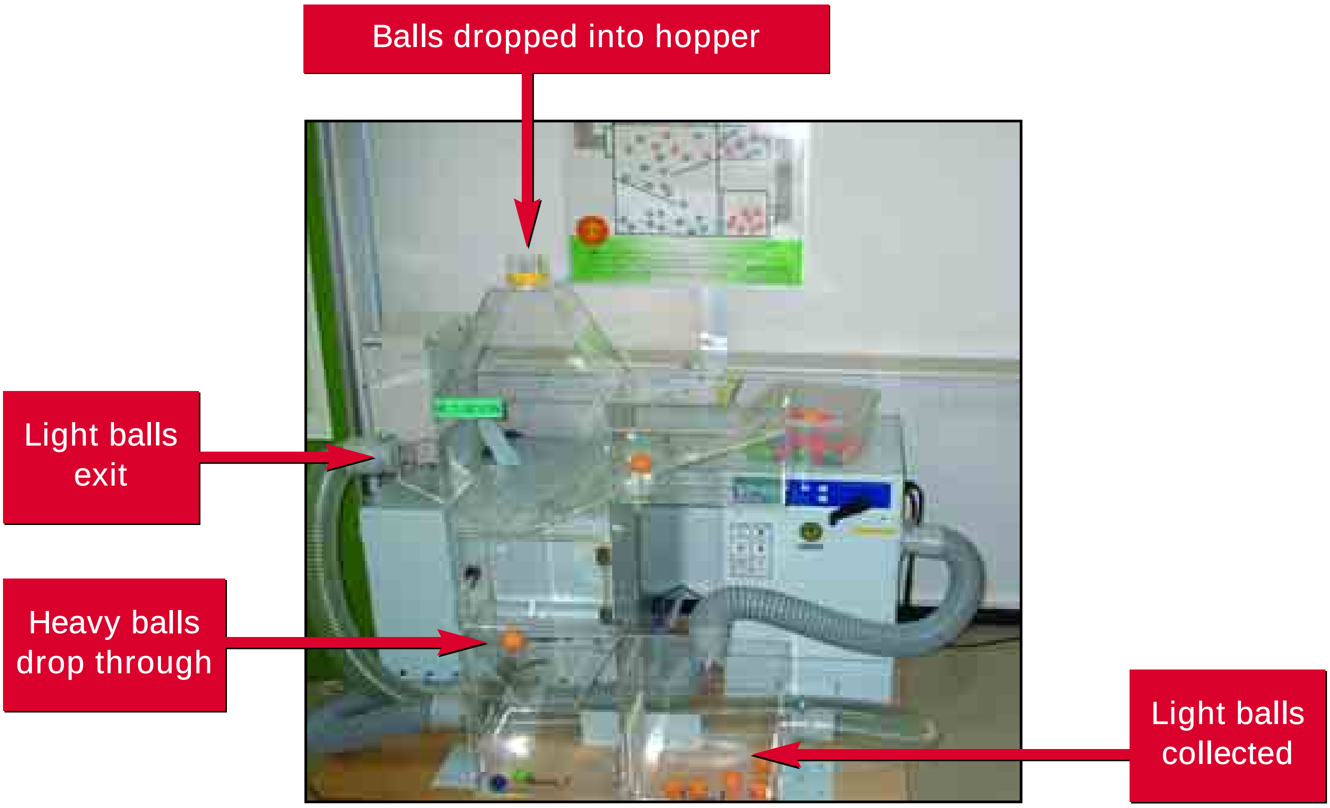


Exhibit E.2 Demonstration of separating differing materials by weight at METEC

This is also the case with the next demonstrator shown in Exhibit E.3 which deals with magnetic and nonmagnetic items, as seen in the plant where the fridges and washing machines are shredded and the different metals are separated.

Small magnetic and nonmagnetic bolts are dropped into the hopper. The magnetic bolts are attracted to the wheel and after half a revolution are dislodged by the blade, the nonmagnetic bolts falling straight through.

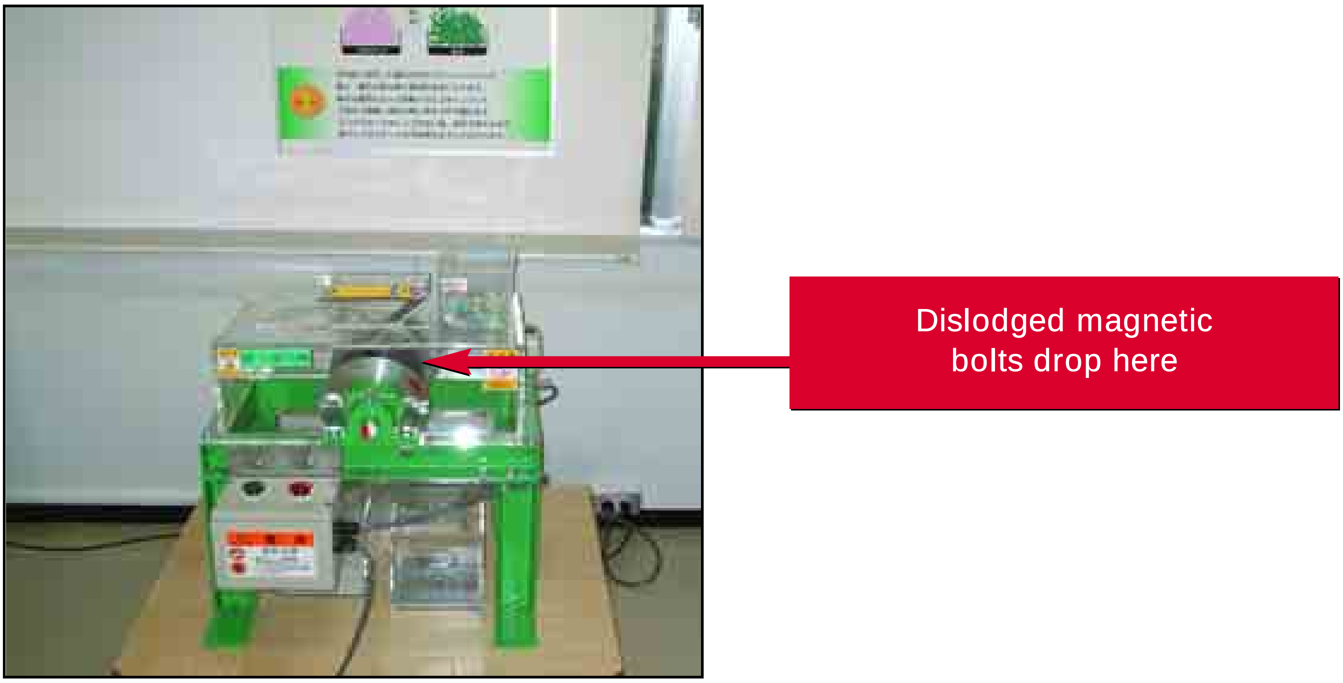


Exhibit E.3 Demonstration of separation of magnetic and nonmagnetic items at METEC

Exhibit E.4 shows individual letters from school children who have visited the facility on a school trip expressly to understand the need for recycling. There are also several publications that back up the demonstration unit, one of which is mentioned in this report.

Exhibit E.4 Letters from school children who have visited METEC

Exhibit E.5 Part of the education story at METEC

Exhibit E.6 It's not waste, it's treasure! (banner at METEC)

While units of this education type exist in the UK in places such as the Science Museum and elsewhere, being able to see the full-scale units in operation dismantling TVs, washing machines and fridges as at METEC gives them added impact.

For more information about METEC see link www.panasonic.co.jp/eco/en/metec.

Proof of education in action

The recycling ethos extends into everyday life with virtually every drinks dispenser having a built-in collection point for bottles and cans. In most stores there are facilities for recycling paper, plastic and even batteries.

Another example is a cleaning crew sorting waste from a train that has just been cleaned (Exhibit E.7). As can be seen from the photographs the Japanese have decided that industry should take the lead. This is part of the normal train cleaning process to segregate waste – every train undergoes this process each time it returns to the terminus (maybe another differentiating experience for Mr Branson to emulate!)

Exhibit E.7 Waste from trains is separated into plastic, paper and metal (mainly cans)

Appendix F

LIST OF EXHIBITS

Appendix G

GLOSSARY

~	approximately
≈	approximately equal to
€	euro (£1 ≈ €1.45)
¥	yen (£1 ≈ ¥200)
3Rs	reduce, reuse, recycle
ABS	acrylonitrile-butadiene-styrene
A/C	air conditioner
ACCA	Association of Chartered Certified Accountants (UK)
AD	active disassembly
ADSM	active disassembly using smart materials
AEHA	Association for Electric Home Appliances (Japan)
B2B	business-to-business
BP	boiling point
^{o}C	degrees Celsius
CAD	computer-aided design
CARE	Comprehensive Approach for the Recycling and Eco-efficiency of Electronics (EUREKA network)
CEO	Chief Executive Officer
CFC	chlorofluorocarbon
CMR	closed material recycling
CO2	carbon dioxide
CRT	cathode ray tubes
DEM	Disassemblability Evaluation Method
DTI	Department of Trade and Industry (UK)
DVD	digital versatile disc
E&E	electrical and electronic
EC	European Commission
ECP	Environmentally Conscious Product (Hitachi Ltd, Japan)
EFSOT	Environment-Friendly SOldering Technology (EC project)
EfW	energy from waste
EoL	end of life
EU	European Union
F	fax
FP5	Framework Programme 5 (EC)
g	gravitational force
GDP	gross domestic product
GPL	Green Purchasing Law (Japan)
h	hour
HARL	Home Appliance Recycling Law (Japan)
HCFC	hydrochlorofluorocarbon
HEART	High Efficient Applicable Recycle Technology (system, Japan)
ID	identification

IMS	Intelligent Manufacturing Systems
IP	intellectual property
IPF	International Plastic Fair
IPR	intellectual property right(s)
ISO	International Organization for Standardization
ITP	International Technology Promoter (network, DTI)
JV	joint venture
kg	kilogram
km	kilometre = 1,000 m
kWh	kilowatt-hour
L	left
LCA	Life Cycle Assessment (method)
LCD	liquid crystal display
LPEUR	Law for Promotion of Effective Utilisation of Resources (Japan)
m	metre
MEI	Matsushita Electric Industrial Co Ltd (Japan)
METEC	Matsushita Eco Technology Centre Co Ltd (Japan)
METI	Ministry of Economy, Trade and Industry (Japan)
mm	millimetre = 0.001 m
MSW	municipal solid waste
OEM	original equipment manufacturer
Pb	lead
PC	personal computer
PCB	printed circuit board
PDA	personal digital assistant
PDF	portable document format
PERL	Production Engineering Research Laboratory (Hitachi Ltd, Japan)
PET	polyethylene terephthalate
PLA	polylactide
PMG	precious metal group
PP	polypropylene
ppm	parts per million
PS	polystyrene
PV	photovoltaic
PVC	polyvinyl chloride
R	right
R22	refrigerant 22 (chlorodifluoromethane: $CHClF_2$)
R115	refrigerant 115 (chloropentafluoroethane: C_2ClF_5)
R134	refrigerant 134 (1,1,1,2-tetrafluoroethane: $C_2H_2F_4$)
R502	refrigerant 502 (azeotropic mixture of 48.8% R22 + 51.2% R115)
R&D	research and development
RDF	refuse-derived fuel
REM	Recyclability Evaluation Method
RoHS	Restriction of Hazardous Substances (EU directive)
S&T	science and technology
SEEDA	South East England Development Agency (UK)
SME	small to medium enterprise
SMT	surface mount technology

Sn	tin
t	tonne = metric ton = 1,000 kg
T	telephone
TV	television
UK	United Kingdom
US(A)	United States (of America)
VCR	video cassette recorder
WEEE	waste electrical and electronic equipment
WIP	work in process
W/M	washing machine
y	year

Other DTI products that help UK businesses acquire and exploit new technologies

Grant for Research and Development – is available through the nine English Regional Development Agencies. The Grant for Research and Development provides funds for individuals and SMEs to research and develop technologically innovative products and processes. The grant is only available in England (the Devolved Administrations have their own initiatives).
http://www.dti.gov.uk/r-d/

The Small Firms Loan Guarantee – is a UK-wide, Government-backed scheme that provides guarantees on loans for start-ups and young businesses with viable business propositions.
http://www.dti.gov.uk/sflg/pdfs/sflg_booklet.pdf

Grant for Investigating an Innovative Idea – is designed to help UK businesses develop innovative products, processes or services that are in the very early stages of development.
http://www.dti.gov.uk/innovative-idea/index.htm

Knowledge Transfer Partnerships – enable private and public sector research organisations to apply their research knowledge to important business problems. Specific technology transfer projects are managed, over a period of one to three years, in partnership with a university, college or research organisation that has expertise relevant to your business.
http://www.ktponline.org.uk/

Knowledge Transfer Networks – aim to improve the UK's innovation performance through a single national over-arching network in a specific field of technology or business application. A KTN aims to encourage active participation of all networks currently operating in the field and to establish connections with networks in other fields that have common interest.
http://www.dti.gov.uk/ktn/

Collaborative Research and Development – helps industry and research communities work together on R&D projects in strategically important areas of science, engineering and technology, from which successful new products, processes and services can emerge.
http://www.dti.gov.uk/crd/

Access to Best Business Practice – is available through the Business Link network. This initiative aims to ensure UK business has access to best business practice information for improved performance.
http://www.dti.gov.uk/bestpractice/

Support to Implement Best Business Practice – offers practical, tailored support for small and medium-sized businesses to implement best practice business improvements.
http://www.dti.gov.uk/implementbestpractice/

Finance to Encourage Investment in Selected Areas of England – is designed to support businesses looking at the possibility of investing in a designated Assisted Area but needing financial help to realise their plans, normally in the form of a grant or occasionally a loan.
http://www.dti.gov.uk/regionalinvestment/

The DTI Global Watch Service provides support dedicated to helping UK businesses improve their competitiveness by identifying and accessing innovative technologies and practices from overseas.

Global Watch Information

Global Watch Online – a unique internet-enabled service delivering immediate and innovative support to UK companies in the form of fast-breaking worldwide business and technology information. The website provides unique coverage of UK, European and international research plus business initiatives, collaborative programmes and funding sources.
Visit: www.globalwatchservice.com

Global Watch magazine – distributed free with a circulation of over 50,000, this monthly magazine features news of overseas groundbreaking technology, innovation and management best practice to UK companies and business intermediaries.
Contact:
subscriptions@globalwatchservice.com

UKWatch magazine – a quarterly magazine, published jointly by science and technology groups of the UK Government. Highlighting UK innovation and promoting inward investment opportunities into the UK, the publication is available free of charge to UK and overseas subscribers.
Contact:
subscriptions@ukwatchonline.com

Global Watch Missions – enabling teams of UK experts to investigate innovation and its implementation at first hand. The technology focused missions allow UK sectors and individual organisations to gain international insights to guide their own strategies for success.
Contact:
missions@globalwatchservice.com

Global Watch Secondments – helping small and medium sized companies to send employees abroad or receive key people from another country. Secondments are an effective way of acquiring the knowledge, technology and connections essential to developing a business strategically.
Contact:
secondments@globalwatchservice.com

Global Watch Technology Partnering – providing free, flexible and direct assistance from international technology specialists to raise awareness of, and provide access to, technology and collaborative opportunities overseas. Delivered to UK companies by a network of 22 International Technology Promoters, with some 8,000 current contacts, providing support ranging from information and referrals to more in-depth assistance with licensing arrangements and technology transfer.
Contact: itp@globalwatchservice.com

For further information on the Global Watch Service please visit
www.globalwatchservice.com

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