


Patent Landscape Report on

E-Waste Recycling Technologies

2013

PATENT LANDSCAPE REPORTS PROJECT

in cooperation with BASEL CONVENTION

WIPO
WORLD
INTELLECTUAL PROPERTY
ORGANIZATION

The WIPO patent landscape report project is based on the Development Agenda project DA_19_30_31_01 "Developing Tools for Access to Patent Information" described in document CDIP/4/6, adopted by the Committee on Development and Intellectual Property (CDIP) at its fourth session held from November 16 to November 20, 2009.

The purpose of each report is three fold:

- It attempts to research and describe the patterns of patenting and innovation activity related to specific technologies in various domains such as health, food and agriculture, climate change related technologies, and others.
- WIPO attempts to collaborate for each report with institutional partners (IGOs, NGOs, public institutions of Member States) working in the respective field and having an interest in a specific topic. The collaborative work in the planning and evaluation phases may also serve as a vehicle for these institutions to familiarize themselves with the utilization and exploitation of patent information and related issues of patent protection. WIPO welcomes proposals for collaboration.
- Each report also serves as an illustrative example for retrieving patent information in the respective field and how search strategies may be tailored accordingly. It therefore includes detailed explanations of the particular search methodology, the databases used and well documented search queries that should ideally enable the reader to conduct a similar search.

Each report of this project is contracted out to an external firm selected in a tendering procedure. The tender is open to a limited number of bidders that were pre-selected based on their submission of an Expression of Interest (EOI). WIPO invites the submission of further EOIs by qualified providers.

More Information on the project, the ongoing work, and a compilation of reports published also by other institutions is available at: *www.wipo.int/patentscope/en/programs/patent_landscapes/pl_about.html*

For specific information, requests or proposals, please contact us at: patent.information@wipo.int

Patent Landscape Report on E-Waste Recycling Technologies

A patent landscape report prepared

for the

World Intellectual Property Organization (WIPO)

by Thomson Reuters IP Analytics

– Ed White and Rohit Singh Gole –

In cooperation with the

Basel Convention Secretariat

November 2013

EXECUTIVE SUMMARY

The present Patent Landscape Report (PLR) forms part of WIPO's Development Agenda project DA_19_30_31_01 ("Developing Tools for Access to Patent Information") described in document CDIP/4/6 adopted by the CDIP at its fourth session held from November 16 to November 20, 2009. This report is prepared in the context of collaboration of WIPO with the Secretariat of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (SBC, website: www.basel.int), which is administered by the United Nations Environment Programme (UNEP). The report aims at providing patent based evidence on the available technologies and the patenting trends in the area of electronic waste (e-waste) recycling and material recovery, while it is intended to provide background and supporting information to the Partnership for Action on Computing Equipment under the Basel Convention and complement the Guideline on Material Recovery and Recycling of End-of-Life Mobile Phones and the Guideline on Environmentally Sound Material Recovery and Recycling of End-of-Life Computing Equipment.

The report covers in detail patent applications and granted patents within the space of e-waste processing, and the recycling and recovery of materials from consumer products at the end of their useful life. Additionally, the report uses reference information such as news and other business data sources to extend the information into real-world applicability, and also to verify the interest and commercial activity of entities mentioned within the study.

The patent landscaping process applied to the e-waste field has uncovered several interesting facets of the electronic waste industry. Specifically, the patent activity of global e-waste innovation points strongly to the commoditization of electronic waste; in particular as a source of high value materials, such as rare earth metals (e.g. lanthanum, neodymium and praseodymium) that are commonly used in modern electronic items. A similar trend is also shown for noble metals, in particular silver, but also gold and platinum.

Confirming this trend are the high levels of patent applications from metallurgy and refractory corporations, such as JX Nippon Mining and Metals, Kobe Steel, Mitsui Mining and Smelting and others. These companies are not just applying for patents; they are in some cases investing heavily in them, seeking protection for their research in multiple jurisdictions around the world, in a process which adds substantially to the cost of patent prosecution. This is particularly the case for Japanese corporations where multiple translations into English, French and Chinese may be required.

This commoditization of e-waste is evident in a certain level of specialization of commercial entities in different parts of the world. The International Labour Organization recently published a report on the flow of e-waste streams from developed economies such as Europe and the US to Asia, in particular to China and India. [1]

From the patent analysis it is clear that for example domestic Chinese registered innovation tends to deal with the dismantling of electronic items, separation of waste streams and focuses on devices at a component level, e.g. printed circuit boards, batteries etc. Conversely, innovation from developed economies is more focused on the complete device, e.g. a television, computer or mobile phone.

The clearest trend however is the emergence of Chinese domestic patent activity overall within the e-waste industry. Patent application rates have increased seven-fold in just 6 years, and is largely driven by academic institutions. This perhaps indicates the existence of incentive schemes for academic patent filing, a point bolstered by the fact that very few Chinese domestic patent applications are also filed in other jurisdictions – a common occurrence for patent rights from other territories. Therefore, it is difficult as yet to assert what the wider implication of this explosion of intellectual property (IP) activity in China will ultimately be. The huge growth also means that the majority of these patents are still applications, as applications tend to remain pending for a period of 4 years or more, and other metrics of patent quality such as citation rates and patent sales are also somewhat tied to age.

Whatever the outcome, of no doubt is that Chinese innovation in the e-waste industry is occurring, and growing rapidly.

Acting as a counterpoint to the quick emergence of China as a major source of inventions is the slump in activity of Japanese corporations.

Measured as a whole over the last thirty years, Japanese consumer electronics and metals firms represent the largest and most dominant portfolios – entities such as Panasonic, Hitachi and Toshiba. However, the patent output of Japan in aggregate peaked in 2001 and has almost halved in the last 12 years, remaining stagnant at a new lower level for the last 5 years.

Overall, patent activity within e-waste closely mirrors the rate of growth exhibited by mentions of the topic in the media, confirming that growing economic interest in dealing with end-of-life electronics is occurring alongside and spurring on global innovators.

GENERAL FILING TRENDS

- The vast majority of activity in e-waste is Asian in nature, followed by activity from Europe. The United States makes up a relatively small proportion of activity, indicating a potential disinterest by US entities in e-waste technology.
- Activity in e-waste patented innovation is concentrated in the post-2000 time period.

[1] "*The global impact of e-waste: Addressing the Challenge*", International Labour Organisation, December 2012, http://www.ilo.org/wcmsp5/groups/public/---ed_dialogue/---sector/documents/publication/wcms_196105.pdf

- During this period, there are two distinct phases of activity; an early, secondary peak in activity occurring in 2000 which subsequently falls away, followed by a second phase of increasing activity which may not yet be complete.
- The two phases of activity are driven primarily by a slump in patent output from Japanese corporations and a corresponding large-scale expansion of activity from China.
- However, Chinese (and to an extent Japanese) patent activity is predominantly local. Out of 1,430 inventions first filed in China just 15 have been filed in another patent authority – a rate of just 1%. The overall number is a similar volume to far smaller economies, such as the Netherlands, Austria, Sweden and Australia.
- There has been a strong dilution in the level of international patent protection due to the increases in activity from China, Russia and Korea – the majority of which is protected locally in just a single patent jurisdiction.
- Patents that are filed in multiple jurisdictions originate predominantly from Japan, the US and Germany.

TECHNOLOGY FINDINGS

- From a technical viewpoint, the landscape can be divided into three key concepts:
    - Materials that are being recovered and recycled from e-waste streams, items such as plastics and metals
    - Sources of e-waste and the processing of these sources, such as batteries, displays, cabling and printed circuit boards
    - The processes and logistics involved in e-waste treatment or recycling, such as magnetic sorting, IT related management of recycling systems and similar items.
- The majority of the innovation in the space is concentrated on individual discrete components of devices, primarily batteries and printed circuit boards.
- Common processing steps in the landscape include disassembly and subsequent waste separation, with a tertiary topic around decontamination.
- From a materials perspective, activity in terms of total number of patent filings is concentrated in non-ferrous metals (e.g. copper, nickel etc.), plastics, ferrous metals and hazardous materials (e.g. arsenic, antimony and primarily, lead).
- Smaller topics within this high level view include “other” recovered materials outside of those listed, such as ceramics or rubbers, and rare earth metals.

- There has however been a large increase in patent activity concerning the recovery of rare earth metals as well as extraction or recovery of noble metals (i.e. gold, silver or platinum) from e-waste streams.

- Recovery of rare earth metals not only is fast growing, but also is one of the most heavily protected technologies in terms of geographic extension of protection. Taken together, this data point strongly infers that the field is a major emerging topic of interest to patent applicants.

- Further, US-based activity concentrates on rare earth extraction – a higher absolute number of patent families from US based applicants than Chinese based applicants. China is the source of 90% of the primary extraction of rare earth metals and the materials are not typically sold as an open commodity. This being the case, there is a strong incentive for US (and indeed, Japanese and European) electronics manufacturers to source these important elements outside of the closed market.

- It was noted that growth in a specific class of recovered materials may be being driven by regulation concerning solder. Solder has historically been an alloy of lead and tin with various proportions used for different applications of solder. However, in recent years there has been a strong movement towards the removal of poisonous lead from consumer electronics, and this has seen the replacement of lead in solder alloys by pure tin, but more commonly tin, silver and copper solders.

- There are peaks in activity across all of these mentioned materials – lead, tin, silver and copper, and indeed copper and silver recovery have been both growing sharply over and above tin recovery as a topic, indicating a movement coinciding with regulatory change in the solder industry. Furthermore, the primary noble metal extracted from e-waste appears to be silver, and this is likely due to the solder regulations; for example the European Union Waste Electrical and Electronic Equipment Directive (WEEE) 2012/19/EU[2] and Restriction of Hazardous Substances Directive (RoHS) 2011/65/EU[3] that came into effect in 2011.

- E-waste patent activity mentions mobile devices or other telephony equipment relatively rarely in comparison, despite the strong likelihood of these items making up a very large proportion of real-world e-waste streams. Two potential reasons for this discrepancy include:
    - Mobile devices are strongly tied to "computing" equipment, and it is difficult in modern parlance to separate the two; therefore, mobile device e-waste technology may have been split between the computers/laptops category and the telecoms device category

[2] http://ec.europa.eu/environment/waste/weee/index_en.htm

[3] http://ec.europa.eu/enterprise/policies/european-standards/harmonised-standards/restriction-of-hazardous-substances/index_en.htm

- E-waste innovation focused on mobile devices aims primarily at the components *within* the device, rather than the device itself. Therefore innovation in processing and recycling mobile devices is spread across several different categories such as displays, batteries, printed circuit boards etc.

- Growth sectors in mobile device e-waste recovery include a gathering focus on battery and printed circuit board e-waste within mobile devices and increasing use of chemical separation techniques and decontamination of mobile device waste streams. Also growing is the recovery of silver from mobile devices punctuating the data point seen across the landscape as a whole.

COMMERCIAL FINDINGS

- Activity in the w-waste landscape is relatively "top heavy", i.e. a large proportion of the total number of patent rights in the landscape is assigned to relatively few entities. More than one quarter of the patent families in the collection derive from just 21 patent applicants, all of whom have 40 or more e-waste inventions in the portfolio.

- Seen in reverse, just fewer than 2,500 entities have fewer than 5 inventions, but this only provides around a third of the entire landscape.

- All of the largest portfolios are based in developed economies, with none within the BRICS countries (Brazil, Russian Federation, India, China, South Africa). BRICS activity is strongly tied to the smallest portfolios, indicating that activity in these countries (primarily China) is highly diversified and spread across hundreds of different entities.

- Just 9% of the activity in the landscape comes from not for profit entities such as Academic or Research Institutions; however, academic patent activity is growing more rapidly than commercial activity when measured on a percentage growth basis.

- The growth rate in academic patent activity implies a tie to the high growth rates emanating from China, and indeed the analysis of major academic/government patent applicants shows this. Indeed, the top 30 research institutes in the landscape are all based in Asia. Overall, however, Chinese activity is particularly dominant, as well as being predominantly recent in comparison to other entities. This is in part due to the heavy usage of Chinese Utility Models by these entities, a type of patent that publishes particularly quickly.

- The largest not-for-profit entity is the Japanese AIST organization with 50 inventions going back over a decade in the field – indicating a strong research theme for the organization and therefore likely embedded expertise.

- Another institute of interest is KIGAM in Korea (Institute of Geoscience and Minerals). The inclusion of such a research institute in a landscape concerning e-waste acts as yet more evidence of the nature and importance of e-waste to materials recovery – particularly mineral and metal recovery.

- The first non-Asian not-for-profit entity in the landscape is the Fraunhofer Gesellschaft in Germany with 5 families followed by CNRS in France with 4 families.

- Japanese consumer electronics company Panasonic is the most active applicant in terms of widely filed/likely commercialized IP rights, followed by German specialist materials company HC Starck, Japanese metals corporation JX Nippon Mining & Metals, Sumitomo and Belgium chemical company Solvay.

- Assessment of the industrial nature of corporations includes several non-electronics firms, namely several corporations whose primary interest is in metals extraction – JX Nippon, Mitsui Mining and Smelting, Kobe Steel etc., which likely acts as confirmation of the nature of the e-waste landscape as transferring to a commodity economic model.

- All of the most prolific patent applicants in the landscape as a whole are Japanese firms; in particular Japanese consumer electronics firms as well as metals and refining corporations. There is strong association of plastic recycling with Japanese entities, in particular Japanese consumer electronics companies, indicating that this is their primary historical concern when it comes to e-waste processing.

CONTENTS

PART 1 – INTRODUCTION AND BACKGROUND TO THE PROJECT

In recent years, significant international transboundary movement has evolved in personal computers and associated hardware, used electronic equipment and used cellular telephones for the removal of usable parts, for refurbishment and reuse and for processing for the recovery of raw materials. Transboundary movement of these goods is forecast to increase significantly as more and more countries produce electrical and electronic equipment[4] and tighten control over acceptable disposal methods, adopt processes to recover valuable constituents and use safe practices to deal with the hazardous constituents in e-wastes (e.g. cadmium, lead, beryllium, CFCs, brominated flame retardants, mercury, nickel and certain organic compounds).

While offering some economic benefits, massive import of e-wastes coupled with the same wastes being generated locally is placing a heavy health and environmental burden, in particular to developing countries. Huge amounts of wastes, both hazardous and solid, is burned or dumped, e.g. in the rice fields, irrigation canals and along waterways. The open burning and toxic dumping pollute the land, air and water and exposes men, women and children to poisonous emissions and effluents. [5] The health and economic costs of this trade are neither borne by the developed countries nor by the waste brokers who benefit from the transaction.

As the use of mobile phones, computers and ICT equipment in general expands in all countries, their many benefits are joined by new challenges at their end-of-life. ICT equipment contains many metals, plastics and other substances, some of which are hazardous as indicated above, but some of which are valuable resources equipment (e.g., gold, silver, palladium, copper, aluminum, and plastics) that should not be wasted but can be recovered for use in new products. Recovery can also provide raw materials to the market with a lower environmental footprint than mining. Recently, the recovery of rare earth metals has attracted particular attention in view of scarce natural resources.

To avoid exposure of people and communities to the hazardous substances, and reduce the use of resources, end-of-life ICT equipment should be re-used - if possible - otherwise should be sent for material recovery/recycling at facilities that recycle electronics and that

[4] **Electrical and electronic equipment (EEE)**: equipment which is dependent on electric currents or electromagnetic fields in order to work properly including components that can be removed from equipment and can be tested for functionality and either be subsequently directly re-used or re-used after repair or refurbishment, Basel Convention, Draft Glossary of Terminology, 30 November 2012 .

[5] http://www.ilo.org/wcmsp5/groups/public/---ed_dialogue/---sector/documents/publication/wcms_196105.pdf

undertake environmentally sound management (ESM)[6] in their operations, and only as a last resort be sent for environmentally sound final disposal.

Numerous obstacles have been identified by developing countries in regard to their ability to manage e-wastes in an environmentally sound way. These include: lack of easily accessible information (on flows, quantities, available technology, legislative/trade requirements of countries importing new products, who will require increasingly strict standards for minimization and re-use, recycling and recovery); lack of trained personnel; inadequate legislations; inadequate infrastructure for collection, recycling and recovery; lack of public awareness; and lack of economic alternatives to activities carried out by the informal sector and small family repair shops.

Further background information on e-waste management, the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal and international activities related to e-waste management can be found in Annex E of the present report.

In order to better understand the technology development cycle, the geographic distribution of innovation, research topics and primary actors within e-waste related R&D, this study utilizes a process of assessing the patent activity associated with e-waste via a methodology known as patent landscaping.

Patent landscaping is a process whereby larger, specifically selected collections of patent documents (whether granted or otherwise) are analyzed to derive important technical, legal and business information.

The collections of patent documents can be selected according to whether they relate to a specific technological subject matter, for example an industrial process or material; or the collection can be defined at a much wider level such as an industry, such as is the case for the e-waste report. Similarly, one can also select a group of competitors within an industry, or simply the internal patent portfolio of a single organization.

While patents are publicly available information, aggregating data from multiple different sources (i.e. the various patent offices around the world), formatting and preparing it for analysis and then the analysis itself is no small task. A single patent document is typically 10-20 pages in length and contains technical details of the invention claimed. This deep information needs to be organized and mined for the approach undertaken or the device invented. Further, the document also contains bibliographic information such as the inventors' names, their employer, address information, the location of the patent application filing and other useful information that must be formatted, cleaned and prepared prior to in-depth analysis.

Patent information inherently contains commercially relevant information, due to the cost involved of filing and successfully prosecuting the application and the economic investment that the applicant has performed in researching and developing the invention itself – this being the primary motivation to organizing formal protection of an intellectual property right.

---

[6] http://www.basel.int/Implementation/PartnershipProgramme/PACE/PACEGuidanceDocument/tabid/3246/Default.aspx

Aggregation of patent information therefore provides technical and commercial conclusions, such as macro-economic or geographic trends in innovation or identifying changes in activity or technology commercialization strategy – whether industry wide or from a single organization. It also provides context of the major actors and players within a space as well as identifying more niche corporations or research institutions with expertise and interest in the field.

The objective of this patent landscape report is to provide a comprehensive overview of available technologies for the e-waste recycling and material recovery, including the recycling of e-waste components, as far as they are described by patent applications, to illustrate them with selected patent applications, and to identify the trends and patterns of patenting activity in this area.

Key references for this report were the related technical guidelines developed under the Basel Convention[7]:

• Guideline on Material Recovery and Recycling of End-of-Life Mobile Phones

• Guideline on Environmentally Sound Material Recovery and Recycling of End-of-Life Computing Equipment[8]

These Guidelines describe a chain of steps in e-waste management in general and the material recovery and recycling in particular. The landscape does not include all steps of e-waste management. Refurbishing/repairing, reuse of the devices etc. and also final disposal is not explicitly included. The recycling chain covered by the report includes only end-of-life equipment, i.e. it commences with and includes the dismantling and disassembling of devices, the separation or sorting of components or materials after dismantling, and the further processing (e.g. shredding, smelting etc.) of the dismantled components for the recovery and recycling of materials.

The scope of the landscape and its respective patent search is focused on the recycling of e-waste from ICT equipment, in particular mobile phones and computing equipment. Technologies which are only relevant for the management of e-waste originating from electrical appliances and electrical and electronic household equipment are not explicitly included, but may overlap considerably with relevant process; therefore technologies that can be equally applied to ICT and computing equipment, or to electrical appliances and electrical and electronic household equipment are included in the study.

The report aims at identifying patent families (including utility models) that claim inventions related to the above e-waste recycling and material recovery and within the scope as defined above. The landscape report exclusively researches inventions described in patent publications and not any other source of technical information for inventions.

As the study only aims at providing an overview of patent activity in the area of e-waste recycling and material recovery, it does not focus on aspects of validity of protection or freedom-to-operate, i.e. it does not comment on whether a patent that has been granted for a particular patent application has entered into force or is still valid. Claims have only been used as general guidance as to what types of subject matter is claimed as the invention.

[7] http://archive.basel.int/industry/mppiwp/guid-info/guidmaterial.pdf
[8] http://archive.basel.int/industry/compartnership/docdevpart/ppg21DraftGuidelineFinal-2011-03-15.pdf

However, in order to assess coarsely the level of innovation of applications, for each patent family, whether the family comprises at least one publication of a granted patent (based on the publication kind codes of patent family members) has been researched (see column of the excel sheet).

The report describes patterns or trends of patenting activities in this field by including a standard statistical analysis of the search results, e.g. with breakdown by main applicants, patent activity over time, priority countries (i.e. offices of first filing, OFF), geographical distribution of patent family members (i.e. offices of subsequent filings/second filing, OSF), distribution of patenting activity by type of technology and related components.

The report also includes, to a certain extent, information on the market environment, e.g. the activities of top applicants, or links between patent applications and those that have been commercialized. This information was sourced from databases such as Newsroom and from the corporations' websites themselves.

PART 2 – DESCRIPTION OF THE SEARCH METHODOLOGY

This section of the report provides a detailed explanation of the process of creating a collection of patent documents related to the field of electronic waste processing or material recovery.

Any patent search methodology, whether for patent landscaping purposes or other patent-related research, requires three primary fundamental steps:

- Selection of data sources and patent coverage
- Understanding and selection of appropriate patent classifications
- Understanding and selection of appropriate terminology related to the subject matter

This section of the report focuses on these three elements and describes the process undertaken for the creation of a collection of patent documents that accurately describe the e-waste landscape.

2.1 DATA SOURCES

The study uses the *Derwent World Patents Index™,* a database of patent applications and granted patents from 50 patent jurisdictions around the world produced by Thomson Reuters.

DWPI is a database that goes back to around 1965 for certain sources[9], but in essence can be described as an *editorially created* database of patents. The database is created editorially in the sense that the key content of patent applications and granted patents such as novel feature, applications, benefits are re-abstracted from the original text of the patent document into a standard format.

The database is also re-indexed by Thomson Reuters staff to an in-house patent classification system[10].

The DWPI database also organizes the raw patent information into families using a definition specific to the DWPI database. As each patent application or granted patent is published, the DWPI system compares the new document to the existing database and identifies any “equivalent” invention, e.g. in terms of claimed technical content. In this manner, the

[9] *For full details of the DWPI coverage and patent families, see DWPI Global Patent Sources*

[10] *For full details of the DWPI classification system, see DWPI Classification System*

database creates families of patent documents[11] that substantially relate to the same invention.

This process for so-called Thomson DWPI families differs from other definitions of patent families, that may be more administrative in their approach, e.g. exclusively compare priorities, and do not account for similar or indeed differing subject matter.

Overall, the usage of the DWPI database provides comprehensive global coverage back far enough in time for accurate descriptions of the landscape. In addition, the architecture of the database provides for good analytical capability, in particular:

- The database includes the following patent classifications for accurate and comprehensive record retrieval:
  - US Patent Classification
  - Cooperative Patent Classification (CPC)
  - International Patent Classification (IPC)
  - Japanese File Index (FI) and F Terms
  - DWPI Classification (editorially applied)
- The structure of the DWPI patent family allows for the usage of patent family and invention as synonyms.

2.2 COLLECTION COLLATION METHOD

The following steps were used to create and then refine the search methodology:

1. Creation of search strings including specific terminology with which to interrogate the database for e-waste related patent documents;
2. Analysis of the results to identify key classifications (DWPI, IPC, Cooperative Patent Classification and Japanese F-Terms);
3. Iteration of the search utilizing relevant classification terms to provide a more comprehensive dataset;
4. Analysis of the dataset to identify regions of off-topic subject matter;
5. Further iteration of the search to remove off-topic subject matter to the extent possible;
6. Finalization of the search string.

[11] *A single patent only provides a statutory monopoly for the patented technology within the legal jurisdiction of the authority that granted the patent. This means that inventors must file applications for a patent in each jurisdiction where they foresee a need for protection; for subsequent applications they usually claim the priority of the first filing.*

The usage of keyword and classification search strings for the creation of discrete technology datasets in patents and literature databases is a standard best practice for information science, informatics and bibliographic data of this type.

Throughout the above process, consultation took place with WIPO and the Basel Secretariat (UN Environment Program) to review and inform the search.

2.3 IDENTIFIED CLASSIFICATIONS OF RELEVANCE

The following patent classifications were identified in the course of the search creation procedure. The procedure for the identification of these classifications primarily concerned statistical analysis of returned patent datasets using defined terminology concerning e-waste, and initial reviews of highly relevant codes.

Not all the codes were used alone; where codes have been used in conjunction with other terminology, this has been noted below.

Derwent Manual Codes

V04-X01C Electronic Materials Waste Recovery and Recycling

V04-X01G E-wastes Decontamination and Disposal

X16-M Battery Materials Recovery

X25-W04 Industrial Waste Disposal; Recycling Processes and Systems *(used in conjunction with e-waste terminology)*

International Patent Classifications and CPC Codes

A62D0101* Harmful chemical substances made harmless, or less harmful, by effecting chemical change *(used in conjunction with e-waste terminology)*

B03B000906 General arrangement of separating plant; specially adapted for refuse *(used in conjunction with e-waste terminology)*

B03C0001* Magnetic separation techniques *(used in conjunction with e-waste terminology)*

B09B0003* Disposal of solid waste *(used in conjunction with e-waste terminology)*

B29B0017* Recovery of plastics or other constituents of waste material containing plastics *(used in conjunction with e-waste terminology)*

B29B001702 Separating plastics from other materials *(used in conjunction with e-waste terminology)*

C08J0011* Recovery or working-up of waste materials *(used in conjunction with e-waste terminology)*

C09K001101 Recovery of luminescent materials *(used in conjunction with e-waste terminology)*

C22B* Production and Refining of Metals *(used in conjunction with e-waste terminology)*

H01B0015* Apparatus or processes specially adapted for salvaging materials from cables

H01J000952 Recovery of material from discharge tubes or lamps

H01M000652 Reclaiming serviceable parts of waste cells or batteries

H01M001054 Reclaiming serviceable parts of waste accumulators

Japanese F-Terms

4D004AA22 Processing of solid wastes; Electric Products

4D004AA23 Processing of solid wastes; Battery

4D004AA24 Processing of solid wastes; Mounted substrate and Printed Circuit Board

4F401AC05 Separation, recovery or treatment of waste materials containing plastics; Consumer Electronics

4F401AC07 Separation, recovery or treatment of waste materials containing plastics; Electric wires, cables or insulating materials

4F401* Separation, recovery or treatment of waste materials containing plastics *(used in conjunction with e-waste terminology)*

4K001* Manufacture and refinement of metals *(used in conjunction with e-waste terminology)*

2.4 COMMENTS ON NOISE REDUCTION METHODS

Any large scale and wide ranging search strategy will inevitably return noise, i.e. irrelevant or off topic patent documents.

This is to be expected and can be tolerated, e.g. to the extent that this noise does not bias significantly trends observed in the related statistical analysis. In particular, the nature of patent landscaping and the use of advanced analysis techniques mitigate the effect of off topic hits, as any large scale areas of off topic subject matter can be easily identified and removed.

It is however more difficult to lessen the effects of many small, distinct off topic subject areas, each with few documents, that in aggregate may materially affect the results of the landscape study.

Specific items during the course of the e-waste search process creation included:

- Where terminology was allowed to exist unrestricted by classification, several different uses of the term “waste” and “recovery” were encountered. In particular: waste heat, waste water, recovery of data, power wastage and recovery of electronic signals, voltages and currents.

These topics were removed manually from the dataset using specific keywords related to them.

- The use of the acronym "PCB" for both Printed Circuit Board and Polychlorinated Biphenyl. Initially suspected to be noise, a decision was made to retain the Polychlorinated Biphenyl documents due to their overlap with electric transformers. While possibly tangential in nature due to differing power levels compared to typical consumer electronics, it was felt that the decontamination of power electronic elements could be of potential interest.

The primary method of concentrating the dataset onto topics of interest used a search-wide restriction of patent documents to the classification areas previously identified, as well as removing documents that fell into sections D (Textiles, Paper) or E (Fixed Constructions) of the IPC/CPC shared hierarchy. Further, documents in sections F (Mechanical Engineering, Lighting, Heating, Weapons, Blasting) or G (Physics) that were not also specifically covered by one of the relevant classification codes were also removed.

Each search string (see Annex B) used keywords and/or technology classification codes and indexing as appropriate to produce relevant individual technology collections. It is likely that there is some overlap between technology and inclusion of noise in the data; however, to the extent possible this has been minimized.

2.5 SEARCH STRING CREATION AND QUALITY CONTROL

The creation of the search string was performed iteratively, with the results of each generation of search string reviewed and evaluated to inform and tailor the search to become more accurate.

As each search string is created, the results are sampled and reviewed for relevancy, and keywords and classifications amended as appropriate. Further, the results of each string are data mined for further key terms of interest, synonyms and alphanumeric technology classification codes of relevance, which are then incorporated in revised search strings. This process is repeated until revisions perform only minor variations in results. At this point, the search string is locked in its configuration (see Annex B).

2.6 FINAL SEARCH STRATEGY

The finalized search was constructed using the following elements. These elements are listed in detail in Annex B.

1. Classification-only search, including DWPI Manual Codes, IPC/CPC Codes and Japanese F-Terms, unrestricted by keywords [Search 1]

2. Keyword search restricted by specific classification codes, including DWPI Manual Codes, Japanese F-Terms and IPC/CPC Codes [Search 2]

   This section also provided an equivalent search to e-waste key terms via the inclusion of specific DWPI Manual codes for:

   Mobile Devices and Cellular Telephones

LCD Displays

Printed Circuit Boards

Electronic Components, such as resistors, capacitors or inductors and derivations thereof

Discrete Semiconductor Devices, Integrated Circuits

Discharge tubes, cathode ray tubes, plasma displays and related equipment

Memories, Thin Films Circuits and Hybrid Electronic Devices

Audio Visual Equipment and TV/Broadcast Receivers

3. A full keyword search, with no restriction by classification (as yet) [Search 3]

Restrictions to these searches consisted of the following items:

1. All relevant patent classifications, whether IPC, CPC, Japanese F-Term of Derwent Manual Code, in places at a higher level of the taxonomy [Search 4]
2. Any patent documents with the term "e-waste" or its variants mentioned prominently [Search 5]
3. Specific removal of off topic subject matter as mentioned above [Search 6]
4. Restriction of patent documents first filed on or after January 1st 1980 [Search 7]

The number of patent families related to each of these search elements and the effect of the restrictions is shown in figure 1.

The full search strategy used for the e-waste patent landscape project is available in Annex B.

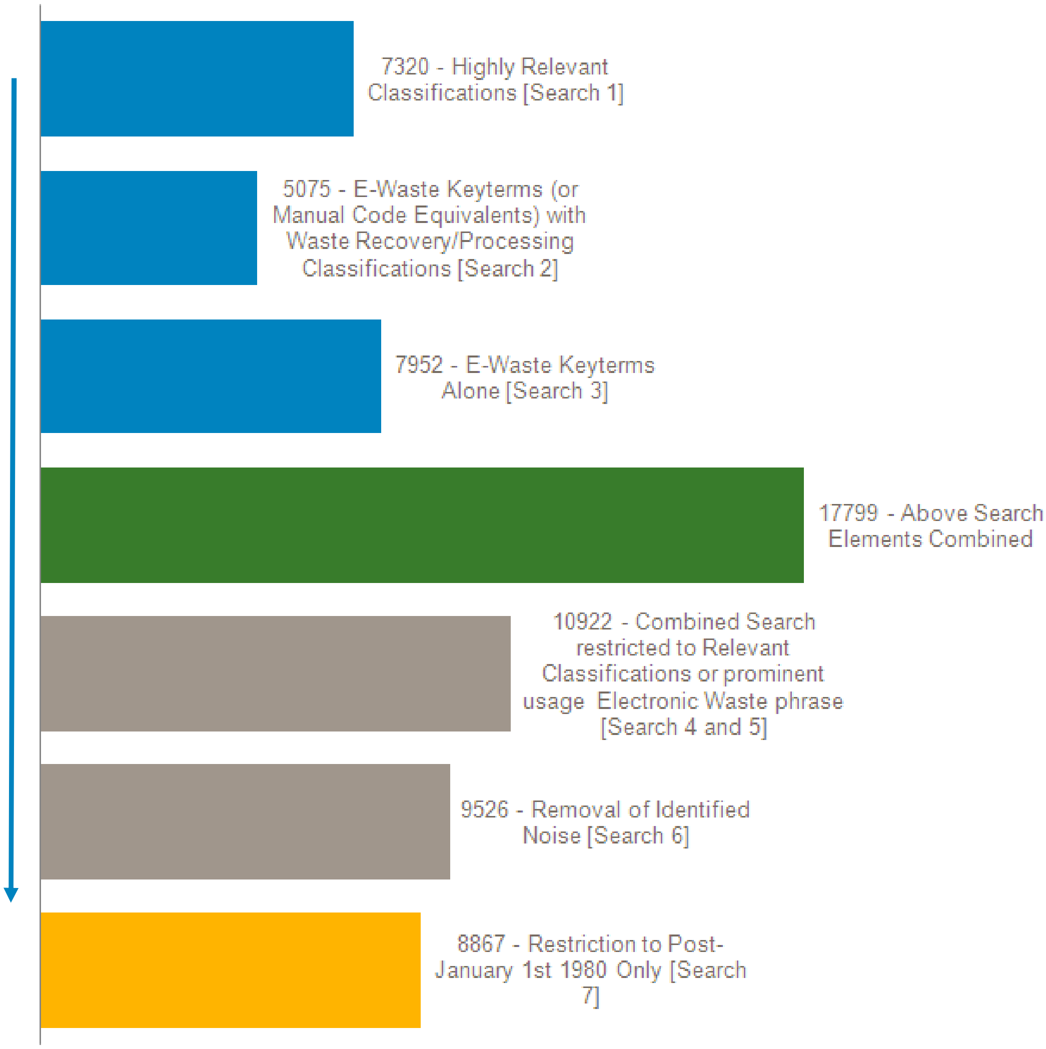


Figure 1 – Number of Returned DWPI Patent Families per Search Strategy Element

2.7 DATES AND COUNTS

All counts of records in the study refer to DWPI patent families or inventions, and not to individual patent documents. For example, the European application, European granted patent and the US granted patent for a single invention family is counted as “1” in all the analyses in this report unless otherwise noted.

This provides a more accurate measure of the level of inventive activity from an entity within the technical space, and a truer picture of the overall level of innovation across the field as a whole.

As each DWPI record contains potentially many individual publication events all with different dates, the report uses the earliest known office of first filing[12] date for each patent family. The

[12] *Office of first filing or Priority refers to the first application for a particular invention which when filed at any patent office becomes the “priority application”, with the date of this event defining the priority date. The patent office location of the first filing is defined as the priority country. The office of first*

tables and charts included in the report use this date unless otherwise noted, because it provides the most accurate indication of the time of the inventive activity.

The definition of patent sources, i.e. the location from which patent families are emanating, is based on the Office of First Filing. It should be noted that this definition is not 100% accurate, but provides a useful and fair method of identifying the habitual first filing location of entities, which is typically their home patent office.

2.8 PATENT APPLICANT NAMING VARIATIONS

The name of the organization to which inventors assign their invention (typically, their employer) varies considerably both within a single entity and over time.

For example, IBM can patent both under the acronym and as International Business Machines. Even within these two distinctions, variations in syntax, spelling and formatting can create problems with formal accurate analysis of entity names.

Furthermore, the acquisition of a company, or indeed the divestiture of subsidiaries can create issues with proper identification of patent ownership.

Therefore there is a requirement for normalizing the various name variants that exist within the dataset, as well research into mergers, acquisitions and subsidiaries to provide an accurate reflection of the ownership of patent rights within the landscape.

This process is performed using various methods, including:

- Identifying and correcting minor variations in names, e.g. IBM versus I.B.M.
- Identifying likely candidates for aggregation, such as distinct entities that share inventors; performing research on name variants for definitive identification
- Aggregating known historical mergers and acquisitions

Additionally, these methods provide a good method for minimizing the number of records that are not yet associated with an organization – e.g. unassigned US patent applications.

---

filing event provides the patent applicant with a grace period to file on the same invention in other patent jurisdictions (offices of second filing) without loss of the “novelty” requirement for patentability.

PART 3 – INTRODUCTION TO E-WASTE PATENT LANDSCAPE

The patent collection created and analyzed during the course of this study was created in conjunction with WIPO and the Basel Convention Secretariat (UN Environment Program), and consists of patent applications and granted patents within the Derwent World Patents Index concerning e-waste processing, recycling or recovery of materials from e-waste products.

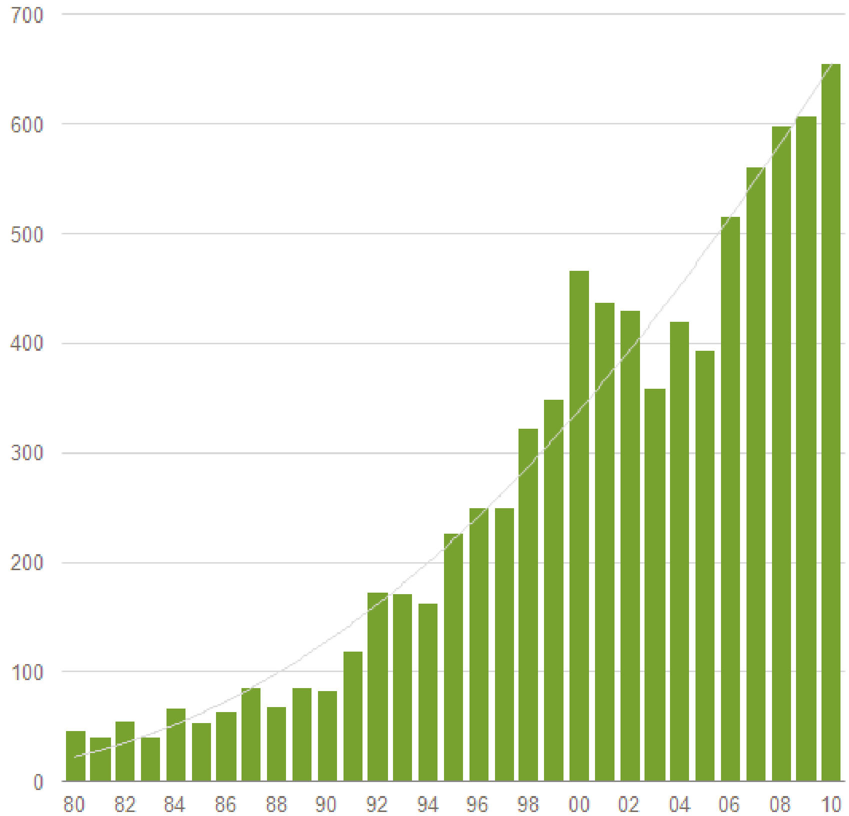


Figure 2 – Number of Patent Families per Year, 1980 to 2010; Earliest First Filing Year; Excludes Incomplete Years[13]

[13] *Patent families are measured by the earliest known "priority" or first filing event in the inventions history. Patents are typically retained by patent offices for 18 months or more after filing before they are published. This delay means that the last complete year of information available for patent information is 2010.*

Figure 2 shows the timeline of activity of the collection of 8,867 inventions or patent families indentified to be relevant through search. This timeline shows strong growth in activity since 1980, with activity concentrated in the post-2000 time period.

During this period, there are two distinct phases of activity; an early, secondary peak in activity occurring in 2000 which subsequently falls away, followed by a second phase of increasing activity which may not yet be complete. This is because the highest activity seen within the collection occurred for patent families first filed in 2010, which is the last year of complete information for this particular metric.

The earliest first filing year or the earliest priority year associated with each patent family is the most commonly used metric for patent activity performance measurement due to it being fixed in time; various different patent authorities have different periods of confidentiality and rules concerning publication of applications and grants; furthermore, the date is the most closely tied to the date of “innovation”, where the applicant has decided to register patent rights around the invention.

Measuring the earliest first filing date rather than publication dates has the effect of introducing a measurement “horizon” as patent documents are typically held confidential at patent offices until their publication, usually for a period of 18-months after initial filing. As data collation for the e-waste project occurred in mid-Q2 2013, this leaves 2010 as the last complete year of patent information (18 months prior to May 2013 being November 2011).

The two phases of activity in the overall timeline shown in figure 2 implies multiple phases of innovation activity, and indeed this is borne out when the data is analyzed at a national level (see figure 9).

Figure 3 shows a summary of the subject matter covered by the e-waste patent landscape in the form of a thematic concept map. This visualization shows the most commonly occurring concepts and phrases within the project collection, and has been further enhanced by annotation of the major themes via coloration.

In general, the collection can be divided into three key concepts:

- Materials that are being recovered and recycled from e-waste streams, items such as plastics and metals
- Sources of e-waste and the processing of these sources, such as batteries, displays, cabling and printed circuit boards
- The processes and logistics involved in e-waste treatment or recycling, such as magnetic sorting, IT related management of recycling systems and similar items.

The map in figure 3 will be mined further in later sections of the report for specific items, but its presentation here is intended to provide the reader with a holistic view of the current state of e-waste innovation. In particular, the concentration of effort surrounding battery processing is key, as a major item containing potentially several difficult to handle or hazardous chemicals, as well as the focus on printed circuit boards.

Also key is the large effort around materials recovery – primarily plastics, but also items such as noble metals and rare earths.

Figure 3 - Thematic Concept Map of e-waste Patent Landscape[14]S

[14] *ThemeScape® is a text-mining application that acquires and analyzes free text. The algorithms it uses require no application of thesauri or other outside sources of information, and only the free text itself is used by this text-mining tool. The more text the application acquires, the more likely it will be that the output will provide an accurate summary of the major themes present. After analyzing the text in multiple documents, it pulls together those documents that share related text and pulls apart those with less related text. The outcome is presented as a topographical map. Each document is placed on the map in a unique position that is the vector sum of its relatedness to all the other documents.*

3.1 E-WASTE PATENT ACTIVITY BY REGION

Patent protection is territorial; a Swiss granted patent only provides for statutory exclusivity to practice that invention in Switzerland. This being the case, applicants must assess which jurisdictions are best suited to protect their inventions.

ThemeScape uses the frequency of occurrence and co-occurrence of words to pick out topics of interest. It aggregates word forms that share a common stem, but it does not directly aggregate synonyms. Instead, synonyms may be gathered under a common theme because of the other words that co-occur with those synonyms. Thus, "battery" and "cell" may be clustered together because of the co-occurrence in the same documents of terms like "electrode, rechargeable, electrolyte" and so on. Conversely, "battery" and "cell" may be separated if the map contains a mixture of documents on electric power and biology, where the two terms have different meanings. In other words, terms are identified as synonyms only by co-clustering based on common context.

The topographical maps presented by ThemeScape are mathematical solutions built on a random selection of a first document and sequential calculation of the relationships of all the other documents. The orientation of the map is random, and the directions up, down, left, or right have no significance, because the n-dimensional solution might have been presented from any angle. Only the proximity of points within the map has meaning, and co-localized documents are highly likely to share concepts.

ThemeScape maps covering patents, abstracts of scholarly papers, news articles, or types of documents can be made. However two types of documents are not pooled and analyzed together. This is because ThemeScape is context-sensitive, and it would separate patent and literature documents from one another based on the very different formal styles of writing that are reflected in these two types of content. Likewise, if documents in two languages are pooled, it will separate them based on the language, and then each language region will be clustered based on term frequency in that language.

ThemeScape can analyze very large numbers of documents. The contour lines on the maps diminish in circumference, encircling regions of higher and higher document concentration. The density is also shown by the map coloration. White snow-capped peaks represent the highest density, while blue expanses (sea level) indicate low density.

The labels in black on the map are selected by ThemeScape based on term frequency in that map region, and they may be adjusted by the analyst. The dots on the map represent single documents. Dots are not shown for all the documents, and instead represent a sampling that allows the other features of the map to be discerned. Within the ThemeScape application, the map can be magnified, searched, probed and highlighted to learn more about its contents.

ThemeScape is reliant on statistical methods that are not equivalent to reading by human judges, and in compensation, it analyzes millions of documents on a scale of minutes and quickly presents an intuitive, high level summary. It enables and guides further review, and provides a first level overview of very complex datasets.

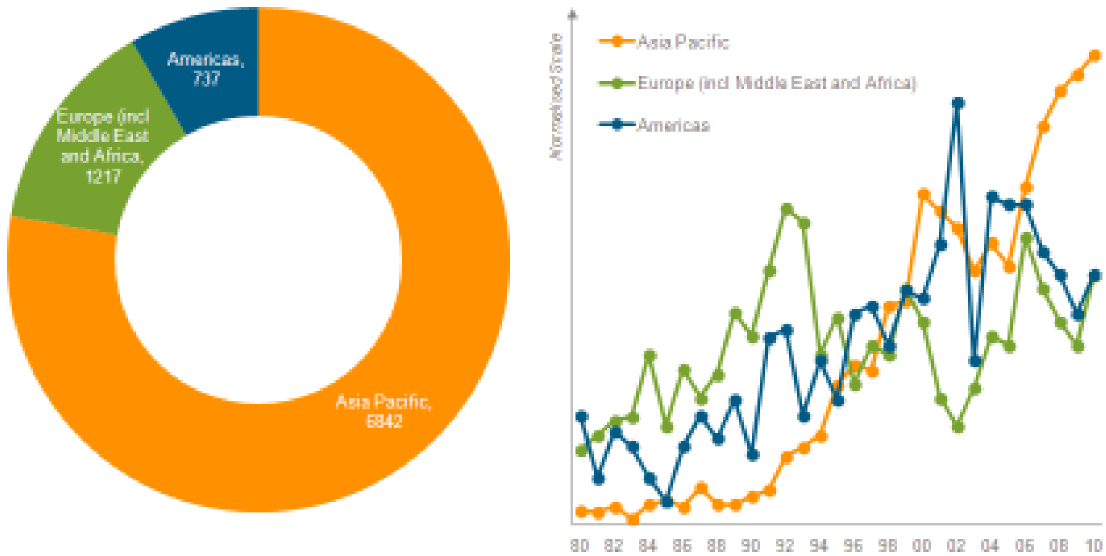


Figure 4 - Source of Patent Activity by Region; Timeline of Activity (normalized scale); Based on Earliest Office of First Filing Location

In many cases, in particular early on in research and development programs, applicants may be unsure of the potential economic returns that the technology could provide, and therefore they must strike a balance between the cost of filing in many different territories versus their estimate of the potential returns the technology could provide.

In practice, most applicants choose to protect their invention in their country of residence at first and then if required extend later – a process for which they generally have a year to decide upon if they wish to benefit of the provisions of the Paris Convention, or typically 30 months if they file a PCT application. The practice of filing locally at first has many advantages – the applicant can use their native language for the application, they can use local (likely cheaper) legal counsel for assistance with drafting and filing their application, and they likely have a greater familiarity with the IP laws and culture within their native jurisdiction.

The outcome of this is that the office of first filing event (the priority filing event) for any given invention correlates strongly to the physical geographic location of the applicant.

This correlation can be exploited to assess where in the world innovation within a given subject matter is emanating from.

Figure 4 summarizes the innovation geography within e-waste at a regional level based on this initial filing location basis.

The vast majority of activity in e-waste is Asian in nature, followed by activity from Europe, the Middle East and Africa (primarily in this case, Europe). The Americas (as would be expected, primarily the United States) makes up a relatively small proportion of activity – and likely points to a certain level of disinterest by US entities in e-waste technology.

Figure 5 moves the analysis from beyond the initial filing to all subsequent filing locations. Therefore, the chart visualizes the market of e-waste from the aggregate view of all applicants' reach of exclusivity – where they feel protection is required in order to extract maximum value from their inventions.

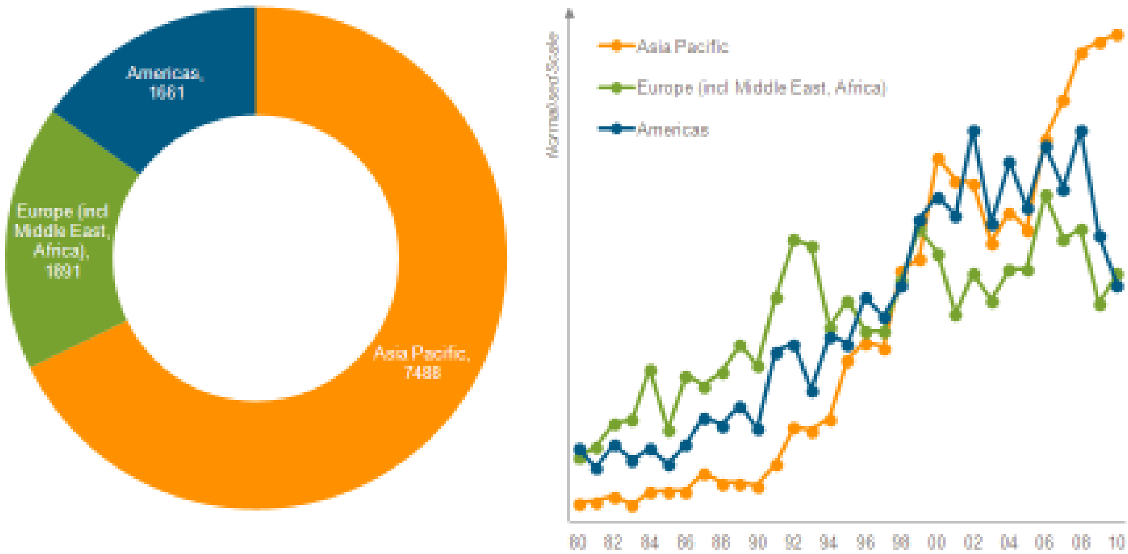


Figure 5 - Filing Locations of Patent Activity by Region; Timeline of Filing Location Activity

In this view, Europe, the Middle East and Africa (EMEA) and the Americas are much better represented, indicating an outflow of technology from Asia into other territories.

Figure 6 confirms this finding to an extent; it shows the number of patent families that have crossed from one region into another and the Americas (including North, South and Latin America) appears to be the most popular choice of global patent applicants.

A final view of this regional analysis is shown in figure 7, and shows the source and destination of cross-regional patent activity. This reveals Asian filings into the Americas as the key transfer of IP rights within the e-waste landscape.

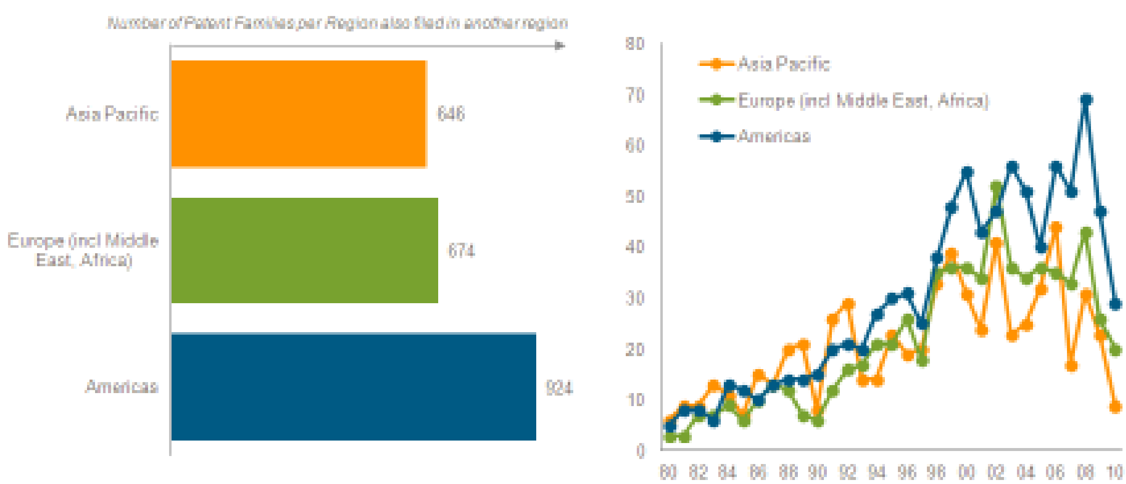


Figure 6 - Cross-Regional Patent Filings; Listed by Source Region also Filing in another Region; Timeline of Cross-Regional Activity by Source Region, by Earliest Priority Year

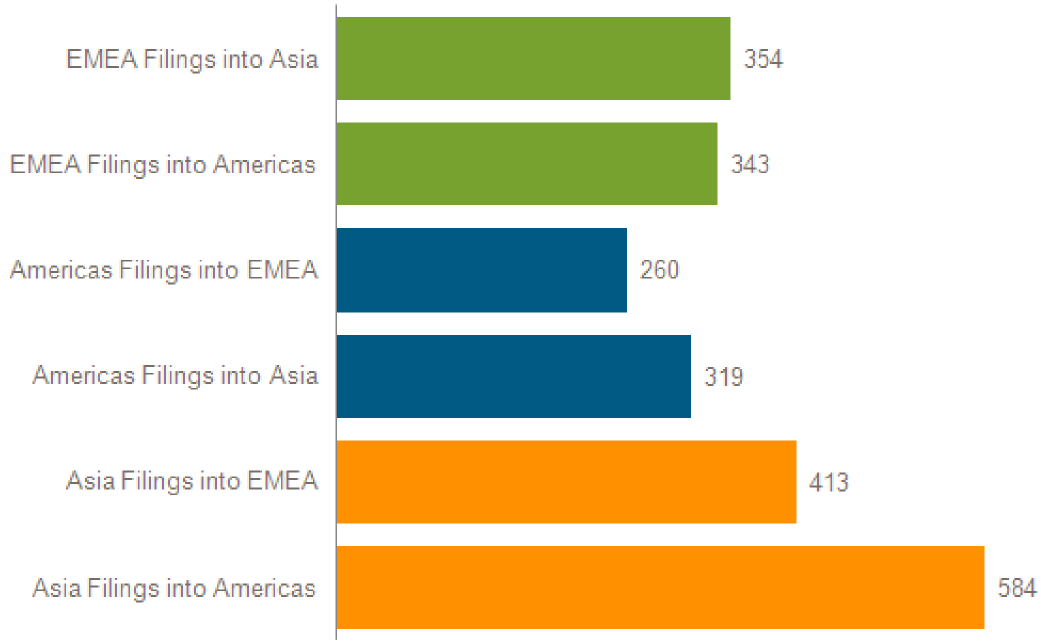


Figure 7 - Source and Destination of Cross-Regional Patent Filing Events; Number of Patent Families

3.2 E-WASTE PATENT ACTIVITY BY PATENT AUTHORITY

The previous section reviewed the e-waste collection at a regional level; this section drills into the activity at a national level.

The analysis rests upon the same correlation between the office of first filing location and the geographic location of patent applicants.

Figure 8 shows the major office of first filing (i.e. the priority filing) locations of applicants in the e-waste landscape. Japan is the pre-eminent source of activity, making up more than 50% of all activity.

China is now the secondary source of activity; however, as figure 9 (timeline of activity by major office of first filing location) shows, this is a relatively new phenomenon. Chinese activity has grown substantially from fewer than 50 new patent families per year prior to 2005, to almost 250 new inventions in 2010.

At the same time, Japanese activity has slumped from over 350 inventions filed in 2000 to activity rates at a similar level of China in the most recent year of data.

Both of these trends provide an explanation of the overall landscape timeline of activity, with the two distinct phases of activity breaking into an earlier Japanese peak in activity and the later and more recent growth in Chinese innovation.

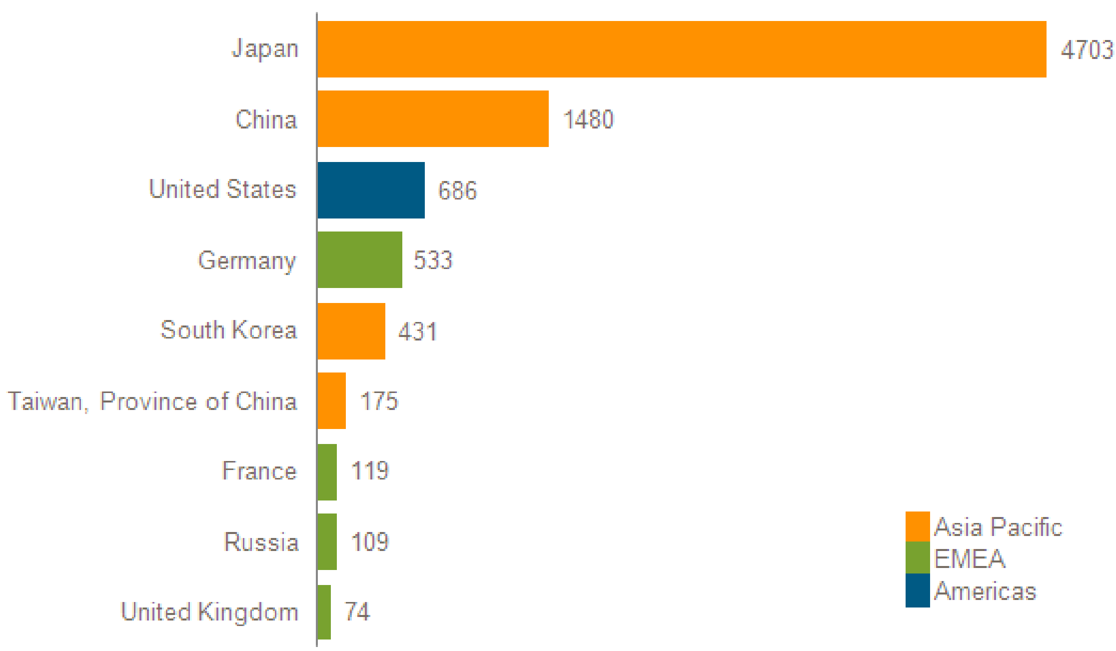


Figure 8 - Major Office of First Filing Locations of e-waste Patent Activity; Number of Patent Families First Filed in Each Territory

Activity from other geographies – for example, the United States and Germany – remains relatively low level. South Korean patent activity in e-waste is however also growing.

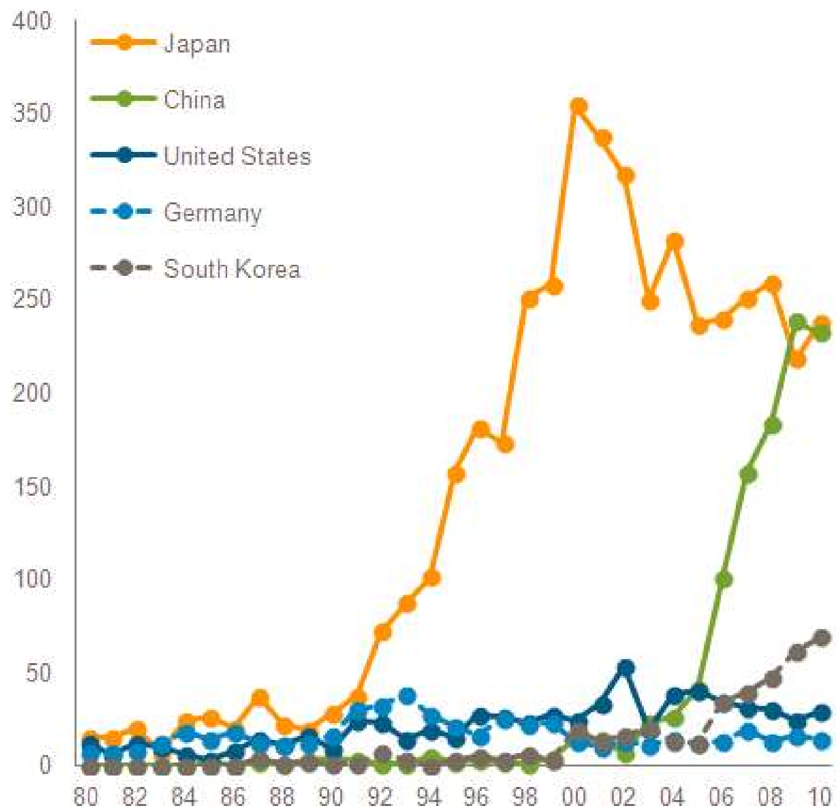


Figure 9 - Timeline of Patent Activity for Top 5 Office of First Filing Locations; Earliest First Filing Year; Excludes Incomplete Years

The timeline in figure 9 is summarized in trend form in figure 10. This shows the compound annual growth or decline in patent activity between 2006 and 2010, and highlights the growth of both South Korea and China, as well as the plateau and stagnation of activity from Japanese-based entities.

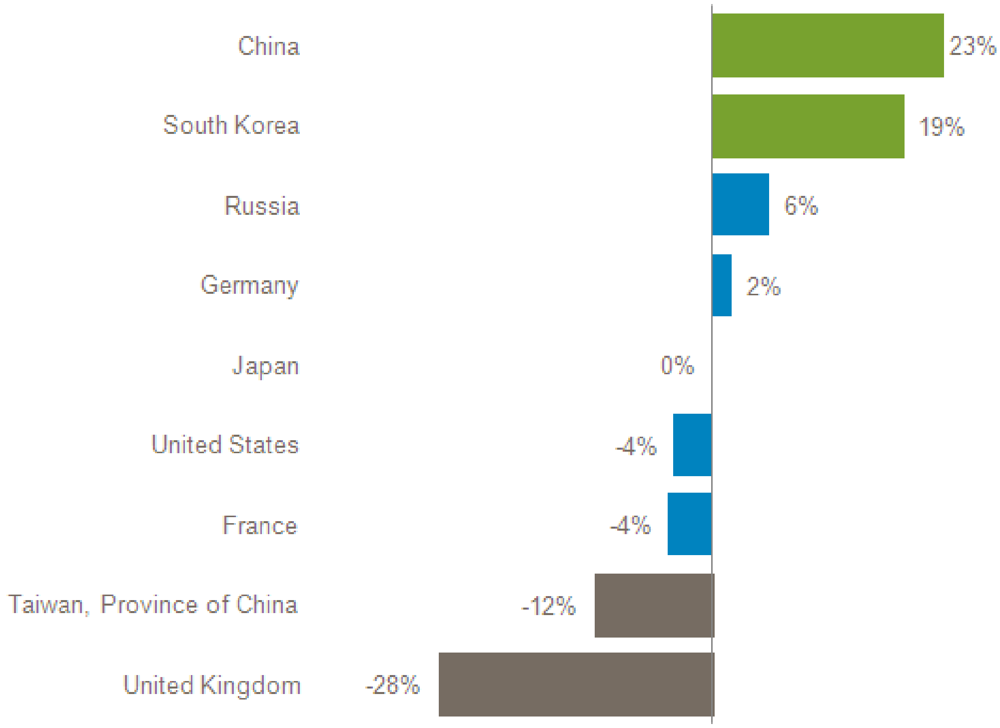


Figure 10 - Recent Changes in Patent Activity; Growth or Decline; Measured as Compound Annual Growth or Decline between 2006 and 2010; Based on Earliest First Filing Year

3.3 FULL LIST OF OFFICES OF FIRST FILING

The table below shows full office of first filing details for the full e-waste landscape, with the number of patent families shown for each authority. Also shown in the table is the classification of each country into Developed Economies (e.g. Japan, United States), the BRICS (Brazil, Russia, India, China and South Africa) or other economies, such as Malaysia and Mexico.

Table 1 - Number of Patent Families per Office of First Filing;

Offices of First Filing	Number of Patent Families	Developed Economy	BRICS	Other Economies
Japan	4703	■		
China	1480		■	
United States	686	■		
Germany	533	■		
South Korea	431	■		
Taiwan, Province of China	175	■		
Russia	154		■	
France	119	■		
United Kingdom	74	■		
Patent Co-operation Treaty	71			
European Patent Office	50	■		
Italy	48	■		
Australia	31	■		
Sweden	28	■		
Switzerland	27	■		
Brazil	26		■	
Austria	21	■		
Czech Republic	20	■		
Spain	20	■		
Hungary	19			■
Canada	18	■		
Netherlands	18	■		
Romania	15			■
India	13		■	
Belgium	11	■		
Israel	11	■		
Denmark	8	■		
Finland	8	■		
Poland	6			■
Norway	6	■		
Malaysia	4			■
Mexico	4			■
South Africa	4		■	
Ireland	4	■		
Slovakia	3			■
Chile	2			■
Ukraine	2			■
Luxembourg	2	■		
New Zealand	2	■		
Bulgaria	1			■
Croatia	1			■
Kazakhstan	1			■
Philippines	1			■
Turkey	1			■
Venezuela	1			■
Greece	1	■		
Monaco	1	■		
Portugal	1	■		
Singapore	1	■		

3.4 FULL LIST OF OFFICES OF SUBSEQUENT FILING

This table shows the full list of offices of subsequent (second) filing within the dataset for references purposes. This list is necessarily shorter in length from the office of first filing analysis in Table 1 due to the limitations of patent family coverage within the patent dataset. DWPI (the patent data source for the project) covers 50 distinct patent authorities around the world; however coverage of these patent authorities differs over time. In addition some patent authorities listed as the Office of First Filing are not covered in the DWPI database.

In addition, it appears that a group of specific patent offices are the general locations of subsequent filings, such as the United States, China, the European Patent Office and Taiwan, Province of China. This indicates that these countries expect an inflow of patent applications from other territories.

Table 2 - Number of Patent Families per Office of Subsequent Filing; Complete Collection

Offices of Subsequent Filing	Number of Patent Families
Patent Co-operation Treaty	1031
European Patent Office	990
United States	891
China	606
Japan	497
Germany	460
South Korea	403
Australia	359
Canada	297
Taiwan, Province of China	266
Spain	156
India	112
Brazil	99
Mexico	77
South Africa	68
Russia	63
Norway	59
United Kingdom	56
France	55
Czech Republic	47
Hungary	33
Finland	31
Netherlands	25
Israel	24
Singapore	22
Italy	20
Denmark	17
New Zealand	14
Philippines	14
Austria	13
Belgium	13
Slovakia	13
Portugal	12
Sweden	8
Romania	3
Switzerland	2
Ireland	2
Malaysia	2
Luxembourg	1
Poland	-1
Hong Kong	-
Vietnam	-
Thailand	-
Indonesia	-

3.5 GEOGRAPHIC MAPPING ANALYSIS OF MAJOR SOURCES OF E-WASTE INNOVATION

Figure 11 shows a geographic visualization of the major, minor and medium sources of patent applications and granted patents within the e-waste landscape.

All of the BRICS countries (Brazil, Russia, India, China and South Africa) are represented, though South Africa has just 4 patent family first filings.

Activity is particularly concentrated in Asia Pacific, with activity from Japan, China, South Korea, Taiwan, Province of China, and Australia.

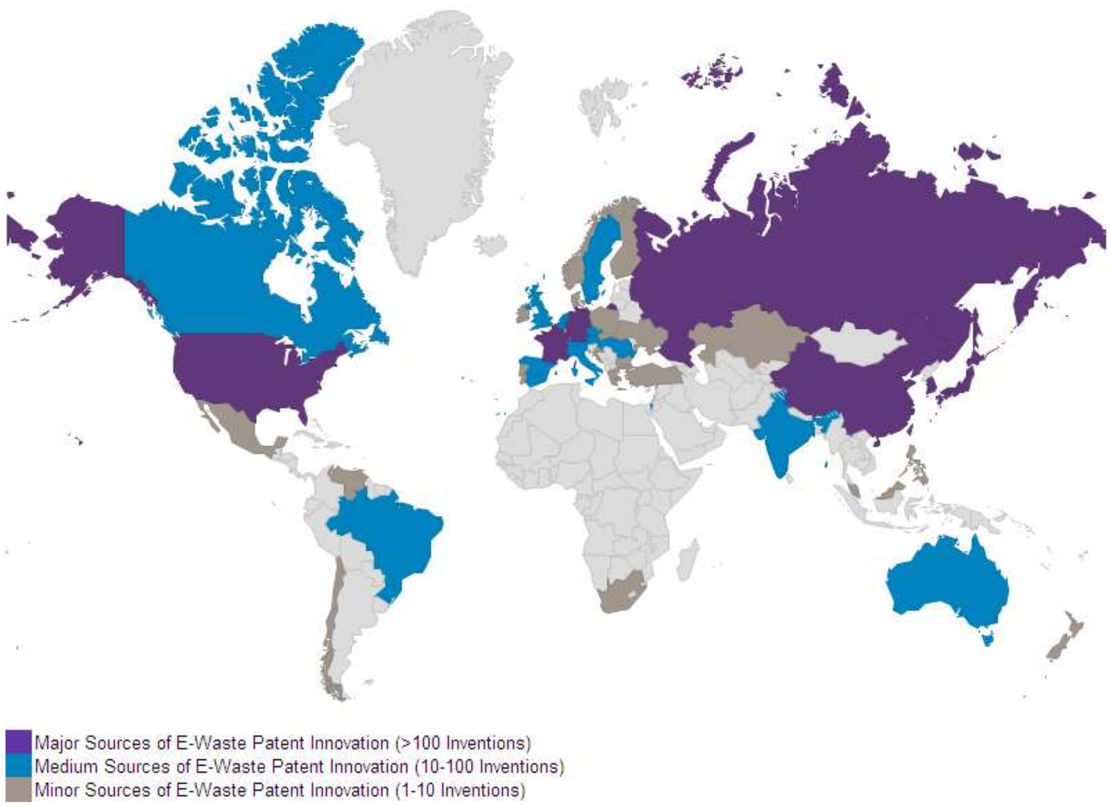


Figure 11 - Geographic Map of Sources of e-waste Patented Innovation; Based on Office of First Filing; Excludes Regional Patent Offices

3.6 DIFFERENCES IN IP PROTECTION STRATEGY IN E-WASTE BY LOCATION

While Japanese and Chinese patent activity dominates the landscape in terms of overall numbers of patent applications and granted patents, this volume in itself does not tell the entire story of intellectual property commercialization.

It was mentioned earlier that an applicant chooses where to protect its technology based on markets and where exclusivity is best placed in order to recoup the investment in technology and potentially build commerce around the invention.

Individual inventions that are protected in multiple locations reflect two potential positions of the applicant – a) organizations with existing businesses in multiple territories with a need to protect in multiple locations and, b) individual technologies of a higher intrinsic value or robustness that warrant broader geographic protection.

As the number of different locations into which an individual invention is protected correlates closely to a large increase in the cost of protection, patent families on average filed in more territories to an extent should be considered of a higher intrinsic quality, or at least likely to be used more extensively by their owner.

Figure 12 measures the average level of geographic protection for patents of the major offices of first filing by giving the average size of families orginating from the respective jurisdiction. The count of countries used for this calculation excludes filings via the PCT process, as these documents do not themselves produce granted patents; therefore excluding these documents from the metric allows for differentiation of inventions only filed via the PCT route. The primary finding of this chart is that Chinese-based patent applicants only protect their IP locally in China (a similar finding is also evident for Russian-based applicants).

Out of 1,430 inventions first filed in China, just 15 have to date also been filed in another patent authority – a rate of 1%. Therefore, e-waste technology from Chinese applicants appears to be primarily local in nature.

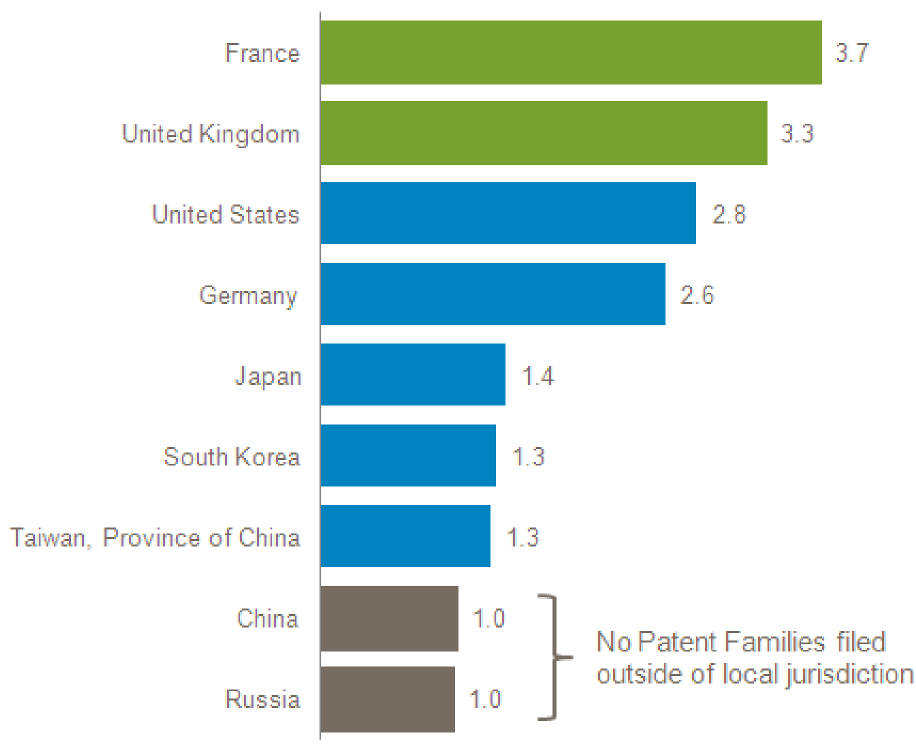


Figure 12 - Average Number of Filings Events (including First Filing) per Major Office of First Filing Location; Excludes PCT Application Filing Events

Similar levels of protection are also evident for the other Asian territories – Japan also has a relatively low level of international patent protection.

Figure 13 summarizes this distribution of IP protection strategies. The chart plots the volume of patent activity (x-axis) against geographic filing breadth (y-axis), and applicants in the US and Europe, while filing fewer patent applicants, file those applications in many more territories.

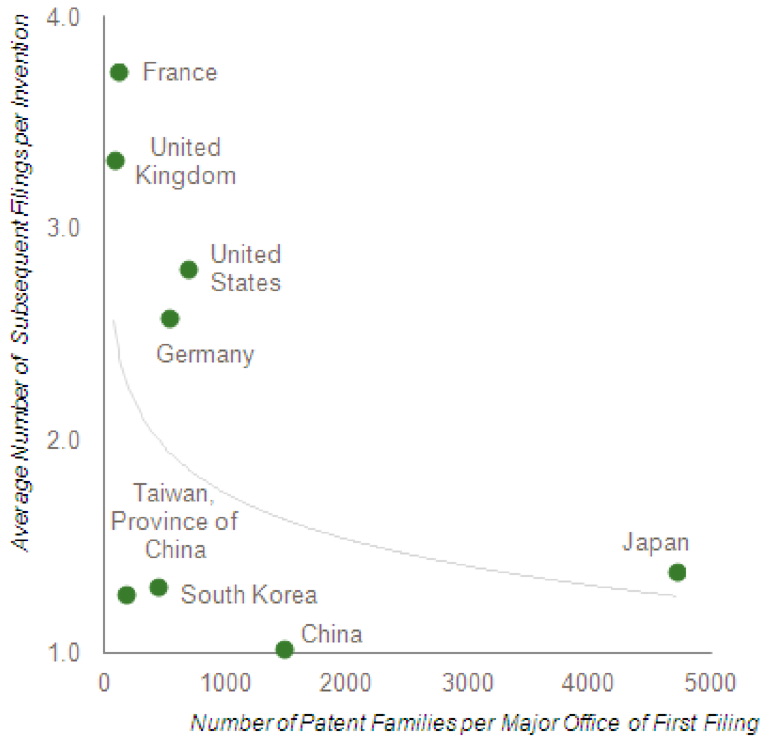


Figure 13 - Plot of Average Number of Filings per Patent Family versus Number of Patent Families per Major Office of First Filing Location

This analysis allows a few potential conclusions:

- E-waste processing is primarily occurring in Asia, and therefore for Asian entities there is little need for protection in the US or Europe; conversely, for US and European innovators additional protection in Asia is required.
- The applicants in Asia are filing many more diverse technologies more speculatively, (i.e. in fewer countries at lower cost), a more scatter-gun approach, while US and European entities are spending more time and resource developing targeted, vetted technologies that may inherently deserve greater and more expensive protection regimes.
- Patent prosecution of, in particular, Chinese and South Korean inventions may not yet be complete due to the large growth rates and therefore this metric may need to be monitored for subsequent commitment by the applicants to getting these patent applications granted locally, and for any follow up filing events in other territories.

3.7 E-WASTE LANDSCAPE ACTIVITY BY ECONOMY TYPE

A further view of the landscape is shown in figure 14 by the type of economy from which patent activity is deriving.

In this analysis, the offices of first filing locations have been grouped as to whether they are considered developed economies, are members of the BRICS group (Brazil, Russia, India, China or South Africa) or are from an emerging or developing economies outside of the BRICS grouping.

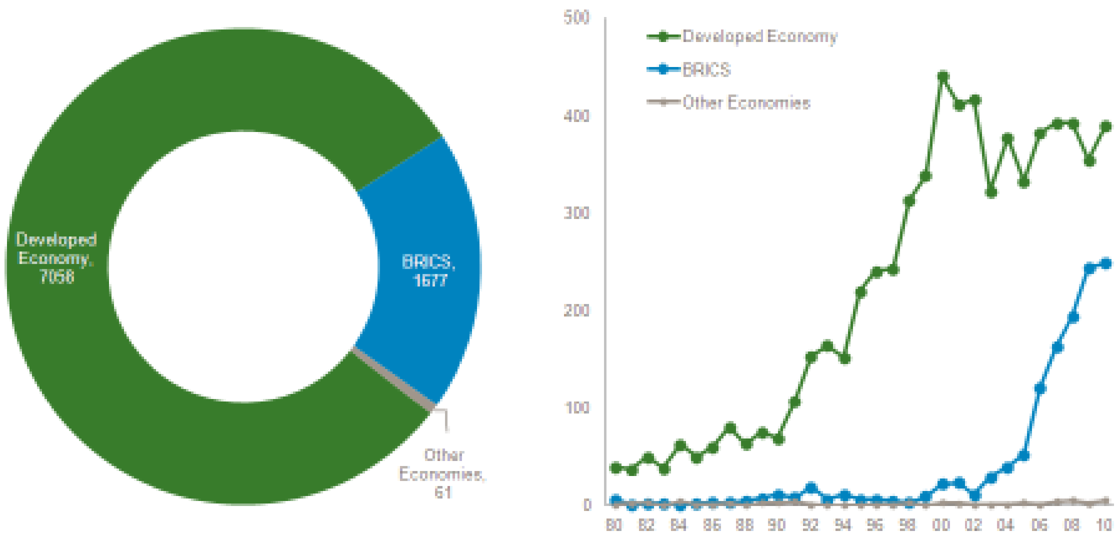


Figure 14 - Breakdown of e-waste Patent Landscape by Economy Descriptor; BRICS equals Brazil, Russia, India, China and South Africa; Timeline of Activity by Economy Category

The analysis serves to further represent the trends within the e-waste landscape as overall plateau of activity from developed economies (primarily Japan, US and Germany) and large-scale growth in activity from the BRICS economies (primarily China and Russia).

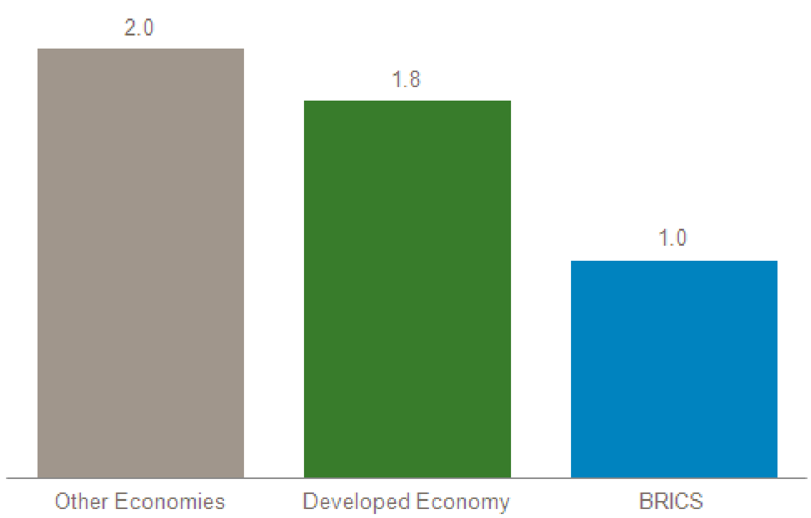


Figure 15 - Average Number of Filings Events per Economy Type across e-waste Patent Landscape

From a forecasting viewpoint, it would be expected that BRICS related activity in e-waste will likely outstrip patent activity from the developed economies by 2014-15 at the earliest.

Figure 15 again summarizes the international or otherwise nature of the patent activity emanating from each economic grouping. Activity from the BRICS economies is almost entirely protected in just a single patent jurisdiction, while activity from developed economies is more international in nature. Also evident from this analysis is the activity from the non-BRICS developing economies, which is also quite broad in its protection regime.

3.8 E-WASTE COLLECTION SUMMARY METRICS – FILING BREADTH, GRANT SUCCESS, PATENT PENDENCY AND MAINTENANCE OF IP RIGHTS

This section summarizes and reviews several fundamental parameters of the global patent activity in e-waste for later usage in conclusion making and to provide a greater understanding of dynamics in the field.

Figure 16 shows the breadth of geographic protection per patent family arrayed over time, and plotted alongside the overall collection activity time-series analysis (in grey).

There has been a strong dilution in the level of international patent protection due to the increases in activity from China, Russia and Korea – the majority of which is protected locally in just a single patent jurisdiction.

Normally, this type of analysis would tend to point to a technology field undergoing a second round of more fundamental research – with the increasing risks associated for individual innovators reflected in their reticence to invest heavily in the protection of their IP rights.

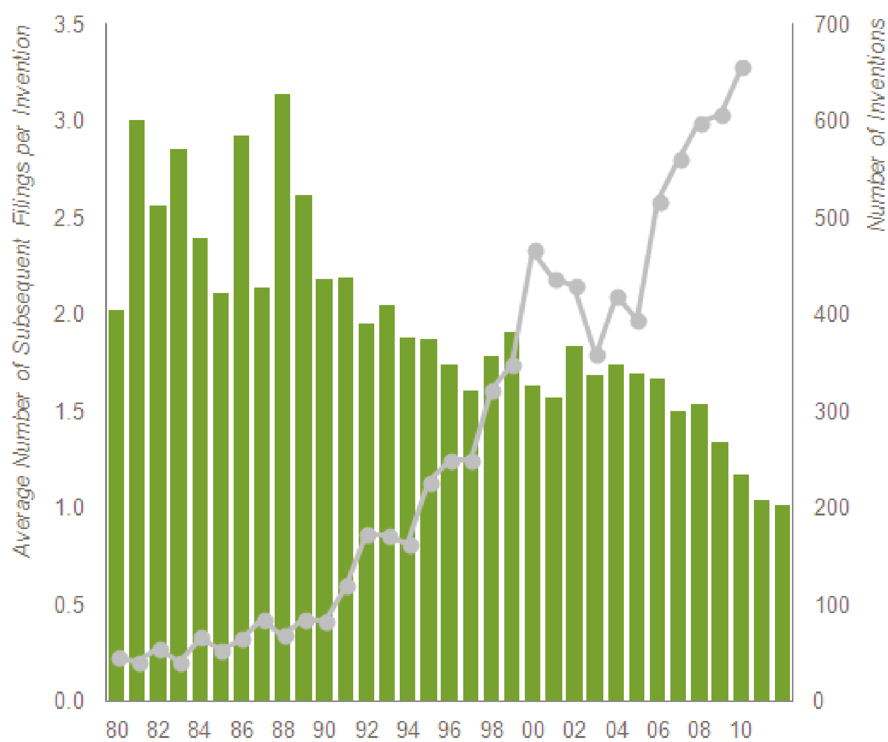


Figure 16 - Average Number of Subsequent Filing Events for Patent Families in e-waste Landscape for Families Filed Each Year; Co-Plotted with overall Timeline of e-waste Activity

However, as it has been shown in this landscape, this is more due to the fact that the e-waste technical landscape is undergoing a diversification of geography rather than technology, and it is this localization and specialization in e-waste processing that is driving the movement towards more local protection.

Figure 17 shows the number and proportion of activity within the landscape by the stage of patent prosecution reached – with families either only containing applications, at least one granted patent (and likely a mix of both applications and grant) or finally whether the family only contains Chinese Utility Models – shorter term, limited examination intellectual property rights.

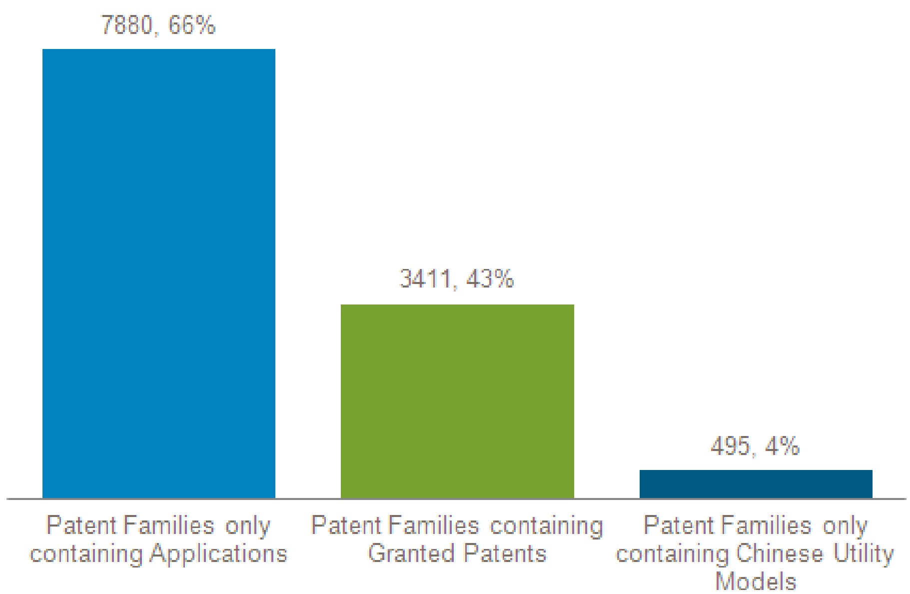


Figure 17 - Analysis of e-waste landscape based on prosecution stage reached and patent type; Number of Patent Families containing only applications; Number of patent families containing (at least one) granted patent; Number of patent families with only Chinese Utility Models

Figure 18 shows the average length of time between an application being filed and a granted patent being published in the same jurisdiction.

This chart will typically tend to zero as the date approaches the present, as for recent years only unusually fast-granting patent applications will be present in the analysis. The chart does however serve to show that the typical “patent pending” time period for the e-waste collection is approximately 4 years from initial filing to grant publication.

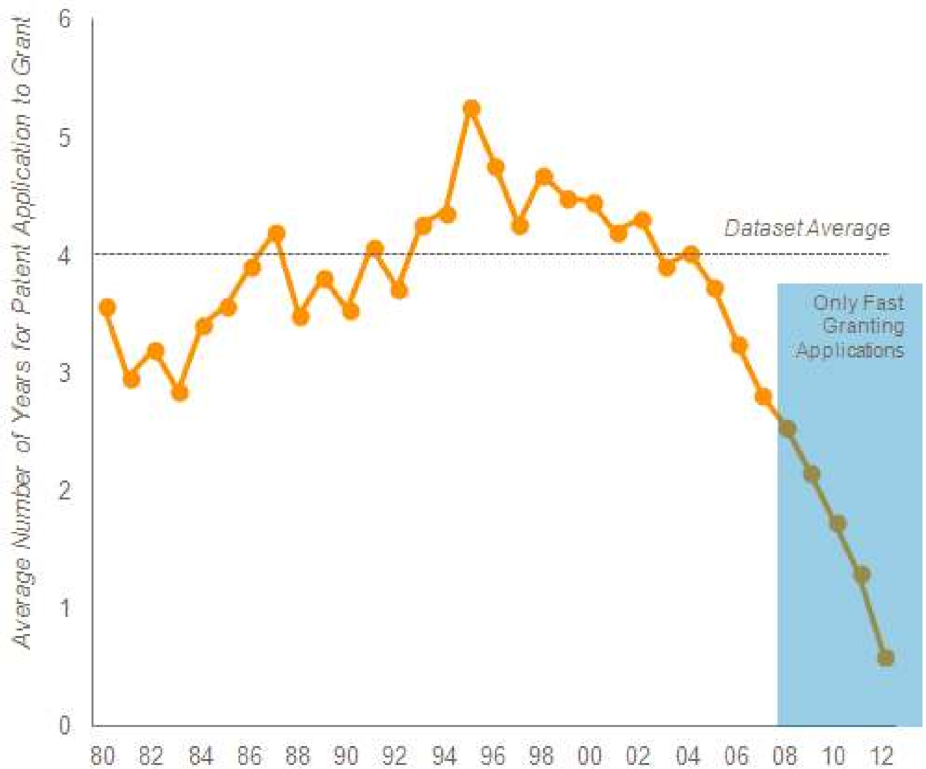


Figure 18 - Average Patent Pending Time Period between Office of First Filing Date and Date of Publication of Granted Patent

This analysis can then be extended to the national level to gain an assessment of the pendency at each patent office within the collection, as shown in figure 18. The analysis in figure 19 excludes any patent family filed within the last 4 years to avoid a bias towards the fast-granting outlier applications.

Several European patent offices appear to perform best in this view, with patents filed in Switzerland and France taking less than 3 years to achieve granted status. One should bear in mind of course the granting procedure and requirements in each jurisdiction which allows for instance a grant without examining for novelty or inventive step.

The major territories of Japan, China, the United States and South Korea all converge on the dataset mean of approximately 4 years of pendency – perhaps indicating a certain level of regression to the mean.

Patents filed in India show the longest levels of pendency, with granted patents typically taking 5 years to issue from initial filing.

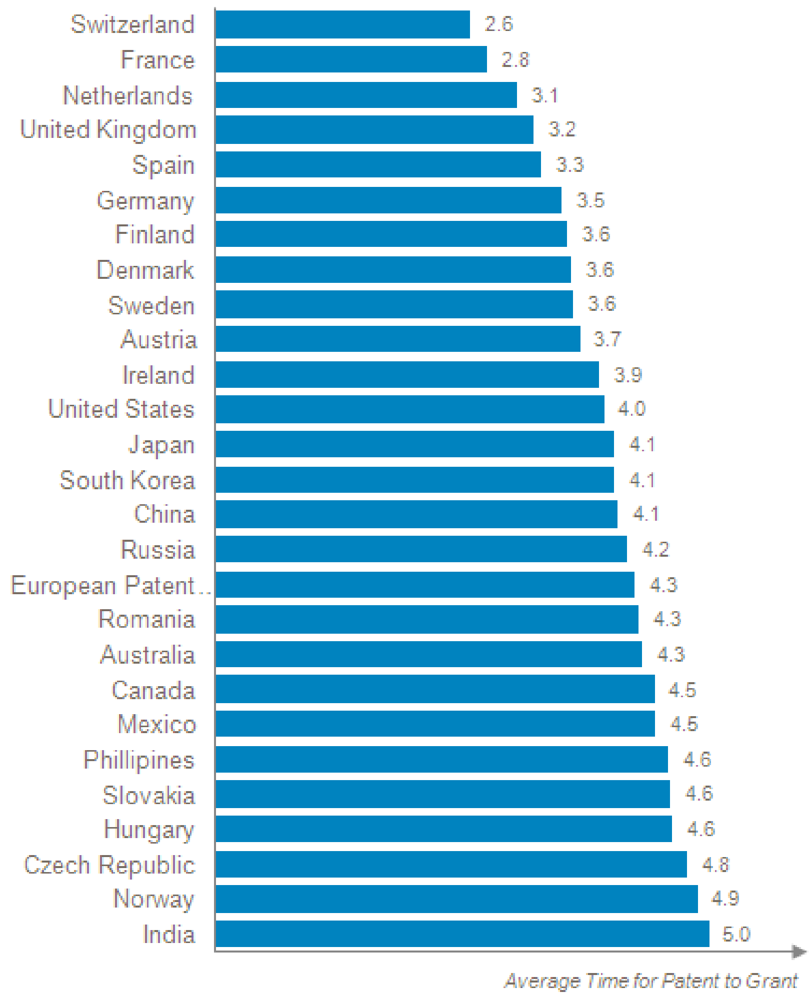


Figure 19 - Average Patent Pendency Time Period; Per Patent Authority; Earliest First Filing to Grant Publication; Excludes patent applications filed since 2008, due to average collection pendency period

Finally in this section, Figure 20 profiles the dynamics involved in the maintenance of the granted patent rights in the e-waste landscape.

Patent rights, while available for a 20 year period, do not automatically gain these 20 years without regular payments of annuity or maintenance fees.

This maintenance of patent rights allows for the rights' owners to drop protection of technologies that move more quickly than a 20 year period and provides the benefit of reducing the burden of administration of potentially obsolete technology. For the patent issuing authority, the requirement to maintain rights means that innovation is likely to become available to public use at an earlier date that would otherwise be the case.

The maintenance schedule of patent rights differs in each jurisdiction, but generally is performed on an annual basis in most authorities except for the United States. In this US, maintenance occurs at 3 set intervals of 3½, 7½ and 11½ years after the patent has granted.

Due to the differing schedule, in many corporations the rigors of the US system tends to drive the maintenance of patents in all other jurisdictions, though it should be noted that a patent family does not have to drop its protection in all countries at once.

The chart in Figure 20 shows the proportion of granted patents still in force (as measured by the lack of an inactivity indicator in legal status codes), arrayed back in time through to 1980.

The chart assumes that rights filed prior to 1983 have automatically expired on reaching the 20 year time standard to almost all patent authorities.

The chart has been modeled with polynomial trend line to provide a good measurement of aggregated maintenance levels across the collection over time.

Also annotated on the chart are the approximate time frames of US patent maintenance (taking into account a 4 year average pendency period, as the chart is calculated using earliest first filing year).

Overall, the maintenance of granted IP rights in the e-waste landscape is high, with 80-85% of rights being maintained for over a decade since initial filing, and almost three quarters of rights being maintained at 15 years post-filing.

This would imply that patent owners in the landscape associated value and economic return on a large proportion of patents in the field. It also implies that the industry is not fast moving, as technologies are not becoming particularly obsolete over a 15 year period.

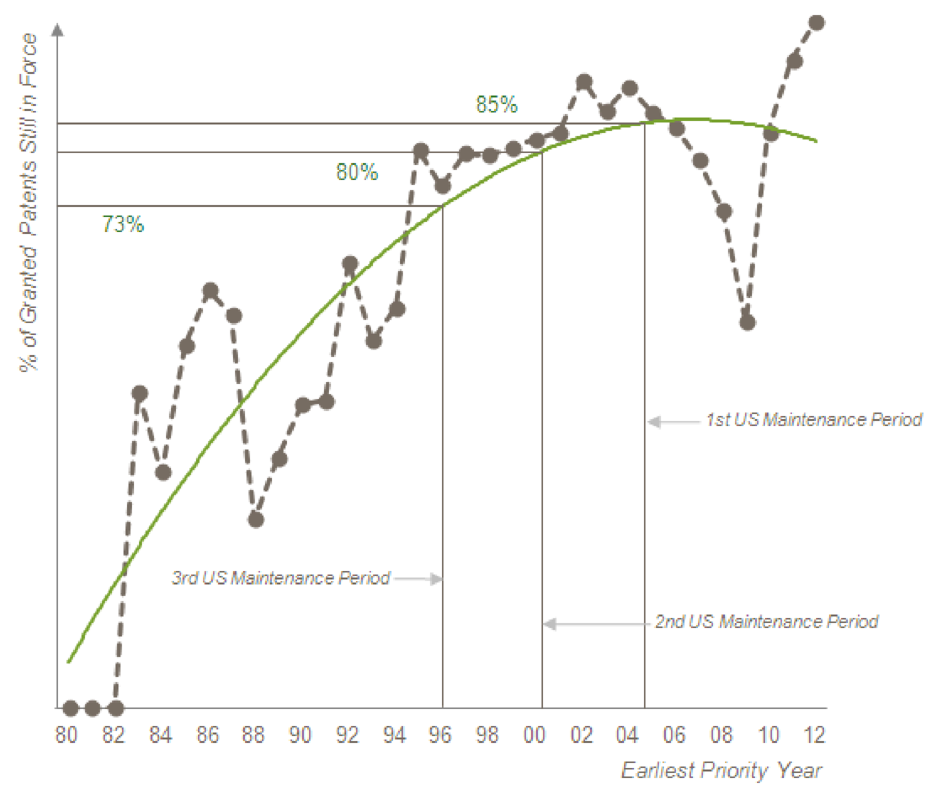


Figure 20 – Profile of Patent Maintenance across e-waste Landscape; Labeled are approximate locations on US Maintenance Periods at 3 ½, 7 ½ and 11 ½ years post grant – based on 4 year Pendency Period at USPTO

3.9 PATENT FILING STRATEGIES BY E-WASTE PATENT APPLICANTS

Figure 21 shows the number of patent families that have been filed in 1, 2 or 3 etc. patent jurisdictions, to provide an understanding of the type of IP strategy by applicants in the e-waste landscape.

7,102 patent families out of the 8,867 in total in the e-waste landscape have been filed in just a single territory, this predominantly being the profile of the Japanese and in particular Chinese based entities within the dataset.

Just 695 patent families have been filed in 5 or more locations; these inventions and the applicants behind them, due to the expense of these patent families, naturally become more interesting in terms of qualifying the commercial interest of corporations and other organizations in e-waste technology.

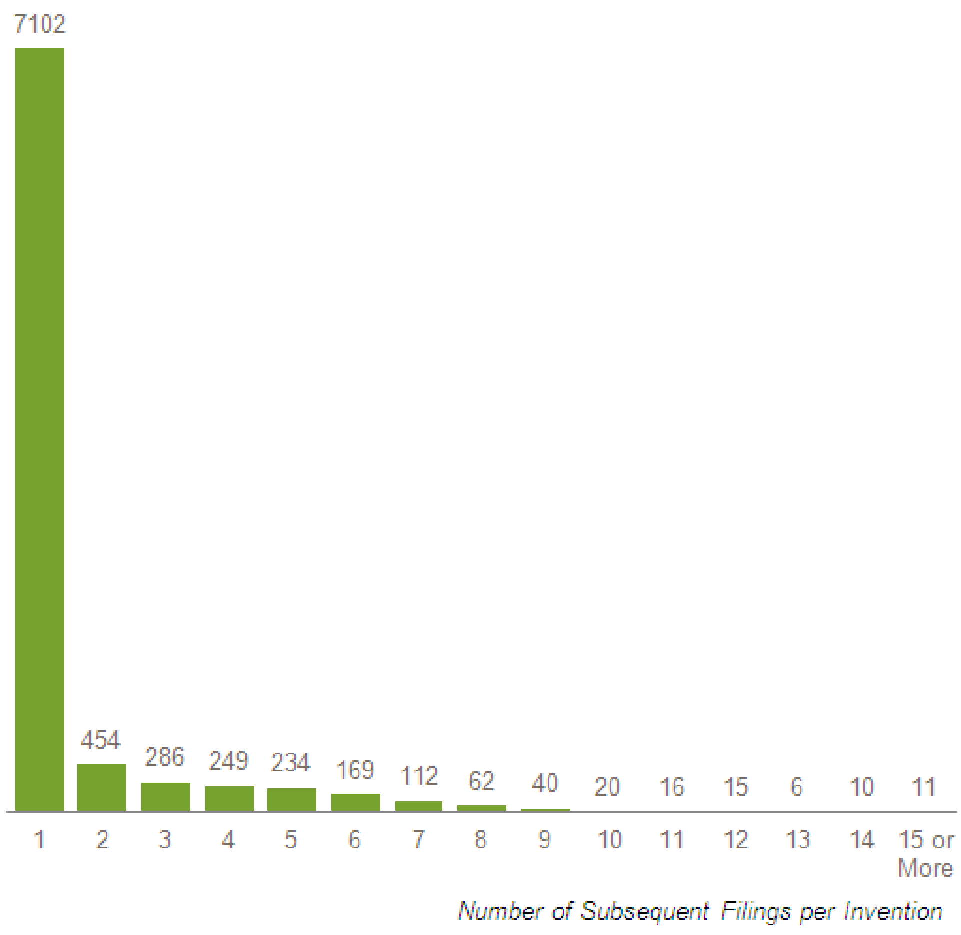


Figure 21 - Assessment of the Patent Protection Strategy of e-waste Patent Applicants; Distribution of Number of Subsequent Filing Events across Landscape

3.10 ANALYSIS OF MULTI-AUTHORITY FILED PATENT FAMILIES

On the previous chart, approximately 1,700 patent families were identified as having been filed in multiple patent jurisdictions.

These records are now analyzed in further detail in terms of geographic source and the timeline of activity.

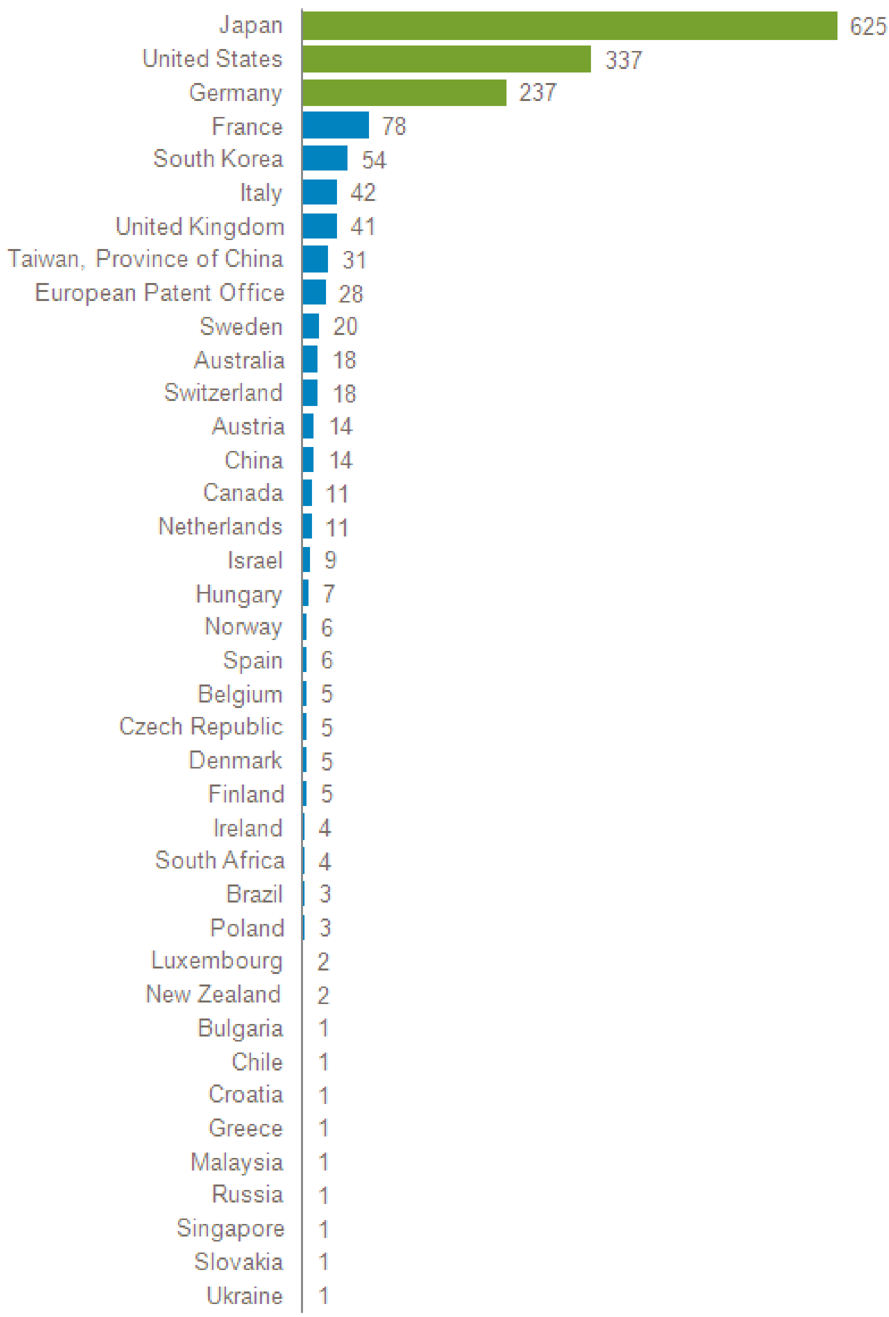


Figure 22 - Office of First Filing for Patent Families with 2 or More Subsequent Filings per Family

Figure 22 shows that three countries are the primary source of these multiple jurisdiction inventions – Japan, the US and Germany.

China, the second largest overall source of e-waste patent activity has just 14 records filed in multiple authorities; however, this figure is comparable to countries such as Netherlands, Austria, Sweden and Australia.

Figure 23 shows how the patent activity filed in multiple authorities is distributed over time. The charts show both absolute numbers of patent families per year as well as a normalized scale version to allow activity trends to be discerned. The normalization is performed by assessing the activity filed in any single year as a proportion of the total activity across all years.

The activity trend is showing that volumes are locked into the same trends up until 2008, when a strong divergence occurs – likely related to the time lag introduced when patent families are filed in multiple patent locations. This divergence is therefore probably associated with a data artifact specific to patent information.

The second item of interest is the acceleration in activity in the complete collection compared to the multi-authority patent families when measured on the absolute scale. This highlights the strongly local nature of the Chinese and Russian patent activity, which is predominantly recent in nature.

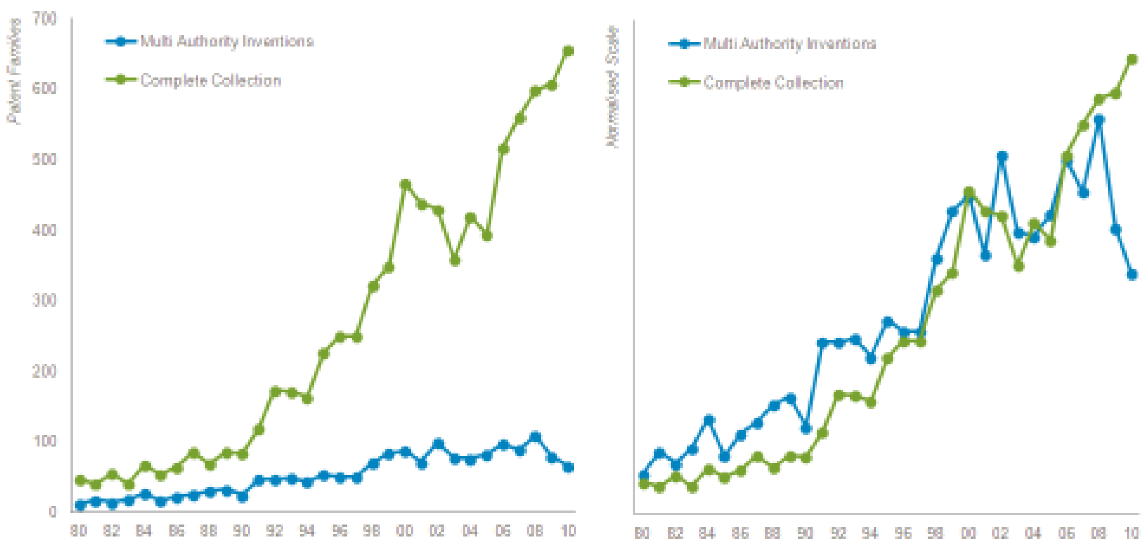


Figure 23 - Number of Patent Families per Year for Multi-Authority Patent Families versus the Complete e-waste Collection (left); Same timeline but with normalized y-axis for comparison of activity rates (right)

3.11 KEY FINDINGS FROM THE LANDSCAPE OVERVIEW

- The vast majority of activity in e-waste is Asian in nature, followed by activity from Europe. The United States makes up a relatively small proportion of activity, indicating a potential disinterest by US entities in e-waste technology.
- Activity in e-waste patented innovation is concentrated in the post-2000 time period.
- During this period, there are two distinct phases of activity; an early, secondary peak in activity occurring in 2000 which subsequently falls away, followed by a second phase of increasing activity which may not yet be complete.
- The two phases of activity are driven primarily by a slump in patent output from Japanese corporations and a corresponding large-scale expansion of activity from China.
- However, Chinese (and to an extent Japanese) patent activity is predominantly local. Out of 1,430 inventions first filed in China just 15 have been filed in another patent authority – a rate of just 1%. The overall number is a similar volume to far smaller economies such as the Netherlands, Austria, Sweden and Australia.
- There has been a strong dilution in the level of international patent protection due to the increases in activity from China, Russia and Korea – the majority of which is protected locally in just a single patent jurisdiction.
- Patents that are filed in multiple jurisdictions originate predominantly from Japan, the US and Germany.
- From a technical viewpoint, the landscape can be divided into three key concepts:
    - Materials that are being recovered and recycled from e-waste streams, items such as plastics and metals
    - Sources of e-waste and the processing of these sources, such as batteries, displays, cabling and printed circuit boards
    - The processes and logistics involved in e-waste treatment or recycling, such as magnetic sorting, IT related management of recycling systems and similar items.

PART 4 – TECHNICAL ANALYSIS OF E-WASTE PATENT LANDSCAPE

4.1 TECHNICAL SEGMENTATION OF THE E-WASTE LANDSCAPE

The collection of almost 9,000 e-waste patent families (including both granted patents and patent applications) was mined in detail for distinct technical approaches, specific waste streams and materials etc. to provide further analytical detail of the innovation trends and activity within the space.

This technical segmentation process was performed with advice and guidance from WIPO and the UN Environment Program so that items of specific interest were reviewed. Further, the data itself was interrogated to provide information on the major topics of interest to e-waste innovators.

Source information for these categories include patent classifications (International Patent Classification, Cooperative Patent Classification, Derwent Manual Codes and Classes) and mining of the claims, abstract or DWPI abstract terminology.

The segmentation can be summarized into three key areas:

- E-waste sources – both in terms of devices being processed or treated at the end of their life, such as telecommunications equipment, displays, medical devices etc., as well as individual components that cross several such device streams such as batteries, printed circuit boards and individual electronic components.
- Processing methodologies – approaches, such as waste stream sorting, waste logistics, dismantling or disassembly, chemical separation/treatment, smelting or heat treatment or decontamination efforts
- Material Recovery – identifying patent innovation with specific recovered items or treated materials, such as metal recovery, plastic recycling or dealing with hazardous waste in the end-of-life products.

In total, 71 distinct technical categories were created, using a process that interrogated patent classification codes (e.g. DWPI Manual Codes or Classes, International Patent Classification or Cooperative Patent Classification) as well as keywords within major areas of the patent specific (e.g. patent claims, the patent specification abstract or the DWPI abstract – a re-edited and summarized version of the patent specification produced by Thomson Reuters).

The 71 categories were also summarized in a discrete set of 15 high level topics covering the major areas of technical activity in the landscape – and thereby providing two levels of detail on which to assess activity.

4.2 MAJOR TOPICS OF INNOVATION IN E-WASTE

The initial analysis of technical activity in e-waste is shown in Figure 24 and utilizes the 15 high level topics. The chart has been colored according the to the topic type (yellow = material recovery, blue = processing, purple = waste stream).

This shows that the majority of the innovation in the space is occurring at the sub-device level, concentrated on individual discrete components of devices, primarily batteries and printed circuit boards.

From a processing perspective, innovation clusters around disassembly and subsequent waste separation, with a tertiary topic around decontamination.

Within the materials space, activity is concentrated in non-ferrous metals (e.g. copper, nickel etc.), plastics, ferrous metals and hazardous materials (e.g. arsenic, antimony and primarily, lead).

Smaller topics within this high level view include “other” recovered materials outside of those listed, such as ceramics or rubbers, and rare earth metals.

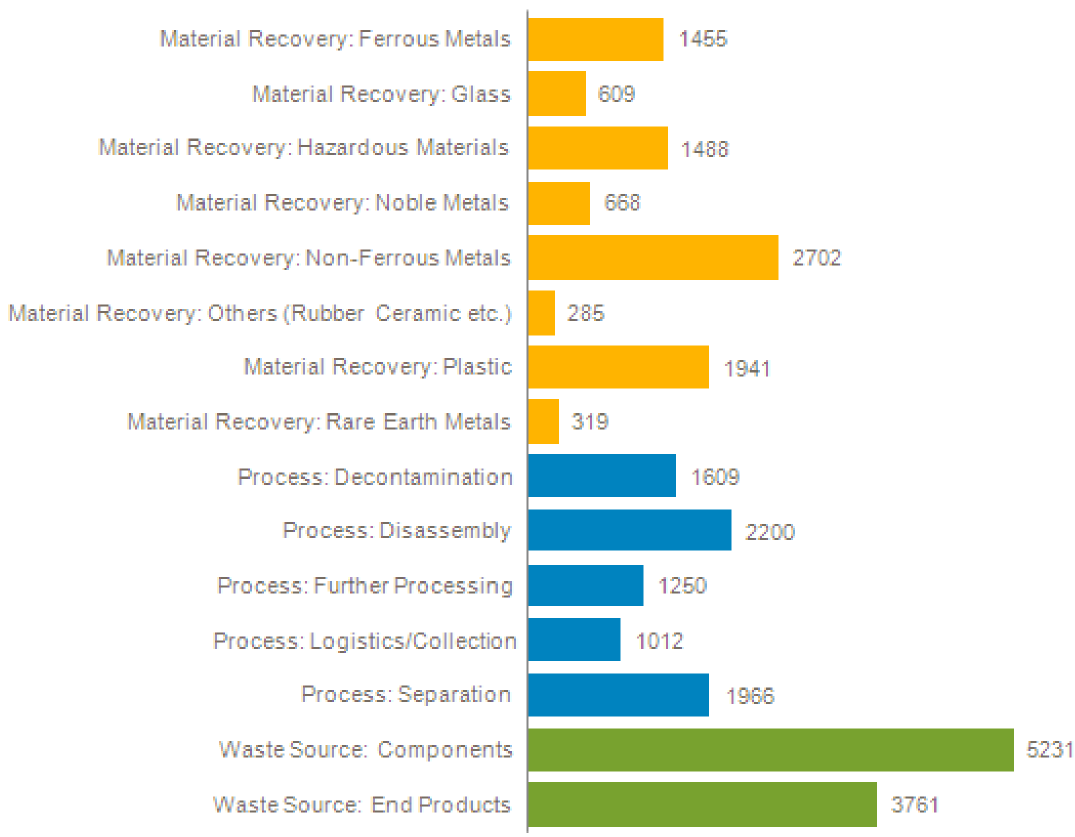


Figure 24 – Analysis of Major Subject Matter within e-waste Landscape; Broken down by Material Recovery, Processing and e-waste Sources

Figure 25 details the activity trends within these 15 topics, as measured by compound annual growth or decline in patent activity rates per topic between 2006 and 2010.

The compound annual growth/decline metric is a measure of the percentage change in activity when compared between 2010 activity levels and 2006 activity levels. The metric is primarily used in financial investments to assess performance of an investment over a time period. For example, an investment of $10 in 2006 returning $100 in 2010 would be measured as a Compound Annual Growth Rate (CAGR) of 78%. Here it is used to identify the growth or decline in patent activity in the various technology sectors surrounding e-waste.

This shows a large expansion in patent activity concerning the recovery of rare earth metals – one of the smallest topics in the landscape.

Also growing in activity is extraction or recovery of noble metals (i.e. gold, silver or platinum) from e-waste streams.

Decrease in recent activity is shown by only a single topic – plastics recovery/recycling, which has dropped only very slightly.

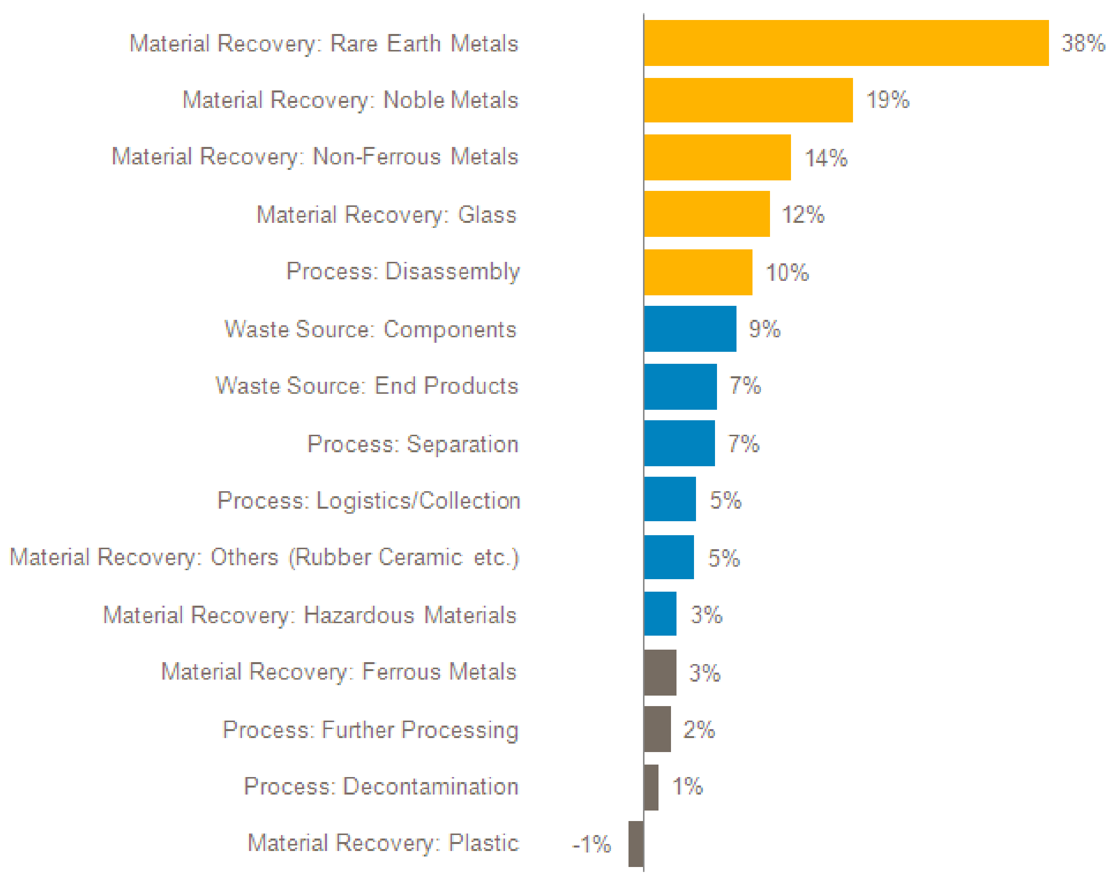


Figure 25 – Analysis of Recent Patent Activity Trends in e-waste Landscape by Major Subject Matter; Compound Annual Growth or Decline between 2006 and 2010; as measured by Earliest First Filing Year

4.3 SPECIALISATION OF E-WASTE INNOVATION BY GEOGRAPHY

Combining the high level topics with the offices of first filing information in the data collection provides an understanding of the focus of applicants in different territories in specific e-waste technologies.

Table 3 shows the proportion of activity from applicants in each territory (based on office of first filing) within each of the 15 high level topics.

Table 4 shows the same information, but provides the absolute number of patent families per office of first filing country and topic.

Table 3 - Analysis of Major Subject Matter in e-waste Landscape by Major Offices of First Filing Location; As % of All e-waste Activity per Office of First Filing Location

High Level Topics	Japan	China	United States	Germany	South Korea	Taiwan, Province of China	Russia	France	United Kingdom
Material Recovery: Ferrous Metals	14%	22%	25%	16%	10%	10%	21%	16%	14%
Material Recovery: Glass	6%	6%	8%	16%	3%	5%	3%	8%	11%
Material Recovery: Hazardous Materials	11%	25%	21%	20%	13%	14%	27%	27%	24%
Material Recovery: Noble Metals	7%	4%	15%	9%	9%	7%	17%	5%	12%
Material Recovery: Non-Ferrous Metals	27%	33%	37%	30%	34%	27%	59%	31%	36%
Material Recovery: Others (Rubber Ceramic etc.)	3%	2%	4%	3%	3%	3%	3%	4%	8%
Material Recovery: Plastic	28%	10%	13%	26%	13%	10%	8%	29%	24%
Material Recovery: Rare Earth Metals	4%	2%	6%	5%	1%	1%	3%	8%	4%
Process: Decontamination	17%	18%	22%	14%	14%	43%	25%	19%	15%
Process: Disassembly	25%	23%	24%	26%	31%	12%	19%	25%	39%
Process: Further Processing	14%	18%	12%	12%	14%	13%	10%	13%	11%
Process: Logistics/Collection	13%	13%	7%	9%	11%	5%	5%	13%	11%
Process: Separation	20%	30%	21%	18%	20%	18%	34%	21%	15%
Waste Source: Components	51%	82%	63%	54%	64%	67%	64%	56%	59%
Waste Source: End Products	49%	29%	41%	33%	47%	33%	15%	46%	54%

Table 4 - Analysis of Major Subject Matter in e-waste Landscape by Major Office of First Filing Location; Number of Patent Families

High Level Topic	Japan	China	United States	Germany	South Korea	Taiwan, Province of China	Russia	France	United Kingdom
Material Recovery: Ferrous Metals	647	321	170	83	45	17	32	19	10
Material Recovery: Glass	287	93	56	86	15	9	5	9	8
Material Recovery: Hazardous Materials	512	375	147	107	55	25	42	32	18
Material Recovery: Noble Metals	321	60	103	49	37	12	26	6	9
Material Recovery: Non-Ferrous Metals	1250	491	251	160	145	48	91	37	27
Material Recovery: Others (Rubber Ceramic etc.)	157	36	28	18	12	5	5	5	6
Material Recovery: Plastic	1331	144	90	141	56	18	12	34	18
Material Recovery: Rare Earth Metals	190	29	41	24	4	2	4	10	3
Process: Decontamination	811	270	151	77	60	76	38	23	11
Process: Disassembly	1168	339	163	136	133	21	30	30	29
Process: Further Processing	644	259	79	66	61	22	16	15	8
Process: Logistics/Collection	593	194	50	46	49	8	7	15	8
Process: Separation	928	442	144	96	86	31	53	25	11
Waste Source: Components	2379	1216	434	289	274	117	98	67	44
Waste Source: End Products	2296	431	281	178	204	58	23	55	40

Major findings from these tables include:

- Chinese entities' relative focus at the "component" level, potentially indicating that e-waste streams are pre-dismantled in Western economies prior to the stream reaching China.
- Russia's focus on the extraction of non-ferrous metals such as lead, copper and nickel.

- Applicants based in Taiwan, Province of China, focus on decontamination of e-waste.
- UK-based applicants focus on disassembly.
- US activity concentrating on rare earth extraction – a higher absolute number of patent families from US based applicants than Chinese based applicants. This last point is potentially important, as 90% of the primary extraction of rare earth metals currently occurs in China and is not typically sold as an open commodity. This being the case, there is a strong incentive for US (and indeed, Japanese and European) electronics manufacturers to source these important elements outside of the closed market.

A further version of the above tables is shown in table 5, and reformats the analysis based around the economic groupings of all the office of first filing locations in the collection.

Table 5 - Specialization of e-waste Topic by Economy Type; BRICS, Developed Economy or Other Economies; As % of All e-waste Activity per Economy Type

High Level Topics	Developed Economy	BRICS	Other Emerging Economy
Material Recovery: Ferrous Metals	15%	21%	13%
Material Recovery: Glass	7%	6%	0%
Material Recovery: Hazardous Materials	15%	25%	31%
Material Recovery: Noble Metals	8%	5%	11%
Material Recovery: Non-Ferrous Metals	29%	36%	31%
Material Recovery: Others (Rubber Ceramic etc.)	3%	2%	2%
Material Recovery: Plastic	25%	10%	15%
Material Recovery: Rare Earth Metals	4%	2%	0%
Process: Decontamination	18%	19%	18%
Process: Disassembly	25%	22%	18%
Process: Further Processing	13%	17%	23%
Process: Logistics/Collection	11%	12%	8%
Process: Separation	20%	30%	25%
Waste Source: Components	54%	80%	56%
Waste Source: End Products	46%	28%	28%

Focus by Developed Economies
Focus by BRICS/Emerging Economies

This shows focus areas of the BRICS countries on:

- Hazardous materials processing
- Non-Ferrous metals extraction
- Further processing, such as smelting or pulverization
- Separation techniques
- Specific components

Topics in which the developed economies appear to specialize include plastics recycling and rare earth metal extraction, further emphasizing the emergence of this topic as a potential additional market for this important class of commodities.

4.4 DETAILED BREAKDOWN OF PATENTED TECHNICAL APPROACHES IN E-WASTE

This section now turns to the detailed 71 specific categories of technology into which the e-waste landscape was segmented.

As stated earlier, these fields are grouped into waste stream, processing steps and recovered materials. Figure 26 shows the number of patent families per category. All three charts follow the same scale to allow proper comparison.

Note that individual patent families can be categorized into multiple fields if warranted, and this duplicate categorization is not limited to just the three groups. For example, an individual patent mentioning the extraction or recovery of both plastic and gold from a printed circuit board would be placed in all three relevant sections.

Therefore, this analysis should be reviewed as a summary of the innovation concepts within e-waste.

Each section is analyzed below for major themes and concepts.

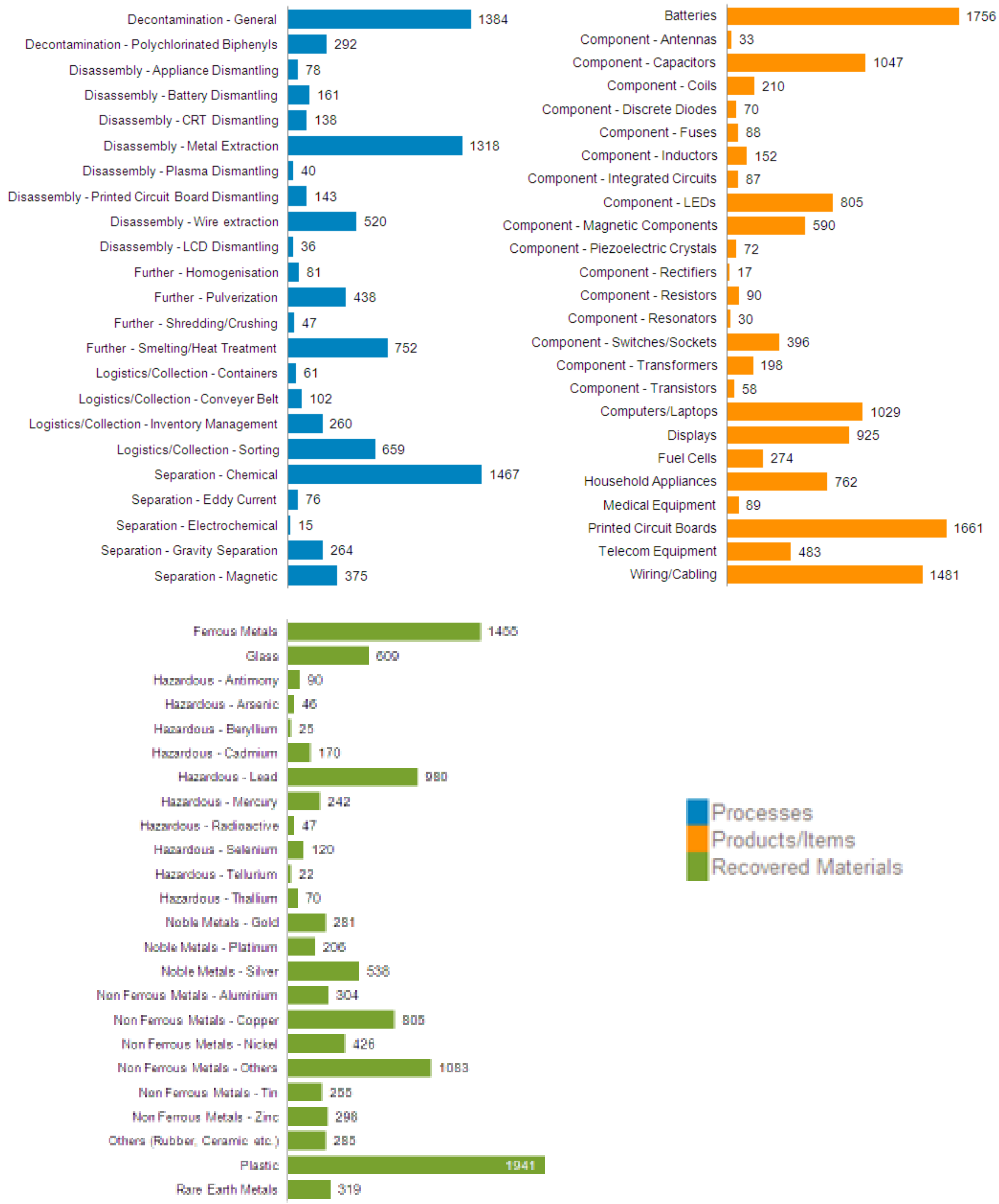


Figure 26 - Number of Patent Families per Technology Category; Broken down by e-waste Item, Processes or Processing Details and Materials Recovered

4.5 PROCESSING INNOVATION

There are three primary sectors of innovation in e-waste processing: decontamination, chemical separation and metal extraction. As noted above, individual inventions can occur in multiple categories, and it is likely that the peaks in metal extraction and chemical separation are inter-related, as chemical extraction of metals is likely a major process step in itself.

Secondary topics in processing include:

- Wire extraction
- Smelting or heat treatment
- E-waste sorting
- Pulverization of e-waste

4.6 WASTE STREAM TYPES

Three topics again dominate the type of e-waste around which patent activity has clustered: battery disposal, treatment and recycling; dealing with printed circuit boards; and wire or cable treatment.

These three topics represent more than 50% of the patent collection, and therefore should be considered the primary waste streams in e-waste.

Secondary topics include a mix of end products and components, such as:

- Capacitors – these components make up a large proportion of electronics on a printed circuit board and contain exotic and often hazardous materials used as dielectrics.
- LEDs – another common PCB sub-component and typically in a discrete package, these components also contain a mix of material classes, such as semiconductors, ferrous and non-ferrous metals and plastics.
- Magnetic components – an interesting class in that these are likely a primary source of rare earth metals, in particular neodymium.
- Computers/laptops; Displays; Household Appliances – these three topics are the primary "end product" types mentioned in the landscape. Note that displays is somewhat of a hybrid topic, as these can be both end products in television or computer monitor form, or components, such as part of a mobile device, laptop or tablet device.
- Telecoms equipment – this topic is one of high interest, primarily due to the lack of activity. The image selected for the front page of this report concerns the large amount of mobile device waste – driven by the subscriber business model and fast obsolescence of the mobile device industry, mobile phones make up a very large proportion of the e-waste streams in most countries. However this position is *not*

represented in the patent landscape. This point will be further investigated in a later section.

4.7 RECOVERED MATERIALS

Plastics and ferrous metals are the primary items recovered from e-waste, followed by “other” non-ferrous metals (outside of copper, nickel, zinc, aluminum and tin). Within the non-ferrous metals listed, the most commonly mentioned include copper and tin.

Note that a large proportion of the secondary items mentioned in the recovered materials may be driven by regulation concerning solder.

Solder has historically been an alloy of lead and tin with various proportions used for different applications of solder. However, in recent years there has been a strong movement towards the removal of poisonous lead from consumer electronics, and this has seen the replacement of lead in solder alloys by pure tin, but more commonly tin, silver and copper solders.

There are peaks in activity across all of these mentioned materials – lead, tin, silver and copper, and indeed copper and silver recovery have both grown sharply over and above tin recovery as a topic, indicating a movement coinciding with regulatory change in the solder industry. Furthermore, the primary noble metal extracted from e-waste appears to be silver, and this is likely due to the solder regulations; for example the European Union Waste Electrical and Electronic Equipment Directive (WEEE) and Restriction of Hazardous Substances Directive (RoHS) that came into effect in 2011.

4.8 TECHNOLOGY TRENDS IN E-WASTE

Figure 27 summarizes the major changes in patent activity that occurred since 2006 in technology segments with greater than 100 patent families.

Four topics show extensive growth in patent output:

- Dealing with hazardous cadmium and battery dismantling – likely two related topics as most cadmium in industrial use is utilized in rechargeable nickel-cadmium batteries.
- Use of conveyor belts in e-waste logistics and waste stream sorting operations
- Recovery of rare earth metals

Also highlighted in the chart are the noble metals categories, all of which showed growth over the last 5 years.

In line with the overall growth of activity since 2006 across the landscape as a whole, the majority of topics have increased in output. However, several categories have declined, the largest declines being within household appliance waste streams (somewhat of an overlap topic within the project collection) and also the treatment and decontamination of polychlorinated biphenyls (PCB).

This latter subject matter was the cause of some debate during the project due to its potential off-topic nature within pure e-waste streams. Indeed, the subject matter is strongly tied to the inclusion of these materials within power transformers – a more typical electrical distribution technology rather than e-waste per se.

The topic was allowed to be retained due to the potential for tangential relevance (i.e. some subject matter of the patent or patent application is relevant, but not all – for example dealing with polychlorinated biphenyls in lower power transformers or transformers of under determined power); however the topic has seen a strong decline in activity in recent years, likely pointing to its lack of relevance to the wider e-waste topic due to the counter-trend exhibited.

Dealing with mercury as a hazardous waste stream has increased in patent output between 2006 and 2010. An analysis of the timeline for mercury shows that activity has drifted between 5 and 13 new inventions all the way back to the 1980s. Indeed, mercury e-waste patent activity was strongest in the time period 1995-2000.

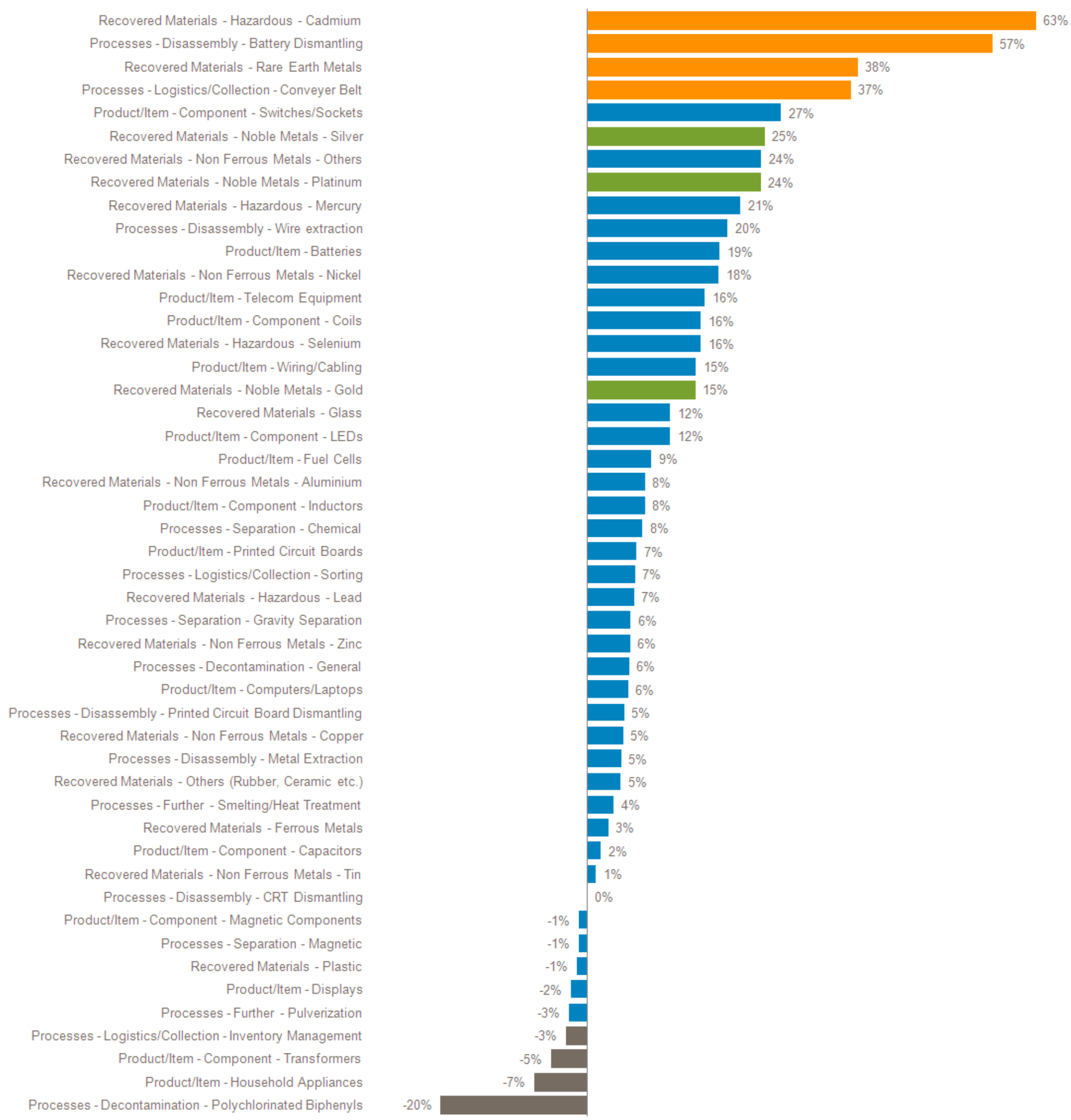


Figure 27 - Recent Technology Trends for Major Technology Areas; Categories with >100 Patent Families; Compound Annual Growth or Decline, 2006 to 2010

4.9 SPECIFIC TOPIC FOCUS – NOBLE METALS

This section of the report focuses on the trends and patent activity within the noble metals category – a field which has seen considerable growth in patent innovation since 2006.

Table 6 summarizes the waste streams into which patents mentioning noble metals extraction co-occur, and highlights the fact that majority of the work within this field is specific to the processing and treatment of printed circuit boards.

Table 6 - Focus on Noble Metal Recovery; Analysis of e-waste Sources of Noble Metal Recovery

Sources of Noble Metal Recovery/Recycling	Total Inventions
Printed Circuit Boards	238
LEDs	109
Computers/Laptops	87
Wiring/Cabling	85
Displays	78
Batteries	65
Telecom Equipment	52
Capacitors	51
Fuel Cells	45
Magnetic Components	38
Switches/Sockets	35
Household Appliances	34
Integrated Circuits	18
Fuses	9
Resistors	9
Inductors	7
Medical Equipment	7
Piezoelectric Crystals	7
Coils	6
Discrete Diodes	6
Transistors	5
Antennas	2
Transformers	1

Table 7 further analyses these sources based on the specific noble metal (silver, gold or platinum). The previous expected correlation between silver as an expanded component within consumer electronics solder is confirmed in table 6, and therefore the growth in noble metal extraction is strongly tied to the change in the regulatory environment surrounding consumer electronics.

Gold is also strongly tied to the PCB due to the element's use in electrical connections (good conductivity and strong corrosion resistance) and because of its inclusion in for example semiconductor packages.

Platinum is to some extent decoupled from the circuit board, with strong data points in LEDs (e.g. platinum as an organometallic complex in organic LED devices) and electrochemical storage technologies such as batteries and fuel cells, where platinum is used as a catalyst material.

Table 7 - Analysis of e-waste Sources of Noble Metals; Broken down by Noble Metal Type

Sources of Noble Metal Recovery/Recycling	Silver	Gold	Platinum
Printed Circuit Boards	204	124	53
LEDs	94	60	40
Computers/Laptops	70	42	13
Wiring/Cabling	72	31	17
Displays	68	23	9
Batteries	44	19	30
Telecom Equipment	51	28	12
Capacitors	46	16	7
Fuel Cells	34	11	30
Magnetic Components	30	22	7
Switches/Sockets	31	16	6
Household Appliances	25	17	10
Integrated Circuits	13	8	4
Fuses	7	6	3
Resistors	8	4	1
Inductors	4	4	1
Medical Equipment	7	3	3
Piezoelectric Crystals	7	4	
Coils	5	1	1
Discrete Diodes	6	3	
Transistors	4	4	
Antennas	2		
Transformers			1

The timeline of activity overall within noble metal recovery from e-waste is shown in Figure 28, and highlights the strong recent nature of the innovation within this space.

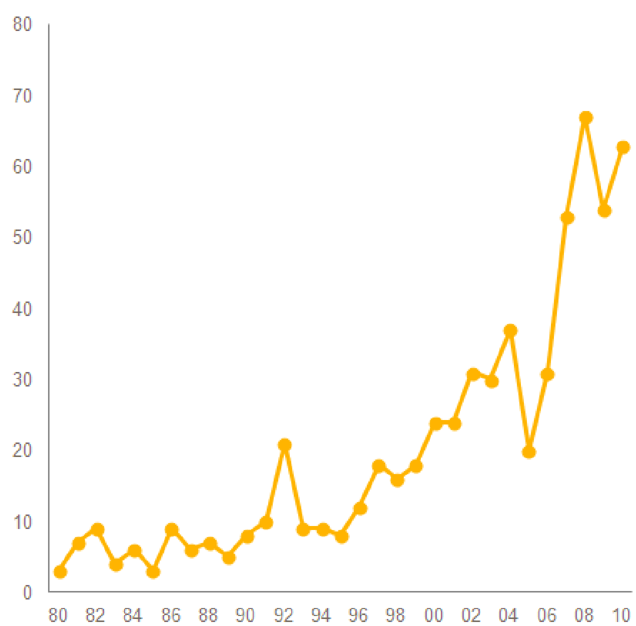


Figure 28 - Timeline of Activity in e-waste Nobel Metal Recovery

Finally, Table 8 analyses the extraction or recovery of noble metals from e-waste at an office of first filing country level to determine the sources of innovation in this sector.

Japan is the primary source of activity, followed by the United States; however Chinese activity overtook US output in 2009 and looks set to continue in output growth. South Korean activity is also concentrated in the most recent time period.

Table 8 - Timeline of Noble Metal e-waste Activity by Office of First Filing Country

Priority Country	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	Total (All Years)	Comments
Japan	12	2	3	5	5	9	8	8	13	12	21	19	18	12	11	31	38	24	32	321	*Primary Source of Noble Metal Recovery Innovation*
United States	3	2	1	1	5	4	2	7	2	5	6	2	11	3	4	5	8	4	7	103	*Secondary Source*
China										2	1		2	1	4	7	5	9	12	60	*Fast Growing Interest*
Germany	3	1	2	2		4	3		1			3	2	1	2	2	3		1	49	*Waning Interest*
South Korea						1	2		2		2	1	1	1	3	2	5	10	5	37	*Fast Growing Interest*
Russia	1	2	2		2		1	2	2	4		2	2		1				2	24	
Taiwan, Province of China														1	1	2	2	4	1	12	
United Kingdom	1							1	1								1			9	
Australia											1					1	2	1	1	7	
European Patent Office		1							2			1			1		1	1		7	
France															1		2		1	6	
Hungary																				4	
Italy		1										1				1				4	
Switzerland															1					3	
Israel													1							2	
Romania																				2	
Soviet Union	1																			2	
Spain																				2	
Austria																				1	
Brazil										1										1	
Canada			1																	1	
Czech Republic																1				1	
Mexico																				1	
Monaco																1				1	
South Africa									1											1	
Sweden																				1	

4.10 SPECIFIC TOPIC FOCUS – RARE EARTH METALS

Rare earth metals are elements used in small amounts in almost all consumer electronic devices that contain lasers (e.g. DVD players) or displays that utilize phosphorescence. They are also used for magnetic components (such as in loudspeakers or headphones, or magnetic disk drives), batteries and in glass for optics, such as camera lenses.

Some specific high use rare earths include:

- Neodymium – used in many magnetic applications, such as microphones, speakers and hard disk drive components
- Yttrium, terbium, europium – used as phosphors in many different types of display technology
- Lanthanum – used as electrode material in nickel-metal hydride batteries, such as those used in hybrid vehicles.

The economics of rare earth metals is complex, as more than 90% of the global supply comes from China. This monopoly on rare earths is relatively recent in origin, but correlates to the large increases in demand for the materials as the consumer electronics industry has increased in the number of individual devices produced since the 1990s.

Therefore, the supply and demand of rare earths is somewhat entangled with the vast increase in supply of consumer electronic items that are now reaching the end of their life.

The growth in patent activity concerning the extraction of rare earth metals from e-waste streams is therefore logical due to the high prices these materials earn due to restricted supply. The patent landscape therefore appears to confirm the commodisation of e-waste streams for the extraction of high value items such as rare earths.

Table 9 shows the correlation between patents concerning rare earth recovery and the various e-waste streams. This confirms the known usages of the various rare earths in modern consumer electronics, with strong data-points in magnetic components, batteries and displays.

Table 9 - Focus on Rare Earth Metal Recovery; Analysis of e-waste Sources of Rare Earth Metal Recovery

Sources of Rare Earth Metal Recovery/Recycling	Total Inventions
Magnetic Components	94
Batteries	47
Displays	35
Computers/Laptops	33
LEDs	30
Wiring/Cabling	29
Inductors	27
Printed Circuit Boards	26
Capacitors	25
Telecom Equipment	25
Household Appliances	17
Transformers	12
Fuel Cells	11
Medical Equipment	8
Coils	7
Piezoelectric Crystals	6
Switches/Sockets	4
Fuses	3
Integrated Circuits	3
Transistors	3
Resistors	2

Table 10 reviews the rare earth metal recovery category by processing technology. The table has been further built upon to highlight processing sectors were the rare earth metal extraction patent families are over represented. The primary extraction techniques for rare earths appears to currently be chemical separation, followed by magnetic separation – likely based on the individual properties of the specific element under consideration.

There is also a strong decontamination element to rare earth processing.

Table 10 - Analysis of Processing Technology for Rare Earth Metal Recovery

Processing Technology for Rare Earth Metal Recovery/Recycling	Total Inventions	% of Rare Earth Processing	Category % of Processing Across Whole Landscape	Over or Under-represented in Rare Earth Recovery
Decontamination - General	96	43%	25%	+17%
Decontamination - Polychlorinated Biphenyls	1	0%	5%	-5%
Disassembly - Battery Dismantling	3	1%	3%	-2%
Disassembly - CRT Dismantling	7	3%	3%	+1%
Disassembly - Metal Extraction	79	35%	24%	+11%
Disassembly - Plasma Dismantling	1	0%	1%	-0%
Disassembly - Wire extraction	2	1%	10%	-9%
Further - Homogenisation	1	0%	1%	-1%
Further - Pulverization	18	8%	8%	-0%
Further - Smelting/Heat Treatment	29	13%	14%	-1%
Logistics/Collection - Inventory Management	2	1%	5%	-4%
Logistics/Collection - Sorting	21	9%	12%	-3%
Separation - Chemical	75	33%	27%	+6%
Separation - Eddy Current	2	1%	1%	-1%
Separation - Electrochemical	1	0%	0%	+0%
Separation - Gravity Separation	7	3%	5%	-2%
Separation - Magnetic	26	12%	7%	+5%

Figure 29 shows the quick increase in output of this sector. Early in the report it was identified that rare earth metal extraction was relatively small in comparison to extraction or recovery of other items such as plastic, ferrous metals or tin.

However, none of these other items show the high increase in activity – between 2009 and 2010, patent activity in this sector more than doubled, from 15 patent families per year to over 35. The majority of the applicants responsible for this growth are Japanese entities, but the biggest contributor (Sumitomo) had just 4 out of these 35 new applications; this indicates that this is a real emerging trend and not just an outlier data point from a specific R&D project of an individual corporation.

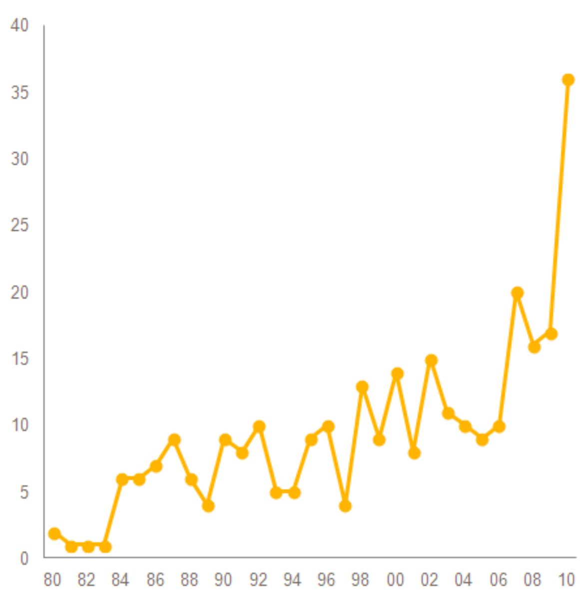


Figure 29 - Timeline of Activity in e-waste Rare Earth Metal Recovery

Finally, Table 11 analyzes the extraction or recovery of rare earth metals from e-waste at an Office of First Filing country level to determine the sources of innovation in this sector.

Japan-based entities are the pre-eminent source of new patent applications concerning rare earth extraction, and this activity is growing quickly. The US is the secondary source, but is not showing a growth trend. China, while relatively low level in output, is however exhibiting a growing interest in the sector.

Table 11 - Timeline of Rare Earth Metal e-waste Activity by Office of First Filing Country

Priority Country	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	Total (All Years)	Comments
Japan	3	3	2	8	7	3	10	6	12	7	10	9	6	3	6	14	13	6	28	15	190	*Primary Source of Noble Metal Recovery Innovation, Fast Growing*
United States	1		1		2	1	2	1	2	1	3		1	4	1	1		1	3		41	*Secondary Source, no trend*
China								1			1	1		1	2	1	2	7	5	6	29	*Growing Interest*
Germany	4	1	2		1			1			1		1		1					2	24	*Intermittent Interest*
France		1		1			1						1					1		1	10	*Intermittent Interest*
South Korea																		1		2	4	*Potential pick-up in activity, all activity recent*
Russia	2																				4	
United Kingdom																1		1		1	3	
Czech Republic													1								2	
Spain																					2	
Taiwan, Province of China												1				1					2	
European Patent Office																			1		1	
Israel																1					1	
Italy																					1	
Monaco																1					1	
Switzerland																					1	

4.11 SPECIFIC TOPIC FOCUS – TELECOMS DEVICES

It was observed earlier in the study that the number of patent families concerning mobile devices did not meet expectations. It was to an extent assumed that the emergence of e-waste as a topic of intense global innovation was tied to the trend towards faster device through-put, a trend primarily shown within the mobile device market.

Corporations routinely update their product catalogue on an annual basis, and there is strong encouragement for users and subscribers to "upgrade" their mobile device on a similar timeframe.

However, e-waste patent activity mentions mobile devices or other telephony equipment relatively rarely in comparison.

Two potential reasons for this discrepancy include:

- Mobile devices are strongly tied to "computing" equipment, and it is difficult in modern parlance to separate the two; therefore mobile device e-waste technology may have been split between the computers/laptops category and the telecoms device category
- E-waste innovation focused on mobile devices aims primarily at the components *within* the device, rather than the device itself. Therefore innovation in processing and recycling mobile devices is spread across several different categories such as displays, batteries, printed circuit boards etc.

Table 12 shows the major topics within with the telecoms/mobile device patents occur together within the same invention, i.e. the invention mentioned both a mobile device and the battery.

The items have been annotated based on whether the sector is experiencing growth in patent activity (purple) or whether the sector has long been a major overlap category (grey).

Table 12 - Focus on Telecoms Device Recycling, Recovery, Processing; Analysis of Major Topics (i.e. with >50 Patent Families) and Timeline

Major Topics in Telecoms/Mobile Device E-Waste (Topics with >50 Inventions)	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	Total (All Years)
Product/Item - Computers/Laptops		2	2	2	5	6	10	5	14	25	20	19	13	14	15	24	24	18	28	22	270
Product/Item - Displays		2	2	1	2		6	3	9	15	7	5	9	8	7	9	15	6	12	10	129
Recovered Materials - Plastic	2	1	1	2	2	1	7	1	6	14	11	9	12	7	6	5	11	6	6	7	118
Processes - Disassembly - Metal Extraction	1	2		3	1	1	3	4	4	10	4	5	4	6	7	2	9	12	11	5	95
Product/Item - Batteries		1			1	2	2		3	5	3	6	1	3	6	5	7	12	17	19	94
Product/Item - Printed Circuit Boards	1	1		1	1		2	3	1	4	4	3	4	1	6	7	12	16	14	6	91
Product/Item - Household Appliances		1					5	5	5	5	12	8	4	4	8	8	9	1	7	3	87
Processes - Separation - Chemical				1	1	1	4		1	5	2	3	4	5	5	8	5	8	16	11	81
Recovered Materials - Ferrous Metals	1			1	1	1	1	3	2	2	6	7	6	3	3	5	8	7	13	7	79
Recovered Materials - Non Ferrous Metals - Others	1	1			1	3		4		2	5	1	2	1	3	7	6	8	21	7	76
Product/Item - Wiring/Cabling	1		1	2			2	5	4	4	4	5	5	3	1	5	10	5	7	6	75
Processes - Decontamination - General	3	3					1	3	1	4	4	3	4	3	3	5	6	11	13	3	73
Product/Item - Component - Capacitors							3	1	1	2	3	5	5	1	4	4	7	7	10	4	59
Product/Item - Component - LEDs		3		1	1		1	3	1	3		3	2	2	1	3	9	6	11	3	53
Recovered Materials - Noble Metals - Silver	1	1						1	1	1	1	3	2	1	1	3	6	11	14	1	51

Major Growth Sectors

Historical Major Sectors in Mobile Device Processing

This analysis goes someway to highlight the overlap of the sector with the computers/laptops category, as well as the displays, batteries and PCB components fields.

The predominant recycling technology has revolved around plastics and metals.

Growth sectors in mobile device e-waste recovery include:

- Gathering focus on battery and printed circuit board e-waste within mobile devices
- Increasing use of chemical separation techniques
- Decontamination of mobile device waste streams
- Recovery of silver from mobile devices

The generic nature of mobile device e-waste processing is summarized in the thematic concept map in Figure 30. The red highlighted patent families are those mentioning telecoms equipment, and the even distribution of these documents across the map confirms the above analysis.

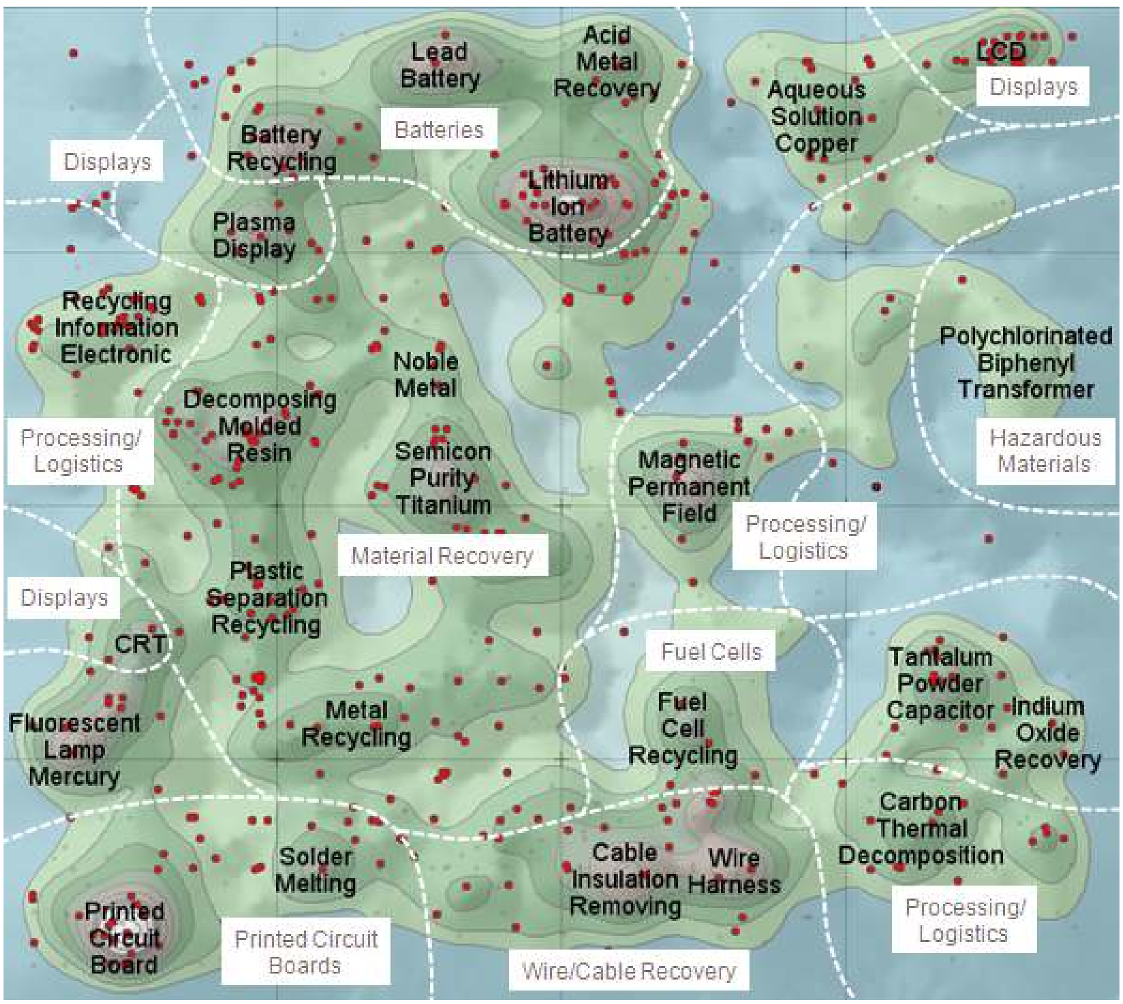


Figure 30 - Thematic Concept Map of e-waste Landscape; Mobile Device/Telecoms Equipment Highlighted

4.12 SUMMARY VIEW OF E-WASTE TECHNICAL APPROACHES – COMMERCIALISATION

Throughout this report, metrics have been applied to dataset that move the analysis of innovation activity beyond simply the number of patents or patent applications within any given sector.

This section moves this further by analyzing the major technical themes within the e-waste landscape at the level of commercialization and investment.

It was stated earlier that there is a strong link between the number of different territories in which an individual application is filed and the level of monetary investment required. Put simply, the more countries in which protection is sought, the higher the level of expense, due to the multiplication of the number of legal counsel involved and the potential for expensive processes such as translation.

Figure 31 arrays the major technology themes in the landscape by this geographic filing breadth (x-axis), as well by the level of recent growth exhibited by patent activity in each sector (y-axis). The chart can be considered a form of SWOT analysis (strength, weakness, opportunity, threat) in that categories that are situated further right and higher up the chart are growing and have been more heavily invested in. Sectors which stand out from the analysis have been individually labeled; other technology areas within the chart which cluster together are not labeled.

Two sectors covered heavily in this study fall into that analysis – recovery of rare earths and noble metals, confirming their emerging importance to the field of e-waste.

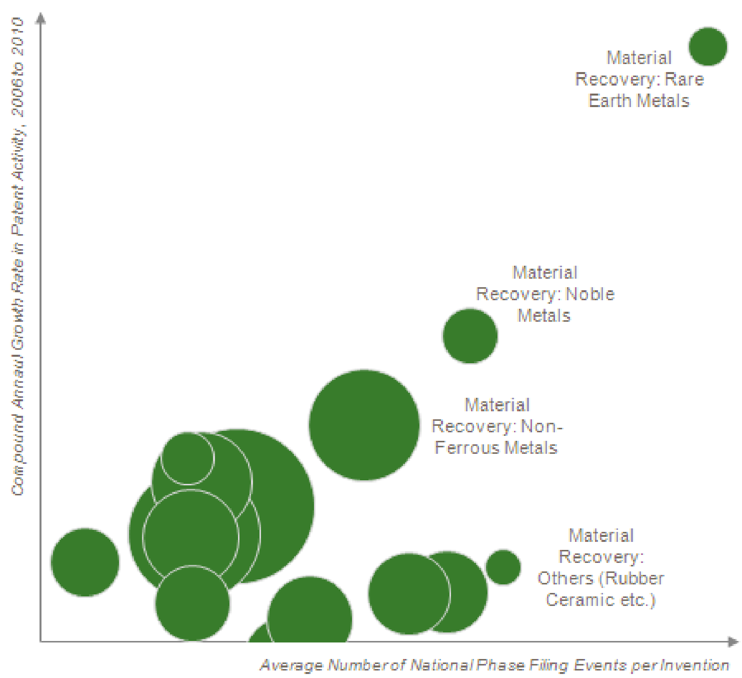


Figure 31 - Model Analysis of Major Subject Matter in e-waste Landscape; Compound Annual Growth versus Average Number of Offices of Subsequent Filing per Invention; Bubble Size reflects Volume of Patent Activity per Subject Area

4.13 KEY FINDINGS FROM TECHNOLOGY ANALYSIS

- The majority of the innovation in the space is concentrated on individual discrete components of devices, primarily batteries and printed circuit boards.
- Common processing steps in the landscape include disassembly and subsequent waste separation, with a tertiary topic around decontamination.
- From a materials perspective, activity in terms of total number of patent filings is concentrated in non-ferrous metals (e.g. copper, nickel etc.), plastics, ferrous metals and hazardous materials (e.g. arsenic, antimony and primarily, lead).
- Smaller topics within this high level view include “other” recovered materials outside of those listed, such as ceramics or rubbers, and rare earth metals.
- There has however been a large increase in patent activity concerning the recovery of rare earth metals as well as extraction or recovery of noble metals (i.e. gold, silver or platinum) from e-waste streams.
- Rare earth metals not only are fast growing, but also are one of the most heavily protected technologies in terms of geographic extension of protection. Taken together, this data point strongly infers that the field is a major emerging topic of interest to patent applicants.
- Further, US-based activity concentrates on rare earth extraction – a higher absolute number of patent families from US based applicants than Chinese based applicants. China is the source of 90% of the primary extraction of rare earth metals and the materials are not typically sold as an open commodity. This being the case, there is a strong incentive for US (and indeed, Japanese and European) electronics manufacturers to source these important elements outside of the closed market.
- It was noted that growth in a specific class of recovered materials may be driven by regulation concerning solder. Solder has historically been an alloy of lead and tin with various proportions used for different applications of solder. However, in recent years there has been a strong movement towards the removal of poisonous lead from consumer electronics, and this has seen the replacement of lead in solder alloys by pure tin, but more commonly Tin, Silver and Copper solders.
- There are peaks in activity across all of these mentioned materials – lead, tin, silver and copper, and indeed copper and silver recovery have both grown sharply over and above tin recovery as a topic, indicating a movement coinciding with regulatory change in the solder industry. Furthermore, the primary noble metal extracted from e-waste appears to be silver, and this is likely due to the solder regulations; for example, the European Union Waste Electrical and Electronic Equipment Directive (WEEE) and Restriction of Hazardous Substances Directive (RoHS) that came into effect in 2011.
- E-waste patent activity mentions mobile devices or other telephony equipment relatively rarely in comparison, despite the strong likelihood of these items making up

a very large proportion of real-world e-waste streams. Two potential reasons for this discrepancy include:

- Mobile devices are strongly tied to “computing” equipment, and it is difficult in modern parlance to separate the two; therefore mobile device e-waste technology may have been split between the computers/laptops category and the telecoms device category

- E-waste innovation focused on mobile devices aims primarily at the components *within* the device, rather than the device itself. Therefore innovation in processing and recycling mobile devices is spread across several different categories such as displays, batteries, printed circuit boards etc.

- Growth sectors in mobile device e-waste recovery include a gathering focus on battery and printed circuit board e-waste within mobile devices and increasing use of chemical separation techniques and decontamination of mobile device waste streams. Also growing is the recovery of silver from mobile devices punctuating the data point seen across the landscape as a whole.

PART 5 – COMMERCIAL ANALYSIS OF E-WASTE PATENT LANDSCAPE

Any analysis of patent activity within a given field should exploit the ownership nature of the IP rights, and thereby derive a focus on the commercial implications of patent activity.

While it is true that patent rights naturally derive from individual inventors, the practicalities of modern commerce mean that these rights most often fall under the ownership and stewardship of organizations which employ inventors.

This section of the study focuses on the nature of the patent activity in e-waste from these patenting organizations.

5.1 DISTRIBUTION OF E-WASTE PATENT ACTIVITY BY PORTFOLIO SIZE

A primary metric in any landscape analysis is the size of the portfolios from organizations active in the technology, and how the landscape is distributed amongst the various large, medium and small patent portfolios. These portfolios sizes have been transposed into a series of "tiers" which describe large portfolios as those with 40 or more inventions, medium sized portfolios with between 5 and 39 inventions, small portfolios of fewer than 5 inventions and finally a 4th tier of inventions not assigned to an organization.

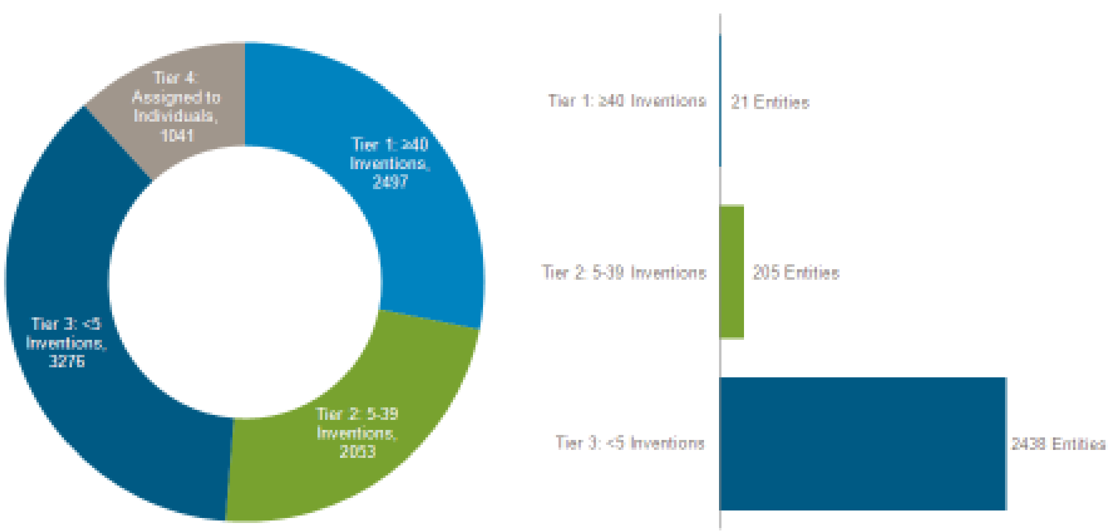


Figure 32 – Distribution of Patent Activity within e-waste Landscape by Portfolio Size; Number of Entities per Portfolio Tier

Figure 32 models this distribution in e-waste, and shows that over a quarter of the patent families in the collection derive from just 21 patent applicants, all of whom have 40 or more e-waste inventions in the portfolio.

Another way of saying this is that there are just fewer than 2,500 entities that have fewer than 5 inventions, but that this "long tail" of activity only provides around a third of the entire landscape.

Thus, the dataset is to an extent quite top heavy, with a small number of organizations controlling a large proportion of the technology within e-waste.

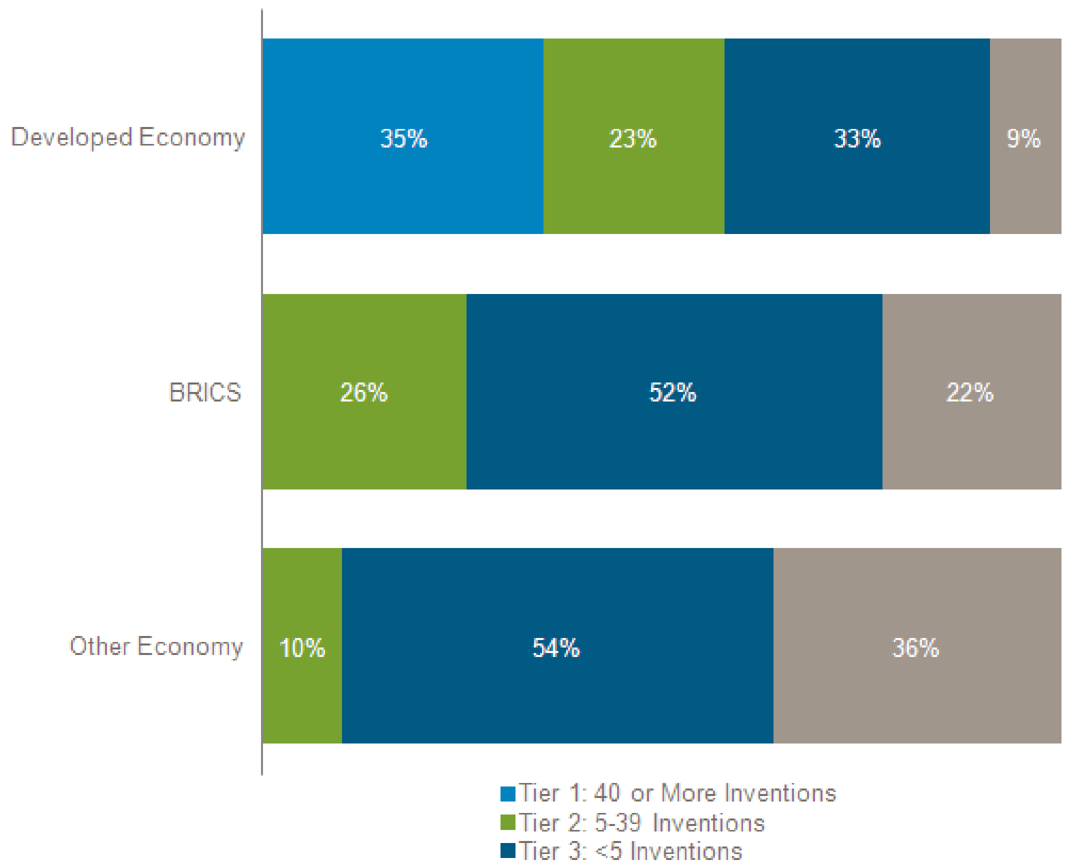


Figure 33 - Distribution of Portfolio Size Tiers across Economy Types

Figure 33 shows how these portfolios are distributed amongst the economy groupings (developed, BRICS or other emerging economies).

The largest portfolios are all based in developed economies, with none of them within the BRICS countries. Conversely, BRICS activity is strongly tied to the smallest portfolios, indicating that activity in these countries (primarily China) is highly diversified and spread across hundreds of different entities.

This finding is shown in more detail in Figure 34, which shows the offices of first filing locations of the smallest patent portfolios in the landscape. While Japan is still the top location, its dominance is greatly reduced compared to the landscape as a whole (see Figure 8, Part 3).

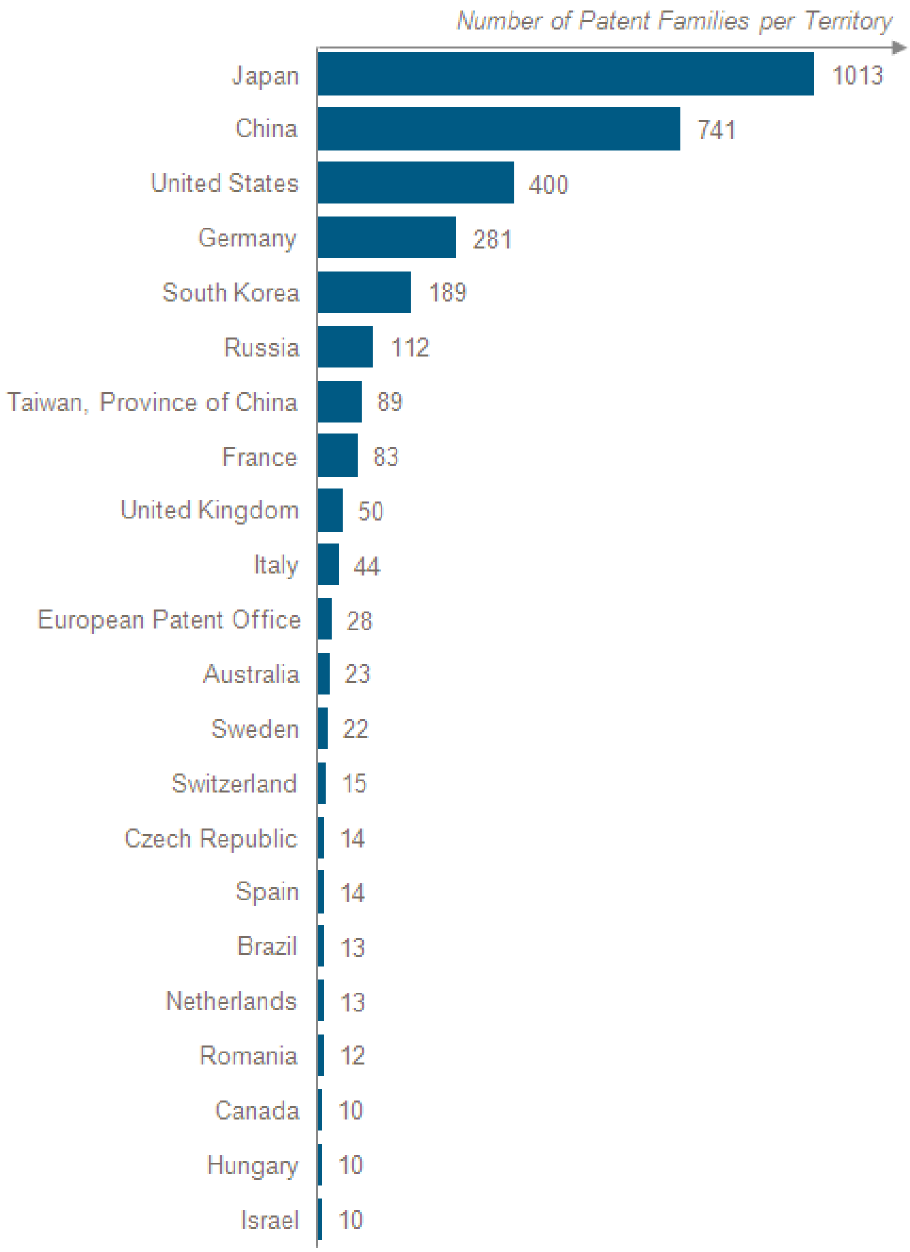


Figure 34 – Office of First Filing Locations of Tier 3 (Small) Portfolios

5.2 ACADEMIC VERSUS CORPORATE PATENT ACTIVITY

A further model of the type of organization active in the landscape is to review the patent applicants and identify whether they are academic or government research institutions or corporations.

Figure 35 shows that just 9% of the activity in the landscape comes from these types of entity, with just under 80% of the activity from for-profit organizations.

The timeline view in Figure 36 shows however that academic patent activity is growing very quickly, and on a normalized basis (comparing activity distribution), more rapidly.

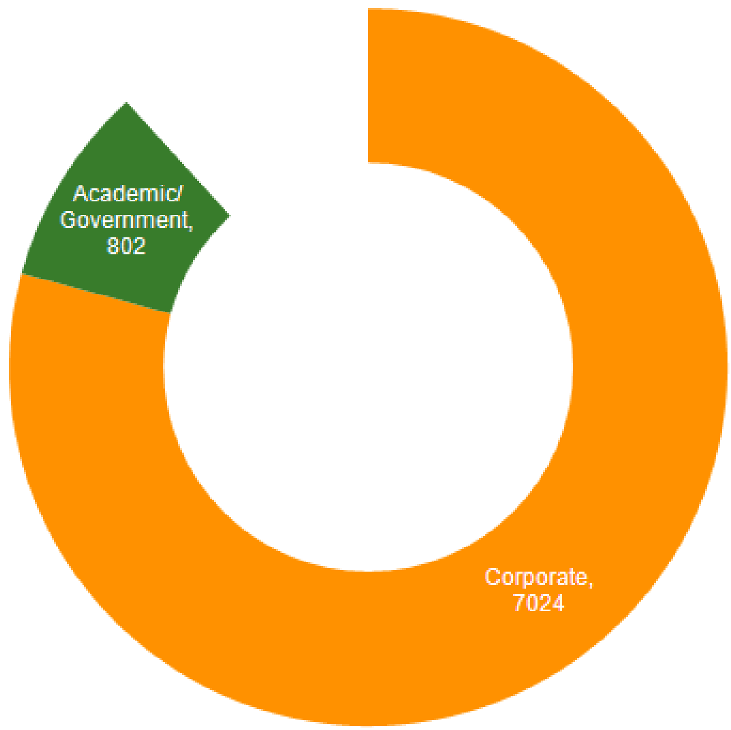


Figure 35 - Assessment of Patent Applicant Type and Distribution across e-waste Landscape; Academic or Government Applicant versus Corporate Applicant

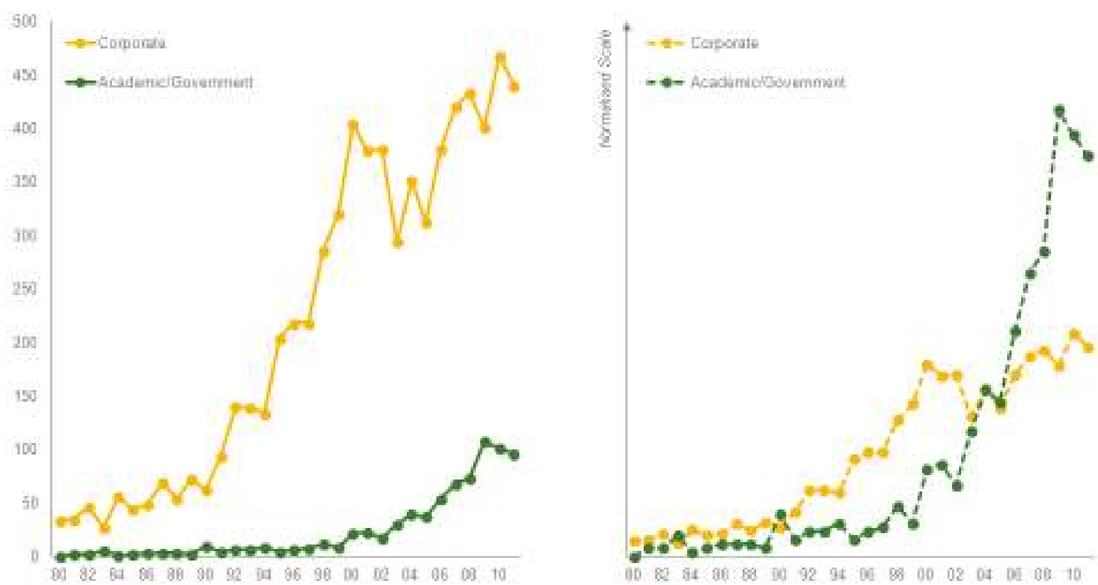


Figure 36 - Timeline of e-waste Patent Activity by Applicant Type, Academic or Government Applicant versus Corporate Applicant; Charts show both absolute numbers per earliest first filing year and activity trend on a normalized scale (% of total activity filed in any given year)

The growth rate in academic patent activity implies a tie to the high growth rates emanating from China, and this does indeed appear to be the case. Figure 37 shows that more than 50% of the academic activity in the landscape is due to Chinese-based research institutions.

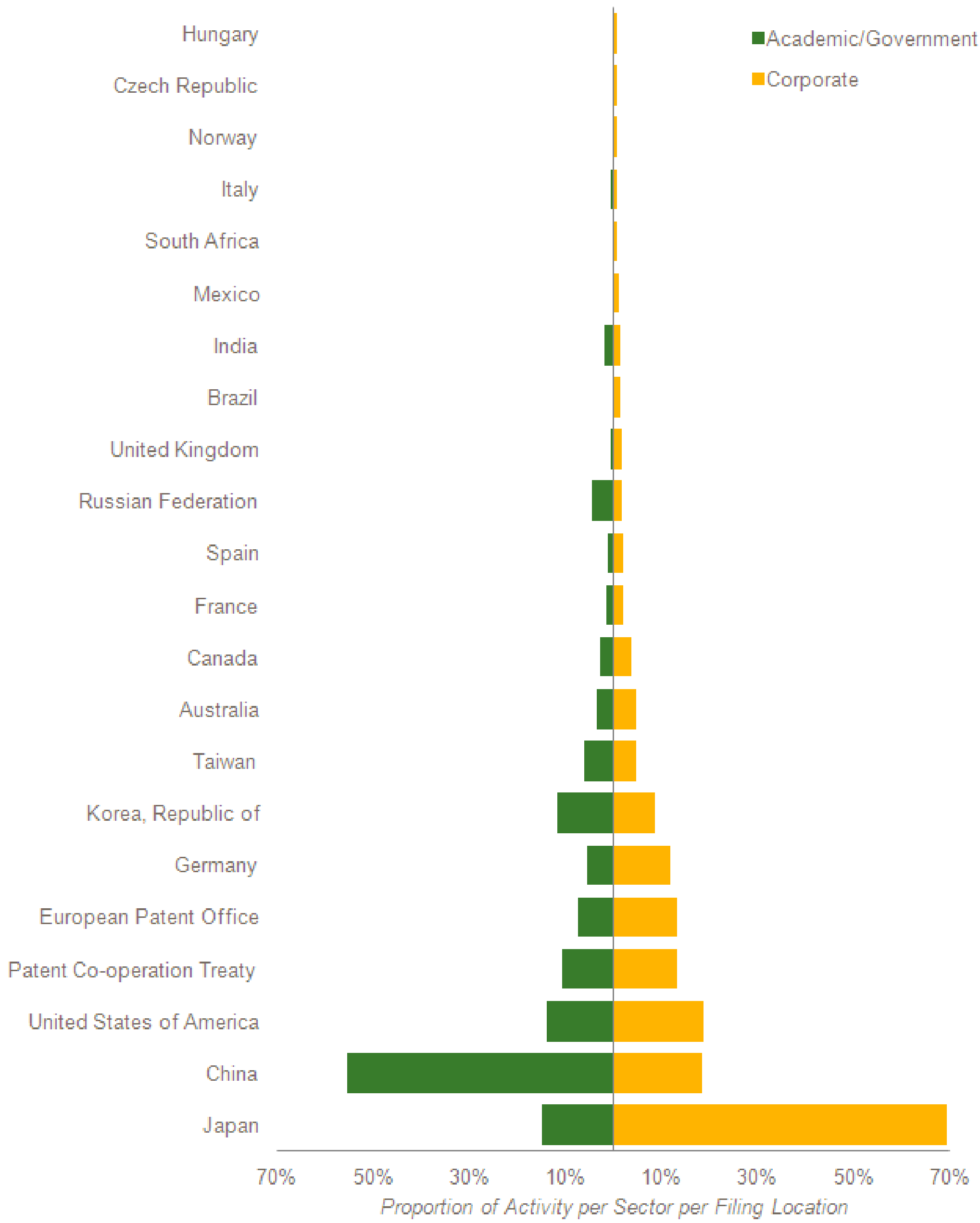


Figure 37 - Breakdown of Academic and Government or Corporate Activity by Office of First Filing Location; As % of Activity per Applicant Sector

5.3 MAJOR PATENT APPLICANTS IN E-WASTE

Reviewing the patent families in this subset reveals the following major patent entities. Figure 38 lists the corporations with 5 or more patent families, each of which have been filed in 5 or more territories.

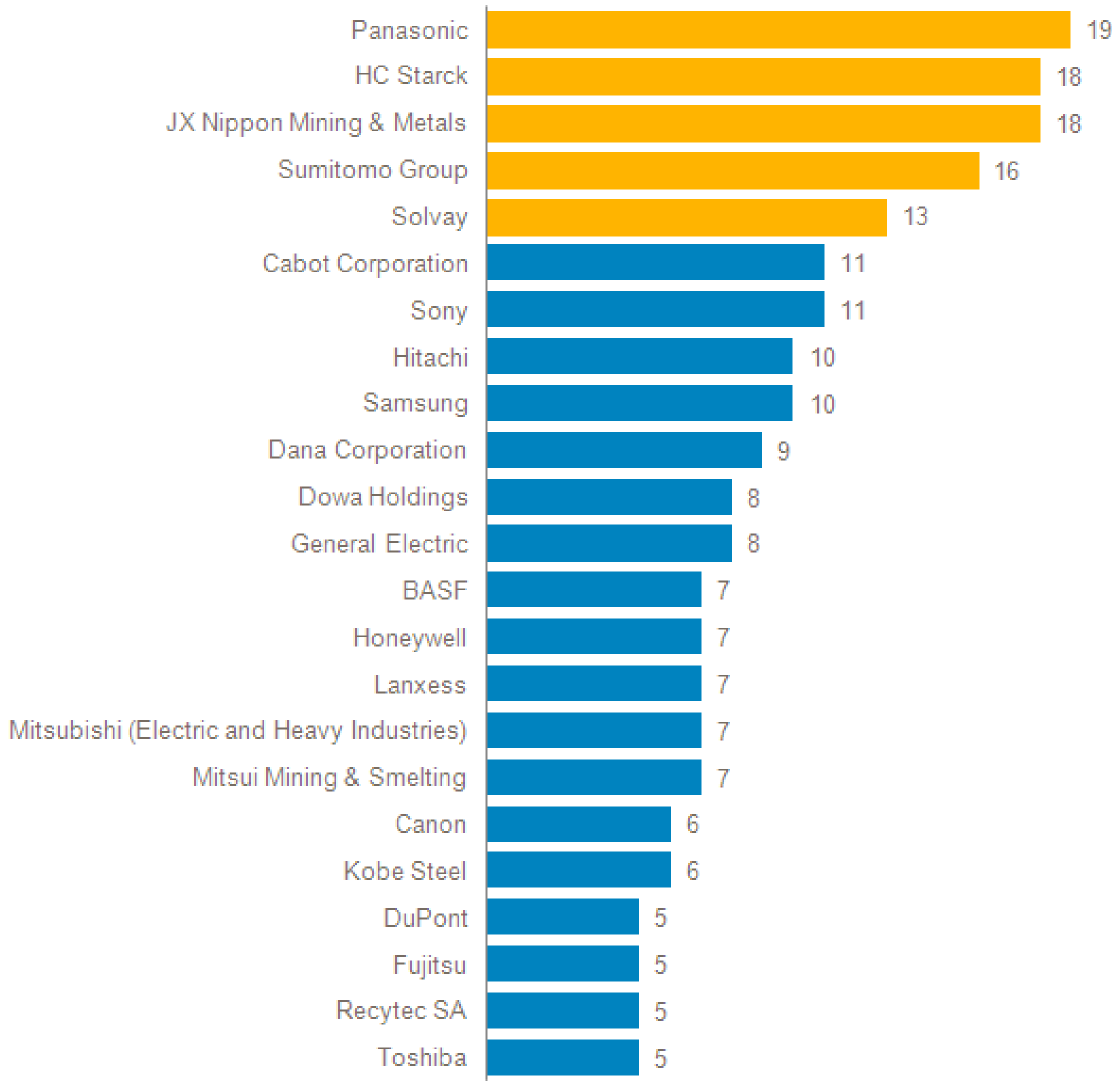


Figure 38 - Patent Applicants seeking protection in 5 or more Territories; Number of Patent Families with this high level of protection

Japanese consumer electronics giant Panasonic is revealed as the most active applicant at this scale of protection, followed by German materials specialist company HC Starck, Japanese metals corporation JX Nippon Mining & Metals, Sumitomo and Belgium chemical company Solvay.

This list of corporations includes several non-electronics firms, indeed several corporations whose primary interest is in metals extraction – JX Nippon, Mitsui Mining and Smelting, Kobe

Steel etc., which likely acts as confirmation of the nature of the e-waste landscape as transferring to a commodity economic model.

Table 13 provides a breakdown of the sub-technologies of interest to these listed corporations, as measured as a proportion of their complete e-waste portfolios.

Table 13 - Breakdown of Major Subject Matter of Entities Filing in 5 or More Territories; as % of all Patent Families per Portfolio in the landscape

High Level Topics	Panasonic	HC Starck	JX Nippon Mining & Metals	Sumitomo Group	Solvay	Cabot Corporation	Sony	Hitachi	Samsung	Dana Corporation	Dowa Holdings	General Electric	BASF	Honeywell	Lanxess	Mitsubishi (All)	Mitsui Mining & Smelting	Canon	Kobe Steel	DuPont	Fujitsu	Recytec SA	Toshiba
Material Recovery: Ferrous Metals	0%		1%	3%	6%	29%		1%	9%	60%	2%	13%	13%	18%	67%	1%	2%		5%	10%	2%		1%
Material Recovery: Glass	1%				13%		1%					4%				0%		2%				17%	
Material Recovery: Hazardous Materials	2%		10%	2%		14%	1%		3%	7%	3%	8%		9%	33%	0%		2%				50%	1%
Material Recovery: Noble Metals		4%	3%				2%				3%	8%	20%		33%	1%	3%		1%	30%	2%	17%	
Material Recovery: Non-Ferrous Metals	1%	17%	15%	2%	38%	36%	3%	1%	9%		5%	17%	20%	36%	44%	0%	8%		4%		2%	50%	1%
Material Recovery: Others (Rubber Ceramic etc.)	1%			0%	13%											0%	2%						
Material Recovery: Plastic	3%			1%	25%		5%	1%	6%			17%	13%		44%	1%		4%			7%	17%	1%
Material Recovery: Rare Earth Metals	1%	9%	2%	1%	25%	21%		0%		7%		8%		9%		0%			1%			17%	
Process: Decontamination	0%	22%	9%	2%	13%	14%		1%	6%		2%	8%	7%	27%		1%			2%			33%	1%
Process: Disassembly	2%	13%	1%	2%	6%	7%	2%	0%	3%			8%	20%		22%	1%		2%	1%		2%	50%	
Process: Further Processing	1%	4%		0%	6%	43%	1%	0%	6%	7%		4%	13%					2%					1%
Process: Logistics/Collection				0%				1%	9%	7%	2%						2%	2%				17%	1%
Process: Separation	1%	9%		1%	19%		2%	0%	9%			4%		9%			3%	2%	1%	10%		67%	

From this analysis we can see that Dana Corporation and Lanxess have a strong specialization and commercial interest in ferrous metal recovery from e-waste sources. Lanxess also has interests in non-ferrous metal and plastic recycling.

Recytec SA has the most diverse, widely filed patent portfolio (though the volumes from the corporation are low; specializations occur in Hazardous Material recovery, non-ferrous metals, e-waste disassembly and separation.

5.4 MAJOR PATENT APPLICANTS BY REGION

Moving on from widely filed patent rights, Tables 14 through 16 list the top patenting entities by geographic region (Asia Pacific, Europe Middle East and Africa, Americas), andlist the total number of patent families registered, the location of the organizations headquarters,giving a description of the entity's primary industry.

These tables are included for reference purposes to aid identification of patent applicants of specific interest to the reader.

Table 14 - Major Patent Applicants from Asia Pacific; Based on Office of First Filing Locations

Entity	Total Inventions	HQ	Industry
Mitsubishi (All)	343	Japan	Conglomerate, Chemicals, Electronics, Industrial
Panasonic	298	Japan	Consumer Electronics
Hitachi	273	Japan	Conglomerate, Chemicals, Electronics, Industrial
Sumitomo	249	Japan	Conglomerate, Chemicals, Electronics, Industrial
Toshiba	164	Japan	Consumer Electronics
Sharp	130	Japan	Consumer Electronics
JFE Holdings	119	Japan	Metals and Refractory
JX Nippon Mining & Metals	115	Japan	Metals and Refractory
Dowa Holdings	114	Japan	Metals and Refractory
Sony	82	Japan	Consumer Electronics
Toyota	79	Japan	Automotive
Mitsui Mining & Smelting	63	Japan	Metals and Refractory
Nippon Steel	63	Japan	Metals and Refractory
Ricoh	57	Japan	Consumer Electronics
National Institute of Advanced Industrial Science & Technology (Japan)	50	Japan	Research Institute

Table 15 - Major Patent Applicants from the Americas; Based on Office of First Filing Location

Entity	Total Inventions	HQ	Industry
General Electric	20	US	Conglomerate
Dana Corporation	15	US	Automotive
Archimedes Technology Group	12	US	Waste Management
Honeywell	11	US	Conglomerate
Cabot Corporation	10	US	Specialty Chemical
DuPont	10	US	Industrial Chemical
General Motors	10	US	Automotive
Exide Technologies	7	US	Batteries, Waste Management
HC Starck	7	Germany	Metals, Refractory, Waste Management
Osram	7	Germany	Lighting
Carestream Health	6	US	Healthcare
Eco-Bat Technologies	6	US	Waste Management
Empire Technology Development LLC	6	US	-
Kodak	6	US	Industrial Chemical/Consumer Products
Resource Concepts Inc	6	US	Consulting Engineers
GTE	5	US	Defunct
IBM	5	US	Conglomerate
Kinsbursky Brothers	5	US	Waste Management
Tekna Plasma Systems	5	US	Industrial Plasma Systems

Table 16 - Major Patent Applicants from Europe, Middle East and Africa (EMEA); Based on Office of First Filing Locations

Entity	Total Inventions	HQ	Industry
HC Starck	16	Germany	Metals, Refractory, Waste Management
Solvay	15	Belgium	Industrial Chemical
BASF	11	Germany	Industrial Chemical
Daimler	11	Germany	Automotive
Siemens	10	Germany	Conglomerate, Engineering, Electronics
ABB	9	Switzerland	Conglomerate, Electrical Equipment
Lanxess	9	Germany	Specialty Chemicals
ALD Vacuum Technologies	8	Germany	Industrial Metallurgy Equipment
Keramchemie GmbH	8	Germany	-
Akkumulator es Szarazelemgyar	6	Hungary	-
Bayer	6	Germany	Industrial Chemical
Deutz AG	6	Germany	Engine Manufacture
Philips	6	Netherlands	Consumer Electronics, Lighting
Recytec SA	6	Switzerland	Waste Management
Umicore & Co KG	6	Germany	Specialty Chemicals, Waste Management
voestalpine AG	6	Austria	Metals and Refractory

5.5 SUMMARY OF MAJOR PORTFOLIO CHARACTERISTICS

Table 17 shows the major portfolios from the three major regions into which the landscape has been divided, and details the type of patent filing strategy each applicant has undertaken, as well as providing an indicator of the impact their inventions have had on downstream activity.

This last metric is provided through the use of patent citation statistic – i.e. the number of occasions a particular patent family has been referenced by downstream patent applications – either through the patent examination procedure or through applicants putting forward relevant prior art.

Table 17 - Assessment of the e-waste Patent Portfolio Characteristics of Major Asia Pacific, EMEA and Americas Patent Applicants

Region	Entity	Total Inventions	Filing Breadth	Times Cited	Citations per Invention
Asia Pacific	Mitsubishi (All)	343	1.2	665	1.9
	Panasonic	298	1.6	837	2.8
	Hitachi	273	1.3	1056	3.9
	Sumitomo	249	1.4	602	2.4
	Toshiba	164	1.3	548	3.3
	Sharp	130	1.1	188	1.4
	JFE Holdings	119	1.1	226	1.9
	JX Nippon Mining & Metals	115	2.1	256	2.2
	Dowa Holdings	114	1.4	292	2.6
	Sony	82	1.9	291	3.5
	Toyota	79	1.5	129	1.6
	Mitsui Mining & Smelting	63	2.0	276	4.4
	Nippon Steel	63	1.3	132	2.1
	Ricoh	57	1.3	118	2.1
	National Institute of Advanced Industrial Science & Technology (Japan)	50	1.4	43	0.9
Americas	General Electric	20	3.4	151	7.6
	Dana Corporation	15	4.4	269	17.9
	Archimedes Technology Group	12	2.6	128	10.7
	Honeywell	11	4.8	138	12.5
	Cabot Corporation	10	6.3	355	35.5
	DuPont	10	4.4	205	20.5
	General Motors	10	3.9	31	3.1
	Exide Technologies	7	3.0	90	12.9
	HC Starck	7	8.3	351	50.1
	Osram	7	2.2	35	5.0
	Carestream Health	6	2.0	2	0.3
	Eco-Bat Technologies	6	2.7	35	5.8
	Empire Technology Development LLC	6	1.1	-	-
	Kodak	6	2.3	107	17.8
	Resource Concepts Inc	6	1.0	38	6.3
	GTE	5	1.0	75	15.0
	IBM	5	2.4	207	41.4
	Kinsbursky Brothers	5	1.2	22	4.4
	Tekna Plasma Systems	5	3.4	52	10.4
EMEA	HC Starck	16	8.3	351	21.9
	Solvay	15	7.9	127	8.5
	BASF	11	4.5	69	6.3
	Daimler	11	2.7	101	9.2
	Siemens	10	2.7	45	4.5
	ABB	9	2.4	43	4.8
	Lanxess	9	4.8	14	1.6
	ALD Vacuum Technologies	8	3.0	52	6.5
	Keramchemie GmbH	8	1.4	16	2.0
	Akkumulator es Szarazelemgyar	6	6.3	13	2.2
	Bayer	6	3.3	46	7.7
	Deutz AG	6	3.5	51	8.5
	Philips	6	3.0	38	6.3
	Recytec SA	6	7.2	66	11.0
	Umicore & Co KG	6	3.5	10	1.7
	voestalpine AG	6	6.2	59	9.8

Patent citation is a common tool for assessing impact, as inventions which gather many such citations are highly likely to be influencing further innovation within the space. In this case, citation statistics are aggregated across the portfolios to provide an overall view of the impact of the inventions associated with each applicant.

Two firms are highlighted in the table as having particularly widely filed patent families as well as high citation impact rates – Cabot Corporation and HC Starck (the latter listed in two regions due to varying selection of the office of first filing).

From an overall perspective, and reflecting the wider landscape trend previously seen, the US and European based entities are those that appear to project their IP rights into several different locations, indicating a desire to commercialize their technology in multiple market locations. Conversely, Asian (predominantly Japanese) patent applicants tend to file their patents locally within Asia.

Table 18 summarizes the technical approaches of these major patent applicants, and provides reference information for the reader to aid the identification of corporations or organizations of interest.

The two companies identified in the previous analysis (Cabot and HC Starck) are shown to have interest in smelting/heating or metal extraction, specifically of non-ferrous metals.

One notable point from this table is the strong association of plastic recycling with Japanese entities, in particular Japanese consumer electronics companies, indicating that this is their primary historical concern when it comes to e-waste processing.

Table 18 - Profile of the Technical Interests of Major Patent Applicants from Asia Pacific, Europe (incl Middle East and Africa) and the Americas; Major Subject Matter within Portfolio - e-waste Sources (Devices), Processes and Recovered Materials

Region	Entity	Total Inventions	Primary Product/Item	Primary Processing Category	Primary Recovered Material
Asia Pacific	Mitsubishi (All)	343	Household Appliances	Decontamination - Polychlorinated Biphenyls	Plastics
	Panasonic	298	Displays	Metal Extraction	Plastics
	Hitachi	273	Capacitors	Metal Extraction	Plastics
	Sumitomo	249	Batteries	Chemical Separation	Ferrous Metals
	Toshiba	164	Household Appliances	Decontamination - General	Plastics
	Sharp	130	Displays	Chemical Separation	Plastics
	JFE Holdings	119	Household Appliances	Metal Extraction	Plastics
	JX Nippon Mining & Metals	115	Printed Circuit Boards	Decontamination - General	Ferrous Metals
	Dowa Holdings	114	Printed Circuit Boards	Decontamination - General	Silver
	Sony	82	Displays	CRT Dismantling	Plastics
	Toyota	79	Batteries	Decontamination - General	Nickel
	Mitsui Mining & Smelting	63	Batteries	Decontamination - General	Other non-Ferrous
	Nippon Steel	63	Household Appliances	Decontamination - Polychlorinated Biphenyls	Ferrous Metals
	Ricoh	57	Computers/Laptops	Metal Extraction	Plastics
	National Institute of Advanced Industrial Science & Technology (Japan)	50	Printed Circuit Boards	Decontamination - General	Other non-Ferrous
Americas	General Electric	20	Printed Circuit Boards	Decontamination - General	Ferrous Metals
	Dana Corporation	15	Wiring/Cabling	Smelting/Heating	Ferrous Metals
	Archimedes Technology Group	12	Coils	Decontamination - General	Radioactive
	Honeywell	11	Printed Circuit Boards	Decontamination - General	Other non-Ferrous
	Cabot Corporation	10	Capacitors	Smelting/Heating	Other non-Ferrous
	DuPont	10	LEDs	Chemical Separation	Silver
	General Motors	10	Batteries	Decontamination - General	Ferrous Metals
	Exide Technologies	7	LEDs	Decontamination - General	Glass / Lead
	HC Starck	7	Capacitors	Metal Extraction	Other non-Ferrous
	Osram	7	Capacitors	Decontamination - General	Copper
	Carestream Health	6	Several	Decontamination - General	Ferrous Metals / Silver
	Eco-Bat Technologies	6	Batteries	Battery Dismantling	Ferrous Metals
	Empire Technology Development LLC	6	Batteries	Battery Dismantling	Several
	Kodak	6	Several	Chemical Separation	Other non-Ferrous
	Resource Concepts Inc	6	PCBs/Wiring	Metal Extraction	Silver
	GTE	5	Magnetic Components	Chemical Separation	Mercury
	IBM	5	Printed Circuit Boards	Chemical Separation	Plastics
	Kinsbursky Brothers	5	Batteries	Decontamination / Metal Extraction	Lead, Nickel, Rare Earths
	Tekna Plasma Systems	5	Wiring/Cabling	Decontamination - General	Silver
EMEA	HC Starck	16	Capacitors	Decontamination - General	Other non-Ferrous
	Solvay	15	Wiring/Cabling	Chemical Separation	Rare Earth Metals
	BASF	11	Batteries / PCBs	Metal Extraction	Ferrous Metals
	Daimler	11	Batteries	Decontam/Sorting/Pulverizing	Plastics
	Siemens	10	Switches/Sockets	Decontamination	Other non-Ferrous
	ABB	9	Batteries/Wiring	Metal Extraction	Several
	Lanxess	9	LEDs	Metal Extraction	Ferrous Metals
	ALD Vacuum Technologies	8	Several	Metal Extraction/Smelting	Other non-Ferrous
	Keramchemie GmbH	8	Batteries	Metal Extraction	Cadmium
	Akkumulator es Szarazelemgyar	6	Batteries/LEDs	Smelting/Heating	Lead
	Bayer	6	Household Appliances	Smelting/Heating	Plastics
	Deutz AG	6	Batteries/LEDs	Sorting/Chemical Sep	Several
	Philips	6	Several	Wire Extraction	Several
	Recytec SA	6	Batteries	Several	Mercury/Plastics/Other non-Ferrous
	Umicore & Co KG	6	Batteries	Metal Extraction	Silver
	voestalpine AG	6	Batteries	Metal Extraction	Mercury

5.6 SUMMARY OF MAJOR NOT-FOR-PROFIT ENTITIES IN THE E-WASTE LANDSCAPE

The table below shows the major not-for-profit entities within the e-waste landscape. The table has been sorted so that research institutes and universities that have been more active recently are placed higher up the table.

The first key finding from this table is that all of the entities in this list (i.e. those with more than 7 patent families in the landscape) are based in Asia – specifically China, South Korea, Japan, Taiwan (Province of China) or India.

The first non-Asian not-for-profit entity in the landscape is the Fraunhofer Society in Germany with 5 families followed by CNRS in France with 4 families.

Table 19 - Major Academic and Government Patent Applicants in e-waste Landscape, Timeline of Activity (sorted for more recent activity) and Total Patent Families; Annotated for Geographic Location

Entity	90	91	92	93	94	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	Total
Chinese Academy of Sciences							1	1							1	3	4	2	2	6	3	8	31
Tsinghua University									1		2	2		1		3		1	2	4	1	4	21
Sichuan University																			7			2	9
Tongji University										2						1			1		5	1	10
Beijing Institute of Technology													1			1	3		1	3	4	1	14
Shanghai Jiaotong University											1							2	3		4	1	11
Hefei University of Technology																1			2		3	1	7
Beijing University of Science & Technology	1																4		1	6	2	1	15
Guandong University of Technology																			1	3	2	1	7
South China Normal University													1	3	2	1	2		1		2	1	13
Shanghai University														1			1	1	1	1	1	1	7
Central South University																3		6	9	4		1	22
Beijing University of Chemical Technology																	1	1	1	2		1	6
KIGAM Korea Institute of Geoscience and Minerals										1	1	4	2		1	2		3	5	6	5		29
National Institute of Advanced Industrial Science & Technology (Japan)										4	4	3	3	4	2	1	8	7	3	7	4		50
Tianjin University	1													1	1		6	6	5	6	1		26
South China University of Technology															1		1		1	4	1		8
Beihang University															1			3	3	2	1		10
Hokkaido University															2		1	2	1		1		7
Nanjing University														1		2	3		1		1		8
Donghua University														1		2	2	3			1		9
Industrial Technology Research Institute (Taiwan, Province of China)			1	1			2		1		5		4	1	1	2	1	3			1		23
KAIST Korea Advanced Institute of Science & Technology										1						2	3	1	2	4			13
Korea Research Institute of Industrial Science & Technology										3			1						1	3			8
Nankai University										2			1	2						1			6
CSIR India											1		1	2	1	3	1						9
Japan Science & Technology Agency											1	2	2	2		1							8
Far East College (Taiwan, Province of China)												1		6									7

China
South Korea
Japan
Taiwan, Province of China
India

The largest not-for-profit entity is the Japanese AIST organization with 50 inventions going back over a decade in the field – indicating a strong research theme for the organization and therefore likely embedded expertise.

Another institute of interest is KIGAM in Korea (institute of Geoscience and Minerals). The inclusion of such a research institute in a landscape concerning e-waste acts as yet more evidence of the nature and importance of e-waste to materials recovery – particularly mineral and metal recovery.

Another entity with potentially strong expertise is the ITRI organization in Taiwan (Province of China).

Overall, however, Chinese activity is particularly dominant, as well as being predominantly recent in comparison to other entities. This is in part due to the heavy usage of Chinese Utility Models by these entities, a type of patent that publishes particularly quickly and therefore somewhat artificially promotes these entities up the table.

5.7 KEY FINDINGS FROM COMMERCIAL ANALYSIS

- Activity in the e-waste Landscape is relatively “top heavy”, i.e. a large proportion of the total number of patent rights in the landscape is assigned to relatively few entities. More than one quarter of the patent families in the collection derive from just 21 patent applicants, all of whom have 40 or more e-waste inventions in the portfolio.

- Seen in reverse, just fewer than 2,500 entities have fewer than 5 inventions, but this only provides around a third of the entire landscape.

- The largest portfolios are all based in developed economies, with none within the BRICS countries. BRICS activity is strongly tied to the smallest portfolios, indicating that activity in these countries (primarily China) is highly diversified and spread across hundreds of different entities.

- Just 9% of the activity in the landscape comes from not for profit entities such as Academic or Research Institutions; however, academic patent activity is growing more rapidly than commercial activity when measured on a like-for-like basis.

- The growth rate in academic patent activity implies a tie to the high growth rates emanating from China, and indeed the analysis of major academic/government patent applicants shows this. Indeed, the top 30 research institutes in the landscape are all based in Asia. Overall, however, Chinese activity is particularly dominant, as well as being predominantly recent in comparison to other entities. This is in part due to the heavy usage of Chinese Utility Models by these entities, a type of patent that publishes particularly quickly.

- The largest not-for-profit entity is the Japanese AIST organization with 50 inventions going back over a decade in the field – indicating a strong research theme for the organization and therefore likely embedded expertise.

- Another institute of interest is KIGAM in Korea (Institute of Geoscience and Minerals). The inclusion of such a research institute in a landscape concerning e-waste acts as yet more evidence of the nature and importance of e-waste to materials recovery – particularly mineral and metal recovery.

- The first non-Asian not-for-profit entity in the landscape is the Fraunhofer Society in Germany with 5 families followed by CNRS in France with 4 families.

- Japanese consumer electronics giant Panasonic is the most active applicant in terms of widely filed/likely commercialized IP rights, followed by German materials specialist company HC Starck, Japanese metals corporation JX Nippon Mining & Metals, Sumitomo and Belgium chemical company Solvay.

- Assessment of the industrial nature of corporations includes several non-electronics firms, indeed several corporations whose primary interest is in metals extraction – JX Nippon, Mitsui Mining and Smelting, Kobe Steel etc., which likely acts as confirmation of the nature of the e-waste landscape as transferring to a commodity economic model.

- All of the most prolific patent applicants in the landscape as a whole are Japanese firms; in particular Japanese consumer electronics firms as well as metals and refining corporations. There is strong association of plastic recycling with Japanese entities, in particular Japanese consumer electronics companies, indicating that this is their primary historical concern when it comes to e-waste processing.

ANNEX A – BUSINESS DATA FOR MAJOR PORTFOLIOS

This Annex contains reference information which captures a business snapshot of the major patent applicants from the patent landscape assessment.

Included for each company are a summary of the nature and location of the business as well as publicly available information regarding the interests of the firm in e-waste processing or recycling of consumer electronics items.

This information has not been aggregated across the corporations, and is intended as further reference information for the reader is terms of the commercial interests of the entities listed.

Note that information on the research and commercial interests of the firms listed as major patent applicants could not be found for all entities.

Where applicable, links are provided in the footnotes so that primary information can be obtained.

MITSUBISHI

Mitsubishi, a group of autonomous Japanese multinational companies, has developed a recycling technology for e-wastes. Mitsubishi claims that the new Mitsubishi Electric technology enables automatic separation of plastic with 99% purity from electronic scraps. The process basically uses the weight difference of different substances and simplifies the removal of plastics by generating static electricity.[15]

In April 2010, Mitsubishi launched a plant representing the Japan's first large scale, high purity plastic recycling system. This recycling system is operated by Green Cycle Systems Corp. (established by Mitsubishi, Japan). The Green Cycle Systems Corp. receives shredded mixed plastics containing various other materials from Hyper Cycle System Co. Ltd.[16]

The flow chart below presents the Mitsubishi Electric Home Appliance Recycling System. The chart describes the synchronized operation that is carried out by Hyper Cycle Systems Co. Ltd and Green Cycle Systems Corp. The used/waste electric home appliances are collected by the Home Appliance Recycling Plant of Hyper Cycle Systems Co. Ltd. Hyper

[15] http://goodcleantech.pcmag.com/recycling/280479-mitsubishi-develops-new-recycling-technology-for-electronics (visited on April 28, 2013)
[16] http://www.mitsubishielectric.com/company/environment/ecotopics/plastics/separation/index.html (visited on April 28, 2013)

Cycle Systems Co. Ltd delivers shredded mixed plastic to Green Cycle Systems Corp. according to the requirements and with the technical support of Mitsubishi.[17]

The Green Cycle Systems Corp. uses the Mitsubishi's Large Scale, High Purity Plastic Recycling technology and provides Mitsubishi Electric high purity materials matched to the required specifications of Mitsubishi.[18]

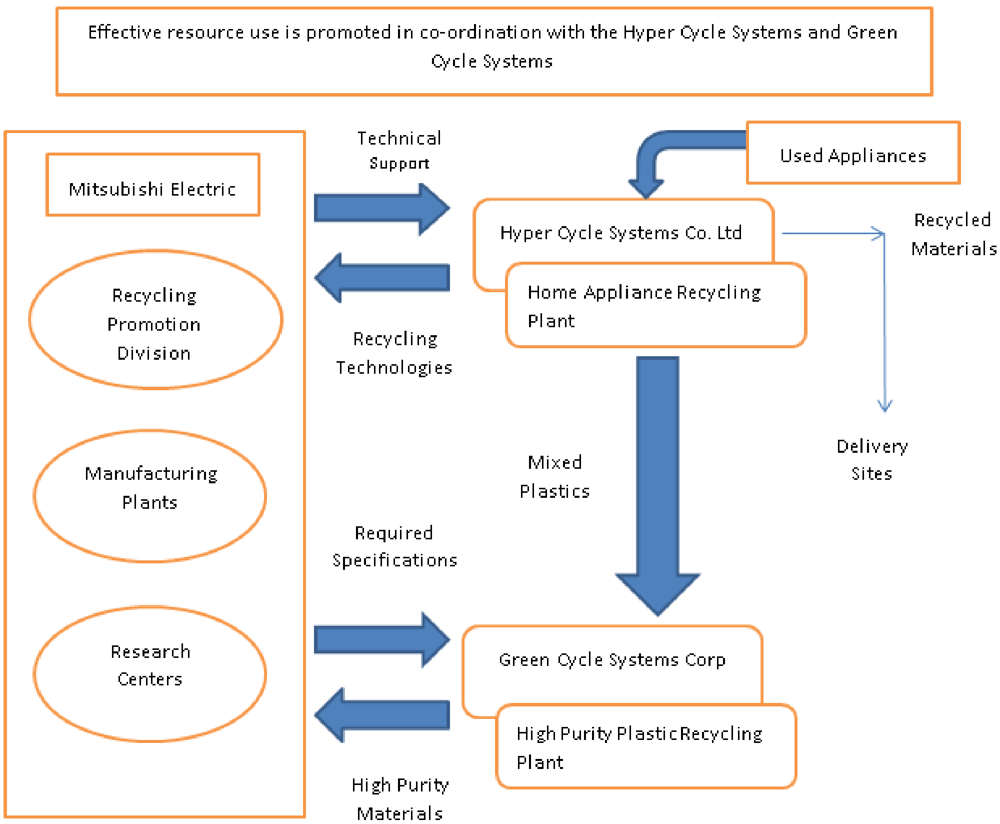


Figure 1: Mitsubishi's Electric Home Appliance Recycling System[19]

---

[17] http://www.mitsubishielectric.com/company/environment/ecotopics/plastics/gcs/index.html (visited on April 28, 2013)
[18] *Id.*

[19] http://www.mitsubishielectric.com/company/environment/ecotopics/plastics/gcs/index.html (visited on April 28, 2013)

MITSUBISHI RECYCLING TREND[20]

The bar chart below shows the recycling volume of Mitsubishi's end-of-life electrical home appliances. In 2011, Mitsubishi processed and recycled products weighing around 85,000 tons and successfully recycled around 75,000 tons of products. There was slight increase in the volume recycled in 2012, as compared to 2010. On the other hand though, there was significant decline in the amount of product processed and recycled in 2012 compared to 2011.

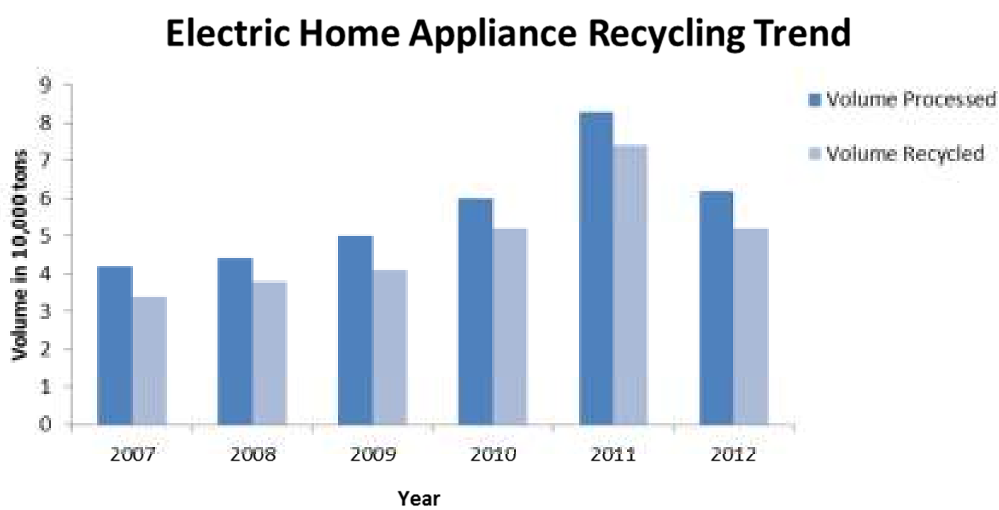


Figure 2: Mitsubishi's Electric Home Appliance Recycling trend

In 2012, Mitsubishi collected a total of 4,891 household and industrial used computers that accounted for a recycling rate of 76%. The table below shows the different types of computers that were recycled by Mitsubishi Electric in 2012.

	Units	Desktop		Notebooks		CRT Displays		LCD		Total	
Collected Weight		14.8		2.9		11.5		10.4		39.6	
		Office	Home	Office	Home	Office	Home	Office	Home	Office	Home
		12.8	2	2.7	0.1	8.9	2.5	10.1	0.3	34.5	4.9
Collected Units		1579		1052		552		1708		4891	
		Office	Home	Office	Home	Office	Home	Office	Home	Office	Home
		1418	161	1003	49	424	128	1651	57	4496	395
Treated Weight	Tons	14.8		2.9		11.5		10.4		39.6	
Recycled Weight	Tons	12.1		2		7.8		8.2		30.1	
Recycling Ratio	%	82		68.3		68.1		78.8		76	

Table 1: Material Recycling from Used Computers (Household and Industrial use) in 2012

[20] http://www.mitsubishielectric.com/company/environment/report/products/recycle/index_print.html (visited on April 28, 2013)

MITSUBISHI RECYCLING TECHNOLOGY[21]

Mitsubishi has developed a proprietary method for separating plastics based on their respective characteristics. The technology developed by Mitsubishi separates plastics at high level of purity and high recovery rates.

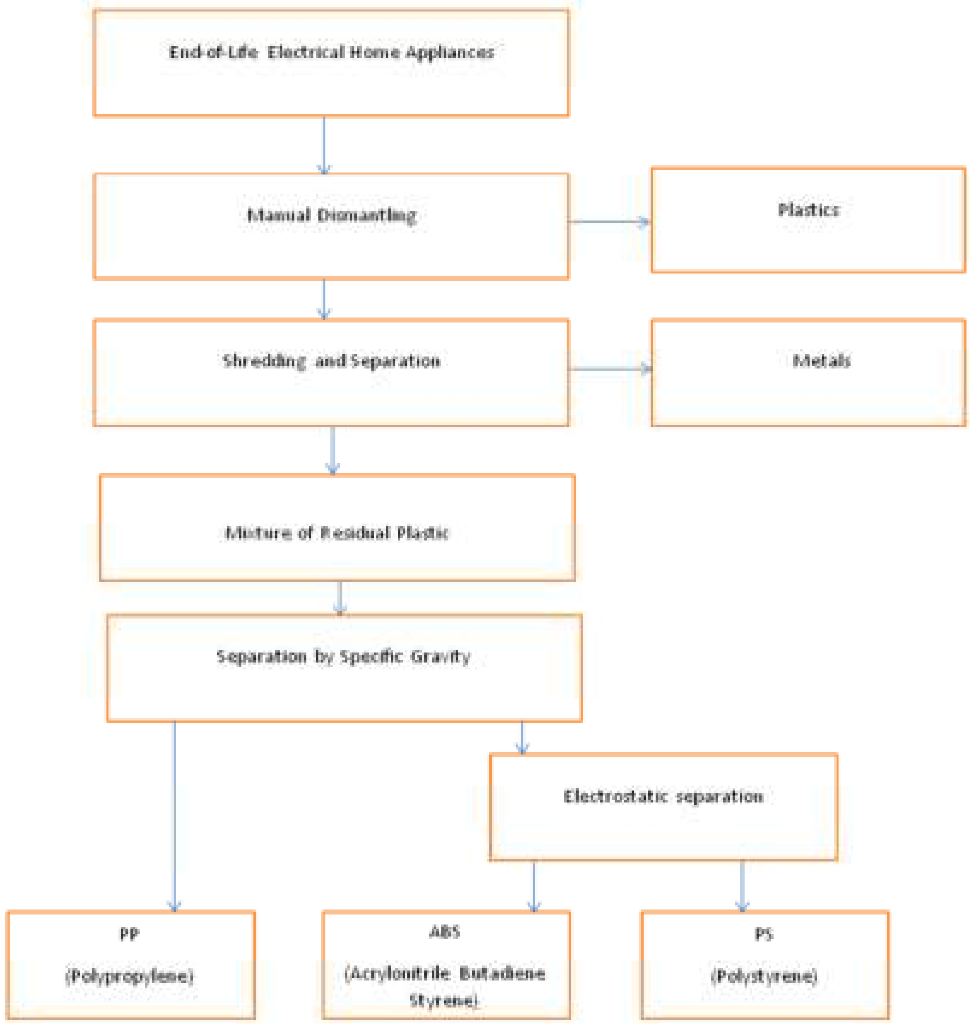


Figure 3: Process for Separating Mixed Plastic at High Levels of Purity

The flow chart above shows the process of separating mixed plastic with high level of purity. The end of life electric home appliances are first dismantled manually from which the plastics are separated. Then in shredding and separating phase, the metals are separated from plastic. This residual plastic is then fed for separation by specific gravity. In separation by specific gravity, the substances in plastic mixture are separated according to the weight of different substances. By using specific gravity separation, polypropylene (PP) plastic substances are separated from the mixture. In order to further separate acrylonitrile butadiene styrene and (ABS) polystyrene (PS) the mixture of residual plastic is then treated with electrostatic separation. In electrostatic separation, a frictional static is generated

[21] http://www.mitsubishielectric.com/company/environment/ecotopics/plastics/separation/index.html (visited on April 28, 2013)

between PS and ABS and then the mixture is passed between the electrode with positive and negative charge. The PS substances are attracted towards positive electrode and the ABS substances are attracted toward negative electrode. The process therefore separates PP, ABS and PS substances from the waste electronic household appliances.

PANASONIC

Panasonic Corp., formerly known as Matsushita Electric Industrial Co., Ltd., is a Japanese multinational electronics corporation headquartered in Osaka, Japan.[22]

In September 2007, Panasonic Corporation of North America, a subsidiary of Panasonic Corp., Sharp Electronics Corporation, operating as a subsidiary of Japan-based Sharp Corp., and Toshiba America Consumer Products, LLC, a subsidiary of Toshiba America, Inc., created Electronic Manufacturers Recycling Management Company, LLC, (also known as MRM) to foster the efficient management of recycling programs. MRM offers its service to all consumer electronics manufacturers and retailers, and already works with over 35 companies.[23]

In January 2009, MRM established a national recycling infrastructure that manufacturers could utilize to provide convenient recycling opportunities for consumers. According to MRM's press release, the MRM Recycling network provided recycling opportunities at 280 locations with at least one recycling center located in each state, making it one of the most comprehensive national recycling networks. MRM planned to continue to expand its program and expected to have established at least 800 drop-off locations by 2011.[24]

Below is a list of companies that participate in MRM collection programs.[25]

AOC	Hitachi America Ltd.	Oki Data	Sonitronix
ASUS	Imation Electronics	Orion	Starlogic
Audiovox	JVC America	Panasonic	Sylvania
Barnes & Noble	Kurio	Philips	Symphonic
Brother	Kyocera Mita	Pioneer	Synaps
Canon	Logitech	PLR IP Holdings	Technics
Eastman Kodak	Magnavox	Quasar	Techno Source USA
Emerson	Memorex	RadioShack	Toshiba
Envision	Mitsubishi	Sansui	Touchmark
Four Star Group	MSI America	Sanyo	VIZIO
Funai Corporation	NEC	Sharp Electronics	Vuescape

22 www.bloomberg.com/quote/6752:JP (visited on April 22, 2013)
23 http://www.panasonic.com/environmental/recycling-electronic.asp (visited on April 22, 2013)
24 http://www.mrmrecycling.com/news.htm (visited on April 22, 2013)
25 www.mrmrecycling.com/ (visited on April 22, 2013)

PANASONIC RECYCLING TREND

The table below shows the recycling of Panasonic since 1999. The recycling volume in the above table is shown for per year in million lbs.[26]

	1999-2006	2007	2008	2009	2010	2011
National Program	724,869	83,435	246,402	2,834,426	4,891,526	4,812,693
Mandated States	242,925	908,888	2,488,323	5,267,713	8,726,146	1,8597,603
Yearly	967,794	992,323	2,734,725	8,102,139	13,617,672	23,410,296
Cumulative	967,94	1,960,117	4,694,842	12,796,961	26,414,653	49,824,949

Table 2: Recycling trend of Panasonic

RECYCLING TECHNOLOGIES[27]

HIGH-PRECISION RESIN SORTING SYSTEM (MASS PRODUCTION EQUIPMENT)

Panasonic developed a high-precision resin sorting system that automatically sorts and recovers plastic materials from residues. This system was introduced into the recycling factory of Panasonic Eco Technology Center Co., Ltd. (PETEC) on a trial basis.

The system uses near-infrared rays to instantly identify specific plastic materials contained in the residues carried on a conveyor, and the plastic materials that are identified are shot down for recovery with compressed air. This system enables the sorting and recovery of plastic materials by type at purity of over 99%, and also enables the removal of plastic materials that contain bromine. The mass production equipment is compact in size, does not require the use of water, and has the potential to process 1,000 tons annually.

NEODYMIUM MAGNET RECOVERY SYSTEM

Neodymium (Nd) and dysprosium (Dy) are critical materials for recovery due to their scarcity and high value. In 2012, Panasonic completed the development of a set of equipment that extracts Nd magnets from used products. Panasonic's recycling factory PETEC has developed and introduced compact systems that do not emit heat or gases and therefore have a low environmental impact. With the introduction of this system in fiscal year 2013, Panasonic expects to recover 1.2 tons of Nd magnets.

[26] http://www.mrmrecycling.com/recycling (visited on April 22, 2013)
[27] http://panasonic.net/eco/factory/recycle/other.html (visited on April 22, 2013)

HITACHI

Hitachi, a Japanese multinational engineering and electronics conglomerate company, was selected by Japan's Ministry of Economy, Trade and Industry to participate in its project to promote recycling of resources which was launched in 2009. The goal of this project was to find a technology for recycling rare earth metals from urban mines such as a high performance magnet from motor.[28]

Hitachi developed a new technology for extracting the rare earth materials from the used electronic products in December 2010.[29] The new technique developed for extracting the rare earth materials will be implemented in the current fiscal year 2013. Hitachi has developed a machine that disassembles computer hard disks and extracts rare earths from the specialized magnets inside. The machine can take apart 100 drives per hour whereas manually a person could disassemble only 12 drives. Hitachi claims that with the help of new technology the company can recover 2 metric tons of magnets per year.[30]

Further, in partnership with the University of Tokyo's Institute of Industrial Science, Hitachi has developed a technique for separating the rare earths from the other materials in the magnet without producing the toxic waste liquid inherent in previous techniques.[31]

Additionally, Hitachi partners with Electronic Manufacturers Recycling Management Company (MRM), LLC in order to support reliable e-waste collection and recycling programs. MRM combines the resources of responsible electronic manufacturers and recyclers to implement collaborative recycling programs for electronic products.[32]

HITACHI RECYCLING TECHNOLOGY[33]

Separation and Collection of Rare Earth Magnets from End-of-Life Products

Hitachi has developed machinery that separates and collects rare earth magnets from hard disks and compressors.

For HDD's a drum type unit spins to shake and prang the HDD's continuously, which loosens screws and disassembles the HDD's into their structural components. HDD's components like casing, disk, rare earth magnet components, etc. are separated. Since the rare earth magnets emerge from the machine separately the workers can then easily pick out desired components by screening them visually.

For compressors, cutting machinery is first used to cut the compressor casing. The rotors containing rare earth magnets are then manually exposed. These rotors containing rare earth magnets are disassembled with rotor ejecting machinery. Further, a device that generates a resonant current to weaken the magnetic field of the rare earth magnets having strong

[28] http://www.hitachi.com/New/cnews/101206.html (visited on April 22, 2013)
[29] *Id.*
[30] http://www.phoenixelectronicsrecycling.com/news/index.cfm/e-waste/hitachi-unveils-new-rare-earth-recycling-technology/view/12 (visited on April 22, 2013)
[31] *Id.*
[32] http://www.hitachi-america.us/products/consumer/tv/support_contact/monitor_recycling/

[33] http://www.hitachi.com/New/cnews/101206.html (visited on April 22, 2013)

magnetic force is used in order to safely collect the rare earth magnets. Finally a rare earth magnet remover causes a vibration to the rotor and only the rare earth magnets inside the rotor are separated and collected.

Extraction of Rare Earths from the Separated and Collected Rare Earth Magnets

Hitachi through partnership with University of Tokyo's Institute of Industrial Science conducted experiments for extraction of rare earth materials from the magnets. These experiments were carried out using dry process instead of conventional method that is by using acids and other chemicals, and neodymium and dysprosium to separate the rare earths and extraction of materials from the other non-rare earth materials like iron in the rare magnets.

Hitachi achieved this by using special extraction material with high affinity for neodymium and dysprosium to separate rare earths and extraction material from the other non-rare earth materials like iron in the rare earth magnet. Then the non-rare earth materials are removed and heat is applied to distill the excess extraction material.

SUMITOMO

Sumitomo Corp., a Japan-based diversified corporation, is aiming to take the advanced recycling technology from Japan to overseas primarily, into fast growing Asian countries. Sumitomo's future objective is to start an e-Waste recycling business for advanced resource recycling, which effectively collects electronics disposed by households including Television sets, refrigerators, mobile phones, computers, etc. From industrial sector they intent to recycle scrap materials like printed circuit boards, etc.[34]

In May 2010, Sumitomo, Dowa Eco-System Co. Ltd., a subsidiary of Japan-based Dowa Mining Co., Ltd., and Tianjin Green Angel Renewable Resource Recovery Co. Ltd. formed a joint venture organization called Tianjin Dowa Green Angel Summit Recycling Co. Ltd. in the Tianjin city of China. Dowa Eco-System Co. Ltd. is engaged into e-Waste recycling, and Tianjin Green Angel Renewable Resource Recovery Co. Ltd. is engaged in the collection of waste home appliances. Tianjin Dowa Green Angel Summit Recycling Co. Ltd. which started its operation in April 2011 is planning to improve its processing capacity to 800,000 units per year in the near future.[35]

Additionally, Sumitomo in partnership with Panasonic, Hangzhou DADI Environmental Protection Engineering Co., Ltd, and Dowa Eco-System Co., Ltd. formed a joint venture called Panasonic DADI DOWA Summit Recycling Hangzhou Co. Ltd. on November 2011 in Hangzhou city, Zhejiang Province of China. Hangzhou DADI Environmental Protection Engineering Co., Ltd. is now one of the China's major recycling companies and is aimed at achieving processing capacity of 1 million units per year.[36]

SUMITOMO RECYCLING TECHNOLOGY

The flow chart below shows the steps used by Sumitomo for recycling of used electrical wires and cables. The Sumitomo Electric Group collects used electric/wires, fiber optical cables and carbide chips for cutting tools and their plastics cases for recycling as materials for new products.[37]

[34] www.sumitomocorp.co.jp/english/business_overview/finance/outline21a.html (visited on April 23, 2013)
[35] *Id.*
[36] *Id.*
[37] http://global-sei.com/csr/environment/recycling.html (visited on April 23, 2013)

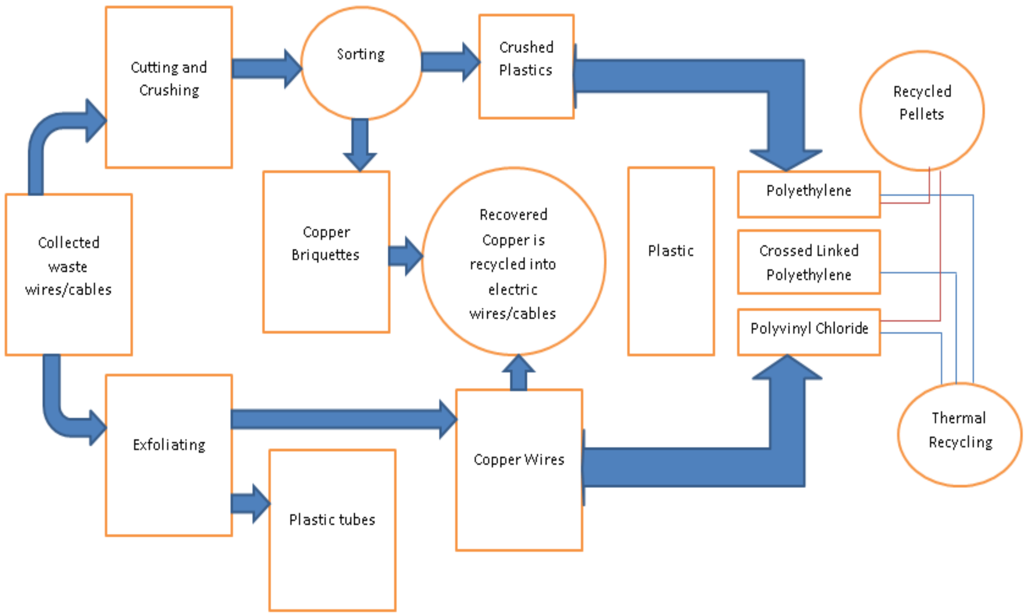


Figure 4: Procedure for recycling of electric wires/cables[38]

As shown in the above figure, the collected thin wasted wires/cables are sorted after cutting and crushing using difference in specific gravity and by using static electricity. Different plastic substances like polyethylene (PE), crossed linked polyethylene (PEX) and polyvinyl chloride (PVC) obtained after sorting process. Further, the recycled pellets obtained from PE and PVC is used in electric wires, cables, etc. Whereas, thick wires/cables undergo exfoliating from which recovered copper wires are used for manufacturing of electric wires/cables and the plastic covering of the thick wires/cables are used for recovering plastic substances like PE, PEX and PVC.

[38] http://global-sei.com/csr/environment/images/img_recycling_02b.jpg (visited on April 23, 2013)

TOSHIBA

Toshiba, a Japanese multinational engineering and electronics conglomerate corporation, launched a voluntary e-waste take back scheme on February 05, 2013 in Malaysia in partnership with the Department of Environment (DOE) and Japan International Corporate Agency (JICA). The prime objective of Toshiba for this scheme was to protect the environment and to support the Malaysian government in developing an effective mechanism to treat household end of life (EOL) electrical equipment's. Toshiba is the only producer in Malaysia to start the voluntary program for both white goods and ICT products. Toshiba has also introduced "Toshiba Voluntary e-Waste take back Scheme" across 14 outlets across Malaysia for a trial period of six months from February 05, 2013 to July 30, 2013.[39]

Toshiba's "Voluntary e-Waste take back Scheme" involve the take back of e-waste products sold by Toshiba like Televisions, Refrigerator, Notebook PC's etc. The participating retailers also accept any e-waste material of any other brand. Toshiba as a responsible corporate continuously educates, promotes and supports the e-waste management program as part of the company's slogan "Committed to the people, Committed to the future".[40]

Toshiba is the first manufacturer to partnership with "Close the Loop" back in 2008, for e-waste recycling of imaging equipment's. Currently, Toshiba is the only organization to accept e-waste from all other imaging consumable manufacturers making it very simple for its customers to recycle. Toshiba has collected more than 200 tons of spent imaging consumables.[41]

Additionally, Toshiba is contributing for the development of an array of eLumber, the recycler's (Close the Loop) patented composite product which is used for building outdoor products as park benches, fences etc.[42]

In September 2007, Toshiba America Consumer Products, LLC , Panasonic Corporation of North America, and Sharp Electronics Corporation, created Electronic Manufacturers Recycling Management Company, LLC, (known as MRM) to foster the efficient management of recycling programs. MRM offers its service to all consumer electronics manufacturers and retailers, and already works with over 35 companies.

In January 2009, MRM established a national recycling infrastructure that manufacturers could utilize to provide convenient recycling opportunities for consumers. According to MRM's press release, the MRM Recycling network provided recycling opportunities at 280 locations with at least one recycling center located in each state, making it one of the most comprehensive national recycling networks. MRM planned to continue to expand its program and expected to have established at least 800 drop-off locations by 2011.

TOSHIBA RECYCLING TREND

In 2011, 79.8% of the total electronic recycle was carried in Japan. Toshiba recycled 15.3% of the total volume in Europe and rest in America, Asia and Oceania. The chart below shows

[39] http://www.asia.toshiba.com/2013/msiatakebackscheme.html (visited on April 25, 2013)
[40] http://pc.toshiba-asia.com/mm/press/launch_of_toshiba_c9aS7h (visited on April 25, 2013)
[41] http://industryanalysts.com/w/2013/02/11/toshiba-recycles-almost-100-tons-of-e-waste-in-2012/ (visited on April 25, 2013)
[42] *Id.*

the breakdown of the volume of end-of-life produced recycled in different regions and Volume of end-of-life products recycled in Japan in 2011.[43]

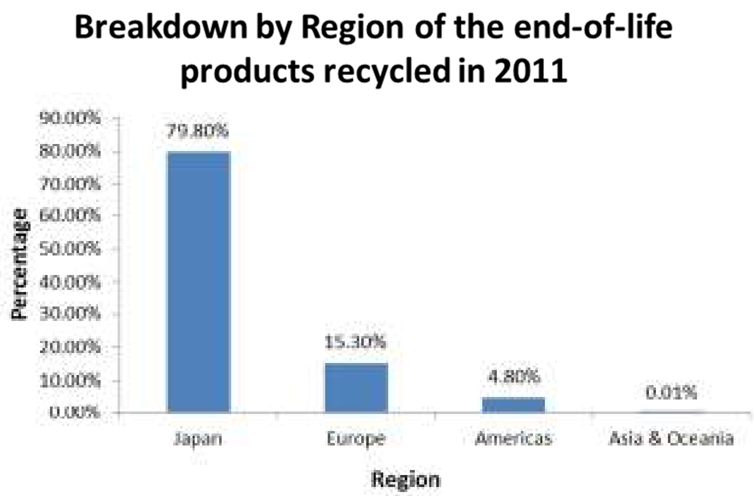


Figure 5: Breakdown by Region of the end-of-life products recycled in 2011[44]

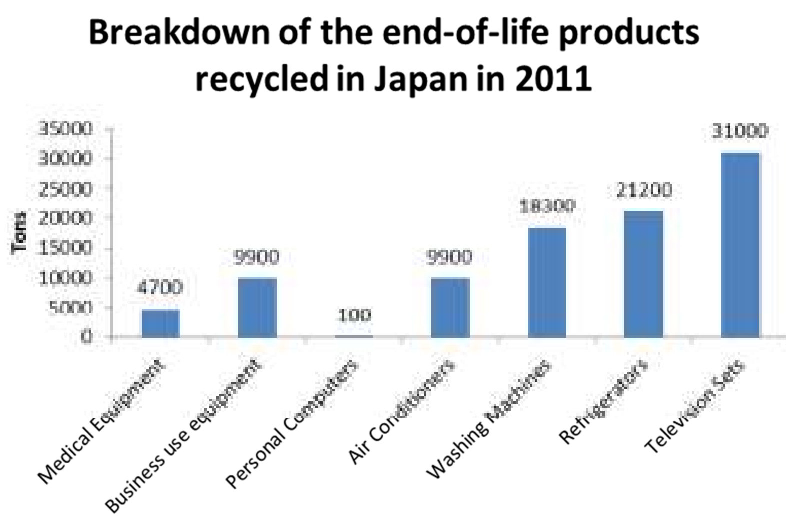


Figure 6: End-of-life products recycled in Japan in 2011

In Asia and Oceania including Singapore, Thailand, Malaysia and New Zealand, Toshiba has voluntarily implemented a PC recycling program. Overall, Toshiba recycled 100 tons of Electronic equipment's from which 80 tons of personal computers were recycled in Asia-Oceania. In Americas, Toshiba collected and recycled around 5,800 tons of end-of-life electronic equipment's. In America, Toshiba is collecting and recycling end-of-life products like television sets, personal computers through Electronic Manufacturers Recycling Management Company, LLC (MRM) jointly operated by Toshiba.[45]

---

[43] http://industryanalysts.com/w/2013/02/11/toshiba-recycles-almost-100-tons-of-e-waste-in-2012/ (visited on April 25, 2013)
[44] http://www.toshiba.co.jp/env/en/industry/recycled.htm#anchorLink2011 (visited on April 25, 2013)
[45] http://www.toshiba.co.jp/env/en/industry/recycled.htm#anchorLink2011 (visited on April 25, 2013)

The chart below shows the breakdown for the end-of-life products recycled in Europe for the year 2011. 15,700 tons of Television sets were recycled in the year 2011 in Europe, accounting to 85.79% of total volume recycled in the year 2011 in Europe.[46]

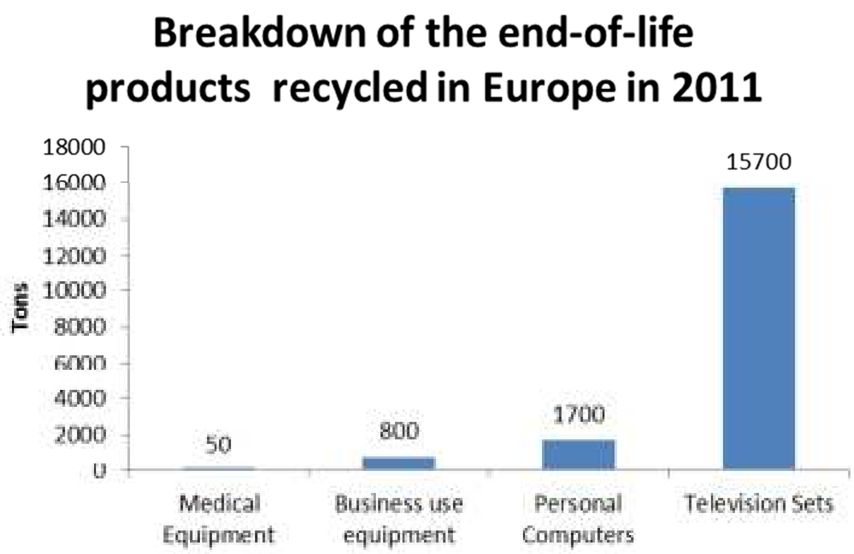


Figure 7: End-of-life products recycled in Europe in 2011

TOSHIBA RECYCLING TECHNOLOGY

The flow chart below shows the procedure for crushing and sorting the end-of-life electric and electronic equipment. When the end of life electronic equipment is to be recycled, it is put into a large plant for crushing and sorting. First, the equipment is crushed in a crushing machine and then the crushed parts are separated by manual visualizing.[47]

In order to collect different recycled materials like iron, aluminum, stainless steel and plastics a combination of mechanical (magnetic, excess current, high magnetism) and manual sorting is used.[48]

---

[46] *Id.*

[47] http://www.toshiba.co.jp/env/en/industry/recycled.htm#anchorLink2011 (visited on April 25, 2013)

[48] *Id.*

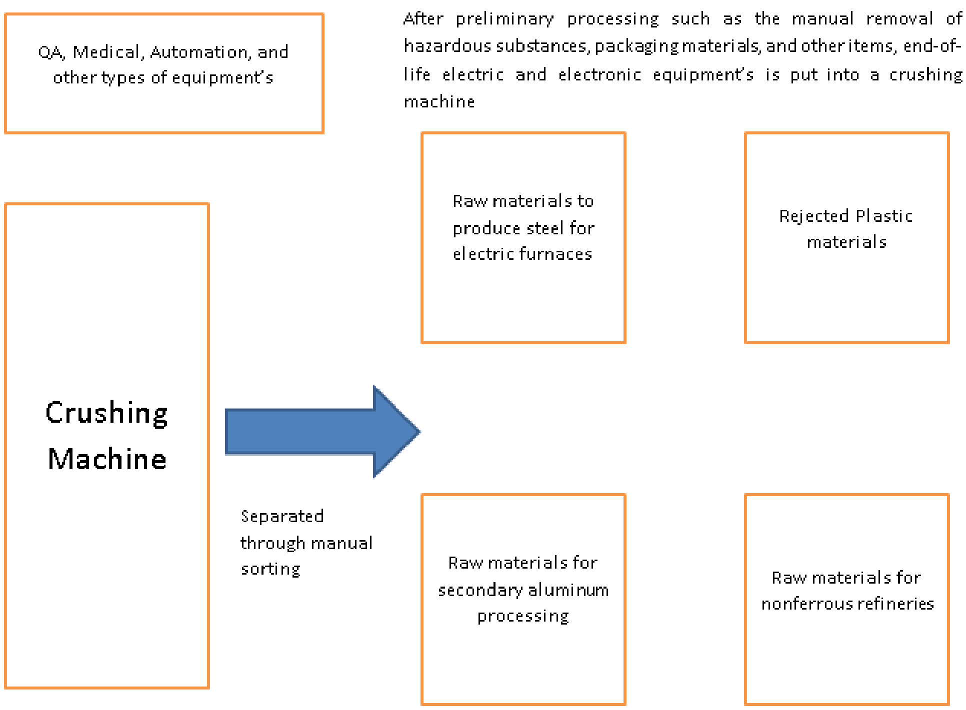


Figure 8: Recycling steps for end-of-life electric and electronic equipment.[49]

[49] *Id.*

SHARP

Sharp Corp. is a Japanese multinational corporation that designs and manufactures electronic products. In September 2007, Sharp, Toshiba America Consumer Products LLC, and Panasonic Corporation of North America, created Electronic Manufacturers Recycling Management Company, LLC, (known as MRM) to foster the efficient management of recycling programs. MRM offers its service to all consumer electronics manufacturers and retailers, and already works with over 35 companies.[50]

In January 2009, MRM established a national recycling infrastructure that manufacturers could utilize to provide convenient recycling opportunities for consumers. According to MRM's press release, the MRM Recycling network provided recycling opportunities at 280 locations with at least one recycling center located in each state, making it one of the most comprehensive national recycling networks. MRM planned to continue to expand its program and expected to have established at least 800 drop-off locations by 2011.[51]

MRM has recycled around 290 million pounds of electronics since it was formed by the electronics giants in the year 2007. The chart below shows MRM's recycling volume every year since its inception.

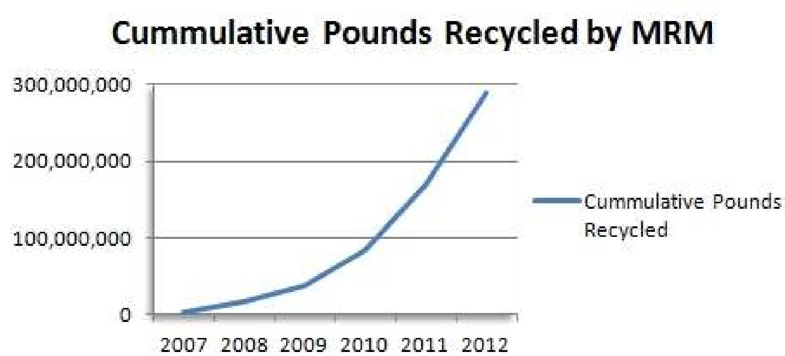


Figure 9: Cumulative pounds recycled by MRM per year[52]

SHARP RECYCLING TECHNOLOGIES

Developing Zeolite from Waste LCD Panel Glass

Sharp has developed this technology in partnership with Osaka Prefecture University. The method uses superheated water to breakdown the organic substances in the LCD panel glass and separate it from other metals.[53] The method is basically used for turning the crushed glass from panels into zeolite via reaction in an alkaline solution. Sharp successfully

[50] http://www.panasonic.com/environmental/recycling-electronic.asp (visited on April 26, 2013)
[51] http://www.mrmrecycling.com/news.htm (visited on April 26, 2013)
[52] http://www.mrmrecycling.com/recycling_ethic.htm (visited on April 26, 2013)
[53] http://resource-recycling.com/node/2071 (visited on April 26, 2013)

created zeolite by reacting pulverized glass in the alkaline solution. Further, Sharp plans to put the technology into practical use in 2015.[54]

Technology to Recover Highly Functional Paint from Scrap LCD Panel Glass

In 2009 Sharp developed a highly functional paint made by using scrap glass discarded during the LCD panel production process. The waste LCD panel glass is finely crushed, and the resulting powder is mixed with the paint base or pigment. The paint developed increases the durability of the products installed outdoors that are exposed to sunlight, wind, rain, sand and dust. These paints are used mainly for the LED lighting that utilizes this paint for its external components.

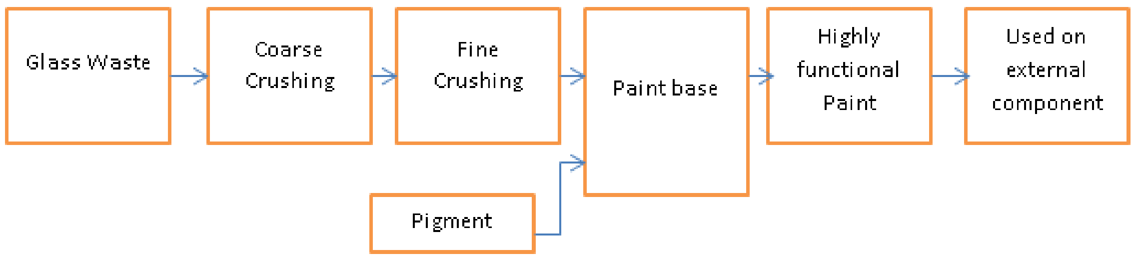


Figure 10: Developing high functional paint from scrap LCD panel glass[55]

Technology to Recover Indium from Waste LCD Panels

In 2009, Sharp jointly with Osaka Prefecture University, developed a recycling technology for waste LCD panels that uses sub-critical water. This sub-critical water dissolves the organic substances of glass and strips away the organic layer from the glass substrate of the LCD panel, and separates and recovers the indium, a rare metal, from the glass.

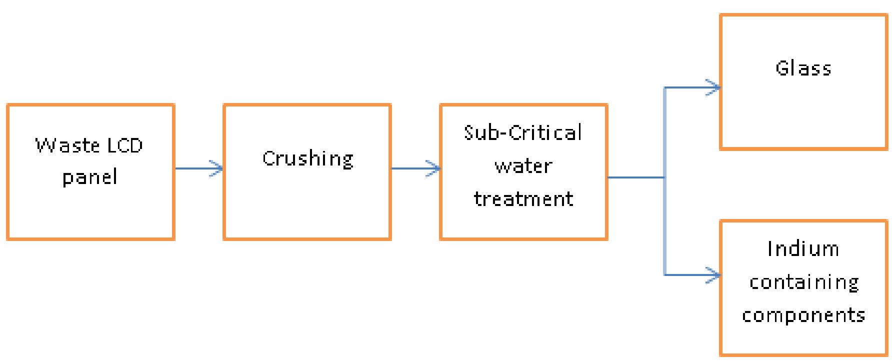


Figure 11: Process to recover Indium from waste LCD panels[56]

[54] http://environmentbusinessinjapan.blogspot.in/2013/01/no-137-technology-to-recycle-liquid.html (visited on April 26, 2013)
[55] http://sharp-world.com/corporate/img/eco/environment/technology/technology_pdf_002.pdf (visited on April 26, 2013)

Process to Disassemble End-of-Life Electronics Products

Sharp developed a new process to disassemble the end-of-life electronic products for recycling easily. In order to disassemble the two combined pieces easily, the washer of the screw is heated at a particular temperature. Due to heating the washer expands and loses its firmness, making it easy to detach the two combined pieces.

[56] http://sharp-world.com/corporate/img/eco/environment/technology/technology_pdf_002.pdf (visited on April 26, 2013)

JFE HOLDINGS

JFE Holdings is a corporation headquartered in Tokyo, Japan. JFE Engineering achieves the reduction of both natural resource consumption and the environmental burden with the aid of JFE Engineering's advanced recycling system.[57]

JFE plays a role in creating a recycling-oriented society by recycling various types of waste. JFE undertakes recycling of flammable waste, container/package waste, solid/liquid industrial waste, metallic waste, wooden waste, used electrical appliances, fluorescent lamps/dry cells and batteries, food waste, etc.[58]

JFE Urban Recycle Corp. (previously known as NKK Trienekens), a subsidiary of JFE Holding, recycles waste electrical appliances under the application recycling law designated for four different categories.[59]

1. Televisions
2. Air Conditioners
3. Refrigerators
4. Washing Machines

The manual dismantling facility of JFE Urban Recycle Corp includes handling gear for removing the old electrical components from the appliance, a weighing scale, a work bench, chlorofluorocarbon collection system accumulation air-conditioner and refrigerator cooling media.[60] The crushing & sorting facility includes a crushing machine, an air sorting device, a magnetic separator, an eddy current separator, a urethane compactor, and a chlorofluorocarbon collection facility for insulation.[61]

JFE RECYCLING TECHNOLOGY

The recycling process includes recycling of waste electronic household appliances like refrigerators, air conditioners, washing machines, TV sets. At a first stage, the electrical appliances are manually dismantled, and cathode ray tube (CRT), plastics, etc. are separated from the television sets.[62]

The plastic obtained after dismantling is utilized as a raw material for blast furnace. In crushing and sorting facility, crushing machine, air separator, magnetic separator, urethane comparator, eddy current separator and chlorofluorocarbon collection facility is used. By using the above technique various materials are obtained from waste electrical appliances. Chlorofluorocarbon (subcontracted) is obtained from the chlorofluorocarbon collection facility, urethane which is used as a raw material for blast furnace is obtained from urethane compactor, Steel scrap which is used as a raw material for steel manufacture is recovered from magnetic separator, the left over nonmagnetic material are forwarded to eddy current separator. Shredder dust is recovered from the eddy current separator which is further

[57] http://www.jfe-eng.co.jp/en/products/environment/recycling/rec01.html visited on April 26, 2013)
[58] *Id.*
[59] http://www.jfe-holdings.co.jp/en/environment/2004/pdf/er2004e54.pdf visited on April 26, 2013)
[60] http://www.jfe-steel.co.jp/archives/en/nkk_giho/85/pdf/85_09.pdf visited on April 26, 2013)
[61] *Id.*
[62] http://www.jfe-steel.co.jp/archives/en/nkk_giho/85/pdf/85_09.pdf (visited on April 26, 2013)

processed at thermo bath and kept under examination. Non-ferrous metal and plastics are recovered from the thermal bath.[63]

The used household electrical appliances are first manually dismantled and the major components are removed. The remaining mixed part/substances are then processed in crusher and then mechanically sorted. The heat insulating urethane in refrigerators is separated by wind sorting, compressed, and are used as blast furnace feed material. Iron and non-ferrous metals are recovered by the magnetic sorting machine and non-ferrous sorting respectively and are used as iron and steel making materials. The plastics which accounts for nearly 30% of home appliances, are directly used in blast furnace waste plastic feeding operation. The recycling ratio of this plant currently exceeds 80%.[64]

DOWA HOLDINGS

Dowa Holdings is a Japan-based holding company. The Company has six business divisions. Dowa group has established a business through the integration of smelting and recycling operations.[65]

Dowa has built one of Japan's largest recycling networks, using the smelting technology to recycle the waste.[66] In October 2006, Dowa established Dowa Eco-System Co. Ltd in order to specifically focus on environmental management and recycling. Eco System Recycling Co. Ltd. recovers gold and other precious metals from scrapped electronics materials and plating solutions.[67]

Dowa Eco-System Co. Ltd and Sumitomo Corporation jointly established a company in Tianjin to launch a business for recycling consumer electronic and home appliances in partnership with Tianjin Green-Angel Renewable Resource Recovery Co. Ltd.[68]

Dowa group has also established a recycling company called Dowa Environmental Management Co. Ltd, in Suzhou City Jiansu Province to operate a general recycling business.[69]

Dowa recycles as many as seventeen different metallic elements using advanced metallurgical technologies. The recovered metal resources are brought back into society as newborn products such as accessories, electric substrates, films, electrical wires, and so forth.[70]

In 2003, Dowa established a new company Nippon PGM America Inc. in United States of America. The company recycles platinum group metals like platinum, palladium and rhodium, from the catalytic converters used to purify automobile exhaust fumes.[71]

---

[63] *Id.*
[64] http://www.jfe-steel.co.jp/archives/en/nkk_giho/88/pdf/88_18.pdf (visited on April 26, 2013)

[65] http://www.reuters.com/finance/stocks/companyProfile?symbol=5714.T (visited on April 26, 2013)
[66] http://www.dowa.co.jp/en/jigyo/ecosystem_summary.html (visited on April 26, 2013)
[67] *Id.*
[68] http://www.sumitomocorp.co.jp/english/news/2010/20100326_030045.html (visited on April 26, 2013)
[69] *Id.*
[70] http://www.dowa-eco.co.jp/en/recycle.html (visited on April 26, 2013)
[71] *Id.*

The two subsidiaries of Dowa, Eco-Recycle Co. Ltd. and Act-B Recycling Co. Ltd disassemble or pulverize obsolete or inoperable home appliances (televisions, refrigerators, washing machine, air-conditioners, etc.), automobiles and office equipment (computers, copiers, phone systems, etc.) in order to recover recyclable material for DOWA Group's Kosaka Smelting & Refining Co., Ltd.[72]

[72] *Id.*

DOWA RECYCLING TECHNOLOGY

The figure below shows the recycling process carried by Act-B Recycling Co. Ltd. The recycling process covers equipment's like personal computers, televisions, washing machines, air conditioners, and refrigerators.

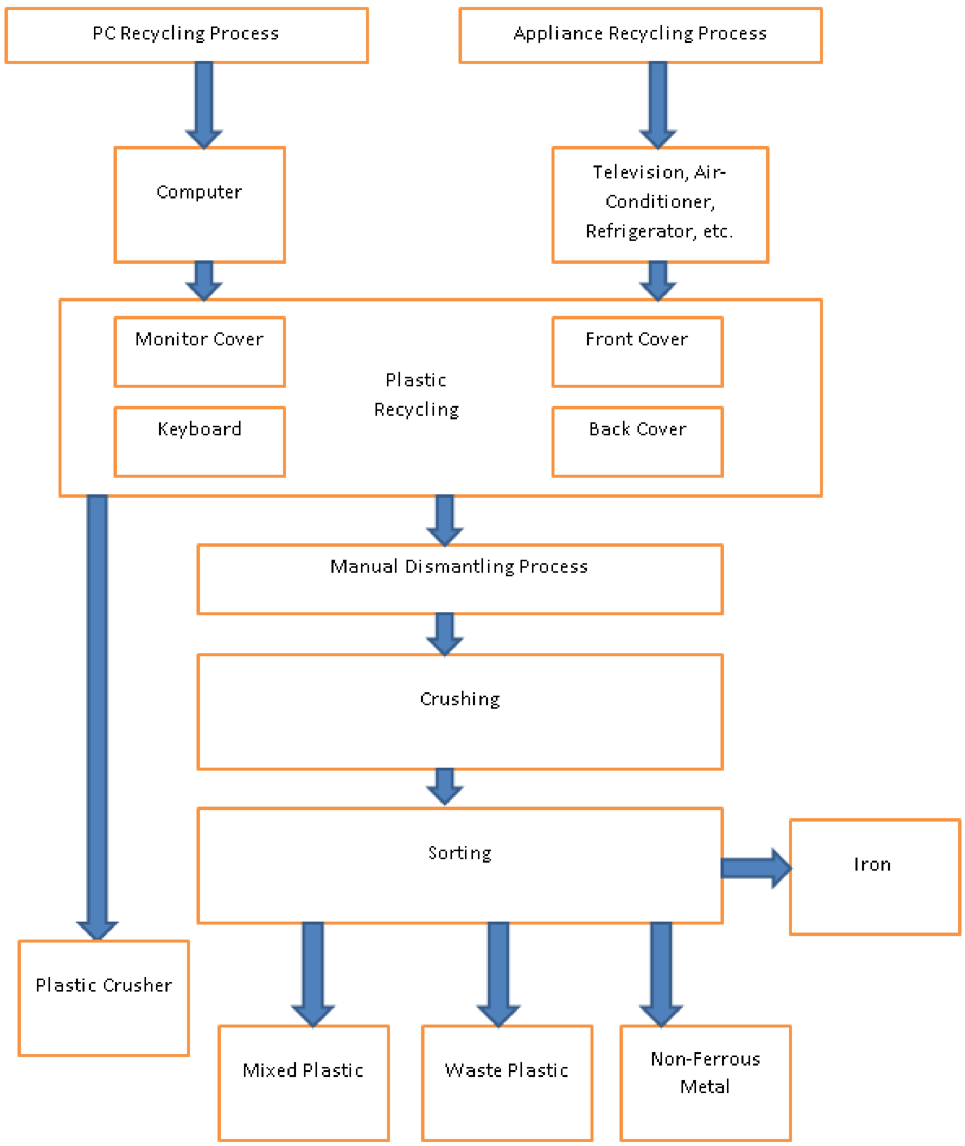


Figure 12: Recycling of e-waste[73]

First, a manual disassembling is carried out and the plastic materials like monitor cover and keyboard from computers, front and back cover of television, washing tub and lid from washing machines, cover of indoor equipment from air conditioners, and tray and vegetable case from the refrigerator is separated for recycling of plastic. Additionally, the main materials collected from the manual dismantling process is circuit boards from televisions

[73] http://www.act-b.co.jp/eng/environment/index2.html (visited on April 26, 2013)

and computers, deflection York, funnel glass, and panel glass from televisions, motor and reducer from washing machines, and compressor, copper pipe and heat exchanger from air conditioners and refrigerators. These materials which are manually dismantled are directly forwarded to traders. Further, the materials that cannot be dismantled manually are then forwarded for crushing. Once these materials are crushed they are then sorted into mixed plastic, waste plastic, non-ferrous magnet and iron. Urethane and chlorofluorocarbon is recovered from the rest of material obtained after crushing process. These recovered materials are then distributed to traders and waste distributers. [74]

[74] http://www.act-b.co.jp/eng/environment/index2.html (visited on April 26, 2013)

SONY

Sony, a Japanese multinational conglomerate corporation headquartered in Tokyo, Japan, had launched a GreenFill recycling service on April 28, 2009. The program was an extension to their take back program for the collection of unwanted potable electronics equipment's.[75]

In November 2011, Sony in Australia launched a pilot project for recycling end-of-life televisions. Sony Australia is the first company to take an initiative in the country prior to the implementation of the new e-waste recycling legislation by the Australian government in July 2012.[76]

Sony is the first major electronics manufacturer to introduce an extensive recycling program called Electronics Product Stewardship Canada (EPSC). Sony Canada's goal is to divert all products from landfill therefore; Sony Canada has offered its customers new ways to return their Sony products for recycling.[77]

SONY RECYCLING TREND

In 2011, Sony recycled approximately 1.412 million CRT televisions and 88,000 flat-screen televisions manufactured by Sony in Japan. The chart below shows the CRT television recycling trend in Japan.[78]

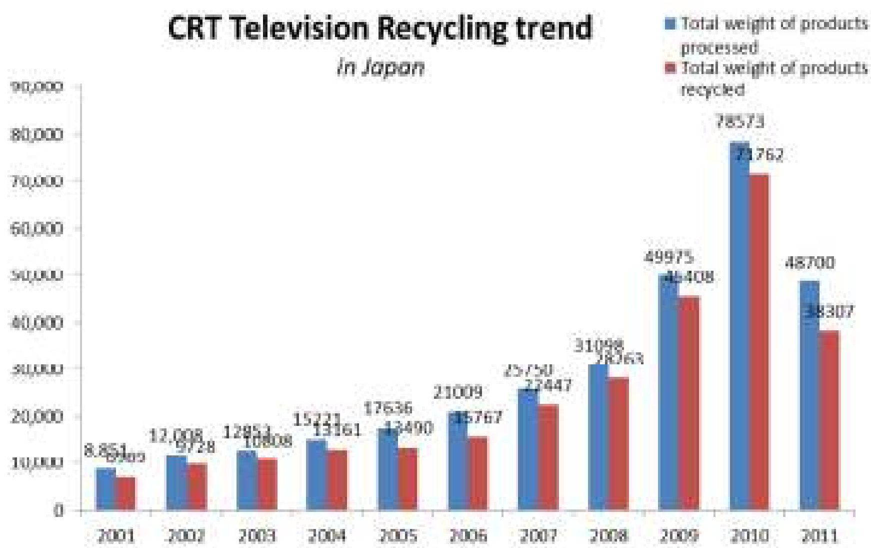


Figure 13: CRT Television Recycling Performance in Japan

The graph below shows the recycling performance of Sony Corp in Japan for Plasma and LCD televisions from 2009-2011.[79]

---

[75] http://www.gizmag.com/sony-electronics-launches-retail-e-recycling-initiative/11552/ (visited on April 26, 2013)

[76] http://www.sony.net/SonyInfo/csr_report/environment/recycle/asia/index.html (visited on April 26, 2013)

[77] http://www.greenlivingonline.com/article/sony-canada-tackles-e-waste (visited on April 26, 2013)

[78] http://www.sony.net/SonyInfo/csr_report/environment/recycle/japan/index1.html (visited on April 26, 2013)

[79] *Id.*

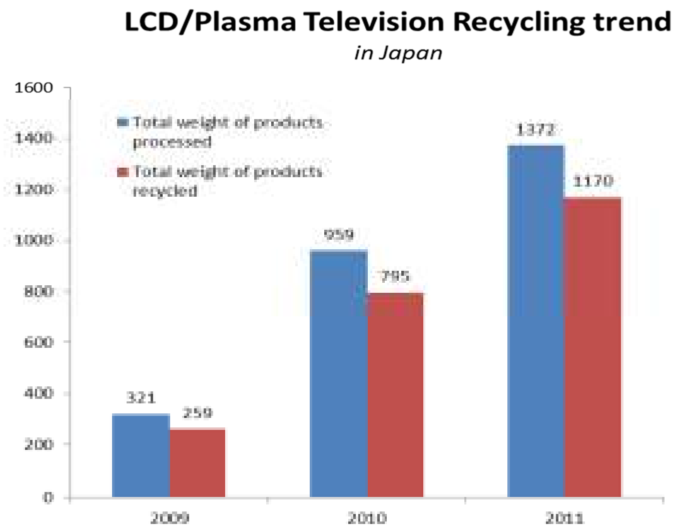


Figure 14: LCD and Plasma Television Recycling Performance

The chart below shows the distribution of the resources recycled by Sony Corp from the recycling of CRT Television sets in the year 2011. Around 50% of the total weight recycled was covered by CRT glass, followed by 31% of other valuable resources. Fair amount of iron and copper were also recycled that is 14% and 5% respectively. About 0.18% percent of nonferrous and ferrous compounds were recycled and 0.03% of aluminum was recycled.[80]

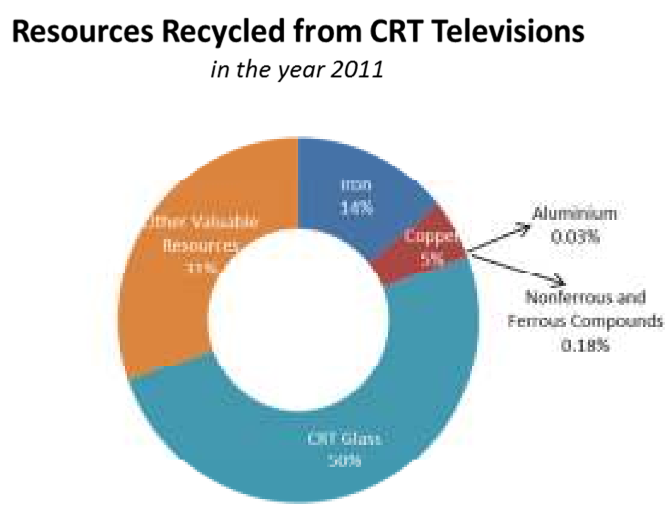


Figure 15: Resources Recycled from CRT Television in the year 2011

[80] http://www.sony.net/SonyInfo/csr_report/environment/recycle/japan/index1.html (visited on April 26, 2013)

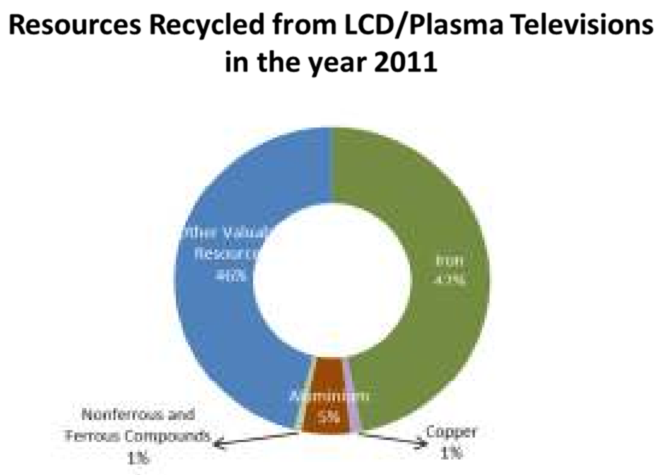


Figure 16: Resources Recycled from LCD/Plasma Television in the year 2011

The chart above shows distribution of the resources recycled from LCD/plasma televisions in the year 2011. Around, 546 tons of iron was recycled in the year 2011 accounting to 47% of the total material recycled. As low as 1% of nonferrous and ferrous compounds and copper were recycled. 46% of mixed valuable materials were recycled and left 5% of Aluminum was recycled.[81]

We did not find any information on recycling technologies that Sony owns.

[81] http://www.sony.net/SonyInfo/csr_report/environment/recycle/japan/index1.html

JX HOLDINGS

In 2012, JX Holdings, a Japanese company, announced that one of its subsidiaries (JX Nippon Tsuruga Recycle) has finished with the setup of new recycling facility for rare earth materials. From this new facility JX Nippon Tsuruga Recycle will be able to recover cobalt, nickel, manganese or lithium from used lithium ion batteries. Additionally, the recycling facility can process positive electrode materials at 50 tons per month, collecting 6 tons of nickel, 10 tons of cobalt, 6 tons of manganese and 10 tons of lithium carbonate.[82]

Further, JX Holding also installed additional two stationary furnaces to pre-process used substrates and electronic components mounted on small appliances raising the processing capacity to 650 tons with 6 furnaces from previous 400 tons with 4 furnaces. The firm also completed construction of the new facilities to collect cobalt and indium from discharged sludge of electronic component manufacturers. The processing capacity is 30 tons per month.[83]

Figure 17: Role of JX Metal trading and JX Nippon Mining & Metal group in resource recycling system

[82] www.japanmetalbulletin.com/?p=20300 (visited on April 26, 2013)
[83] *Id.*

JX RECYCLING TECHNOLOGY

The flow chart below shows recovery of Cathodes from lithium-ion batteries. A waste lithium-ion battery is collected from different sources like from car manufacturers, battery manufacturers, etc. These waste batteries are disassembled then crushed and lastly sorted. Cathode (aluminum sheet) and aluminum package are separated in the sorting process. Leaching process is provided to the sorted cathode from which recycled cathode materials are obtained. The recycled cathode materials further undergo solvent extraction. Electric Co-Ni-Mn lithium carbonate is recovered from the solvent extraction process, and the recovered material is provided to cathode material manufacturer (Isohara Works).[84]

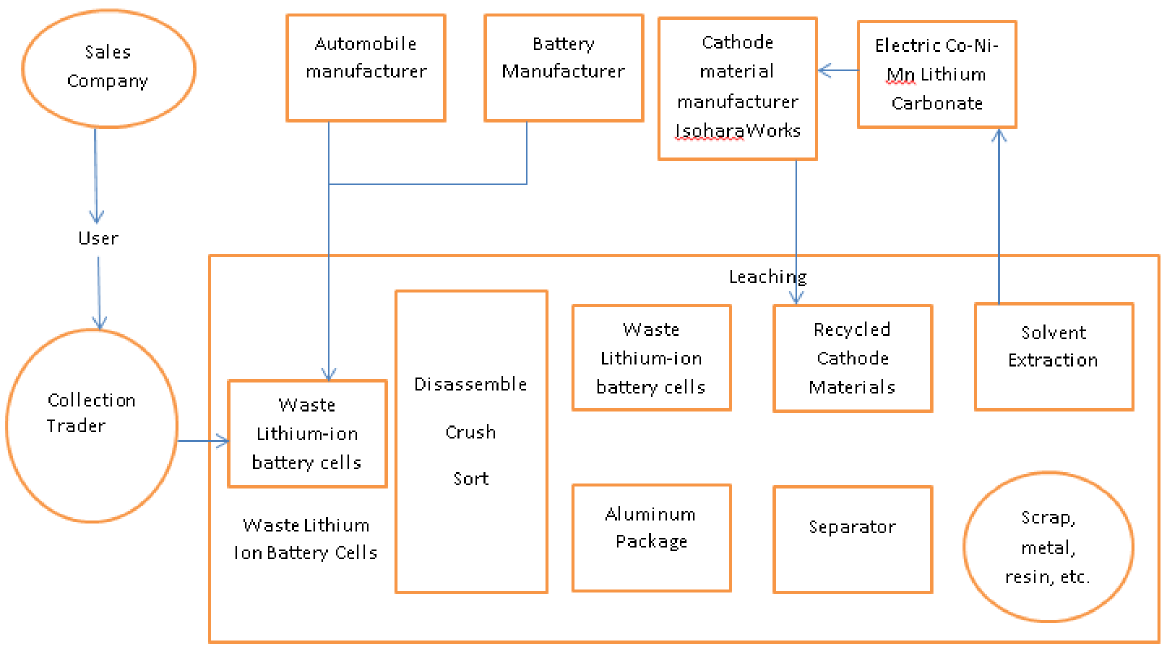


Figure 18: Recovery of Cathodes from Lithium – Ion batteries

[84] http://www.nmm.jx-group.co.jp/english/sustainability/theme/circulation/index.html (visited on April 29, 2013)

TOYOTA

In 2011, Toyota Motor Corp., a Japanese multinational automaker headquartered in Toyota, Aichi, Japan, stated in their environmental report that they have achieved a near-zero waste to landfill. Toyota also mentioned that they have been achieving near-zero waste to landfill for past three years as well. In the year, 2011 Toyota vehicle distribution division recycled nearly 94 % of the waste generated by them.[85]

Toyota recently partnered with Umicore. Umicore has its unique rechargeable battery recycling process, which is driven by patented Ultra High Temperature (UHT) smelting technology. Additionally, Umicore is currently the only player in the world operating two battery pack dismantling lines for hybrid vehicles and full electric vehicles.[86]

In April, 22, 2009 Toyota entered into partnership with Lifespan Technology Recycling for the "Earth Day Event" where electronic equipment's like computers, monitors, TVs, laptops, cables, printers, fax machines, scanners, DVD players, VCRs, and other electronic items can be recycled.[87] Toyota also tries to educate people for protecting the environment by diverting heavy metals and toxic substances from our local landfills.[88]

TOYOTA RECYCLING TECHNOLOGY

In 2010, Toyota promoted first battery to battery recycling business, which recovers nickel from the nickel-hydrogen batteries used in hybrid vehicles and reuses it in new batteries.

[85] http://waste360.com/zero-waste/toyota-reaches-near-zero-landfill-waste-north-america (visited on April 29, 2013)
[86] http://www.recyclinginternational.com/recycling-news/6500/e-waste-and-batteries/europe/toyota-selects-umicore-recycle-batteries (visited on April 29, 2013)
[87] http://www.pr.com/press-release/145500 (visited on April 29, 2013)
[88] http://blog.toyotaofelcajon.com/2013/04/15/toyota-of-el-cajon-to-host-free-weekend-ewaste-recycling-event-in-honor-of-earth-day/ (visited on April 29, 2013)

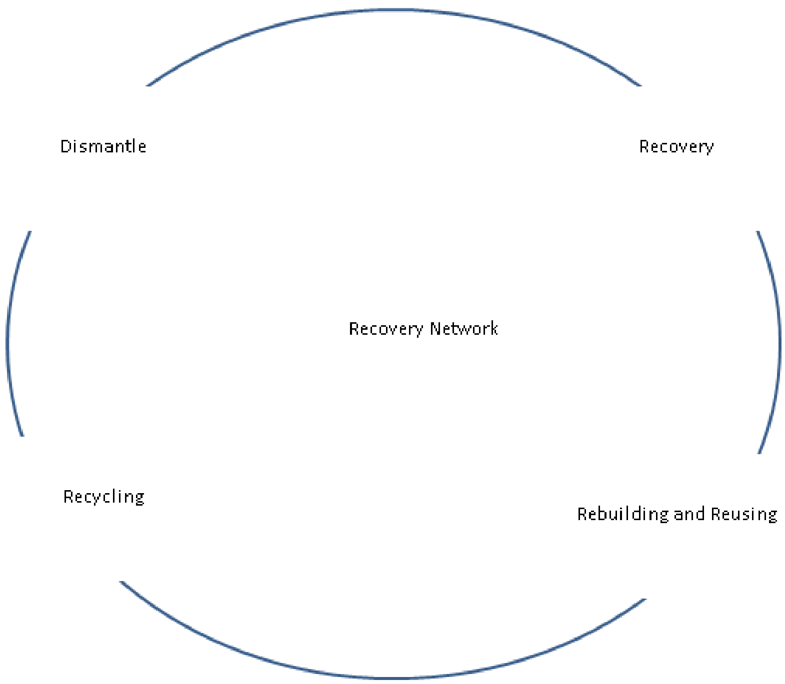


Figure 19: Toyota's Battery to Battery Recycling89

The figure above shows Toyota's first battery to battery recycling process. Firstly, after the hybrid cars receive a battery change or when a hybrid battery reaches the end of its service life, the electric vehicle is dismantled and battery is safely removed. These batteries are then collected and delivered to dealer service centers. In the rebuilding and reusing phase these batteries are again tested and if the batteries are still functional then they are used in hybrid vehicles when they need a battery replacement. The left over nonfunctional batteries are then forwarded for recycling process. In recycling phase the rare metals and all other precious metals in the battery is recovered and further used as resources.[90]

[89] http://www.toyota-global.com/sustainability/csr_initiatives/stakeholders/society/environment.html (visited on April 29, 2013)
[90] *Id.*

MITSUI MINING & SMELTING

Mitsui Mining and Smelting Co. Ltd., a Japan-based company, is mainly engaged into metal business. Mitsui Mining and Smelting produces and supplies nonferrous metals in Japan, other regions of Asia and North America.[91]

Mitsui Kinzoku Recycle, a subsidiary of Mitsui Mining and Smelting, is involved into business with a concern for earth's environment. Mitsui Kinzoku Recycle promotes recovery of nonferrous metals, precious metals and rare earth metals.[92]

Mitsui Kinzoku Recycle recovers and recycles useful metals such as gold, silver, platinum and palladium from waste electronic instruments, circuit boards. They also recycle lead from waste batteries.[93] Mitsui Mining and Smelting formed their first recycling plant for nickel-cadmium batteries in the year 1992. This facility had a processing capacity of 20 metric tons of batteries.[94]

---

[91] http://investing.businessweek.com/research/stocks/snapshot/snapshot.asp?ticker=5706:JP (visited on April 29, 2013)
[92] http://www.mitsui-kinzoku.co.jp/group/mkr/en/gaiyo.html (visited on April 29, 2013)
[93] http://www.globalspec.com/FeaturedProducts/Detail/MitsuiMiningSmelting/Mitsui_Recycling_NonFerrous_Metals/125836/0 (visited on April 29, 2013)
[94] http://business.highbeam.com/436402/article-1G1-12053415/mitsui-plans-recycling-plant-nickelcadmium-batteries (visited on April 29, 2013)

NIPPON STEEL

Nippon Steel Corp., a Japan-based manufacturing company, offers steel making and steel fabrication businesses in Japan and internationally. The company's Steelmaking and steel fabrication segment offers steel sections, flat-rolled products, pipe and tubes, specialty and secondary steel products, pig iron products, steel ingots, rolled titanium products, and aluminum products. Nippon Steel Corporation also provides resources recycling and environment restoration solutions.[95] Recently, Nippon Steel built a pilot plant in Kitakyushu Eco-Town capable of producing 400 liters of ethanol per day from 10 tons of food waste.[96] In 2005, Nippon Steel made a plan to step up its capacity for recycling waste plastics into coke by 30%. In 2007, Nippon Steel started studies on deepening and expanding the cooperation with Kobe Steel in the environmental and recycling areas and iron-making technology exchange. Further, in October 2008, a Joint undertaking of a business of steel dust recycling and direct-reduced iron production and utilization with Kobe Steel (establishment of Nittetsu Shinko Metal Refine Co., Ltd). In 2011, the company has incorporated recycling technology for producing chemical raw materials from Municipal waste plastics.[97]

Nippon Steel incorporates environmentally-designed manufacturing processes called ECO-PROCESS. The company has achieved 99% recycling of its total byproducts generated in steel works. Nippon Steel mainly recycles steel slag and dust, steel cans, plastics of containers and packaging waste and resource from Waste-Tire.[98]

We did not find any information on e-waste recycling technologies that Nippon Steel owns.

---

[95] http://investing.businessweek.com/research/stocks/snapshot/snapshot.asp?ticker=5401:JP (visited on April 29, 2013)
[96] http://www.kleanindustries.com/s/environmental_market_industry_news.asp?ReportID=341815 (visited on April 29, 2013)
[97] www.nssmc.com/en/ir/library/pdf/nscguide2012_e_all.pdf (visited on April 29, 2013)
[98] *Id.*

RICOH

Ricoh is a Japanese multinational imaging and electronics company. Ricoh is focusing on eliminating land disposal of general and industrial waste using following steps:[99]

- Identify waste types / Collect data
- Waste reduction activity
- Divert waste from landfill

The figure below shows Ricoh's land disposal trend. In 2001, Ricoh achieved zero waste to landfill goal. Since 2001 Ricoh is successfully achieving zero waste to landfill goal.

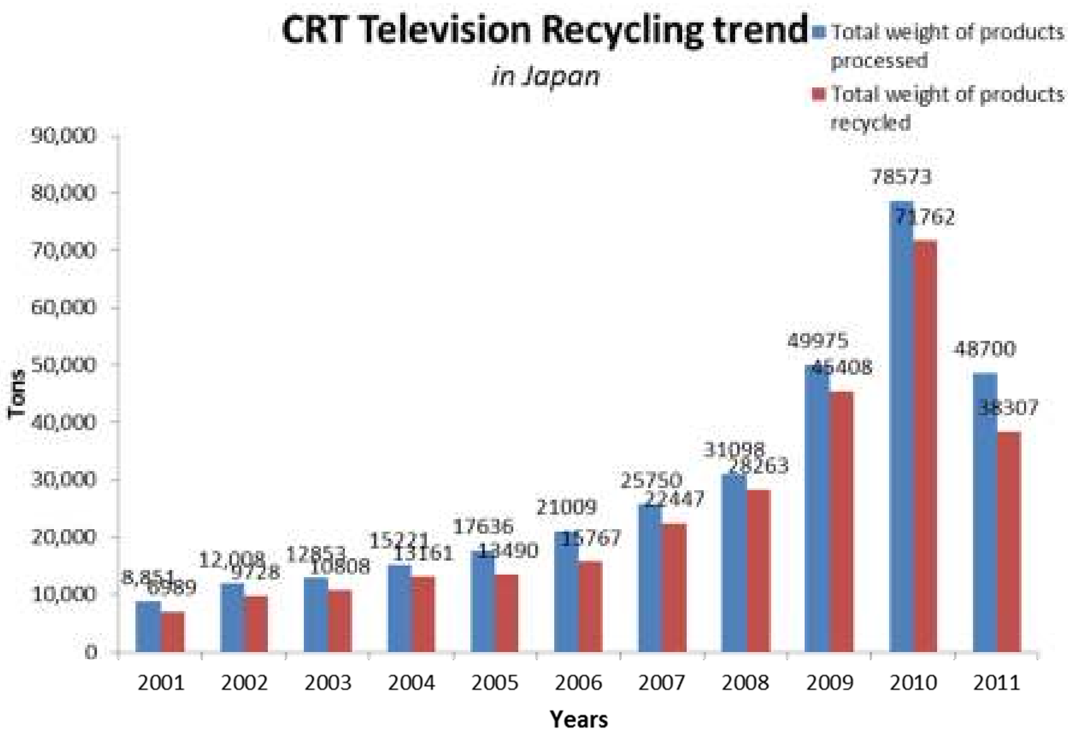


Figure 20: Volume of waste to landfill[100]

Further, Ricoh products are designed in such a way that they enable recycling. Up to 98% of Ricoh products are fully recyclable. Therefore, Ricoh products are generally recycled or refurbished into other products. Ricoh has launched a machine recycling program. This program was started in the year 2000 and since its inception Ricoh has successfully diverted over 180 million tons of machinery from landfill or offshore. In 2010, 1,502 machines were refurbished and resold, and this number increases every year.

We did not find any information on e-waste recycling technologies that Ricoh owns.

---

[99] http://www.rei.ricoh.com/env_activities0landfill.html (visited on April 29, 2013)
[100] *Id.*

SHINKO PANTEC

Shinko Pantec (a subsidiary of Kobe Steel), is a Japan-based company, engaged into chemical business activities. Shinko Pantec also has a technology for processing of electrical equipment and waste oils. Shinko Pantec has a plant in Japan for processing the electrical equipment and waste oils. The capacity of which is about one ton pure polychlorinated biphenyl (PCB) per year.

SHINKO PANTEC RECYCLING TECHNOLOGY

Shinko Pantec has applied two technologies in order to attain the strict Japanese norms for (PCB) decontamination.

1. The electrical equipments like transformers and capacitors are first cleaned with solvent treatment and then dismantled. These equipments are again cleaned with solvent after dismantling.
2. The oils are first treated in a reactor with a specially made sodium dispersion and a promoter to obtain a high reaction rate. In case of high concentrations of PCBs a moderator is added to avoid the formation of polymerization products containing chlorine, formed from the chlorinated species.

EBARA

Ebara, Tokyo, a Japan-based public company, makes environmental and industrial machinery such as pumps and turbines. It is the first company to incorporate the XERO concept, i.e. “zero emissions research initiative”. Ebara’s product converts industrial and municipal waste into useful chemicals such as ammonia, methane, hydrogen and gasoline. Ebara’s fluid bed gasification combustion and ash melting system effectively recovers valuable metals like iron, copper and aluminum by recycling.[101]

We did not find any information on e-waste recycling technologies that Ebara owns.

[101] http://www.iisd.org/business/viewcasestudy.aspx?id=64 (visited on April 29, 2013)

CANON

Canon Inc., a Japanese multinational corporation specialized in the manufacture of imaging and optical products, including cameras, camcorders, photocopiers, steppers, computer printers and medical equipment, is building a strong recycling network throughout the globe. Canon has started developing its recycling centers for collection and recycling in Japan, Europe, America, Asia and Oceania.

CANON RECYCLING TECHNOLOGY

Canon is involved in recycling of plastics from used products for application in new Canon products. As shown in the figure below, collected business machines are first disassembled and sorted. After disassembling and sorting the outer casing of business machine that is engineering plastic and the paper supply cassettes that is the commodity plastics is pulverized and washed. All the foreign particles present in the plastic is removed in this phase.[102]

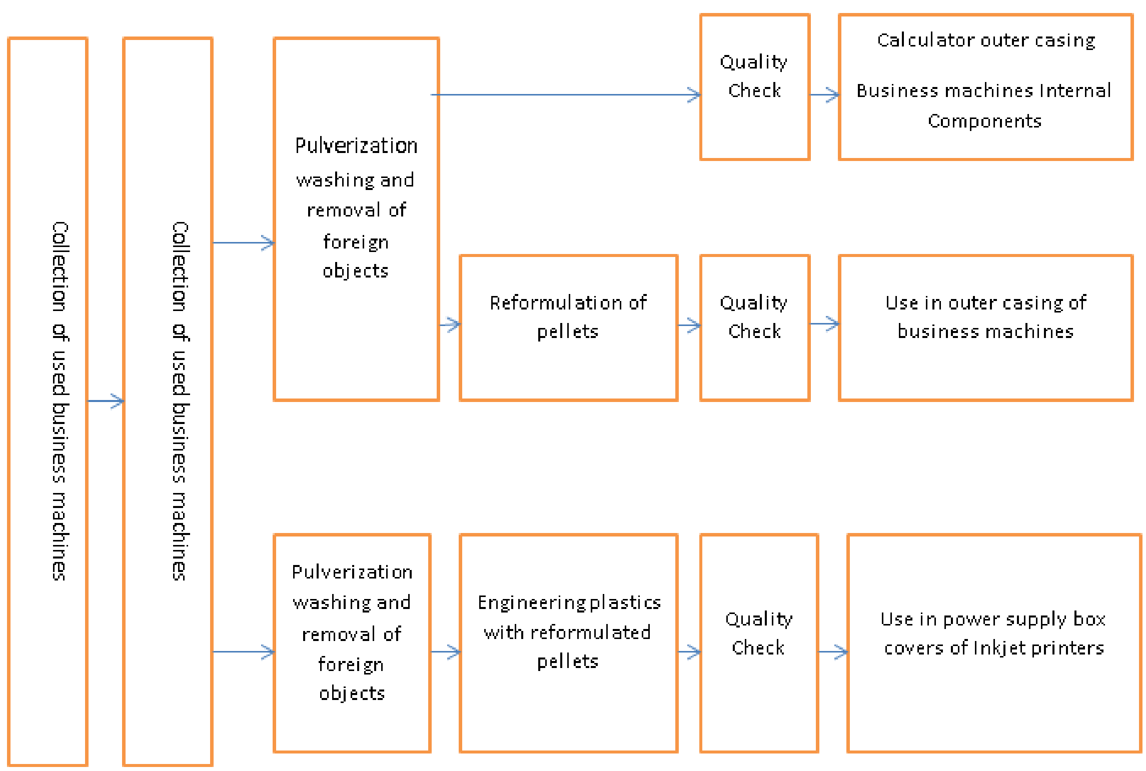


Figure 21: Recycling of Plastic Materials from Business Machines

[102] http://www.canon.com/csr/report/en/06_2.html (visited on April 29, 2013)

FUJITSU

Fujitsu Ltd., a Japanese multinational information technology equipment and services company headquartered in Tokyo, Japan, recently announced the development of the PC industry's first recycling system that collects old disks at it recycling centers. The company has developed a technology by which it can recycle these old compact disks and utilize the recovered plastics for the manufacturing of bodies of the new laptops, notebook etc.[103]

Fujitsu has been in partnership with US-based AnythingIT for the past 10 years. They jointly offer clients the highest possible return trade-ins as well as compliant e-waste recycling services.[104]

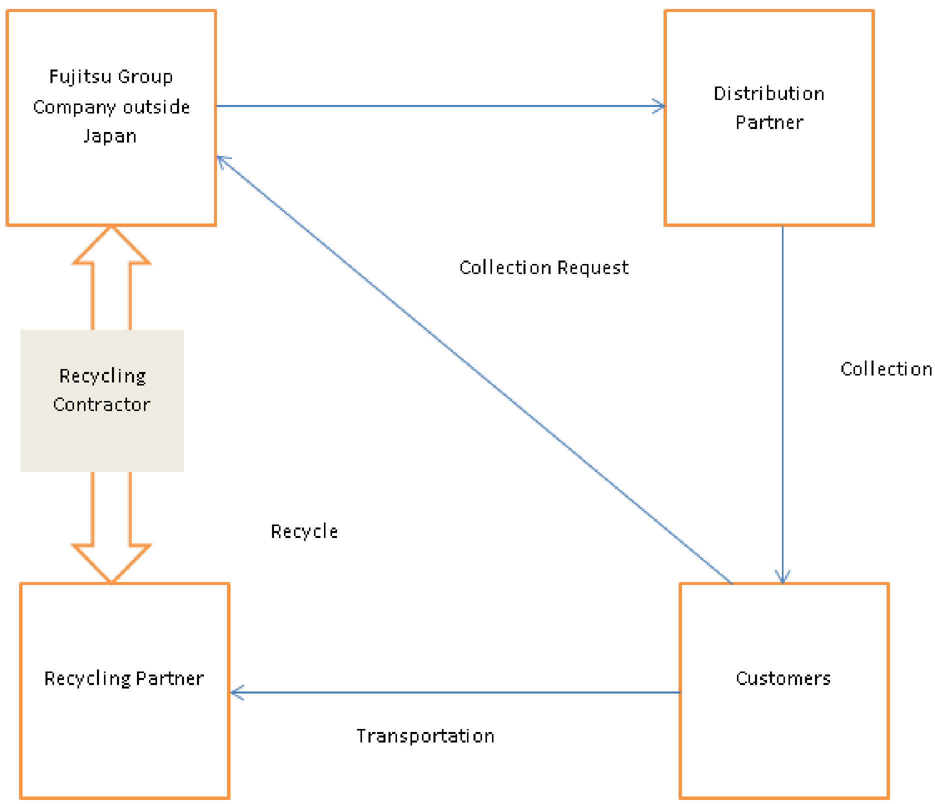


Figure 22: Fujitsu overseas recycling flow[105]

The figure above shows Fujitsu's overseas recycling flow. Customers after end of life of their products file a collection request of their end-of-life product. Fujitsu with the help of their distribution/collection contractors collects the end-of-life product from the customers and further sends it to their recycling partner for recycling of the product.

103 http://www.ecochunk.com/1999/2012/08/25/fujitsu-to-make-bodies-of-notebook-pcs-from-recycled-cds-and-dvds/ (visited on April 29, 2013)
104 http://fujitsu-fedex.anythingit.com/ (visited on April 29, 2013)
105 http://www.fujitsu.com/global/news/pr/archives/month/2007/20070313-01.html (visited on April 29, 2013)

FUJITSU RECYCLING TREND

The charts below show the volume of Information Technology hardware waste collected and processed per year since 2008. The largest volume of waste was collected in 2009, which was 404,105kkg out of which only 1,532kg of hardware accounted for waste to landfill. In 2011, around 348,317kkgs of hardware waste was collected and processes out of which all processed hardware were recycled. Fujitsu, in the year 2011 achieved an exact 0% waste to landfill goal.[106]

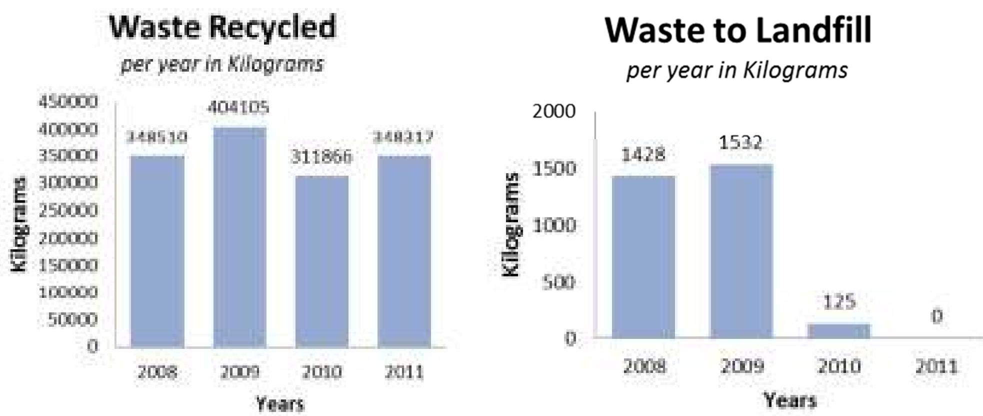


Figure 23: Information Technology Hardware Waste and Recycling[107]

FUJITSU RECYCLING TECHNOLOGY

Fujitsu recycles waste electronic home appliances at their subsidiary recycling plant "Fuji Ecocycle Ltd." As shown above Fujitsu successfully recycles ferrous materials, nonferrous materials, plastic materials and fuel i.e. urethane from the waste electric home appliances.

[106] http://www.fujitsu.com/uk/about/local/corporate-responsibility/csr-report/environment/it-recycling/ (visited on April 29, 2013)

[107] *Id.*

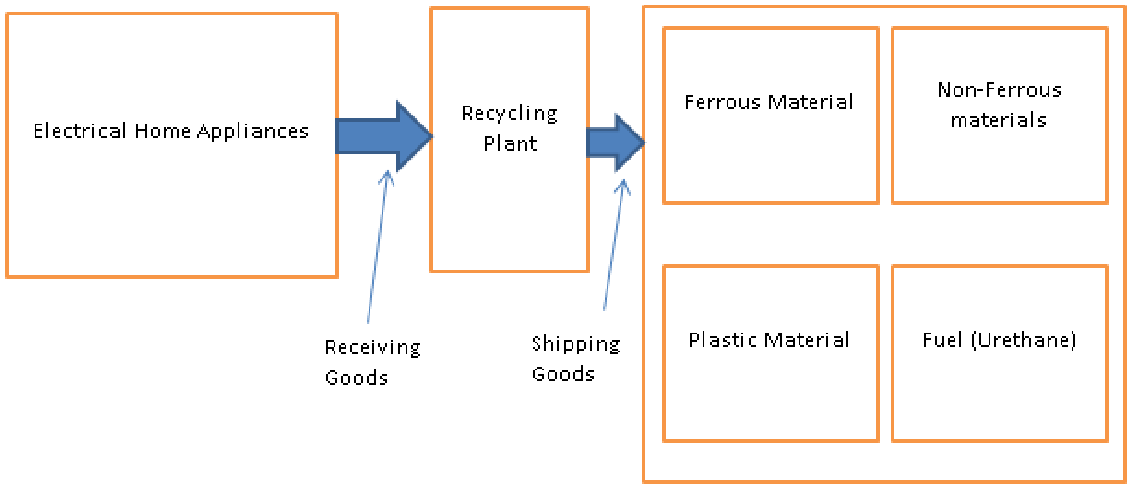


Figure 24: Disposition flow of used electric home appliances[108]

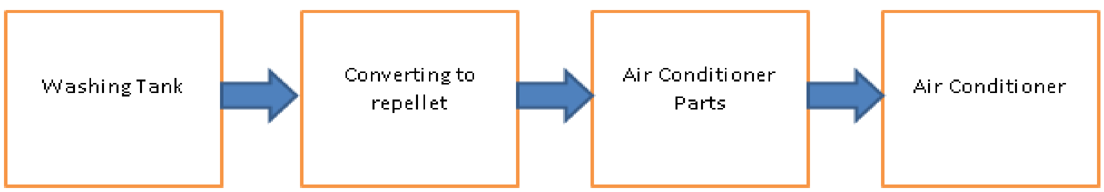


Figure 25: Closed Recycling

Fuji Ecocycle Ltd. recovers Polypropylene (PP) materials from the washing tank of used washing machines. These PP materials are recycled to repellet and further used in air conditioners. A large size plastic crushing machine is used for the crushing of large washing tanks (which is outsourced).[109]

[108] http://www.fujitsu-general.com/global/corporate/eco/factories/recycling.html (visited on April 29, 2013)
[109] *Id.*

FURUKAWA ELECTRIC

Furukawa Electric, a Japanese company, is involved in superconductivity cables. Furukawa Industrial S.A (FISA), a subsidiary of Furukawa Group, has organized the industry's first LAN cable collection and recycling program, which covers entire Brazil. The plastic from the recovered LAN cables is processed at FISA's plant, and copper wiring is sent to copper processing companies for recycling.[110] Below is the chart showing the quantity of LAN cables collected per year.

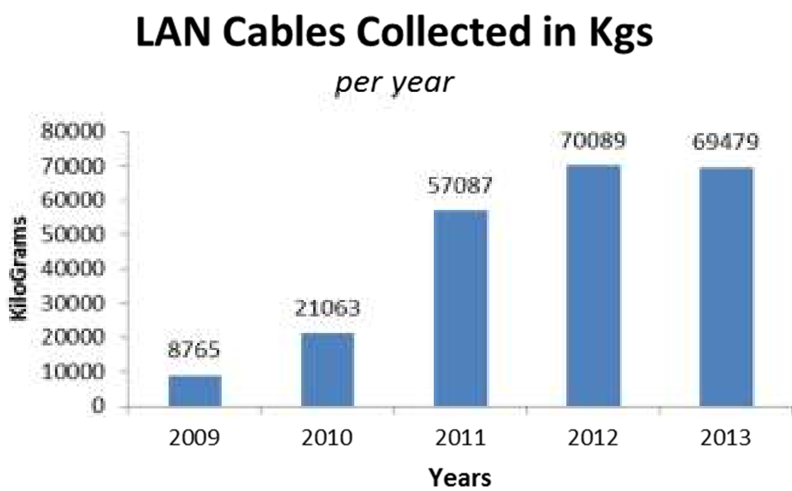


Figure 26: Amount of LAN cable collected per year.

FURUKAWA ELECTRIC RECYCLING TECHNOLOGY

The flow chart below is of the thermo-plasticizing process used by Furukawa for obtaining recycled material using the cross-linked polyethylene (XLPE) waste from the electric wires and cables and processed into nuggets preparatory to be discharged. The XLPE waste is then sorted or separated and is cleaned so that the foreign matter if present can be removed. The XLPE waste is then broken down into particles of a size suitable for feeding into the processing equipment. Further, the XLPE particles are loaded into the feeder unit and supplied continuously in measured quantity to the thermo-plasticizing equipment. The thermo-plastic material is then discharged from the equipment and then cooled and transformed into pellets.[111]

[110] http://www.furukawa.co.jp/english/csr/social/affiliated.htm (visited on April 29, 2013)
[111] http://www.furukawa.co.jp/review/fr023/fr23_17.pdf (visited on April 29, 2013)

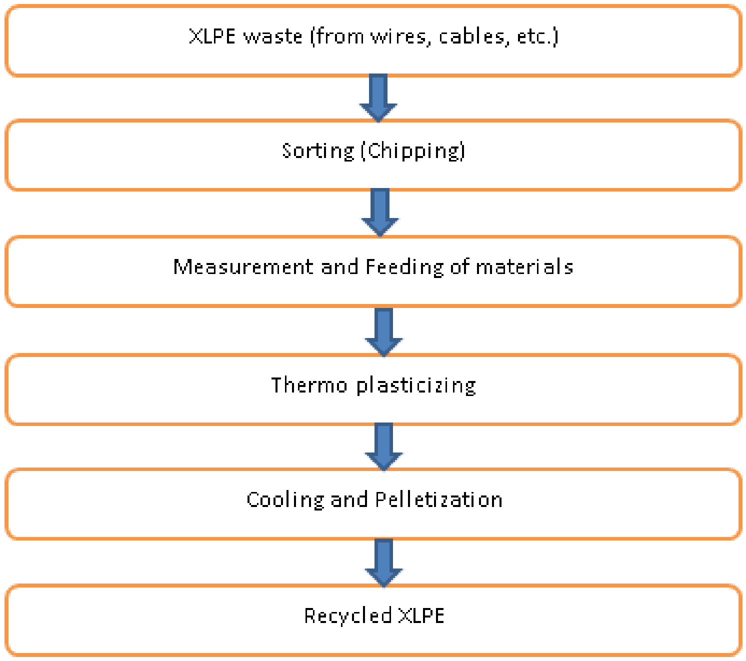


Figure 27: Flow chart of Thermo-Plasticizing process for recycling of XLPE waste from electric wires and cables

NEC CORPORATION

In the year 2012 NEC collected electronic equipment's approximately around 199,000 units which is 6.8% greater than the previous year. The collected electronic equipment's were Desktop PCs, Laptops, CRT and LCD Displays.[112]

In the year 2012, a total of 815,339 kg of Desktop PCs were collected and about 642,128 kg were successfully recycled. NEC reused 502,964 kg of recycled Desktop PCs. NEC also collected Laptops of around 200,108 kg from which they recycled 136,252 kg of Laptops and reused about 62,129 kg of recycled Laptops.

Further, NEC also collected CRT displays and LCDs. Around 239,388 kg of CRT display and 526,892 kg of LCDs were collected out of which 239,388 kg of CRT Display was recycled that is 100% recycle was achieved and 388,222 kg of LCDs were recycled. NEC reused 170,277 kg of CRT Display and 336,413 kg of LCDs.

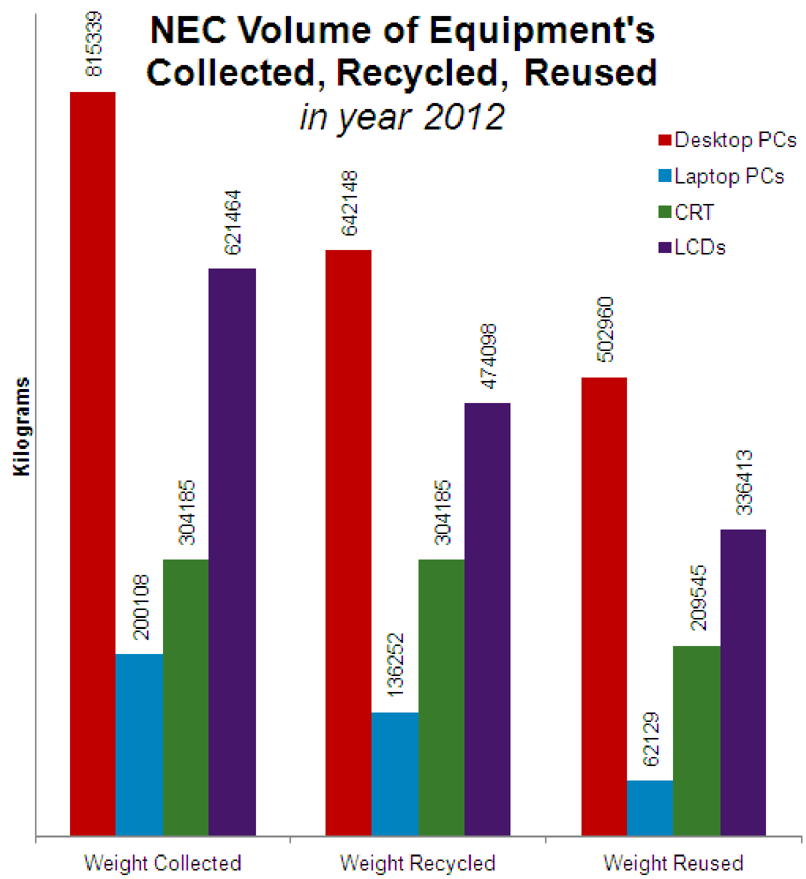


Figure 28: NEC volume of electronic equipment collected, recycled and reused[113]

112 http://www.nec.com/en/global/eco/data/recycle.html#2 (visited on May 1, 2013)
113 *Id.*

NEC RECYCLING TECHNOLOGY

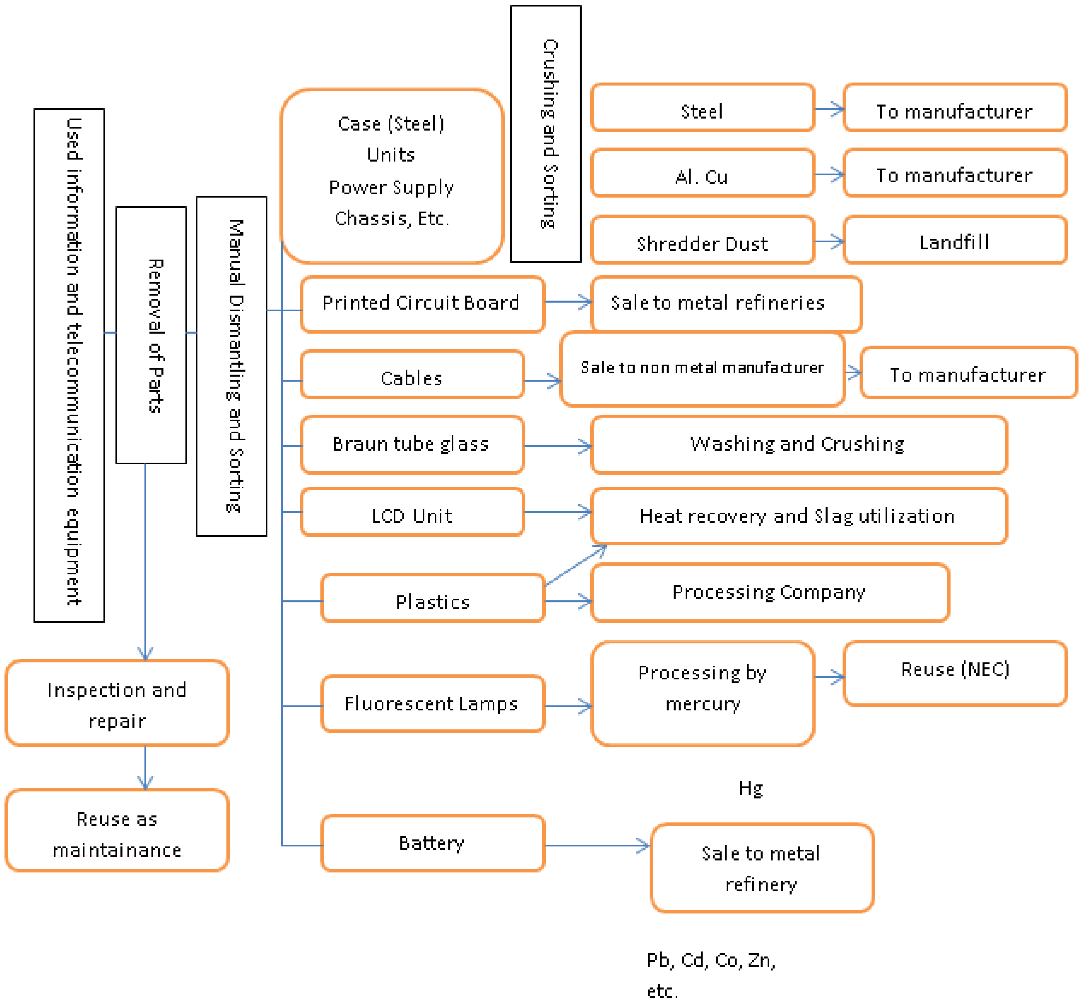


Figure 29: Recycling /Reusing flow of NEC Corp

The figure above shows recycle/reuse flow for an electronic/ telecommunication equipment. First the equipment's are inspected for reusability if the product can be reused then it is further repaired. If not then the product is dismantled and sorted manually. The cables are sold to the non metal manufacturers; PCB's are sold to the metal refineries. NEC Corporation uses the fluorescent lamps after processing them with mercury. [114]

[114] http://www.nec.com/en/global/eco/product/recycle/it/ (visited on May 1, 2013)

OTHER SIGNIFICANT ENTITIES

Below is a list of companies that do not fall within the top tier 1 assignee list but have significant market presence in e-waste recycling.

AERC Recycling Solutions

AES Electronics Recycling Inc.

AnythingIT Inc

Attero Recycling Pvt.

Blue Star Recyclers

Centillion Environment & Recycling Ltd.

Ceylon Waste Management Pvt. Ltd.

Cimelia ResourceRecovery Pte Ltd.

Desco Electronic Recyclers

DP Electronic Recycling Inc.

Eco Recycling Ltd.

ECOvanta

eCycle Solutions Inc.

Electronic Recyclers International Inc.

Endeavor Power Corp Inc.

Envirocycle Inc.

Enviro-Hub Holding Ltd.

E-Waste System Inc.

FCM Recycling Inc.

Gallegos Sanitation Inc.

Garb Oil & Power Corp.

Green Technology Solutions Inc.

GreenTek Reman Pvt. Ltd.

Hydromet Corp Ltd.

InTarvo Technologies Ltd.

Magnum Computer Recycling

Maxus Technology Corp.

MRI (Aust) Pty Ltd.

Ontario Electronic Stewardship

PGM Refiners Pty Ltd

REACT E-Cycling Inc.

Remondis International GmbH

Round2 Inc.

ShanksWaste Management Ltd.

Sims Recycling Solutions (SRS)

Stena Technoworld AB

TechnoCycle Inc.

TechWaste Recycling Inc.

Trash hauler Waste Management Inc.

U.S. Micro Corp.

Universal Recycling Technology LLC

Waste Diversion Ontario

ANNEX B – PATENT LANDSCAPE SEARCH

(((MC=(V04-X01C OR V04-X01G OR X16-M) OR AIOE=(H01B0015* OR H01J000952* OR H01M000652* OR C09K001101 OR H01J000952 OR H01M001054) OR FTC=(4D004AA22 OR 4D004AA23 OR 4D004AA24 OR 4F401AC05 OR 4F401AC07))*

OR

((((AIOE=(B09B0003 OR B29B0017* OR C22B* OR C08J0011* OR B03B000906 OR A62D0101* OR B03C000100) OR MC=(X25-W04) OR FTC=(4F401* OR 4K001*)) AND (TID=(PCB or (printed ADJ2 circuit ADJ2 board*) OR display OR wiring OR (comput* ADJ (equipment OR apparatus)) OR laptop or (tablet adj (computer or device*)) OR ICT OR (integrated ADJ2 circuit*) OR LCD or (liquid ADJ crystal ADJ display) OR PDP or (plasma ADJ2 display) OR semiconductor OR LED or (light adj emitting adj (diode OR device)) or OLED OR electronic* OR mobilephone or ((handy OR mobile OR portable OR cellular OR handheld) ADJ2 (device OR telephon* OR phone* OR radio*))) OR USE=(PCB or (printed adj2 circuit adj2 board*) OR display OR wiring OR (comput* ADJ (equipment OR apparatus)) OR laptop OR (tablet ADJ (computer OR device*)) OR ICT OR (integrated adj2 circuit*) OR LCD OR (liquid ADJ crystal ADJ display) OR PDP OR (plasma adj2 display) OR semiconductor OR LED OR (light ADJ emitting ADJ (diode OR device)) or OLED OR electronic* OR mobilephone OR ((handy OR mobile OR portable OR cellular OR handheld) ADJ2 (device OR telephon* OR phone* OR radio*))) OR MC=(W01-C01D3C OR U14-K01* OR V04* OR V01* OR V02* OR V03* OR V05* OR U12* OR U13* OR U14* OR W03* OR W04* OR T01-L*)))*

OR

(((TID=(PCB or (printed adj2 circuit adj2 board) OR display OR wiring OR (comput* ADJ (equipment OR apparatus)) OR laptop OR (tablet ADJ (computer OR device*)) OR ICT OR (integrated adj2 circuit*) OR LCD OR (liquid ADJ crystal ADJ display) OR PDP OR (plasma adj2 display) OR semiconductor OR LED OR (light ADJ emitting ADJ (diode OR device)) or OLED OR electronic* OR mobilephone OR ((handy OR mobile OR portable OR cellular OR handheld) ADJ2 (device OR telephon* OR phone* OR radio*))) OR USE=(PCB or (printed adj2 circuit adj2 board*) OR display OR wiring OR (comput* ADJ (equipment OR apparatus)) OR laptop OR (tablet ADJ (computer OR device*)) OR (integrated adj2 circuit*) OR LCD OR (liquid ADJ crystal ADJ display) OR PDP OR (plasma adj2 display) OR semiconductor OR LED OR (light ADJ emitting ADJ (diode OR device)) or OLED OR electronic* OR mobilephone OR ((handy OR mobile OR portable OR cellular OR handheld) ADJ2 (device OR telephon* OR phone* OR radio*)))) AND TID=(reclaiming OR reclamation OR recover* OR recuperation OR recuperate OR scrap OR garbage OR trash OR waste OR recyc* OR salvag* OR disposal OR decontam* OR dismantle* or disassembl* or (end adj of adj life) or (end near2 life))) NOT ALLD=((waste adj (heat or gas or water or fluid or liquid)) or ((data or*

system or operating or hardrive or (hard adj (disk or drive)) or heat or clock or energy OR power OR current OR voltage OR signal) near2 recover))))*

AND

(AIOE=(H01M000652 OR H01J000952 OR C09K001101 OR H01M001054 OR B03B000906 OR A62D0101 OR B03C0001* OR B09B0003* OR B29B0017* OR H01B15* OR B29B001702 OR B29B001704 OR C08J001108 OR C08J11* OR C08J001112 OR C22B*) OR MC=(V04-X01C OR V04-X01G OR X16-M*)))*

OR

(TID=((ELECTRONIC ADJ2 WASTE) OR (E ADJ WASTE) OR EWASTE) OR NOV=((ELECTRONIC ADJ2 WASTE) OR (E ADJ WASTE) OR EWASTE) OR USE=((ELECTRONIC ADJ2 WASTE) OR (E ADJ WASTE) OR EWASTE) OR ADV= ((ELECTRONIC ADJ2 WASTE) OR (E ADJ WASTE) OR EWASTE)))

NOT (AIOE=(D OR E OR H01L0021) OR ALLD=(((data or water or heat or charge or coolant or power) NEAR3 (recover* or recyc*)) or ((food or energy) adj2 (waste or recover*)) or (waste adj2 developer)) OR TID=(repair* OR maintenance) OR AIOE=((F OR G) NOT (B OR C))))*

AND PRD>=(19800101)

Legend:

Highly Relevant Classification-Only Search Element [Search 1]

Relevant Classifications and Relevant e-waste Terminology [Search 2]

E-Waste Terminology Alone [Search 3[

Search Restrictions based on a) relevant classifications [Search 4], b) prominent mention of the specific phrase Electronic Waste or variants [Search 5], c) removal of identified noise topics [Search 6] and d) to document first filed on or after January 1^{st} 1980 [Search 7].

Glossary of Searched Field Codes:

MC: DWPI Manual Codes

AIOE: Any IPC or European Classification

FTC: Japanese F-Term Classifications

TID: DWPI Title Field

NOV: DWPI Novelty Field

USE: DWPI Use Field

ADV: DWPI Advantage Field

ALLD: Full DWPI Abstract

PRD: Priority Date Field

Glossary of Logic and Proximity Operators:

AND: Both terms must occur in the record

OR: One or the other terms must occur in the record:

NOT: One term but not the other must occur in the record

ADJ, ADJ2, ADJ3 etc.: Terms must occur next each, in order shown, within 1, 2 or 3 terms etc.

NEAR, NEAR2, NEAR3: Terms must occur next to each other, in either order, within 1, 2 or 3 terms etc.

ANNEX C – GLOSSARY

Term	Definition
Americas	Includes the countries of both North and South America, e.g. Brazil, United States, Canada.
Asia Pacific	Includes the countries of the Far East - e.g. China, Japan, South Korea etc.; South Asian countries such as India and Australia/New Zealand
Electronic Waste, E-Waste	Term defining a consumer electronics product, or similar device using items such as printed circuit boards, electronic components, batteries or other component that has reached the end of its useful life.
EMEA	Europe, the Middle East and Africa
Filing Breadth	A measure of the number of patent authorities in which the same invention has been filed. As this largely increases the level of fees the applicant has expended on the invention, it is tied to the the level of commercial return the applicant would expect to get.
Granted Patent	Also known as an "Issued Patent", a succesful patent application, which is generally re-published containing the finalised specification - the details of which may have changed since the application was first lodged.
National Phase Filing Event	The additional filing that takes place for a patent in further patent jurisdictions. See Office of Subsequent Filing.
Office of First Filing	The first location in which a particular invention has a patent application filed. Also known as the priority filing location.
Office of Subsequent Filing	Additional patent jurisdictions in which the applicant wishes to protect their invention.
Patent	An instrument that provides the holder a statutory right to exclude others (corporations or individuals) from practicing the invention claimed in their patent specification. Practicing the invention varies in different legal jurisdictions, but generally entail selling, marketing, exporting or importing articles which include the patented subject matter. Patents typically provide a exclusivity period of 20 years from the date the patent was first filed. Patent rights are not usually automatically granted; instead applications are filed with the patent office and then examined as to their validity, e.g. whether they are novel, not obvious and have real world usefulness. Patent validity varies considerably from country to country. Also note that lesser "patent-like" IP rights exist, such as Utility Models, that generall have lesser examination procedures as well as shorter exclusivity periods.
Patent Applicant	The organisation or individual applying for a patent.
Patent Application	The specification provided to a patent office by an inventor or their employer that details the invention over which they wish to claim exclusvitiy. Applications are examined as to whether they fulfill various validity requirements; three of which are novely, non-obviousness and usefulness.
Patent Assignee	The organisation to which a patent is assigned ownership; typically the inventor's employer.
Patent Citation	During patent examination/filing procedures, the examiner and/or the applicant will reference relevant patents or patent applications that currently exist in the public domain. Reversing this process allows for the analysis of the number these downstream citations an indivdiaul patent family has obtained over the course of its publication period. Patents with greater numbers of citation events are generally thought to be more impactful in their field, though individual data artifacts (such as citation bias) can occur and need to be accounted for.
Patent Claims	The section of a patent specification that contains the claimed invention by the inventor.
Patent Classification	Typically alpha-numeric codes that define discrete technologies, used both during patent search procedures and for further classification and grouping of sub technologies within a collection. Codes provide a method of retrieving and reviewing patents independent of the language used, overcoming shortfalls in key word searching due to synonyms and foreign languages. Example would be Derwent Manual Codes S02-A01A: Mechanical measurement using rules, micrometers, wheels. Types of classification include the International Patent Classification, European Classification, US Patent Classification, Japanese F-Terms, Cooperative Patent Classification and Derwent Manual Codes.
Patent Family	The collection of related patent documents (applications and granted/issued patents) that substantially cover the same basic invention.
Patent Search	The process of collating a dataset containing patent records of relevance.
PCB	Note that the technology area contains two distinct technologies both referred to by the acronym PCB: 1)Polychlorinated Biphenyls, a toxic pollutant used as a dielectric and coolant fluid in power electronics equipment, e.g. for example in transformers, capacitors, and electric motors. 2) Printed Circuit Boards, used to interlink and provide a base structure for electronic components such as integrated circuits and discrete components such transistors, resistors, inductors and capacitors. Where PCB is used as an acronym, the specific definition is also referred to.
Pendency	The period of time during which a patent application is filed at a patent office, but has not yet issued as a granted patent.
Priority Filing	The first location in which a particular invention has a patent application filed. Also known as the office of first filing.

ANNEX D – AUTHOR

BACKGROUND ON CONSULTANT – ED WHITE

Ed White, based in London, delivers research and analysis projects using advanced statistical analysis of scientific and technical data sources, primarily patent information. The reports are designed to provide intelligence on technical or competitive trends to senior client executives and decision makers. Mr. White has worked with clients in wide range of technologies and industries including: steel making, recovery of energy from slag, automotive drive trains, oil and gas, aviation, telecommunications, semiconductors, consumer products, food and beverages, and medical devices. Client companies have included large multinational corporations, SMEs and academic and government institutions.

Ed's responsibilities also include providing expert insight and best practice knowledge on Thomson Reuters' products and services and assessing customer requirements. He guides prospective project engagements through the procurement process and contract management, and works with internal constituencies within the company to scope and propose project engagements.

Ed also regularly represents Thomson Reuters in the intellectual property and research & development communities, performing speaking engagements and writing articles on IP-related topics. He has been a guest lecturer at the University of Bologna, and has led numerous public and confidential client workshops.

In an earlier role, Ed became intensely familiar with the editorial process involved in the creation of Thomson Reuters enhanced Derwent World Patents Index (DWPI) content, and was himself an abstracter and indexing specialist for incoming patent documents. His technical areas of specialty include biological, chemical and physical sensors and detection instrumentation, cathode ray tubes, plasma and field emission displays and plasma processing tubes.

Ed has been at Thomson Reuters for over 10 years, has a Bachelor of Engineering (Hons) from the University of Nottingham and is a Member of the Institution of Engineering and Technology.

BACKGROUND ON CONSULTANT – ROHIT SINGH GOLE

Rohit Singh Gole, based in India, delivers research and analysis projects using advanced statistical analysis of scientific, technical, and business data information. The reports are designed to provide intelligence on technical or competitive trends to senior client executives and decision makers. Client companies have included large multinational corporations, SMEs and academic and government institutions.

Rohit is responsible for getting involved with clients, understanding scope of work, setting up processes, training teams, and getting involved with them in various aspects of the work.

Rohit has extensively worked with clients on variety of projects including landscape analysis, patent to product mapping, and prior-art/validity searches, infringement analysis, freedom-to-operate searches in the domain of surgical technologies, bioMEMS, foods and beverages, home care and personal care products, wastewater treatment technologies, petroleum processes, and fast moving consumer goods sector.

Rohit’s responsibilities also include spearheading intellectual property competitive intelligence projects across varied domains including bio-medical, foods and beverages, packaging materials, polymeric materials, applications of polymers and polymeric blends etc. He also heads business information research (BIR) team, which involves work related to profiling and analyzing non-practicing entities (NPEs), collecting basic company information, litigation history, company profiling, and compliance & risk analysis. He also prepares industry reports by analyzing patents and business/market information.

In an earlier role, Rohit became intensely familiar with patent docketing, domain monitoring, and trademark infringement services. He also handled patent legal research projects involving extensive research on patent statutes of US and Europe and case laws defining boundaries of the patent statues.

Rohit has been at Thomson Reuters since July 2008. He has about 5 years of experience in intellectually property and business research and holds a Bachelor’s of Technology degree in Biological Sciences & Bioengineering from Indian Institute of Technology (IIT), Kanpur, India.

ANNEX E – BACKGROUND INFORMATION

Background Information on Electronic Waste (E-waste) Recycling and Material Recovery Technologies (information provided by the Basel Convention Secretariat, UNEP)

E-waste programmes and projects under the Basel Convention

Based on the Nairobi Declaration on the Environmentally Sound Management of Electrical and Electronic Waste (2006), several activities and projects addressing this waste stream have now been implemented under the Basel Convention, Basel Convention regional centres, UNEP, UNIDO, NGOs and other organizations worldwide. This include awareness raising activities; detailed inventories; initiation of pilot schemes on collection and segregation of e-wastes, including take-back schemes; initiate pilot repair, refurbishment and recycling schemes; and training of customs and enforcement officers to control or verify export or import of electrical and electronic wastes and work on the identification of electronic wastes in the Harmonized System of the World Customs Organization. Notably, many e-waste projects are being implemented under the auspices of the Basel Convention in particular in Asia Pacific region since 2005 and in Africa since 2009.

The following Asian countries have supported and are participating in the project activities: Cambodia, China, India, Indonesia, Malaysia, the Philippines, Singapore, Sri Lanka, Thailand and Viet Nam. In addition, the South Pacific Regional Environment Programme has completed a regional e-waste inventory for the Pacific island countries. Activities involving detailed inventories of e-waste in Cambodia, Malaysia, Thailand and Viet Nam are also being carried out. Two sets of technical guidelines were completed under the leadership of the Basel Convention Regional Centre for South East Asia on the methodology of e-waste inventory and environmentally sound management and "3R" (reduce, reuses, recycle) of end-of-life e-products.

For the E-waste Africa project, a comprehensive set of activities which will build local capacity to address the flow of e-wastes and electrical and electronic products destined for reuse in African countries and will augment the sustainable management of resources through the recovery of materials in e-wastes. The project is being implemented by the Basel Convention Regional Centres based in Nigeria and Senegal, in cooperation with partners including the Swiss Federal Laboratories for Materials Science and Technology (EMPA), the Oko Institute, the European Union Network for the Implementation and Enforcement of Environmental Law (IMPEL), UNESCO and PACE. The project will run through to 2012. In addition to pilot activities, technical guidelines and manuals for the environmentally sound management (ESM) of e-waste have been developed or under development. However, more investment is needed in developing countries in order to effectively solve their mounting problems in e-waste generation and management.

Further details on the e-waste programmes and projects are available in information leaflets on the Basel Convention publications website (http://www.basel.int/TheConvention/Publications/BrochuresLeaflets/tabid/2365/Default.aspx):

- Meeting the challenge of e-waste in Africa.
- Environmentally sound management of used electrical and electronic equipment (e-waste) in Asia-Pacific.

Partnership Programmes and Guidelines on E-waste

The sixth meeting of the Conference of the Parties adopted the Basel Convention Partnership Programme under decision VI/32 as part of its 10-year Strategic Plan, convinced that the active involvement and support of industry and business organizations and non-governmental organizations is necessary to achieve the aims of the Basel Convention (meeting documents see: http://www.basel.int/TheConvention/ConferenceofthePartiesCOP/PreviousMeetings/PreviousMeetingsDocuments/tabid/2409/Default.aspx?meetingId=1&sessionId=3). The Partnership Programme to date has included two initiatives in its framework: the Mobile Phone Partnership Initiative (MPPI) and the Partnership for Action on Computing Equipment (PACE). The MPPI was launched in 2002, during the sixth meeting of the Conference of the Parties to the Basel Convention, when 12 manufacturers signed a Declaration entering into sustainable partnership, with the Basel Convention and in cooperation with other stakeholders, to develop and promote the environmentally sound management of end-of-life mobile phones. Following the success of the MPPI, PACE was launched at the ninth meeting of the Conference of the Parties to the Basel Convention, which took place in Bali in June 2008. PACE is a multi-stakeholder partnership that provides a forum for governments, industry, non-governmental organizations and academia to tackle the environmentally sound management, refurbishment, recycling and disposal of used and end-of-life computing equipment. PACE is intended to increase the environmentally sound management of used and end-of-life computing equipment, taking into account social responsibility and the concept of sustainable development, and promoting the sharing of information on life cycle thinking. Details of partnership is provided on the PACE website (http://www.basel.int/Implementation/PartnershipProgramme/PACE/Overview/tabid/3243/Default.aspx).

Developing countries will benefit from these Partnerships in that the guidelines produced will be useful to help them in achieving the environmentally sound management of mobile phones and computing equipment as well as from the establishment of pilot collection schemes and for and treatment schemes for used and end-of-life mobile phones and computing equipment in developing countries and countries with economies in transition.

Under partnership programmes, the following e-waste related guidelines and documents were developed:

Mobile Phone Partnership Initiative (MPPI):

(all guidelines and documents developed under the MPPI are available on the MPPI website (http://www.basel.int/Implementation/PartnershipProgramme/MPPI/MPPIGuidelinesandGlossaryofTerms/tabid/3251/Default.aspx)

- Guidance document on the environmentally sound management of used and end-of-life mobile phones
- Guideline on the Refurbishment of Used Mobile Phones
- Guideline on the Collection of Used Mobile Phones
- Guideline on Material Recovery and Recycling of End-of-Life Mobile Phones
- Guideline on the Awareness Raising-Design Considerations
- Guideline for the Transboundary Movement of Collected Mobile Phones
- MPPI Glossary of Terms

Partnership for Action on Computing Equipment (PACE):

(All guidelines (http://www.basel.int/Implementation/PartnershipProgramme/PACE/PACEGuidelinesandGlossaryofTerms/tabid/3247/Default.aspx) and the guidance document (http://www.basel.int/Implementation/PartnershipProgramme/PACE/PACEGuidanceDocument/tabid/3246/Default.aspx) developed under the PACE are available on the PACE website (http://www.basel.int/Implementation/PartnershipProgramme/PACE/Overview/tabid/3243/Default.aspx)

- Guidance Document on the Environmentally Sound Management of Used and End-of-life Computing Equipment
- Guideline on Environmentally Sound Testing, Refurbishment, and Repair of Used Computing Equipment
- Guideline on Environmentally Sound Material Recovery and Recycling of End-of-Life Computing Equipment
- Guidance on Transboundary Movement (TBM) of Used and End-of-Life Computing Equipment
- PACE Glossary of Terms

E-waste under the Basel and Stockholm Conventions

Under the Basel Convention (http://www.basel.int/TheConvention/Overview/TextoftheConvention/tabid/1275/Default.aspx) electrical and electronic wastes (e-wastes) are classified under Annex VIII entries A1180, A1190, A1150 and A2010 and also under Annex IX as B1110. E-wastes are characterized as hazardous wastes under the Convention when they contain components such as accumulators and other batteries, mercury switches, glass from cathode-ray tubes and other activated glass, PCB-containing capacitors or when contaminated with cadmium, mercury, lead, PCBs or POP-PBDEs (Polybrominated diphenyl ethers) listed in the Stockholm convention (http://chm.pops.int/Convention/ThePOPs/tabid/673/Default.aspx) (see also below). Also, precious-metal ash from the incineration of printed circuit boards, LCD panels and glass waste from cathode-ray tubes and other activated glasses are characterized as hazardous wastes. To address the environmental issues related to the increasing transboundary movements of these wastes, and to ensure that their storage, transport, treatment, reuse, recycling, recovery and disposal is conducted in an environmentally sound manner, a proactive approach is essential. The plastics associated with e-wastes may also be covered, under Annex II of the Basel Convention.

In May 2009, the Conference of the Parties amended the Stockholm Convention (http://www.pops.int/) on persistent organic pollutants (POPs) to add certain brominated flame retardants (BFRs)to Annex A: Hexabromobiphenyl (HBB)and two polybrominated diphenyl ethers (Hexabromodiphenyl ether and heptabromodiphenyl ether and Tetrabromodiphenyl ether and pentabromodiphenyl ether).

Like all POPs, these chemicals possess toxic properties, resist degradation, and bioaccumulate. They are transported through air, water and migratory species, across international boundaries and deposited far from their place of release, where they accumulate in terrestrial and aquatic ecosystems.

These chemicals have been widely used in many industrial sectors for the manufacture of a variety of products and articles, including consumer articles. For example, POP-PBDEs have been used in the electronics industry for the manufacture of plastic casings for computer equipment.

Two main guidance documents were developed to evaluate whether the current recycling of products and waste management (Guidance for the inventory of polybrominated diphenyl ethers listed under the Stockholm Convention on Persistent Organic Pollutants) and to provide guidance on best available techniques (BAT) and best environmental practices (BEP) for the recycling and final disposal of products and articles containing POP-PBDEs in an environmentally sound manner (ESM) (Guidelines on best available techniques and best environmental practices for the recycling and disposal of articles containing polybrominated diphenyl ethers (PBDEs) listed under the Stockholm Convention on Persistent Organic Pollutants).

Environmentally sound material recovery / recycling of end-of-life computing equipment:

The guideline on environmentally sound material recovery / recycling of end-of-life computing equipment is a product of the Partnership for Action on Computing Equipment - PACE - and it covers the personal computers and peripherals that hundreds of millions of people are using around the world, and that are also being disposed around the world: central processing units (CPUs), both desktop and laptop; monitors using CRT and LCD flat screen technology; keyboards and mice; printers and scanners. These kinds of computing equipment contain many types of metals, plastics and other substances, some of which are hazardous, some of which are valuable resources, and some of which are both. To avoid exposure of people and communities to the hazardous substances, and reduce the use of resources, end-of-life computing equipment should be re-used or sent for material recovery/recycling at facilities that recycle electronics and that undertake environmentally sound management (ESM) in their operations.

The environmentally sound material recovery / recycling guideline describes the chain of steps that should be taken in order to ensure environmentally sound management in material recovery facilities that recycle electronics, and to encourage operators at each step to know about, work with, and take their responsibility for human health, safety and the environment, so that the entire value chain works in both an economically and environmentally sustainable manner. In the following, a summary extract of the guideline is provided.

In theory, every part of end-of-life computing equipment can find continued beneficial use through the value chain, from direct reuse as a complete computer to a part of a slag-construction aggregate. In practice, there are economic limits to material recovery, and some process residues from all of the six steps will need final disposal, with careful attention for protection of the environment.

Computing equipment contains more than 60 types of metals and other materials, some in large amounts, "primary constituents" such as steel, some in small amounts, "minor constituents" such as silver, and some in very minute amounts, "micro or trace constituents" such as gold. Of course, the exact materials are different for each manufacturer, for each piece of equipment, and they are always changing as the technology changes. Facilities that recover material from end-of-life computing equipment must be prepared for new and old equipment, with new and old technology.

Some of these materials present little or no special hazard or concern, e.g., steel. Certain other materials may present a hazard when they are broken, crushed, shredded or melted, unless environmentally sound management practices are employed. In addition, other substances may be used in recycling, or may be produced. There are three main groups of substances that may be released during material recovery, and that should be of concern:

- Original constituents of computing equipment, such as lead, mercury, etc.,
- Substances that may be added in some recovery processes, such as cyanide; and
- Substances that may be formed by recycling processes, such as dioxins.

To protect their workers and their communities, material recovery facilities should take steps that are guided by environmentally sound management criteria. These criteria work together to both guide and assist a materials recovery facility to achieve environmentally sound management of computing equipment and its recovery.

Applying environmentally sound management criteria, a material recovery facility must first collect end-of-life computing equipment, but only the kinds that it is prepared, qualified and licensed to accept and process. Then it must carefully remove and separate the most problematic constituents - those that contain hazardous substances that may contaminate other materials – such as mercury, batteries, CRTs, which usually need additional processing and/or environmentally sound final disposal. After that, material recovery from remaining computing equipment generally consists of a long series of steps and processes, some going on for a number of months, with each step adding value. All of these processes may also release hazardous substances, and careful worker training and protection, as well as community protection, are necessary parts of sound facility management. The general intent at each step is that complex materials should be sorted and separated as much as possible into similar types of materials, e.g., steel with steel, aluminum with aluminum, copper with copper, etc. At each step a more concentrated output material becomes a more valuable input into another process, until a material is ready for the market as a new material. And material recovery from computing equipment not only minimizes waste disposal, it can also be much more environmentally sound than mining the same raw materials.

Material recovery facilities can sometimes use manual labor in recovery processes, and can sometimes use mechanized and advanced sorting processes. Many facilities use both, depending on which is most efficient for a particular step. In developing countries and countries with economies in transition, if costs of manual labor are low, the manual disassembly path is more often taken. Even in developed countries, in some circumstances manual disassembly and sorting may also be more efficient or necessary in material recovery. It does not require significant technological skills, although worker training to safely carry out specific tasks is always important. It can produce clean sorted materials and working components, such as electronic chips and wires/cables for additional value. These steps are not without risks of exposures to hazardous substances, however, so health, safety and the environment must be strong concerns.

Mechanized material recovery processes, using shredders, grinders and separation technology, are more likely to be high speed - high volume operations, with several shredding steps followed by very modern, sophisticated identification and separation of plastics and metals by optical and X-ray technology, ferrous metals by electromagnets, copper and aluminium by eddy current, etc.

When concentrated streams of metals have been produced, they are usually further refined in metal-specific pyrometallurgical and/or hydrometallurgical processes. Scrap steel can be used in electric arc furnaces to produce new steel. Scrap aluminum can be used in secondary aluminum furnaces to produce new aluminum. Scrap copper, scrap precious metals, and some other non-ferrous (special) metals are commonly recovered from computer circuit boards and other components/fractions in pyrometallurgical processing and/or by metal-specific hydrometallurgical refining. Informal recovery operations, such as acid leaching, on circuit boards and other precious metal-bearing materials are inefficient, and expose workers, communities and the environment to cyanides, strong acids, toxic gasses and other hazards.

Some functional cathode ray tubes (CRTs) may be re-used without change, or may be used to produce televisions or other electronic displays. If they cannot be re-used, clean and sorted CRT glass may be used in the remaining CRT manufacturing facilities to produce new CRT glass. CRT leaded glass can also be used in lead smelters to produce lead.

Most screens with liquid crystal display (LCD) contain mercury lamps as backlights which have to be carefully and manually removed before processing or managed in closed, highly mechanized systems (emerging technologies). The mercury lamps should be properly packaged and sent to specialized mercury recovery facilities. Regular monitoring should be done in the working areas for presence atmospheric and environmental levels of mercury.

Plastics may be recycled if they are separated by type, are mostly free of metals and other contaminants, and do not contain certain hazardous brominated flame retardants (BFRs), unless they can be removed or can legally continue to be used as flame retardants. Plastics can be used in smelting operations as fuel and as reducing agents, if the smelter emissions are well controlled, especially for dioxins and furans.

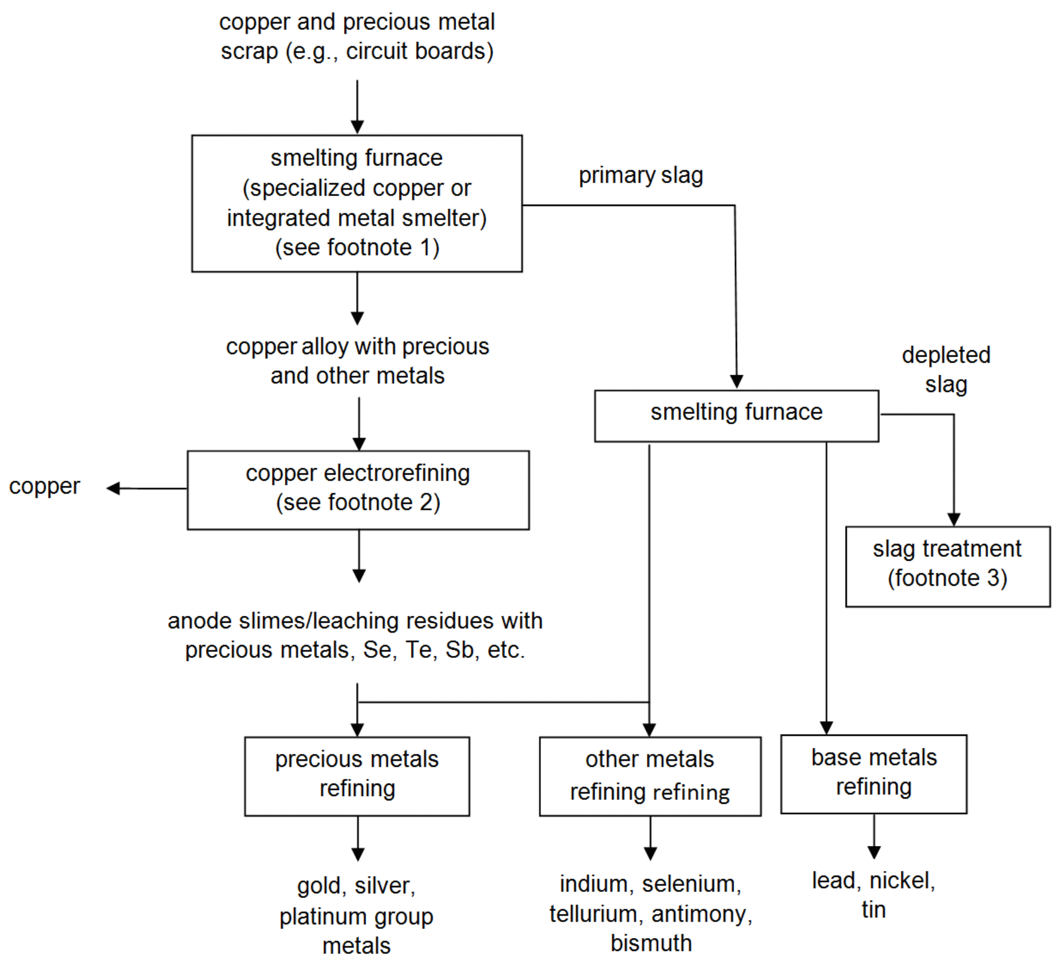
Batteries, derived from computing equipment, now almost always based on lithium and nickel metal hydride chemistry, should be evaluated for continued use as batteries, for which there is a good market (See the PACE Guideline 1.1 for battery standards). If a battery is no longer useable, it should be processed only in specialized facilities that are permitted to safely manage hazardous characteristics such as corrosivity or toxicity. The primary metals of interest are cobalt, nickel and copper, and lithium may also become a valuable target for recovery.

Residues from processing and pollution control systems that cannot be efficiently recovered are likely to contain metals and other substances of concern, which must be carefully managed, often as hazardous waste. These include bag house filters and dust, sweepings, glass fines, phosphors, plastics and slags. Because these waste residues are likely to contain metals, plastics and halogens, disposal in an incinerator that does not have efficient pollution control systems is not suitable. Similarly because process residues may leach hazardous constituents, disposal in an uncontrolled landfill is also not suitable.

Because many residues generated in the material recovery chain are intended for further recovery processes, or for final disposal, and will be classified as hazardous waste, it is important that material recovery, energy recovery and disposal facilities be properly authorized and licensed, and comply with all applicable laws – local, national, regional, multilateral and international, which may include implementation of the Basel Convention, where transboundary movement is undertaken, as is often the case with end-of-life computing equipment.

Figure 1 below gives a flow chart of metal recovery. More examples and detailed description of the processes are provided in the PACE Guideline on Environmentally Sound Material Recovery and Recycling of End-of-Life Computing Equipment (http://www.basel.int/Implementation/PartnershipProgramme/PACE/PACEGuidelinesandGlossaryofTerms/tabid/3247/Default.aspx).

Fig.1: Metal Recovery - Pyrometallurgical Recovery of Copper and Precious Metals



fn 1 – smelters differ in process flow and metals produced. For treatment of materials with plastic content, e.g., circuit boards, special emission pollution control treatment is required for all smelters.

fn 2 – either (1) copper anode directly electrorefined to cathode, and electrorefining residues (slimes) are further treated, or (2) copper alloy is leached, leachate is then electrorefined to cathodes, and leaching residues are further treated. Residues without value are disposed.

fn 3 – slag is stabilized and made suitable for construction products. Residues without value are disposed in controlled disposal operations.

For more information contact WIPO at www.wipo.int

World Intellectual Property Organization
34, chemin des Colombettes
P.O. Box 18
CH-1211 Geneva 20
Switzerland

Telephone:
+4122 338 91 11
Fax:
+4122 733 54 28

WIPO Publication No. 948.4E ISBN 978-92-805-2432-1