INTELLECTUAL PROPERTY OFFICE

Patent landscape analysis of recycling and separation technologies

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Patent informatics project report:
Patent landscape analysis of recycling and separation technologies

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Executive Summary

This report analyses the worldwide patent landscape for recycling and separation technologies for mixed waste streams involving separating specific materials, purifying or upgrading materials and general analysis methods. The dataset representing this technology space shows a good spread of technologies spanning nearly half a century.

Most of the top 30 patent assignees are based in Japan with the US and Germany also having companies appearing in the top 30; the patent filings having a priority in these three countries account for nearly 70% of the entire dataset.

The majority of the dataset comprises patents from corporate organisations, which is not surprising given the scale at which much industrial recycling is performed. There is little international collaboration occurring, contra-indicating effective international knowledge transfer. In general the sector appears to comprise a good combination of both mature and emerging technologies.

The dataset encompasses a broad range of technology marks, primarily due to the search strategy employed. The breakdown of technology activity by year reveals that early increases in patent activity in the late 1980s were predominantly in separating plastics and the arrangement of refuse separating plants. Other developments followed quickly and cumulatively contribute to the overall increase in patenting through the 1990s, possibly incentivised by impending Japanese environmental legislation and influenced by a bias towards Japanese assignees in the dataset.

The top three companies Ricoh, Mitsubishi and NKK are all of Japanese origin and it is not surprising to note that the majority of their work originated in Japan. All three companies have datasets which suggest that they are established companies and which also show that there is, in general, little collaborative activity.

Given Ricoh's history of manufacturing printing/photocopying devices, it is not surprising to note that the majority of Ricoh patents relate directly to the collection or recycling of waste developer. Mitsubishi and NKK both work on similar spreads of technologies such as the recovery of plastics from waste material containing plastics and the disposal of solid waste.

British companies account for less than 2% of the dataset, with no single company having a particularly large portfolio. The top filing companies do not have any recent patents, but more recent filings by British companies appear to be promising, with several different companies filing patents across a broad spectrum of technologies.

One of the desirables specified in the project proposal was identification of underdeveloped technology areas; areas or materials for which technology solutions enabling separation, purification or upgrading of waste materials are not yet widely developed.

By definition this is non-trivial; patent informatics facilitates identification of characteristics, trends and relationships which exist within data. Identification of those which are absent is less straight-forward.

Nonetheless, by examining areas of a patent landscape map which are low-lying in the overall landscape, areas of low technological density can be uncovered. These areas may also relate to emergent areas.

Initially, materials of interest (i.e. the specified metals and plastics) were marked on the patent landscape map to identify any areas which were coincidentally low-lying and specifically lacking in these materials of interest. A candidate area was selected, within which lay a range of patents relating to separation and recovery of plastic from glass-fibre reinforced plastic (GRP). GRP recycling, especially printed circuit boards, where the GRP is itself subject to separation into constituent materials may therefore be under-represented in patented technology.

By analysing the overall landscape map in more detail it was also noted that one area is populated with a significant number of patents relating to the recycling of optical storage media, e.g. compact discs (CDs). Although not an under-represented sector per se, optical storage media waste material separation and recycling can be seen to be the subject of diverse approaches and may still be subject to considerable future development.

A number of science-intensive technology patents were also noted. These occur in sectors of the landscape map which show signs of emergence as applications are developed. It is interesting to see the appearance of a patent from Cranfield University which seeks to identify plastic types by UV illumination and induced fluorescence. This is notable given the general dominance of the technology space by Japanese, German and US assignees but could indicate a good British presence in developing emerging technologies in the sector.

Finally, by highlighting patents in the dataset issued by the Intellectual Property Office (in the UK) it can be seen that much UK technological activity occurs in the sectors of plastics recycling and waste water management.

Given the fairly broad scope of this report, there are several areas which could be expanded on and explored in more detail such as:

- Determination of the presence of other specific material types in the dataset
- Detailed analysis of a particular material type e.g. PET
- Detailed analysis of a particular composite material e.g. glass-reinforced plastic
- Detailed analysis of a particular technology area e.g. recycling of compact discs
- Analysis of recent British companies

Contents

1 Introduction

1.1 Basis for report

For this project the Thomson Reuters World Patent Index (WPI) database was interrogated, which encompasses published patent documents derived from the majority of leading industrialised countries and patent organisations, for example the World Intellectual Property Organisation (WIPO), European Patent Office (EPO) and the African Regional Industry Property Organisation (ARIPO). It should be noted that since by convention patents are usually classified and published eighteen months after filing, the patent record set covering June 2007 – present may not be complete. This should be borne in mind when considering recent patent trends (within the last eighteen months).

Within the WPI database, patents are arranged into patent families i.e. groups of related patent applications in one or more countries. This can then be used to provide an indication of the number of inventions a company may hold, as opposed to how many individual patent applications they might have filed in different countries for the same invention.

Documents making up patent families may have been granted in some or all relevant countries or they may simply refer to published patent applications; these applications may have lapsed or might still be pending grant. Including all patents, whether granted or not, gives a better indication as to the innovative activities of companies than if only granted patents were analysed.

As specified, the data reported herein relates specifically to a worldwide patent landscape analysis for recycling and separation technologies for mixed waste streams involving separating specific materials, purifying or upgrading materials and general analysis methods.

1.2 Priority year, application year and publication year

There are generally three dates which can be associated with a patent application as follows:

Application date: The date on which a physical application was made for a patent. This enables an accurate temporal reflection of the technical content of a patent application.

Priority date: A patent can claim priority from an earlier application. This usually happens for two reasons: a) when an application is filed in one country, international convention dictates that the applicant then has 12 months to file a corresponding application abroad. Thus the patent application would then have a priority date, which indicates the earliest date attributed to the invention; b) an earlier application may contain part of an invention so a subsequent application, made within 12 months of filing, may claim priority from the earlier application. However, in the new application, this date is only valid for that part of the invention which appears in the earlier application. Care should therefore be taken when analysing the priority date of an invention.

Publication date: The date when the patent application was published. This is normally 18 months after the priority date or the application date, whichever is earlier.

The analysis presented in this report is primarily based on priority year to give the earliest indication of innovative activity.

1.3 WO and EP filings

As well as filing in separate national countries, patents can also be filed as International patents (WO) and European patents (EP). WO patents may designate in which national states protection is sought; these patents are then processed in the respective national states and will then be included in the other figures for FR, GB, DE etc. WO patents may themselves designate EP, and these patents will go on to become European patents which may have validity in one or more European states. European patents can also be obtained in their own right. The country of validity cannot be easily determined except on a patent-by-patent basis. Figures for patent families with WO and EP priorities have been included for completeness though no single attributable country is immediately apparent.

1.4 Patent documents analysed

The document dataset identified during search was targeted through the use of keywords and International Patent Classification (IPC) codes in conjunction with patent examiner technology-specific expertise.

Where dates are attributed to patent documents this is the priority date of that patent, the earliest available indication of inventive activity. In certain cases a patent comprises more than one priority date. This should be borne in mind when interpreting the data as explained above.

It is also important to note that prior to analysis, the assignee field data is “cleaned” to de-duplicate database entries, which relate to the same assignee, but where a different form of assignee name is used, for example arising from spelling error, international variation (e.g. Ltd, Pty, GmbH etc.) or equivalence (e.g. Ltd., Limited). This avoids erroneous apparition of apparent multiple assignees which are in fact one and the same. However, this can also mean that some subsidiary companies

might potentially be obscured by larger parent companies. The terms ‘assignee’ and ‘applicant’ are used interchangeably throughout this report, although on occasion the original applicant may nominate or reassign the patent to a different assignee.

1.5 Objectives

This report analyses the worldwide patent landscape for recycling and separation technologies for mixed waste streams involving separating specific materials, purifying or upgrading materials and general analysis methods. Further observations, where appropriate, are provided by considering aspects of the following:

- Technology lifecycle, including present stage of maturity
- Key applicants, including their geographical, technical and collaborative profile
- Key areas of technology growth, including geographical variations
- Key inventors
- Technology sub areas:
    - Separating specific materials from mixed streams
    - Purifying or upgrading materials (from waste/end of life sources)
    - Analysis methods for mixed material (waste) streams
- Identification of key technology sub areas by material e.g.
    - Lead
    - Copper
    - Platinum
    - Other elements
    - Polyethylene
    - Polyolefins
    - Other polymers and polymer types
- Landscape map of the technology space

Section 2 gives a detailed overview of the dataset, breaking it down by the top filing assignees and by technology area. Analysis of a visual representation of the patent landscape is also given. Section 3 provides a summary and offers recommendations for future work.

2 Discussion

2.1 General overview of dataset

Summary data representing the recycling and separation technologies for mixed waste streams dataset is shown in Table 1 below. The figures suggest a good spread of technologies spanning nearly half a century.

Number of Patent Families[1]	18,111		
Years Range From	1961 - 2008		
Peak Year	2000 [1112 Records]		
Top Country	JP		
Top Company Name	RICOH		
Field Choices	Field Name	Number of entries	Field Coverage
People	Inventors	24,479	90%
Companies	Patent Assignees - final cleaned list	7,176	79%[2]
Countries	Priority Countries	61	96%
Years	Priority Years	48	96%
Technology	International Classifications (Advanced)	7029	96%

Table 1 Summary of patent dataset

The plot of the number of patent family priority filings over time, as in Figure 1, suggests a relatively low level of patent activity prior to 1968, with a tenfold increase in the number of patent families by 1975. This period of activity predates the introduction of the Patent Cooperation Treaty in 1978 which facilitated international filings of patent applications and would thus seem to reflect a real increase in technical development during the 1960s and 1970s. Following a small dip in activity during the late 1970s, the number of inventions then remained constant throughout the 1980s. The level of patenting activity then increases sharply into the 1990s and is in line with global patenting trends, with the exception of a small dip in the mid 1990s. There is a mini spurt of activity around the end of the 1990s. This may be because the US Patent Office started publishing patent applications in 2000[3] and therefore may exaggerate this characteristic in the data.

[1] The data used for this analysis is based on patent families, that is, a group of one or more patent applications in multiple countries which correspond to a single invention.
[2] This figure appears to be low because some patent documents do not have an assignee listed effectively removing them from any analysis involving patent companies
[3] The USPTO started publishing patent applications from the 29 November 2000, stemming from a statutory mandate contained in the American Inventors Protection Act of 1999 (AIPA).

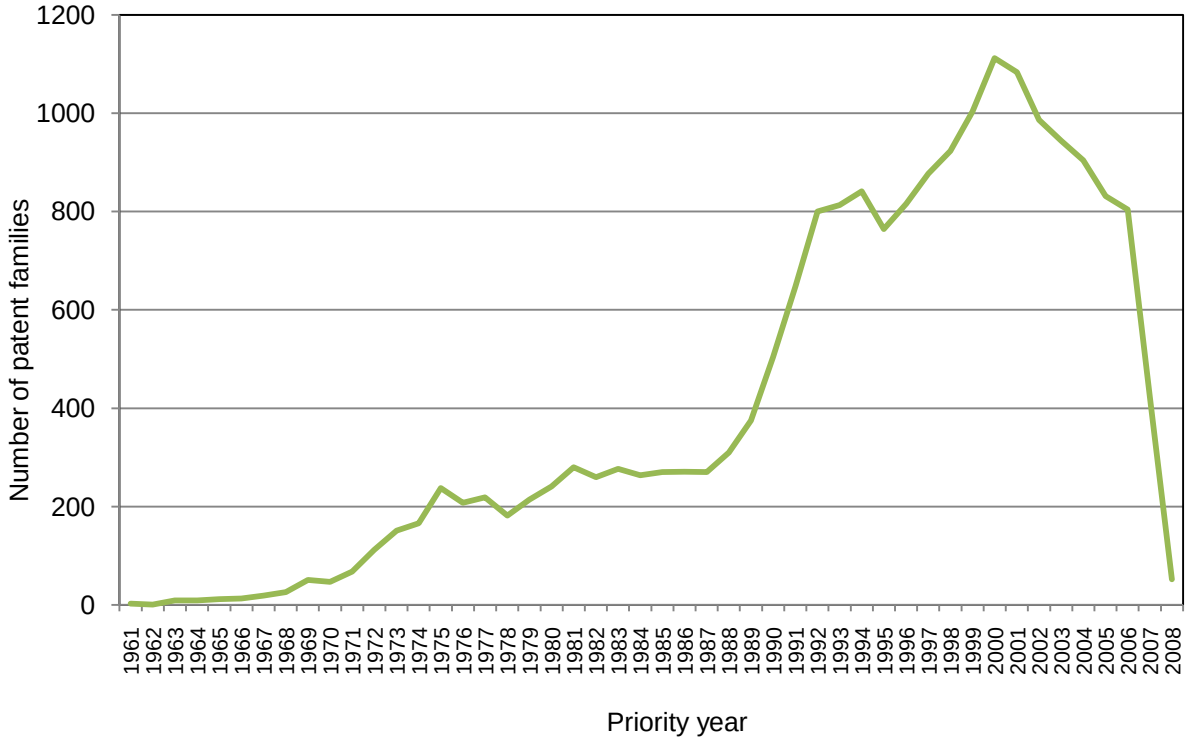

Figure 1 Number of patent families over time

The data shows an overall peak of patent activity in 2000. It should be noted that whilst the patent dataset may be incomplete, due to publication timescales of eighteen months, it may be incomplete further back (as much as five years) because of other anomalies in the various international patenting systems. For this reason, the apparent decline in patent activity after 2001 may not be as extreme as suggested in Figure 1 above. This is confirmed when looking at Figure 2, showing *publication* years (less susceptible to classification and database delays) which shows two periods of growth in the last 5 years; it does, however, confirm that since the turn of the century the overall trend is for a decline in the number of inventions being patented.

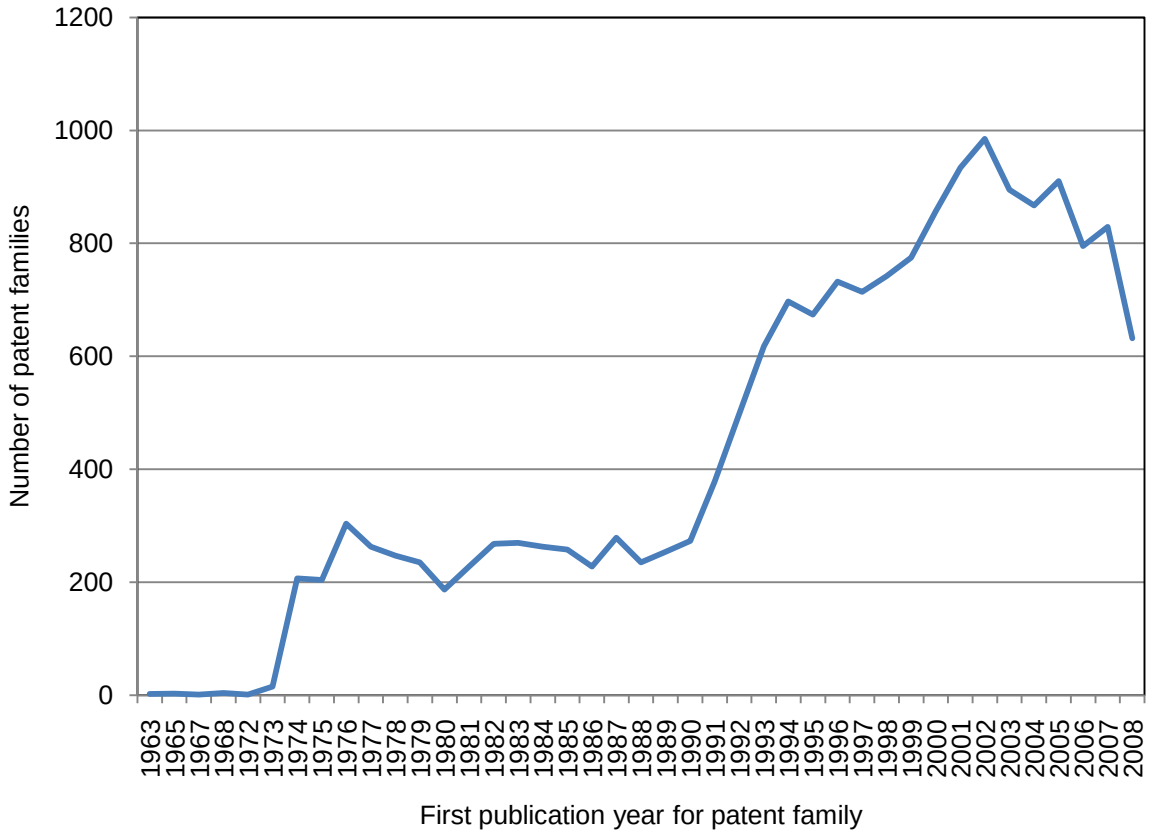

Figure 2 First publication year

2.2 International patent activity

Most of the top 30 patent assignees are based in Japan, as is clearly evident in Figure 3 and Figure 4. The US and Germany also have companies appearing in the top 30 and the patent filings having a priority in these three countries account for nearly 70% of the entire dataset. A full list of standard database country codes is available on the WIPO website[4].

[4] http://www.wipo.int/pct/guide/en/gdvol1/annexes/annexk/ax_k.pdf [accessed March 2009]

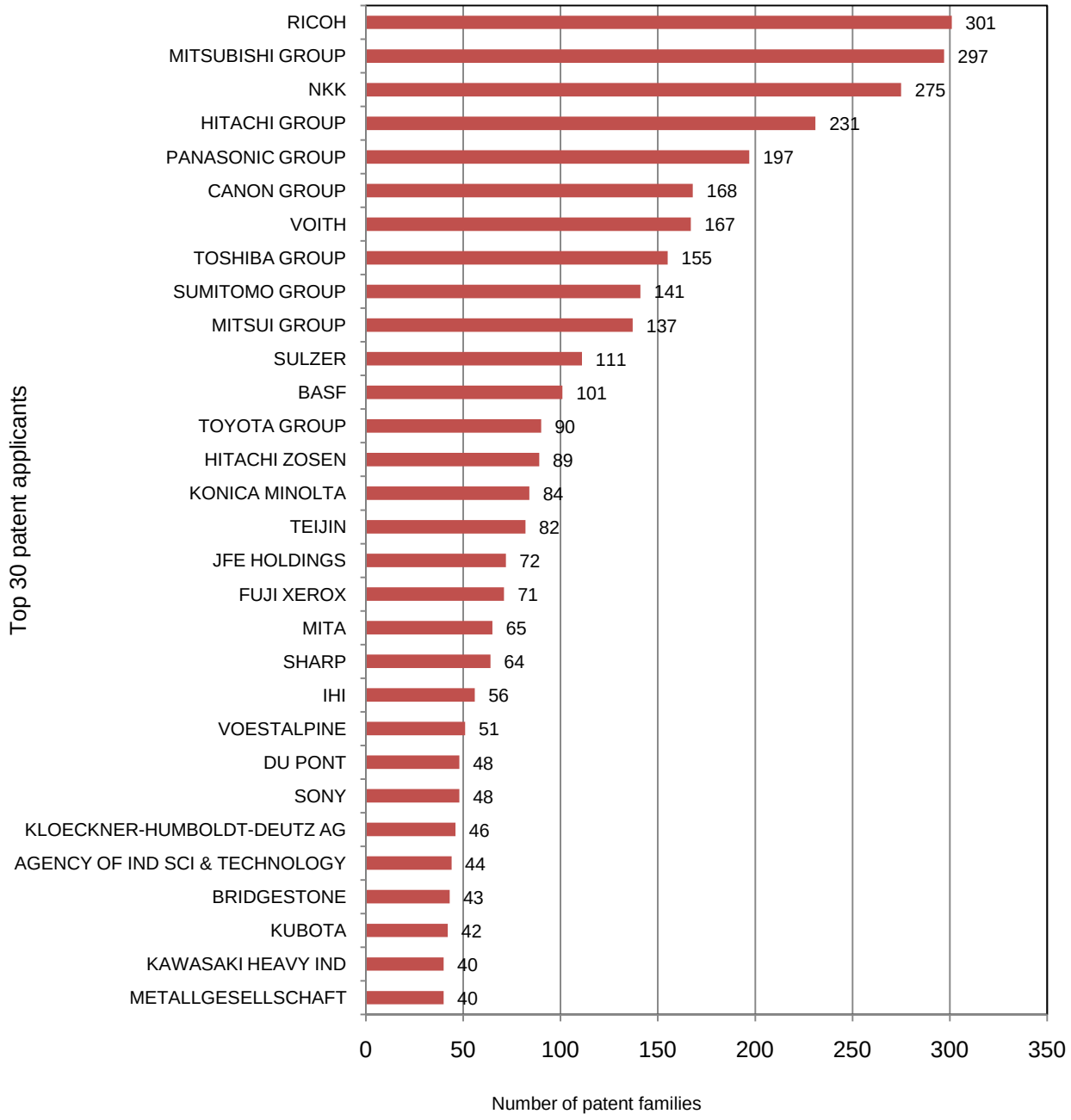

Figure 3 Patent families for top 30 organisations

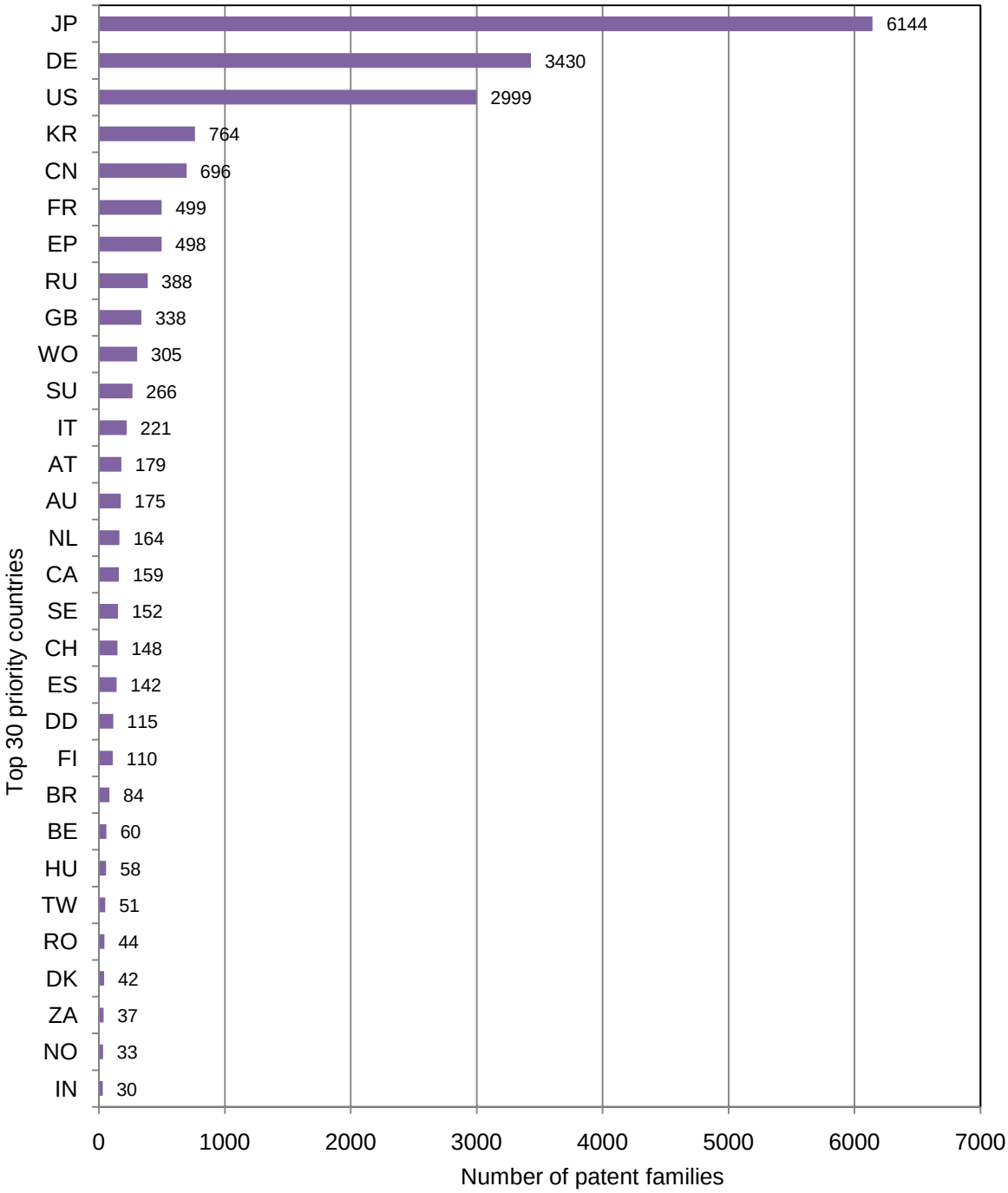

Figure 4 Number of patent families for the top 30 priority countries

Looking at the company breakdown over the years gives a more interesting picture. Figure 5 shows that Japan generally lagged behind the US and Germany prior to the mid-1990s but after this the number of inventions has almost doubled whereas the number of patents having a US or German origin have either remained steady or decreased. This rise may be explained by the increasing concern in Japan over pollution and contamination and impending legislation[5] throughout the 1990s. Clearly

[5] http://www.abanet.org/environ/committees/intenviron/newsletter/feb03/japan2/ [Accessed March 2009]

the Japanese dominance in the dataset will strongly influence the overall data characteristics.

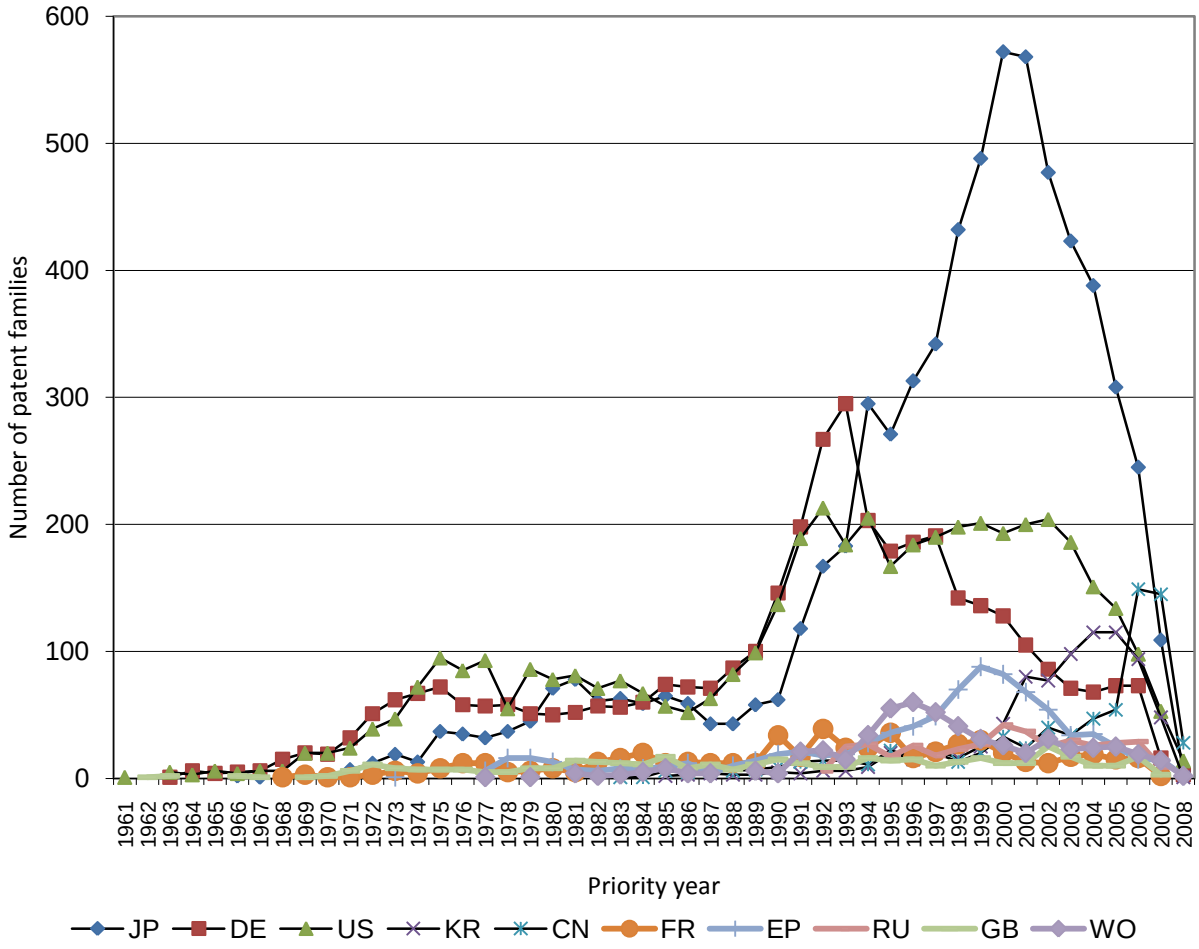

Figure 5 Number of patent families by priority country over time

2.3 Collaboration and technology transfer

Within the dataset there are multiple collaborations involving some of the top companies, as shown in Figure 6. The connecting lines indicate where collaborations have occurred. It is fairly clear from this figure that most of the collaborative activity takes place within single countries. Little cross-border collaboration is a contra-indicator of effective international knowledge transfer. Within this top 50 set of companies, there is an international collaboration involving Hitachi and Der Grüne Punkt, who worked together on the dry treatment of plastic waste (for converting into recyclable agglomerates) in WO 01/17742.

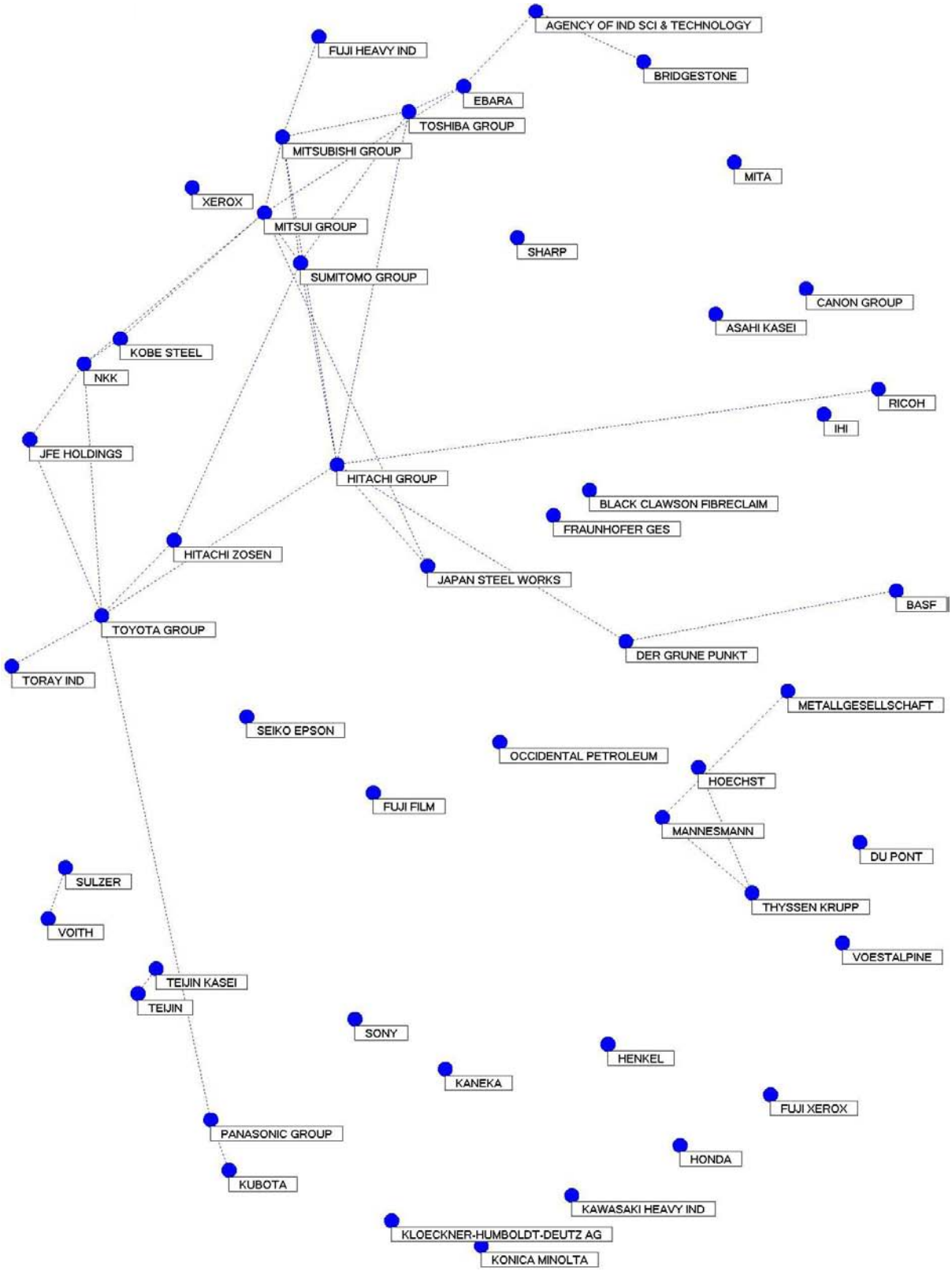

Figure 6 Indication of collaborative activity for the top 50 assignees in the dataset

2.4 Organisation profile

The majority of the dataset, as shown in Figure 7, comprises patents from corporate organisations, which is not surprising given the scale at which some of this industrial recycling is performed. Over-representation of corporate assignees in patent data tends to suggest maturity and applied industrial technology. The remaining 6% of assignees are either government or research institutions and suggests that there might also be active research or policy development work. In such a wide-ranging technology this suggests continuing importance and investment in scientific innovation.

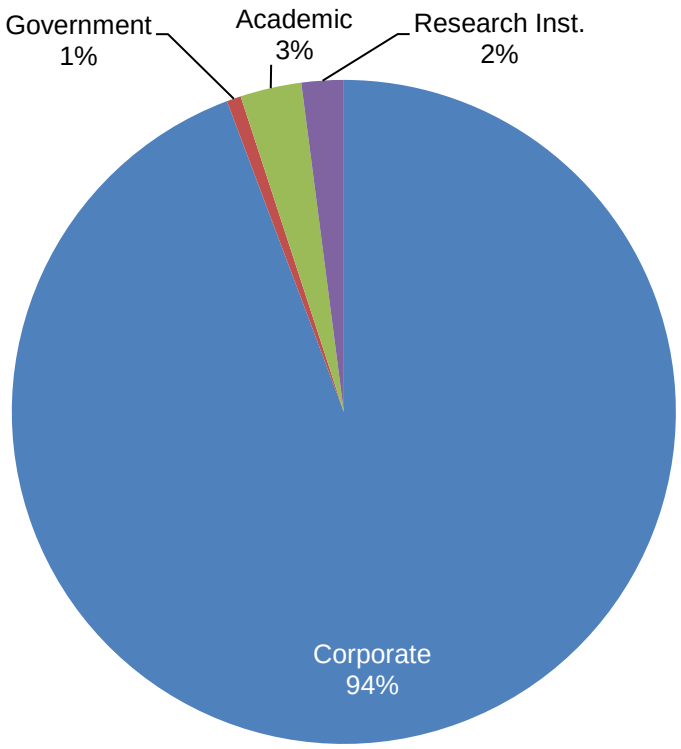

Figure 7 Distribution of institution type

2.5 Patent portfolio distribution

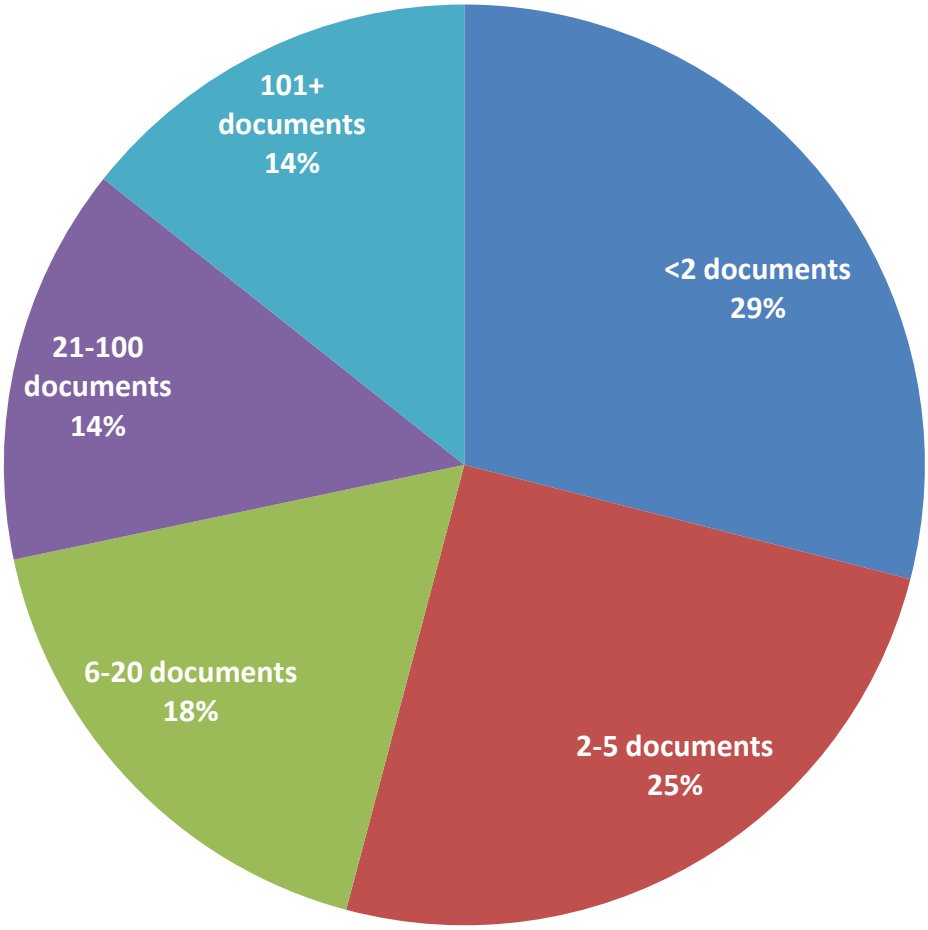

Figure 8 Distribution of patents by activity

Figure 8 shows how the records in the dataset are shared amongst assignees, and their relative strength within the area. The assignees are categorized according to the number of records they hold within the dataset; those in the highest category hold a high number of records, those in the lowest hold only one record.

The size of each segment shows the number of records, not the number of organisations so in theory the larger the high-value segments, the more the dataset is dominated by assignees having large portfolios (potentially indicating a mature technology). If dominated by lower-value segments, this shows a large number of smaller portfolios (potentially indicating a non-incremental, evolving technology area). In the case of this dataset it appears that there is a good mixture of portfolio sizes, suggesting that whilst some areas of technology are mature (14% of assignees having more than 100 documents), there is a history of sector-penetrative development with just over half of assignees having 5 or less patent families to their name. This may indicate consistent development and application of scientific advances, evolving technical and social challenges to which technical solutions are directed, or difficulties to new entrants who are unable to build and sustain a sector-presence.

2.6 Inventor turnover

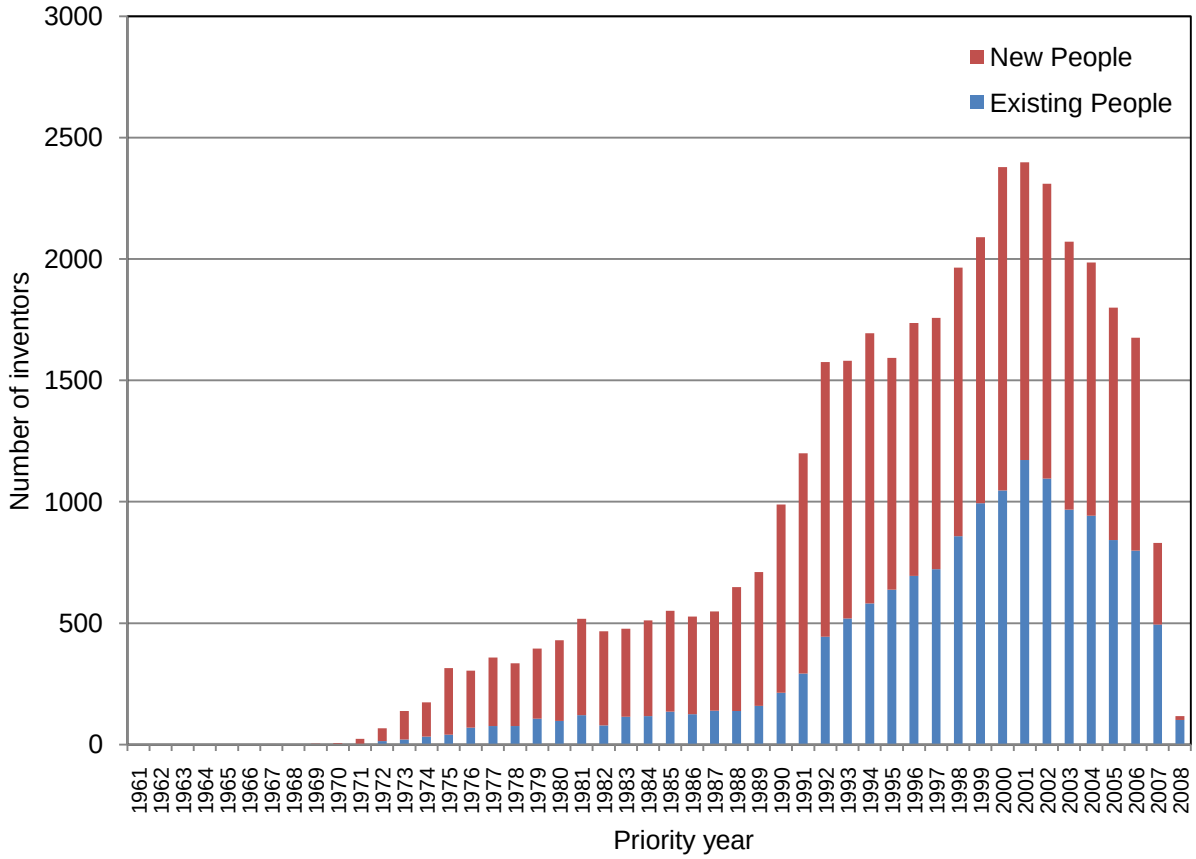

Figure 9 Number of active inventors

Figure 9 is the result of analyzing the patent information to determine how often the same inventors are listed on patents in subsequent years. In this dataset, there seems to be a consistent ratio of new inventors to existing inventors, though in absolute terms it would appear that there are more new inventors almost each and every year. In a technology area which exhibits signs of maturity, one may expect the numbers of existing inventors to be the predominant factor. This dataset, as shown in Figure 8, comprises a mixture of some assignees with large portfolios with others having smaller portfolios; a trend which seems to be reflected in the year-on-year higher ratio of new to existing inventors. A persistent and on-going level of new investment and new entrants to the sector is therefore suggested.

2.7 Technology turnover

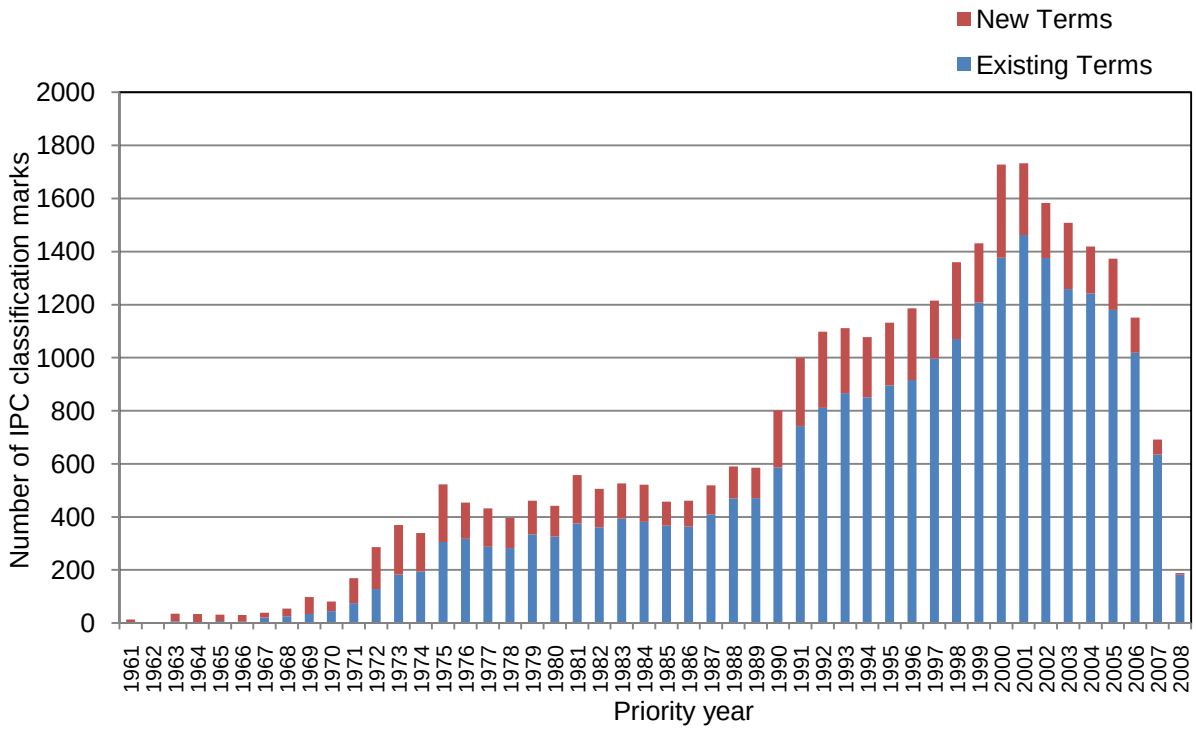

Figure 10 Number of technology terms used

In view of the distribution of company types and their inventor turnover, as discussed above, Figure 10 shows that there is a good core base of technological innovation. The largely blue areas of the graph imply that most inventions build heavily on areas that have been worked in before. However, the red areas do indicate that new technologies are being worked on consistently over time therefore also reinforcing the impression that the dataset is a combination of both underlying mature and emerging technologies.

2.8 Key inventors

The main inventors working across the technologies are, not surprisingly, Japanese. Table 2 below summarises the activities of the top 5 inventors. What is noticeable is the vast number of records each inventor has, showing true expertise in their fields.

Number of Records	Person	Top Organization	Top-3 Collaborators (people)	Year Range	Percentage of Records in Last-3 Years	Top Technology Terms	Unique Technology Terms
63	SATO K	IS KK [18]	INADA S [20]; ISHIDA K [9]; MIYAMOTO M [7]	1983 - 2006	2% of 63	C08J11/24 [21]; C07C69/82 [17]; B09B3/00 [10]; C07C67/03 [10]; B29B17/02 [10]; C08J11/16 [10]	C07C29/128 [3]; C07B37/06 [2]; C07C27/00 [2]; C07C69/76 [2]; B01J27/232 [5]; H05B6/80 [2]
43	ITO M	AGURO GIJUTSU KK [13]	TAKAKURA C [7]; MIURA Y [7]; OGINO E [7]	1980 - 2005	0% of 43	B03B5/28 [18]; B09B5/00 [15]; B29B17/00 [14]	B29C59/00 [2]; B03B5/12 [2]; B01J29/86 [2]
37	KOBAYASHI Y	OIKE TEKKOSHO [26]	ISHII E [4]; SEKI M [2]; FUKUNAGA T [2]; KOYAMA Y [2]; YUKI T [2]; NAGAI M [2]; OGASAWARA M [2]	1987 - 2007	11% of 37	B09B3/00 [12]; B09B5/00 [10]; B02C23/08 [10]	B29C47/76 [2]
30	TAKAHASHI K	TAKASHIGE SANGYO KK [8]	TAKAHASHI M [3]; YAMAMOTO H [2]	1982 - 2006	3% of 30	C10G1/10 [8]; B09B3/00 [8]; B09B5/00 [8]	None
26	ITO T	ORIENT SOKKI COMPUTER KK [5]	NAKAGAWA S [4]; EGUCHI H [2]; SASAKI K [2]; KANEKO M [2]; SEKIGUCHI Y [2]; KATSURAGI H [2]; TOMIUCHI S [2]; ONO T [2]	1980 - 2007	31% of 26	B29B17/02 [11]; B09B5/00 [7]; B09B3/00 [6]; B29B17/04 [6]	G11B7/0055 [3]; G11B5/024 [2]

Table 2 Top 5 inventors

2.9 Technology Analysis

The dataset encompasses a broad range of technology marks, necessarily due to the search strategy employed. The top 30 IPC classification marks appearing in the dataset are shown in Figure 11 below. The top 10 marks are analysed in more detail in Figure 12 with brief explanations of the IPC codes used for the top 10 given in Table 3[6].

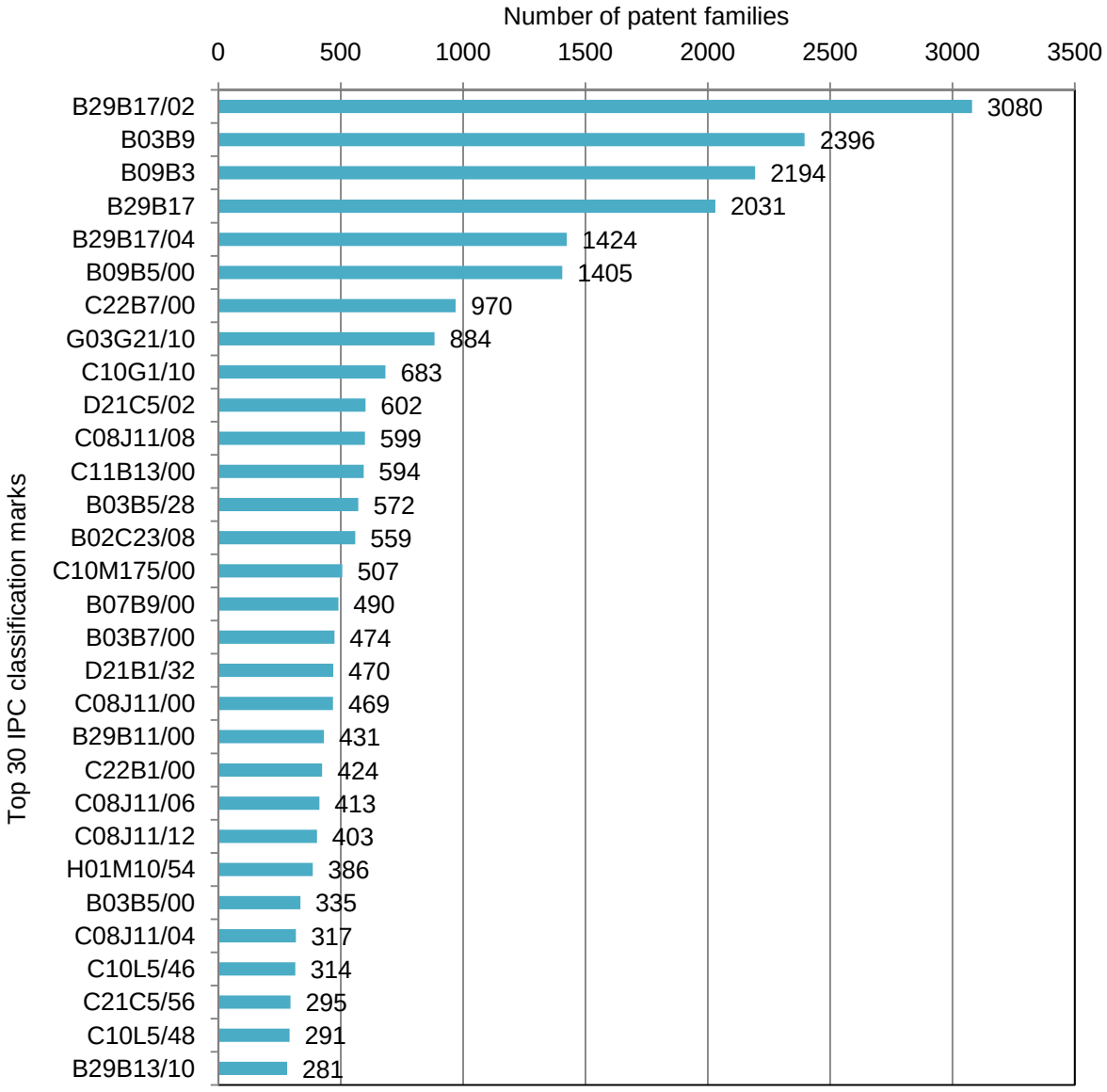

Figure 11 Patent families for the top 30 IPC classification marks

[6] Full meanings of the IPC codes are available from the WIPO website at http://www.wipo.int/classifications/ipc/ipc8/?lang=en [accessed March 2009]

The breakdown in Figure 12 of technology activity by year (as a plot of the occurrence of classification marks by priority year) reveals that early increases in patent activity in the late 1980s (as observed in Figure 1 above) were predominantly in B29B1, separating plastics, and B03B9, arrangement of refuse separating plant. Other developments followed quickly and cumulatively contribute to the overall increase in patenting through the 1990s.

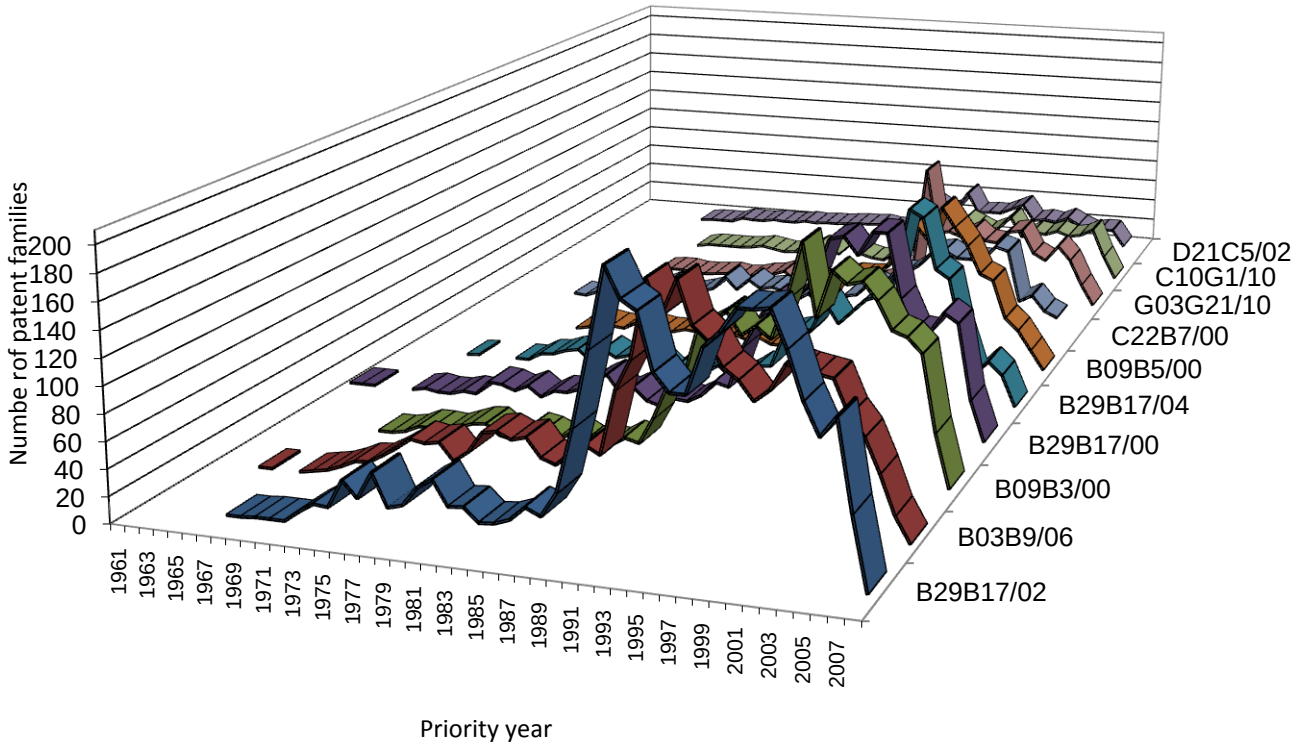

Figure 12 Number of patent families over time by technology

International Patent Classifications		Patents
B29B17/02	Separating plastics from other waste materials	3080
B03B9/06	Arrangement of refuse separating plant	2396
B09B3/00	Destroying or transforming solid waste into something useful or harmless	2194
B29B17/00	Recovery from waste material containing plastics	2031
B29B17/04	Disintegrating plastics from waste material	1424
B09B5/00	Disposal of solid waste (other than dumping/destroying)	1405
C22B7/00	Working-up raw materials other than ores	970
G03G21/10	Collecting or recycling waste developer	884
C10G1/10	Production of liquid hydrocarbon mixtures from rubber or rubber waste	683
D21C5/02	Working-up waste paper to obtain cellulose	602

Table 3 Brief explanation of the top 10 IPC marks used

Certain IPC marks will almost certainly appear in this table given that documents classified in them were included in the search in their entirety given their relevance to this technology space, such as B29B17/02, the separation of plastics from waste materials. Areas such as B09B3/00 and B09B5/00 were not explicitly included in the search as it was concluded that destruction of waste was beyond the scope of this report and that rendering something "useful" may be regarded as more than mere "upgrading"; this is also beyond the scope of this report. However, it is interesting to note that these areas are inherently linked to the general separation/recycling marks given their prominence in the top 10 table.

Table 4 gives a slightly different view of the technology space by looking at the top classification marks for each of the top 3 countries, as well as looking at the more recent technology areas. Each country, unsurprisingly, has patents in a broad range of technology areas. The recent data is not statistically significant, although it includes a range of technologies including catalysts (B01J27), joining of plastics (C08K78), filtration (B01D29), crushing (B02C7) and sieving (B07B1).

Number of Records	Country	Top Organizations	Year Range	Percentage of Records in Last-3 Years	Top Technology Terms	Recent Technology Terms
6144	JP	RICOH [300]; NKK [272]; MITSUBISHI GROUP [256]	1966 - 2008	6% of 6144	B29B17/02 [1271]; B29B17/00 [1129]; B09B3/00 [1124]	B01J27/18 [2]; B29C65/40 [2]; C08K7/14 [2]; E01C13/08 [2]; H02G3/08 [2]
3430	DE	VOITH [156]; BASF [79]; SULZER [73]	1963 - 2008	3% of 3430	B03B9/06 [784]; B29B17/02 [595]; B09B3/00 [406]	B01D29/64 [2]; B02C7/14 [2]; C10G9/18 [2]; F23J1/06 [2]
2999	US	DU PONT [41]; XEROX [30]; OCCIDENTAL PETROLEUM [28]	1961 - 2008	4% of 2999	B03B9/06 [577]; B29B17/02 [442]; C22B7/00 [319]	B07B1/49 [2]; C10L1/10 [2]

Table 4 Technology summary for the top 3 countries

Given the size of the dataset, it is perhaps useful to break it down by the constituent matter. Table 5 and Table 6 give an indication of the specific types of material, processing which is present in the dataset, along with the top companies working therein. It should be noted that these elements have been chosen partly through

their identification on the proposal and partly through observations made during the analysis process. The absence of any particular material should not be construed as meaning that they it is absent from the dataset.

However, what this analysis does provide is a first step towards identification of underdeveloped technology areas, either through analysing areas in which there are few patents or by further analysis of areas which do not explicitly appear in this report. The former is addressed in the Patent Landscape analysis in section 2.12; the latter is beyond the scope of this report.

Company (Number of relevant records out of total company records)		
1st	2nd	3rd
Polystyrene (243 records)		
MITSUI GROUP (10 of 137)	SEKISUI PLASTICS (9 of 17)	TOSHIBA GROUP (8 of 155)
PET (217 records)		
MITSUBISHI GROUP (9 of 297)	IS KK (6 of 18)	TOYOBO (4 of 18)
PVC (200 records)		
MITSUBISHI GROUP (15 of 297)	SOLVAY (6 of 20) SOLVAY & CIE (6 of 16)	NKK (5 of 275)
Polythene (176 records)		
NKK (7 of 275)	MITSUBISHI GROUP (4 of 297)	KAYABA IND (3 of 8) AKW APP & VERFAHREN (3 of 5) NORDENIA VERPACKUNGSWERKE (3 of 4) SHINAGAWA NENRYO (3 of 5) DER GRUNE PUNKT (3 of 28)
Polyolefin (115 records)		
MITSUBISHI GROUP (7 of 297) PARAFFINWERK WEBAU (7 of 17)	SHOWA ELECTRIC WIRE & CABLE (4 of 13) CHUBU DENRYOKU (4 of 12) DER GRUNE PUNKT (4 of 28) IHI (4 of 56) BASF (4 of 101)	MITSUI GROUP (3 of 137) AGENCY OF IND SCI & TECH (3 of 44)
Polypropylene (85 records)		
MITSUBISHI GROUP (6 of 297) NKK (6 of 275)	KOREA OCEAN RES & DEV INST (4 of 5)	BASF (3 of 101)
PTFE (8 records)		
RICOH (1 of 301) DU PONT (1 of 48) US GOV (1 of 26) HOECHST (1 of 29) ZUEBLIN AG ED (1 of 4) ZHONGHAO CHENGUANG CHEM INST (1 of 1)		

Table 5 Summary of top companies having plastics related patents

Company (Number of relevant records of total company records)		
1st	2nd	3rd
Lead (246 records)		
METALLGESELLSCHAFT (6 of 40)	NL IND INC (5 of 6)	KLOECKNER-HUMBOLDT-DEUTZ AG (4 of 46), METALS RECYCLING TECH CORP (4 of 12)
Zinc (192 records)		
METALS RECYCLING TECH CORP (11 of 12)	UMICORE (6 of 11)	METALLGESELLSCHAFT (4 of 40)
Copper (188 records)		
SUMITOMO GROUP (13 of 141)	NKK (6 of 275)	BASF (3 of 101), BOLIDEN AB (3 of 10), HITACHI GROUP (3 of 231), OUTOKUMPU (3 of 16), MITSUI GROUP (3 of 137)
Mercury (9 records 9)		
12 companies with 2 patents e.g. PREUSSAG AG (2 of 13)	75 companies with 1 patent	
Nickel (96 records)		
MITSUI GROUP (8 of 137)	SUMITOMO GROUP (7 of 141)	VARTA BATTERIE AG (4 of 7) CHEVRON RES CO (4 of 18)
Silver (76 records)		
HORIZONS RES INC (5 of 13)	8 companies with 2 patents	55 companies with 1 patent
Manganese (52 records)		
UNIV S. CHINA (3 of 8), SHENZHEN GEM HIGH TECH (3 of 5), NOMURA KOSAN (3 of 5)	9 companies with 2 patents	25 companies with 1 patent
Gold (47 records)		
STORAGE TECHN CORP (2 of 2) SOYUZTSVETMETAVTOMATIKA STOCK (2 of 7)	43 companies with 1 patent	
Cadmium (40 records)		
DRINKARD METALOX INC (3 of 3) METALS RECYCLING TECH CORP (3 of 12)	MITSUI GROUP (2 of 137) COMPLETE RECOVERY PROCESS (2 of 2) NIFE JUNGNER AB (2 of 4) UNIV NANJING (2 of 2)	26 companies with 1 patent
Tin (36 records)		
NIPPON MINING & METALS CO LTD (6 of 7)	30 companies with 1 patent	
Platinum (19 records)		
DEGUSSA AG (2 of 12) MITSUBISHI GROUP (2 of 297)	15 companies with 1 patent	

Table 6 Summary of top companies having patents for relating to selected elements

2.10 Detailed analysis of the top three companies

2.10.1 Legislative effect

It is beyond the scope of this report to analyse the commercial, economic or legislative context within which technology is developed. However, in observing the company data below, it should be borne in mind that the Japanese Home Appliances Recycling Law came into effect in 2001. It may be that this prompted the significant increases in patent activity prior to 2001 visible in each case below. Furthermore, the rises in patent activity throughout the mid 1990s may be explained by the technology 'race' to address growing concerns over soil pollution[7], and associated legislation such as the Basic Environment Law, legislated in 1993[8].

2.10.2 Ricoh

The Ricoh portfolio, summarised in Table 7, has 301 patent families listed spanning back to 1971, indicating that Ricoh is an established company in the sector. As shown in Figure 13, very little work in the name of Ricoh was carried out in the overall technology space until 1994 when filings increased significantly. This feature may evidence an acquisition or a change in patent filing strategy. Subsequent filings only ever peak at just over half the level of 1994 but show that Ricoh have maintained an interest in the areas of technology under consideration.

Company Name	RICOH		
Number of Records	301		
Range of Years	1971 - 2008		
Peak Year	1994 [50 Records]		
Average People / Record	2.8		
Field Choices	**Field Name**	**Number of entries**	**Field Coverage**
People	Inventors	452	98%
Organization	Patent Assignees - final cleaned list	8	100%
Country	Priority Countries	5	100%
Years	Priority Years	48	100%
Technology	International Classifications (Advanced)	166	100%

Table 7 Summary of the Ricoh dataset

[7] http://www.abanet.org/environ/committees/intenviron/newsletter/feb03/japan2/ [Accessed March 2009]
[8] http://www.env.go.jp/en/laws/policy/basic/index.html [Accessed March 2009]

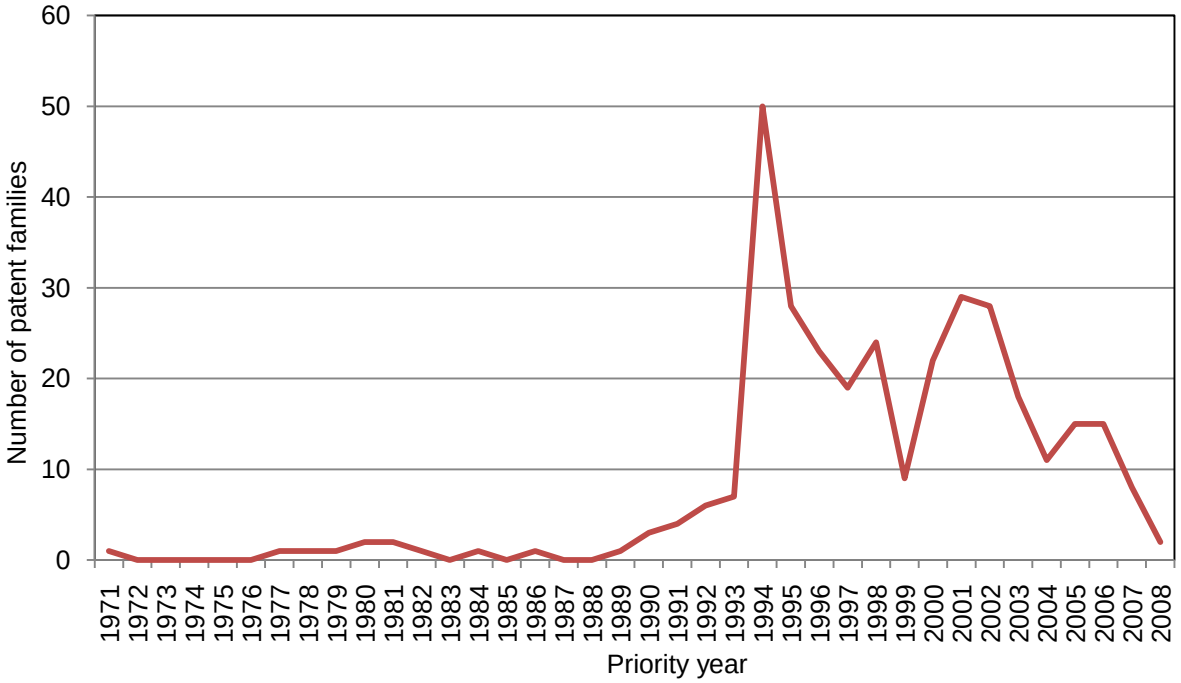

Figure 13 Profile of Ricoh patents over time

As with a lot of major Japanese corporations, most of the inventive work is carried out in Japan, as is clearly shown in Figure 14.

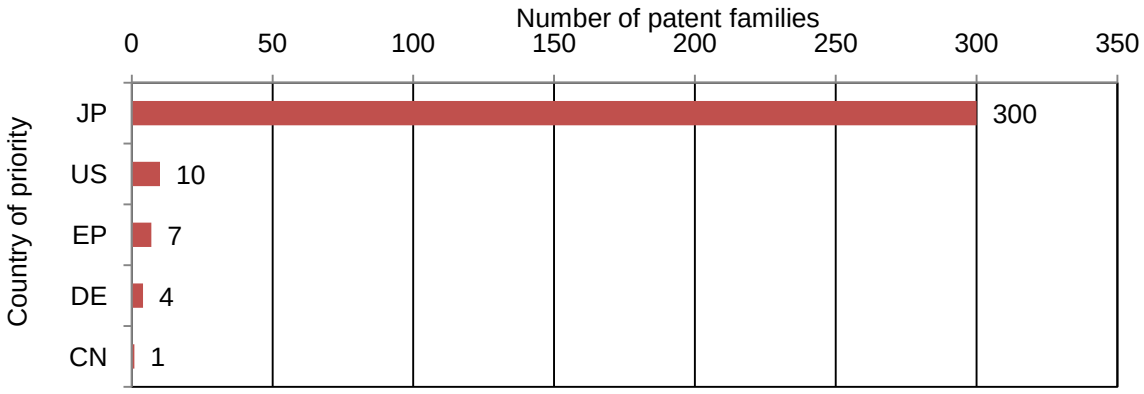

Figure 14 Country of priority for the Ricoh patents

It is interesting to see that the top 15 IPC classification marks all fall within the IPC subclass G03G which relates to electrographic-type inventions. This is not at all surprising given Ricoh's history of manufacturing printing/photocopying devices. The top IPC mark for the dataset by far is G03G21/10 which relates directly to the collection or recycling of waste developer.

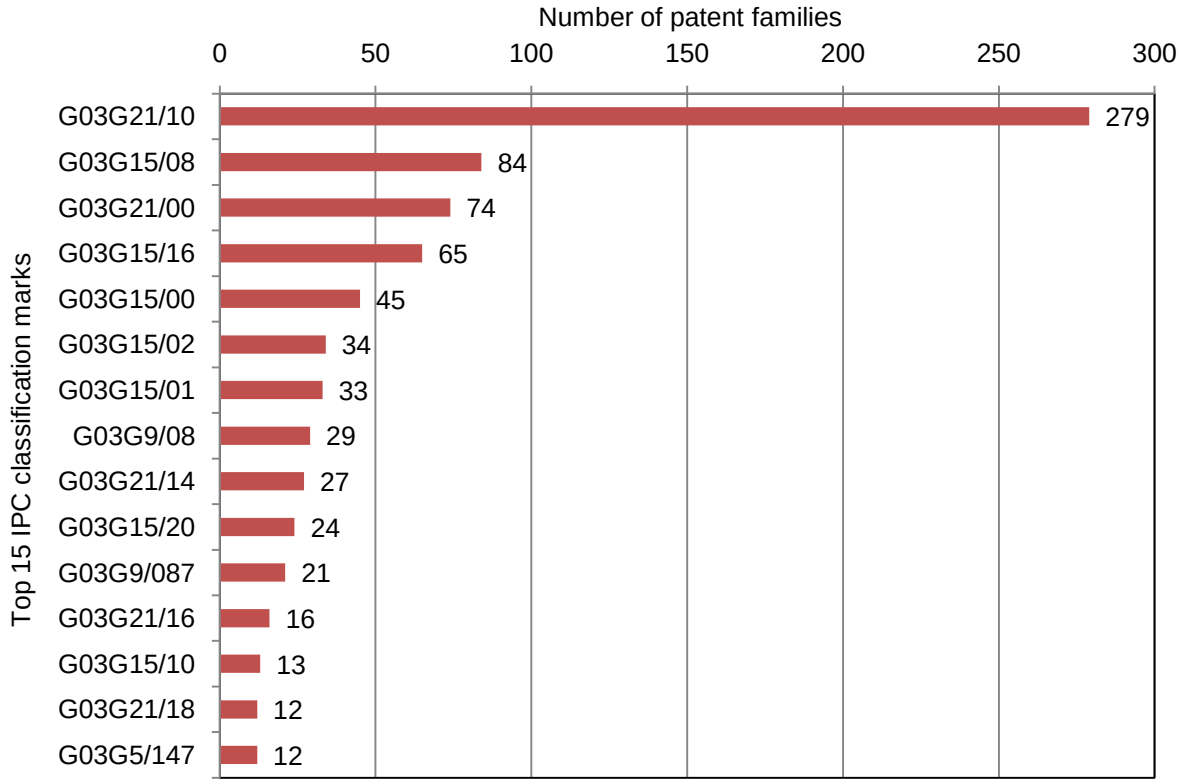

Figure 15 Top 15 classification terms applied to the Ricoh patents

Given the size of the dataset, there are not many collaborations involving other companies. It is interesting to note, however, that those inventions which do arise from collaborations are in different technology areas to their key competences, such as C22B1/244 (binding ores or scrap), C22B21/00 (obtaining aluminium), and B29B17/02 (separating plastics from other waste materials) as shown in Table 8 below.

Number of Records	Collaborative Organization Names	Top-3 People	Top Country	Range of Years	Percentage of Records in Last 3 Years	Top Technology Terms
3	SHINKO FLEX CO LTD	TORII K [3]; MATSUURA H [3]; MORII Y [3]	JP [3]	2001 - 2004	0% of 3	G03G9/08 [3]; C22B1/244 [3]; C22B21/00 [3]
3	SHINKO FREX INC	TORII K [3]; MATSUURA H [3]; MORII Y [3]	JP [3]	2001 - 2004	0% of 3	G03G9/08 [3]; C22B1/244 [3]; C22B21/00 [3]
2	NIIBU KK	OKA K [2]; SOMA S [2]; ITO C [2]; MIYAGAWA F [2]	JP [2]	2001 - 2001	0% of 2	B29B17/02 [2]; B29B17/04 [2]; B03C1/00 [2]; B03C1/02 [2]; B07B1/28 [2]; B07B9/00 [2]
2	A & A TECHNOS KK	OKA K [2]; SOMA S [2]; ITO C [2]; MIYAGAWA F [2]	JP [2]	2001 - 2001	0% of 2	B29B17/02 [2]; B29B17/04 [2]; B03C1/00 [2]; B03C1/02 [2]; B07B1/28 [2]; B07B9/00 [2]
1	NISSHIN CHEM IND CO LTD	None	None	2006 - 2006	100% of 1	None
1	HITACHI GROUP	None	None	1997 - 1997	0% of 1	None

Table 8 Collaborator profile for Ricoh

2.10.3 Mitsubishi

The Mitsubishi dataset, summarised in Table 9, is of a comparable size to that of Ricoh. The 297 patent families spanning back to 1973 is again a sign of an established company. In a similar manner to the Ricoh dataset, the Mitsubishi patent portfolio is sparse in the earlier years. In 1992, the level of innovation jumps around ten-fold and since then it has been relatively active; given the small sample of data, no real conclusions can be drawn about the year-on-year differences in absolute figures.

Company Name	MITSUBISHI GROUP		
Number of Records	297		
Range of Years	1973 - 2007		
Peak Year	2000 [24 Records]		
Average People / Record	3.2		
Field Choices	**Field Name**	**Number of entries**	**Field Coverage**
People	Inventors	553	88%
Organization	Patent Assignees - final cleaned list	43	100%
Country	Priority Countries	6	89%
Years	Priority Years	48	89%
Technology	International Classifications (Advanced)	459	100%

Table 9 Summary of the Mitsubishi dataset

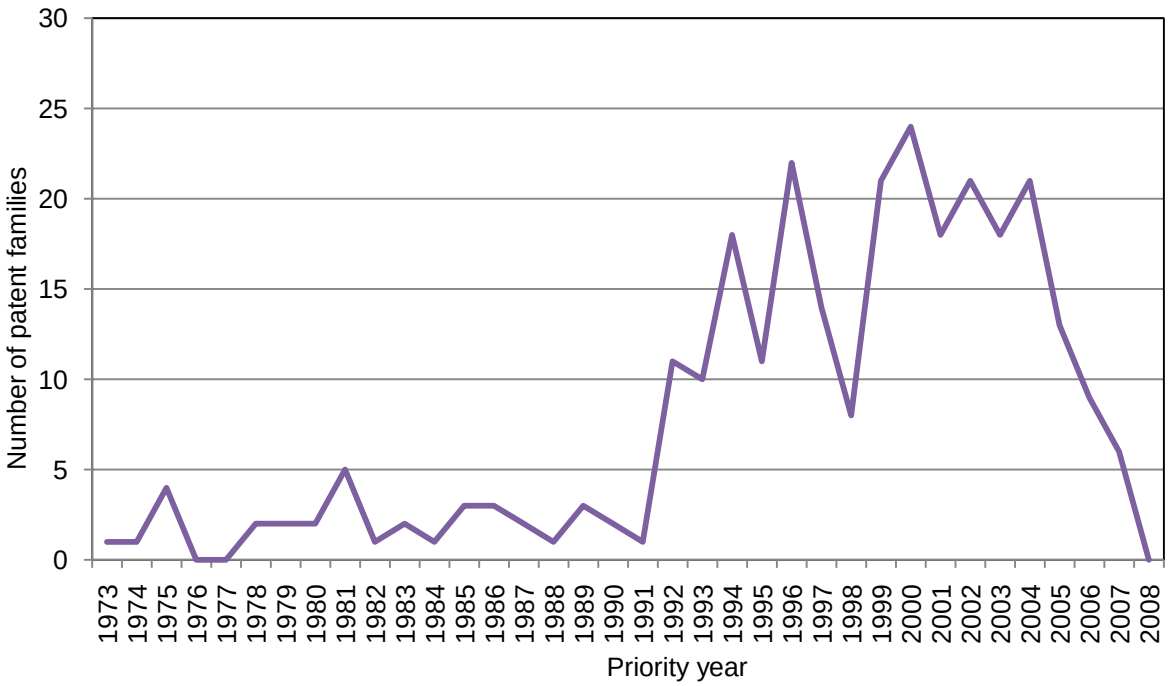

Figure 16 Profile of Mitsubishi patents over time

The country of priority is again very similar to Ricoh: Figure 17 shows the predominance of patents with a Japanese priority.

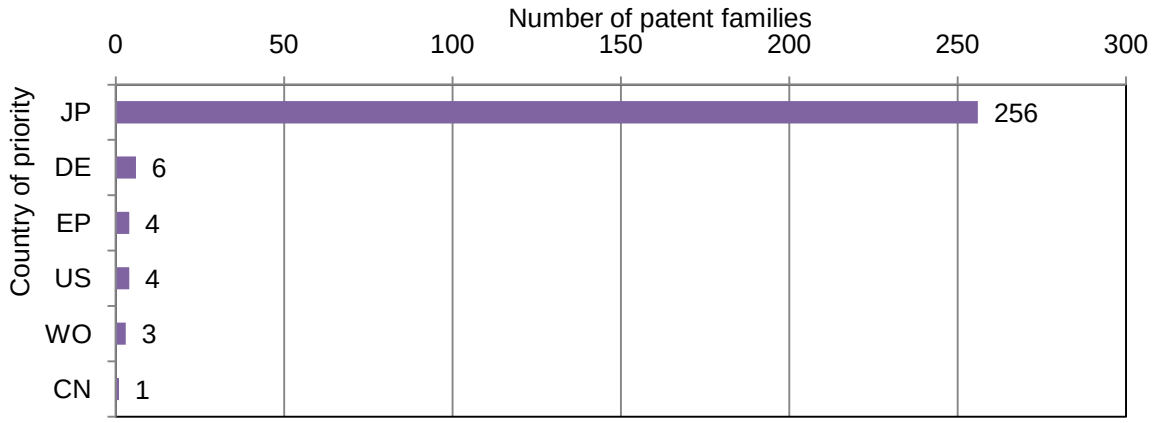

Figure 17 Country of priority for the Mitsubishi patents

Compared with Ricoh, it is noticeable that Mitsubishi don't seem to have concentrated solely in a single sub-sector. The portfolio includes, amongst other things, B29B17 marks (recovery of plastics from waste material containing plastics), B09B marks (disposal of solid waste), C10G1/10 (production of liquid hydrocarbons from rubber/rubber waste) and C08J11 marks (working up of waste materials e.g. polymers).

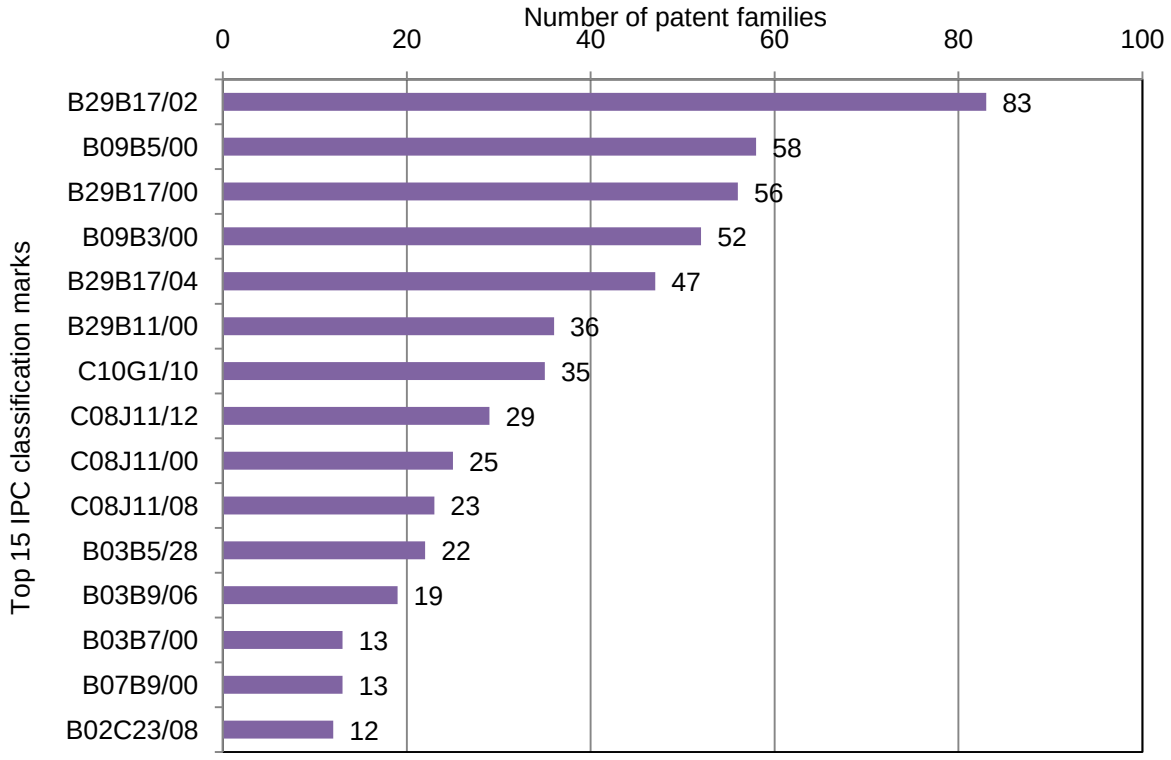

Figure 18 Top 15 classification terms applied to the Mitsubishi patents

Across many different areas of technology, there is some collaborative activity occurring solely with Japanese companies, as shown in Table 10 below.

Number of Records	Collaborative Organization Names	Top-3 People	Top Country	Range of Years	Percentage of Records in Last-3 Years	Top Technology Terms
3	FURUKAWA CO LTD	ITO R [3]; TANMACHI M [3]; TSUDA H [3]	JP [3]	1993 - 1996	0% of 3	C10G1/10 [3]; B09B3/00 [2]
3	TOHOKU ELECTRIC POWER CO	MORIYA T [3]; SAITO Y [3]; TABATA M [3]; MATSUBARA W [3]	JP [3]	1999 - 1999	0% of 3	C08J11/14 [3]; C10G1/10 [3]
3	HITACHI GROUP	ITO R [3]; TANMACHI M [3]; TSUDA H [3]	JP [3]	1993 - 1996	0% of 3	C10G1/10 [3]; B09B3/00 [2]
3	DENSEN SOGO GIJUTSU CENT SH	ITO R [3]; TANMACHI M [3]; TSUDA H [3]	JP [3]	1993 - 1996	0% of 3	C10G1/10 [3]; B09B3/00 [2]
3	CHUO DENKI KOGYO KK	OKADA N [3]; KITAMURA H [3]; SHIRAISHI T [3]; SUGATA Y [3]; SUZUKI T [3]; KOJIMA Y [3]	JP [3]	1996 - 1997	0% of 3	H01M10/54 [3]; B03B5/00 [2]
3	FUJI HEAVY IND	YAMAMOTO H [3]; TOMONO Y [2]	JP [3]	1993 - 1994	0% of 3	B09B5/00 [3]; B29B13/10 [3]; B29B17/00 [3]; B29B17/04 [3]
3	PANAC KOGYO KK	ITO N [3]; NISHIDA K [3]; OOTA K [3]	JP [3]	2004 - 2004	0% of 3	B29B17/02 [3]
3	FUJIKURA LTD	ITO R [3]; TANMACHI M [3]; TSUDA H [3]	JP [3]	1993 - 1996	0% of 3	C10G1/10 [3]; B09B3/00 [2]
3	SHOWA ELECTRIC WIRE & CABLE CO	ITO R [3]; TANMACHI M [3]; TSUDA H [3]	JP [3]	1993 - 1996	0% of 3	C10G1/10 [3]; B09B3/00 [2]
3	SUMITOMO GROUP	ITO R [3]; TANMACHI M [3]; TSUDA H [3]	JP [3]	1993 - 1996	0% of 3	C10G1/10 [3]; B09B3/00 [2]
2	TAIYO DENKO KK	KASHIWAGI H [2]	JP [2]	1990 - 1992	0% of 2	B29B17/02 [2]
2	MITSUI GROUP	None	JP [2]	1975 - 2000	0% of 2	B29B17/02 [2]
2	TOSHIBA GROUP	None	JP [2]	1996 - 1999	0% of 2	None
2	KORITSU DAIGAKU HOJIN OOSAKA FURITSU DAI	YOSHIDA H [2]; TAKAYANAGI H [2]	JP [2]	2006 - 2006	100% of 2	None

Table 10 Collaborator profile for Mitsubishi

2.10.4 NKK

The NKK dataset, summarised in Table 11, is 5-10% smaller than Ricoh and Mitsubishi but the 275 patent families spanning back to 1975 is again a sign of an established company. In a similar manner to both Ricoh and Mitsubishi, the NKK patent portfolio is sparse in the earlier years. In 1995, the level of innovation jumps significantly and since then it has been relatively active. The level of filings shows a good period of activity between 1997 and 2001 but activity has dropped off since then.

Company Name	NKK		
Number of Records	275		
Range of Years	1975 - 2006		
Peak Year	1998 [41 Records]		
Average People / Record	4.3		
Field Choices	**Field Name**	**Number of entries**	**Field Coverage**
People	Inventors	456	97%
Organization	Patent Assignees - final cleaned list	51	100%
Country	Priority Countries	7	100%
Years	Priority Years	48	100%
Technology	International Classifications (Advanced)	391	100%

Table 11 Summary of the NKK dataset

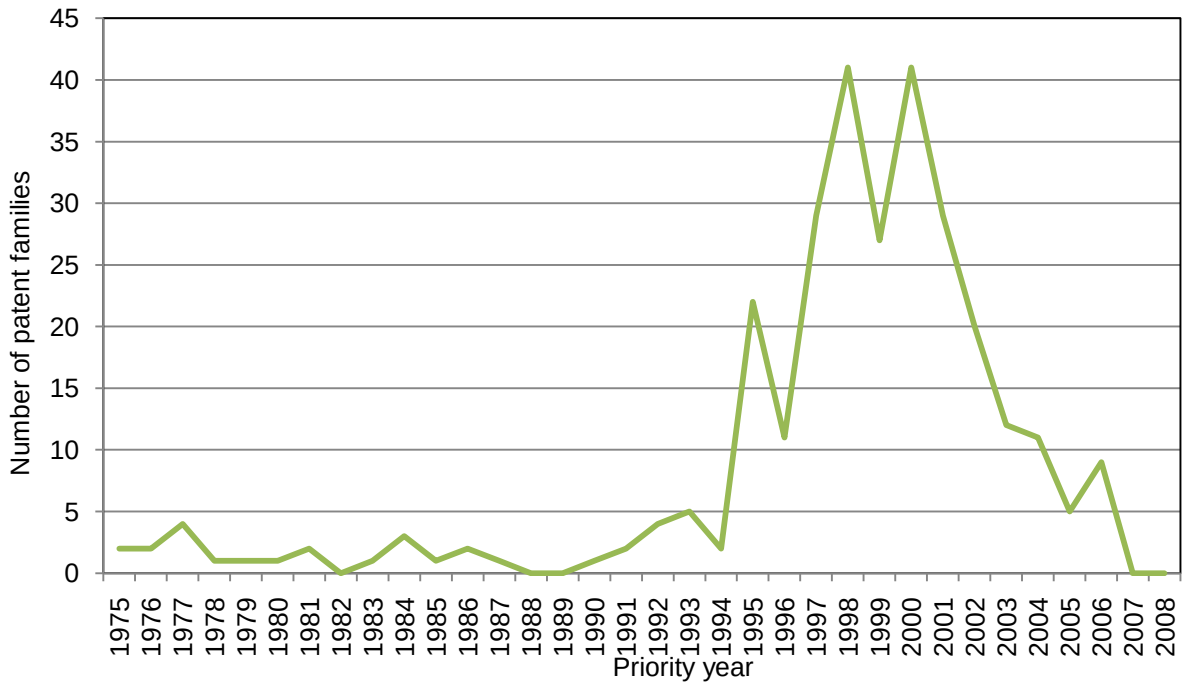

Figure 19 Profile of NKK patents over time

As with the other the Ricoh and Mitsubishi datasets, Japan is the country of priority on virtually all patent filings, as shown in Figure 20.

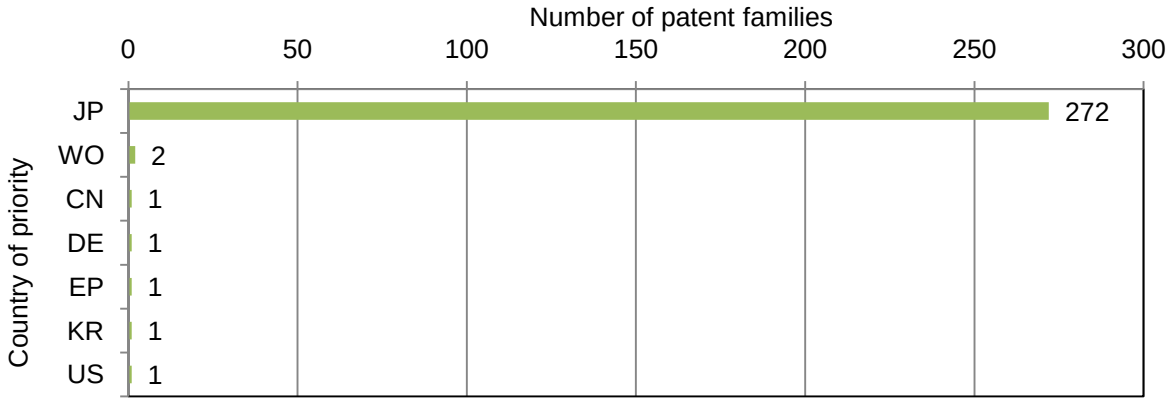

Figure 20 Country of priority for the NKK patents

The range of technologies being worked on, as shown in Figure 21, is similar to those worked on by Mitsubishi and therefore includes, amongst other things, B29B17 marks (recovery of plastics from waste material containing plastics), B09B marks (disposal of solid waste), C10G1/10 (production of liquid hydrocarbons from rubber/rubber waste) and B02C23/08 (separating and sorting of crushed/disintegrated material).

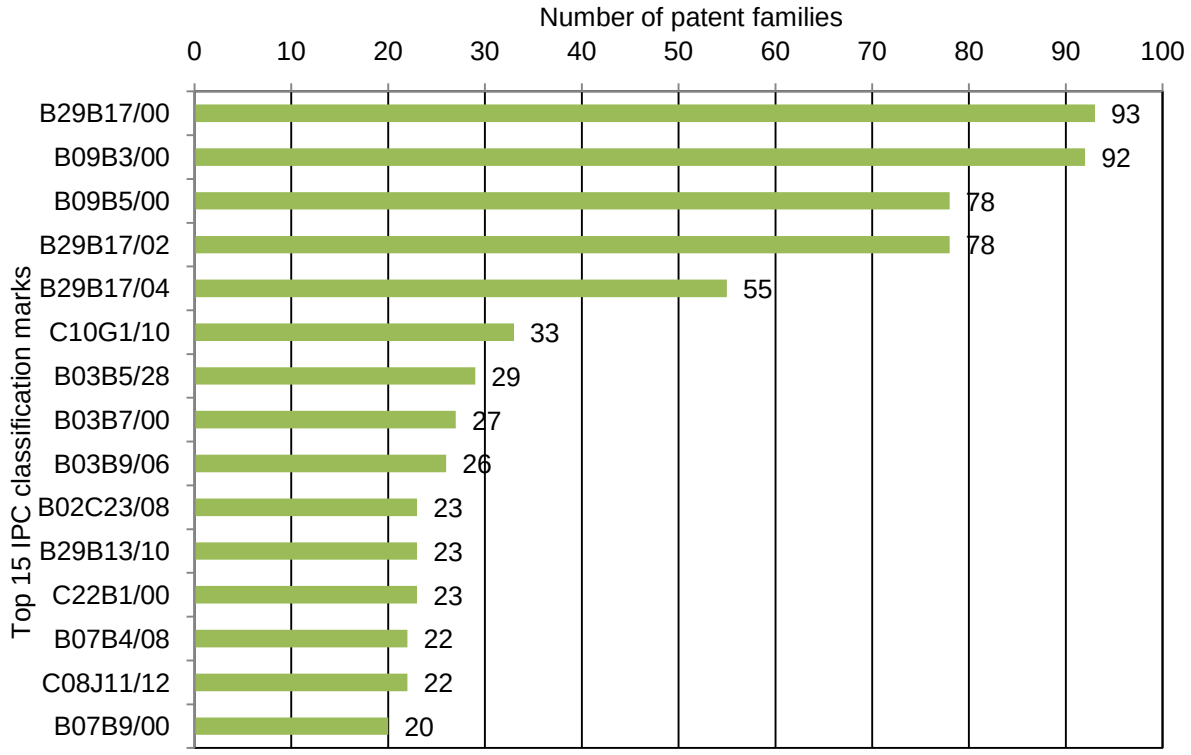

Figure 21 Top 15 classification terms applied to the NKK patents

There is some collaborative activity occurring across many different areas of technology, though solely with Japanese companies, as shown in Table 12 below. It is noticeable that the level of collaboration with other companies is higher than both Ricoh and Mitsubishi.

Number of Records	Collaborative Organization Names	Top-3 People	Top Country	Range of Years	Percentage of Records in Last-3 Years	Top Technology Terms
11	NITTETSU PLANT SEKKEI KK	KOBAYASHI A [3]; MORI Y [3]; SATO T [2]; SHIBATA T [2]; ICHIE A [2]; MITARAI S [2]; NAKAMURA M [2]	JP [11]	1986 - 2006	18% of 11	B09B3/00 [5]; C10G1/10 [3]; B09B5/00 [2]; B03B5/00 [2]; B29B17/00 [2]; B29B17/02 [2]; B03B7/00 [2]; B03C1/00 [2]; B03C1/02 [2]; C08J11/12 [2]
10	JFE HOLDINGS	ASANUMA M [3]; OKADA T [3]; ARIYAMA T [3]	JP [10]	1996 - 2002	0% of 10	B09B3/00 [4]; B29B17/02 [4]; B09B5/00 [3]; B29B17/00 [3]
7	SHIN NIPPON SEITETSU KK	HARADA T [2]; UEMATSU H [2]; KATO K [2]	JP [7]	1995 - 2000	0% of 7	C21C5/56 [4]; F27B3/18 [3]; F27D13/00 [3]
4	SHIN NITTETSU ENG KK	MORI Y [4]; NAKAMURA M [3]; SATO T [2]; SHIBATA T [2]; ICHIE A [2]	JP [4]	2006 - 2006	100% of 4	B29B17/00 [3]
3	KOKAN MINING CO LTD	WATANABE T [3]; OSHIDA H [2]; YAMAGUCHI A [2]	JP [3]	2002 - 2004	0% of 3	B09C1/02 [3]; B09C1/08 [3]; B03B7/00 [3]; B03B9/06 [3]
3	TATSUMI AIR ENG KK	NODA Y [3]	JP [3]	2000 - 2000	0% of 3	B09B5/00 [2]; B29B17/02 [2]; B29B17/04 [2]
3	TETSUBARA KK	ABE H [2]; SAKATANI M [2]; SATO N [2]; IBARAKI T [2]	JP [3]	2002 - 2005	0% of 3	B03B5/00 [3]; B03B9/06 [3]; C04B18/14 [2]; C04B5/02 [2]
2	NKK PLANT KENSETSU KK	None	JP [2]	1999 - 2001	0% of 2	B09B5/00 [2]
2	MITSUI GROUP	None	JP [2]	2001 - 2002	0% of 2	None
2	SHINETSU CHEM IND CO LTD	KOBAYASHI Y [2]; SEKI M [2]; FUKUNAGA T [2]; YUKI T [2]	JP [2]	2001 - 2002	0% of 2	C08J11/08 [2]
2	NIPPON NOSUISAN CON	SEKINO A [2]; SHIMADA Y [2]	JP [2]	1976 - 1977	0% of 2	None
2	NIPPON S E C L	None	JP [2]	2002 - 2003	0% of 2	B09B3/00 [2]
2	NIPPON STEEL CHEM CO	None	None	1979 - 1992	0% of 2	None

Table 12 Collaborator profile for NKK

2.11 British patent families

British companies account for around less than 2% of the dataset, with no single company having a particularly large portfolio. The top 10 British companies are shown in Table 13 below[9] and it can be clearly seen that these companies have not had any recent patent filings in this technology space.

Company name	Latest priority date	Number of patent families
ICI PLC	1996	8
J MCINTYRE MACHINERY LTD	1999	8
ALLIED COLLOIDS LTD	1996	6
UNILEVER	1989	5
NATIONAL RESEARCH DEVELOPMENT CORP	1988	5
BP	2003	4
CORUS	1998	4
BOC GROUP INC	1975	3
ECC INTERNATIONAL LTD	1996	3
STEIN ATKINSON STORDY LTD	1991	3

Table 13 Top 10 British companies

Examples of more recent British innovative activity spanning across multiple technology areas is shown in Table 14 below. It is interesting to note the range of applicant type involved including single applicants, small companies, university-related companies and large corporations.

[9] ICI is now part of the Dutch group Azko Nobel, BOC is part of the German Linde Group and Corus is now part of the Indian Tata Group.

Patent number	Applicant	Topic	Priority year
EP1984436	Rubber Regen	Breaking chemical cross-links in vulcanized rubber	2006/2007
WO2008129287	Finlay Hydrascreens Omagh Ltd	Crushing machine for aggregate and stone	2007
WO2008015424	Reclaim Resources	Treating domestic was materials e.g. plastics to form diesel fuel	2007
WO2008053163	Agritec Systems Ltd	Extracting oil from food waste	2006
GB2435234	N Perks	Removing rubber from motor vehicle tyre	2006
GB2441998	Vetco Gray Controls	Integrated waste management facility for well installation	2006
WO2008059209	Ken Mills Eng Ltd	Paper sorting apparatus	2006
EP1991712	Johnson Matthey	Reprocessing Fischer Tropsch catalyst	2006
WO2008056125	Cambridge Enterprise	Recovery of lead from waste using citric acid solution	2006
GB2424651	AEA Technology	Recovering metals such as cobalt from lithium ion batteries	2006
WO2008017843	Waste and resources action programme	Recycling PET from waste material	2006
WO2007026167	Haydale Ltd	Recycling polymeric materials e.g. cured rubber	2006
GB2438076	W Edmondson	Rotary drum screen for waste water processing plant	2006
GB2446797	Used Tyre Distillation Res Ltd	Recycling carbon-containing material	2006
WO2007068656	Crownstone Ltd	Transforming recycled polyolefin into performance enhanced polymeric material	2006
WO2007091085	University College Cardiff Consultants	Transition metal catalyst removal	2006
GB2444239	Future Fuels Int Ltd	Treating municipal and selected commercial waste (plastics) to produce environmentally friendly fuel	2006

Table 14 Recent patenting activity of British companies/applicants

2.12 Patent landscape analysis

2.12.1 Overall technology map

A list of patents comprising the complete dataset used in the analysis in the previous sections was taken and used as input to patent landscape mapping software. Patents are represented on the map by dots and the more intense the concentration of patents (i.e. the more closely related they are) the higher the topography as shown by contour lines. It should be noted given the number of patent documents involved, not all of them are initially seen on the map as dots; zooming into a particular section would result in more dots appearing.

The patents are grouped according to the occurrence of keywords in the title and abstract and example keywords appear on the map.

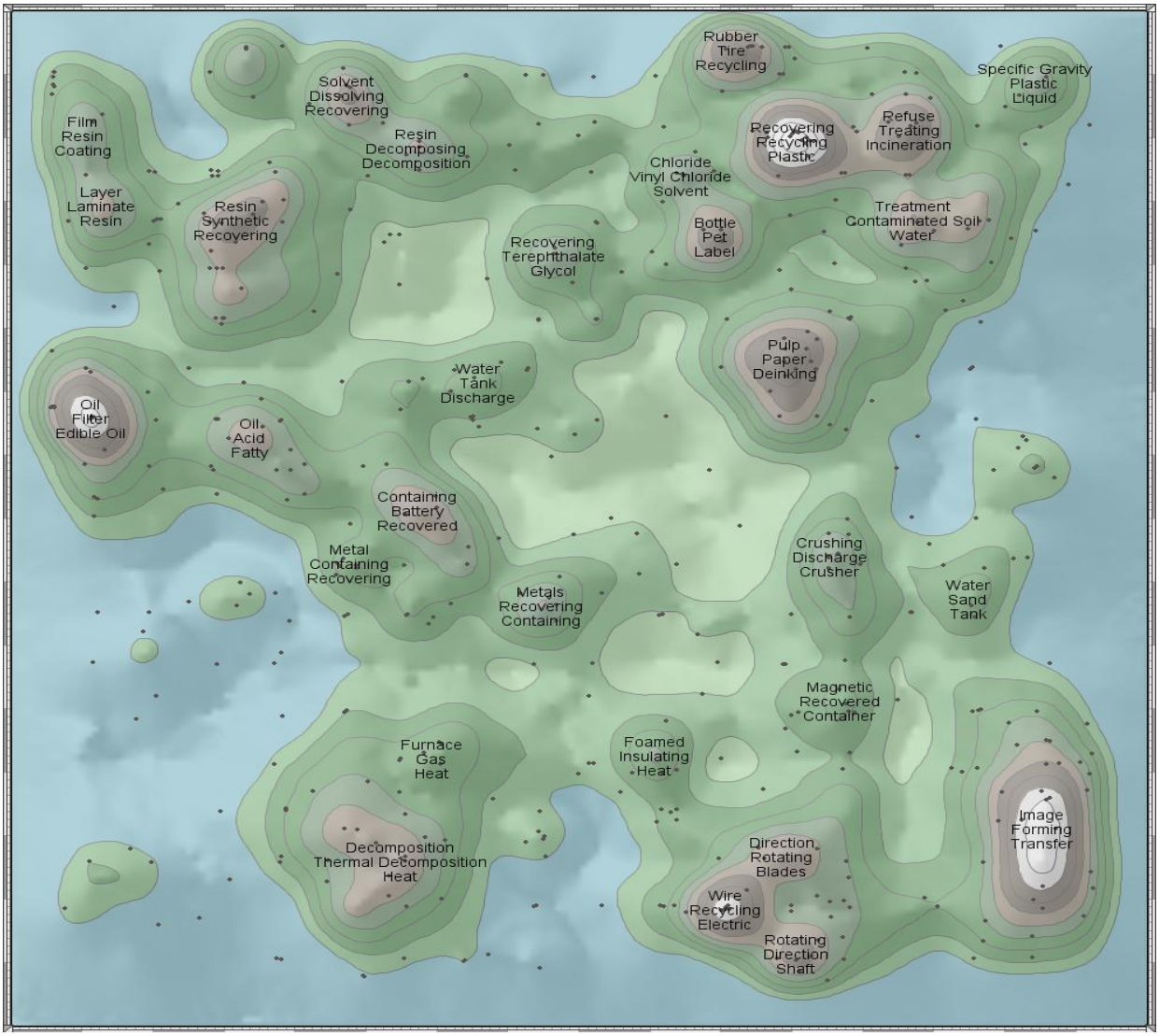

Figure 22 Patent landscape map of entire dataset © Thomson Reuters

2.12.2 Underdeveloped technology areas

One of the desirables specified in the project proposal was identification of underdeveloped technology areas; areas or materials for which technology solutions enabling separation, purification or upgrading of waste materials are not yet widely developed.

By definition this is non-trivial; patent informatics facilitates identification of characteristics, trends and relationships which *exist* within data. Identification of those which are absent is less straight-forward.

Nonetheless, by examining areas of the patent map which are low-lying in the overall landscape, areas of low technological density can be uncovered. These may relate to areas which are dominated by a few strong patents, and are thus under populated, or areas for which patentable technology is not appropriate, or where solutions are not needed.

These areas may also relate to emergent areas. Developing technology tends to be found in the low-lying areas which are analogous to valleys and estuarine areas on a conventional map.

Initially, materials of interest, as discussed in Table 5 and Table 6, were marked on the map (see Figure 23: plastics marked in green and metals marked in red) to see if there were any areas which were coincidentally low-lying and lacking in these materials. One such area of interest has been highlighted and expanded in Figure 24.

Figure 23 Patent landscape showing materials of interest (see Table 5 and Table 6)

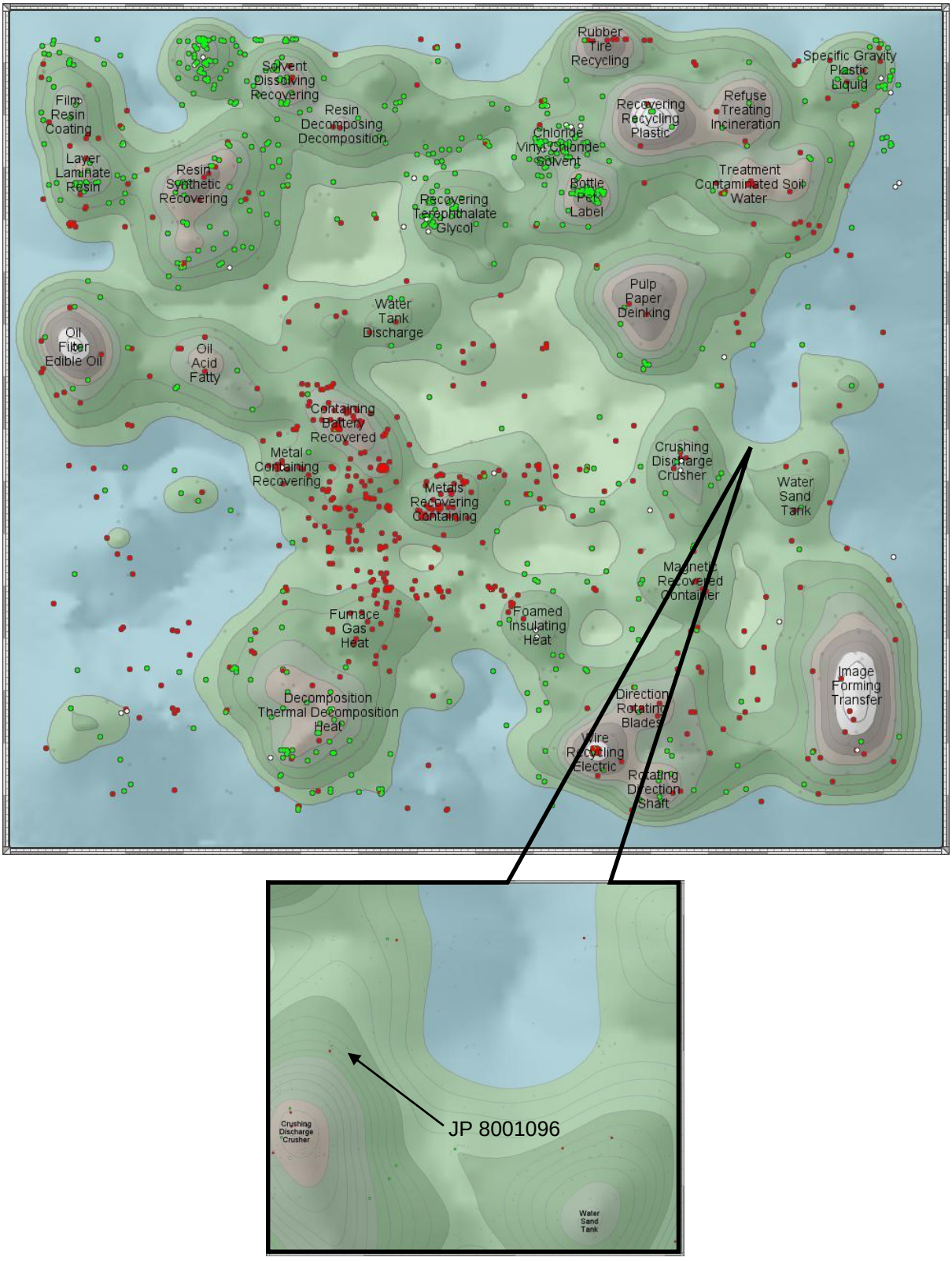

Figure 24 Potential area of interest

JP 8001096 (Sekisui Chem) is an example patent in the area which overlooks the estuary feature on the right hand side of the map and is shown in both Figure 24 and Figure 25. This patent relates to separation and recovery of plastic from glass-fibre reinforced plastic (GRP) by crushing composite material and subjecting it to vibration. By blowing the material with ionised air, electrostatic charge is removed from the crushed plastic and glass fibre thereby allowing the glass fibre particles to be recovered through a suction duct. EP 633110 (Phoenix Fibreglass Inc.) relates to a similar process.

Interestingly, other related crushing and recovery systems on the map do not relate specifically to GRP composite materials recovery. Alternative GRP separation and recovery systems can use heat or pulverisation to provide a powder filler (without necessarily separating glass and plastic). Others such as JP 2004202302 further incorporate a metal recovery step to enable recycling of GRP printed circuit boards (PCB).

GRP recycling, especially PCB, where the GRP is itself subject to separation into constituent materials may therefore be under-represented in patented technology.

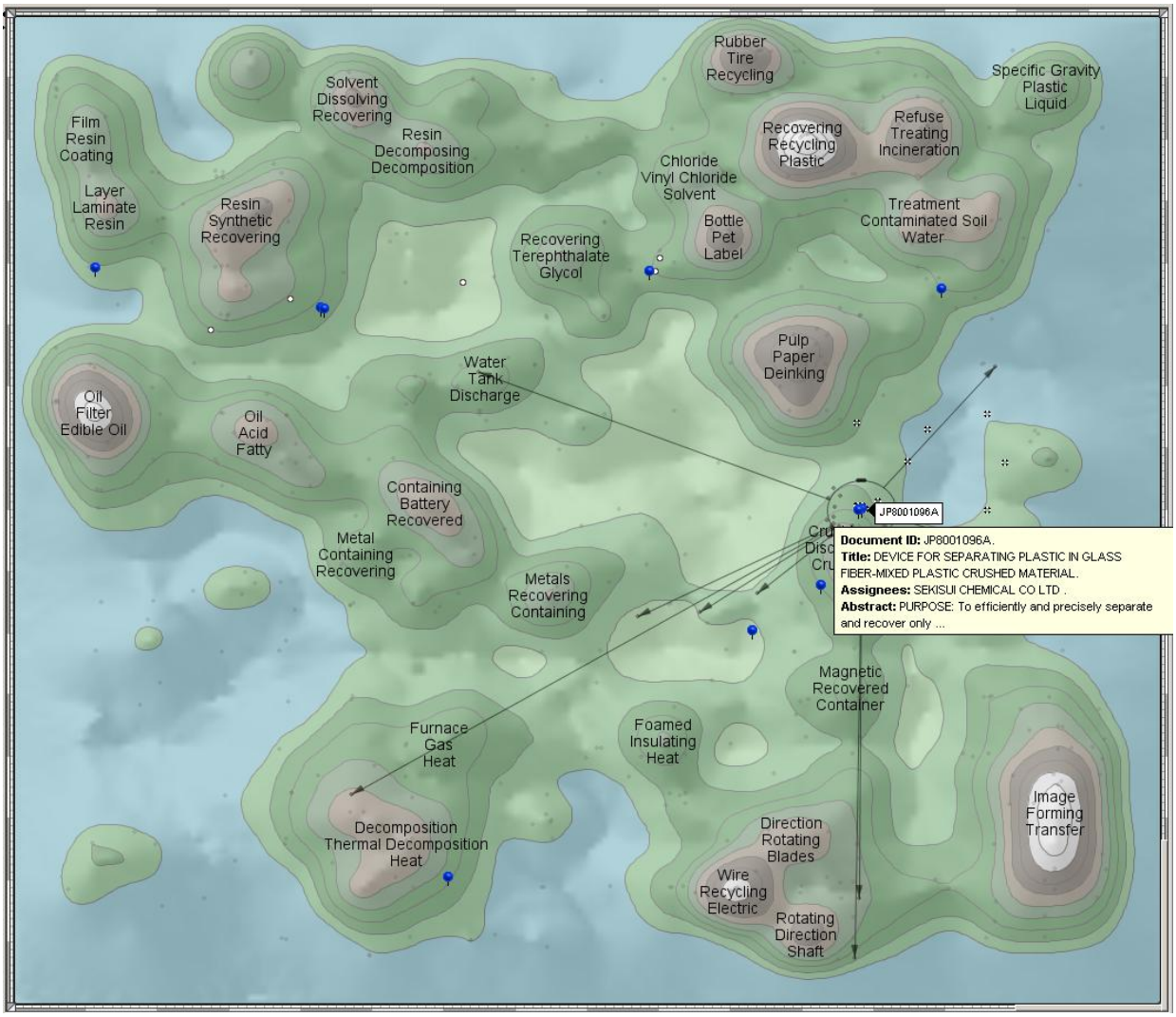

Figure 25 Patent landscape showing JP 8001096 © Thomson Reuters

By analysing the overall landscape map in more detail it was also noted that the top left-hand corner of the map in Figure 25 is populated with a significant number of patents from recycling optical storage media e.g. compact discs (CDs). Whilst several of these patents, e.g. JP 2003025330 (Hitachi), use chemical or alkali baths to separate the metal and plastic components, JP 2005001341 (Orient Sokki) is notable for using microwaves to melt and thereby separate the metal portion.

EP 1273414 (Chen Cheng-Shu) seeks to recover both the metal and plastic component by smashing the CD waste, dissolving the metal in a ‘stripping solution’, recovering and granulating the plastic pieces and recovering the metal through electrolysis. JP 2003266436 (Ricoh) uses dry etching to remove the metal component from a CD enabling recovery of the optical polycarbonate resin base.

Although not an under-represented sector per se, optical storage media waste material separation and recycling can be seen to be the subject of diverse approaches and may still be subject to considerable future development. The saddle area between the two peaks of activity on the map in Figure 26 contains the patents discussed above and is reflective of the technologies which are being developed for this important area of waste treatment.

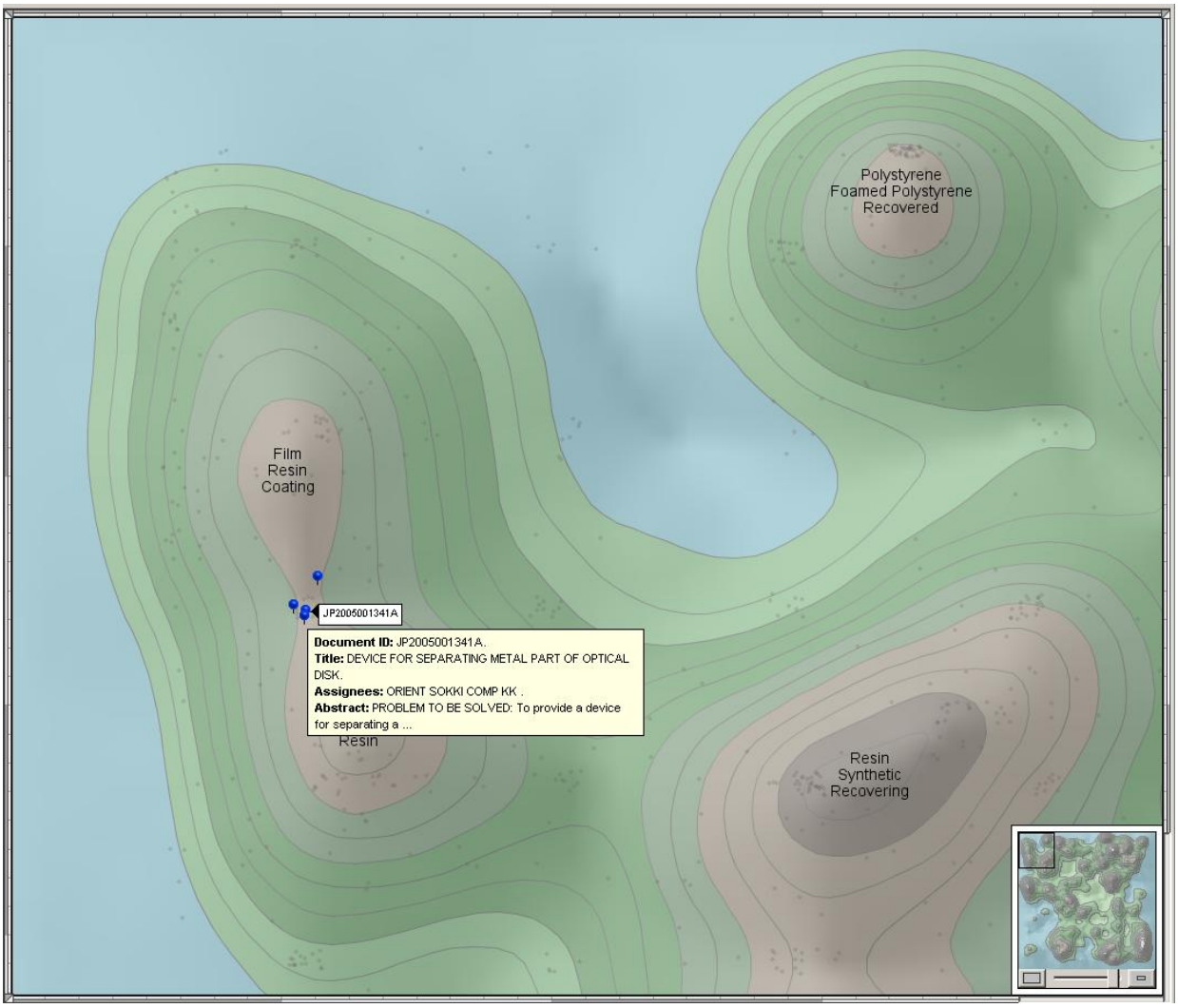

Figure 26 Patent landscape showing selected CD recycling patents © Thomson Reuters

Further investigation of the low-lying topography and related documents reveals a number of science-intensive technology patents which also occur on the map, as shown in Table 15. These relate to sectors which show signs of emergence as applications are developed.

Patent number	Applicant	Description
JP 2002317073	Shinetsu Chemical Co.	Decomposing electroconductive silicone rubber by immersion in non-aqueous alkali and heating to 40 degrees centigrade
JP 2004166542	Japan Science and Technology Agency	Plastic decomposing bacterium belonging to genus Paenibacillus
GB 2330409	University of Cranfield	Identifying plastic types by ultraviolet illumination and induced fluorescence, or a mirror filter to determine spectral characteristics

Table 15 Science-intensive patents in sparsely mapped areas

It is interesting to note the appearance of a British university in this short list given the general dominance of the technology space by Japanese, German and US

assignees but could indicate a good British presence in developing emergent technologies.

2.12.3 GB Patents

Figure 27 reveals where patent protection has been sought in the UK. GB patents are represented by white dots, with blue pins being automatically determined 'key patents'; these tend to be the older patents in the group.

The patents indicated may not have been granted, may not be in force and may not have been assigned to UK resident inventors. Nonetheless, the distribution of GB patents demonstrates that much UK technological activity occurs in the sectors of plastics recycling and waste water management, both located in the top right hand quadrant of the map.

Historical strengths in heat-treatment of waste and recovery of scrap metal are represented in the central lower portion of the map, along with GB 1471949 (Shell) which relates to a process for upgrading coal.

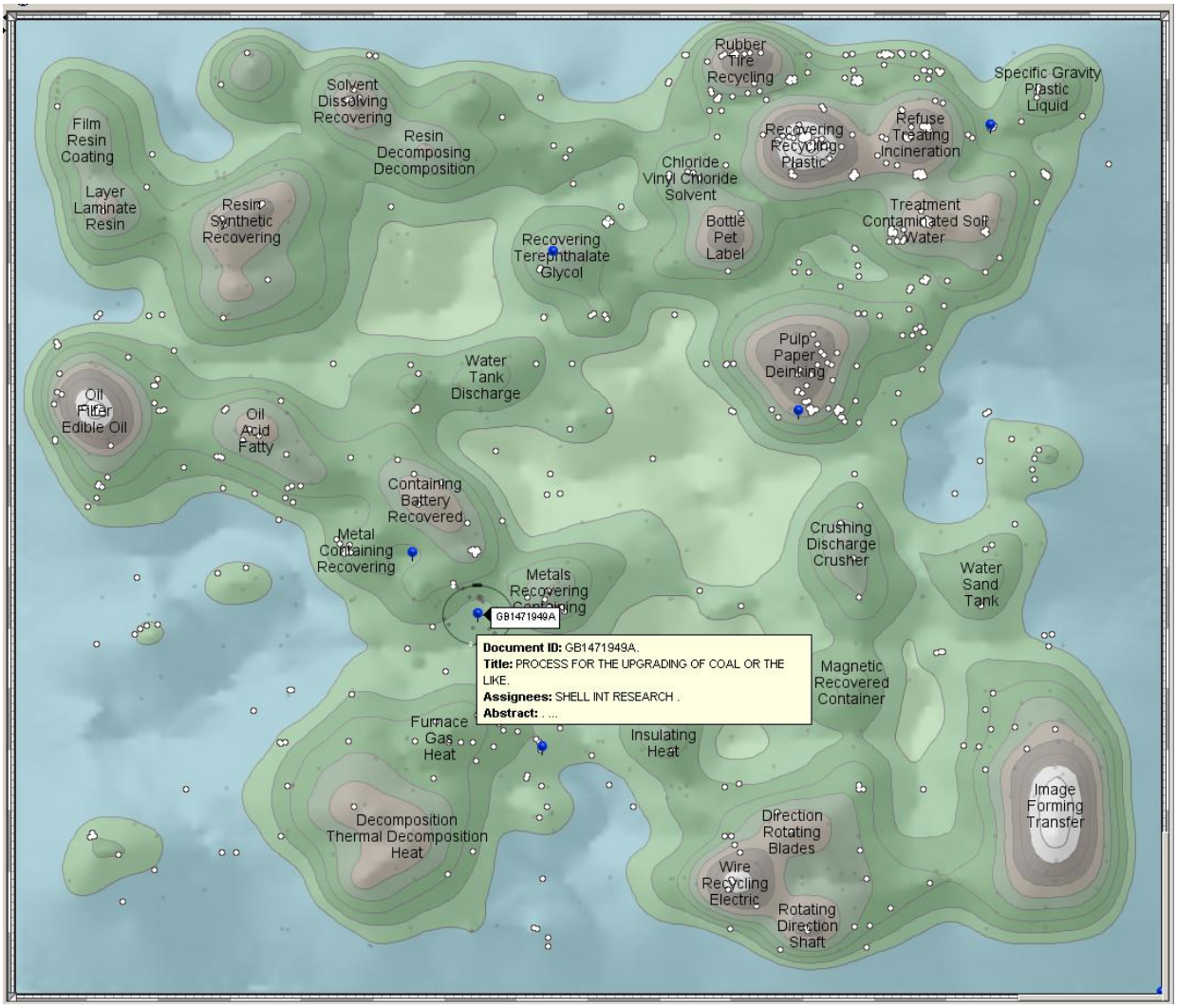

Figure 27 Patent landscape showing 'GB' patents © Thomson Reuters

3 Conclusions

3.1 General overview

The dataset representing the recycling and separation technologies for mixed waste streams technology space shows a good spread of technologies spanning nearly half a century.

Most of the top 30 patent assignees are based in Japan with the US and Germany also having companies appearing in the top 30; the patent filings having a priority in these three countries account for nearly 70% of the entire dataset. It is interesting to note that Japan generally lagged behind the US and Germany prior to the mid-1990s but after this date the number of inventions almost doubled whereas the number of patents having US and German origin have either remained steady or decreased. It is speculated that this rise may have been incentivised by impending Japanese environmental legislation and influenced by the bias towards Japanese assignees in the dataset

By analysing the top companies in more detail, it is clear that most of the collaborative activity takes place within single countries. Such little cross-border collaboration is a contra-indicator of effective international knowledge transfer.

The majority of the dataset comprises patents from corporate organisations, which is not surprising given the scale at which industrial recycling is performed. The over-representation of corporations in patent data tends to suggest maturity and applied industrial technology. The size of the portfolios was noted as a good mixture, suggesting that whilst some areas of technology are mature, there is a history of sector-penetrative development with just over half of assignees having 5 or less patent families to their name. This may indicate consistent development and application of scientific advances, evolving technical and social challenges to which technical solutions are directed, or difficulties to new entrants who are unable to build and sustain a sector-presence.

These trends are also reflected in the turnover of inventors and technology marks. The inventor turnover data suggests a persistent and on-going level of new investment and new entrants to the sector and the technology turnover data reinforces the impression that the dataset is a combination of both underlying mature and emerging technologies.

3.2 Technology analysis

The dataset encompasses a broad range of technology marks, primarily due to the search strategy employed. The breakdown of technology activity by year (as a plot of the occurrence of classification marks by priority year) reveals that early increases in patent activity in the late 1980s were predominantly in B29B1, separating plastics, and B03B9, arrangement of refuse separating plants. Other developments followed quickly and cumulatively contribute to the overall increase in patenting through the 1990s.

Technology areas such as B09B3/00 and B09B5/00 (the destruction/disposal of solid waste) were not explicitly included in the search as it was concluded that destruction of waste was beyond the scope of this report and that rendering something “useful” may be regarded as more than mere “upgrading”; this is also beyond the scope of this report. However, it is interesting to note that these areas are inherently linked to the general separation/recycling marks given their prominence in the top 10 table.

Breaking down the dataset by constituent matter did not result in anything unexpected being noted per se. However, what this analysis does provide is a first step towards identification of underdeveloped technology areas, either through analysing areas in which there are few patents or by further analysis of areas which do not explicitly appear in this report.

3.3 Top three companies

The top three companies Ricoh, Mitsubishi and NKK are all of Japanese origin and it is not surprising to note that the majority of their work originated in Japan.

The Ricoh portfolio has 301 patent families listed spanning back to 1971, indicating that Ricoh is an established company in the sector. Very little work was carried out in the overall technology space in the name of Ricoh until 1994 when filings increased significantly. Subsequent filings only ever peak at just over half the level of 1994 but show that Ricoh have maintained an interest in the areas of technology under consideration.

Given Ricoh’s history of manufacturing printing/photocopying devices, it is not surprising to note that the top IPC marks which are used fall under the IPC subclass G03G. The top mark by far is G03G21/10 which relates directly to the collection or recycling of waste developer.

All the inventions arising from collaborative activity appear to be in different technology areas to their key competences, such as C22B1/244 (binding ores or scrap), C22B21/00 (obtaining aluminium) and B29B17/02 (separating plastics from other waste materials).

The Mitsubishi dataset is of a comparable size to that of Ricoh. The 297 patent families spanning back to 1973 are again a sign of an established company. In a similar manner to the Ricoh dataset, the Mitsubishi patent portfolio is sparse in the earlier years. In 1992, the level of innovation jumps around ten-fold and since then it has been relatively active; given the small sample of data, no real conclusions can be drawn about the year-on-year differences in absolute figures.

Compared with Ricoh, it is noticeable that Mitsubishi do not seem to have concentrated solely in a single sub-sector. The portfolio includes, amongst other things, B29B17 marks (recovery of plastics from waste material containing plastics), B09B marks (disposal of solid waste), C10G1/10 (production of liquid hydrocarbons from rubber/rubber waste) and C08J11 marks (working up of waste materials e.g. polymers). Across many different areas of technology, there is some collaborative activity occurring solely with Japanese companies.

The NKK dataset is 5-10% smaller than both Ricoh and Mitsubishi but the 275 patent families spanning back to 1975 is again a sign of an established company. In a similar manner to both Ricoh and Mitsubishi, the NKK patent portfolio is sparse in the earlier years. In 1995, the level of innovation jumps significantly and since then it has been relatively active. The level of filings shows a good period of activity between 1997 and 2001 but activity has dropped off since then.

The range of technologies being worked on is similar to those worked on by Mitsubishi and therefore includes, amongst other things, B29B17 marks (recovery of plastics from waste material containing plastics), B09B marks (disposal of solid waste), C10G1/10 (production of liquid hydrocarbons from rubber/rubber waste) and B02C23/08 (separating and sorting of crushed/disintegrated material).

There is some collaborative activity occurring across many different areas of technology, though solely with Japanese companies. It is noticeable that the level of collaboration with other companies is higher than both Ricoh and Mitsubishi.

3.4 British patent families

British companies account for around less than 2% of the dataset, with no single company having a particularly large portfolio. The top filing companies do not have any recent patents, the latest being from BP with a priority date of 2003.

More recent filings by British companies appear to be promising with several different companies filing patents across a broad spectrum of technologies within the sector.

3.5 Patent landscape analysis

A list of patents forming the complete dataset used in the analysis in the previous sections was taken and used as input to patent landscape mapping software.

One of the desirables specified in the project proposal was identification of underdeveloped technology areas; areas or materials for which technology solutions enabling separation, purification or upgrading of waste materials are not yet widely developed.

By definition this is non-trivial; patent informatics facilitates identification of characteristics, trends and relationships which exist within data. Identification of those which are absent is less straight-forward.

Nonetheless, by examining areas of the patent map which are low-lying in the overall landscape, areas of low technological density can be uncovered. These areas may also relate to emerging areas. Developing technology tends to be found in the low-lying areas which can be thought of as being analogous to valleys and estuarine areas on a conventional map.

Initially, materials of interest were marked on the map to identify any areas which were coincidentally low-lying and specifically lacking in these materials of interest. A candidate area was selected, within which lay JP 8001096. This patent relates to

separation and recovery of plastic from glass-fibre reinforced plastic (GRP) by crushing composite material and subjecting it to vibration. By blowing the material with ionised air, electrostatic charge is removed from the crushed plastic and glass fibre thereby allowing the glass fibre to be recovered through a suction duct.
Interestingly, other related crushing and recovery systems on the map do not relate specifically to GRP composite materials recovery. Alternative GRP separation and recovery systems can use heat or pulverisation to provide a powder filler. Others incorporate a metal recovery step to enable recycling of GRP printed circuit boards (PCB). GRP recycling, especially PCB, where the GRP is itself subject to separation into constituent materials may therefore be under-represented in patented technology

By analysing the overall landscape map in more detail it was also noted that one area is populated with a significant number of patents related to recycling optical storage media e.g. compact discs (CDs). Several different approaches to recycling such media were noted: the use of chemical or alkali baths to separate the metal and plastic components; the use of microwaves to melt and thereby separate the metal portion; the recovery of both the metal and plastic component by smashing the CD waste, dissolving the metal in a ‘stripping solution’, recovering and granulating the plastic pieces and recovering the metal through electrolysis; and using dry etching to remove the metal component from a CD enabling recovery of the optical polycarbonate resin base.

Although not an under-represented sector per se, optical storage media waste material separation and recycling can be seen to be the subject of diverse approaches and may still be subject to considerable future development.

A number of science-intensive technology patents occur on areas of the map. These are sectors which show signs of emergence as applications are developed. It is interesting to see the appearance of GB 2330409, a patent from Cranfield University, which seeks to identify plastic types by UV illumination and induced fluorescence. This is notable given the general dominance of the technology space by Japanese, German and US assignees but could indicate a good British presence in developing emergent technologies.

By highlighting patents issued by the Intellectual Property Office (in the UK) it can be seen that much UK technological activity occurs in the sectors of plastics recycling and waste water management.

3.6 Recommendations

This report has attempted to cover as broad a range of documents as possible to reflect recycling and separation technologies for mixed waste streams involving separating specific materials, purifying or upgrading materials and general analysis methods.

As a consequence of this, the report has only highlighted certain materials as discussed in the original proposal or noted as interesting during the extensive analysis. Thus there are several aspects which could be expanded on and explored in more detail including:

- Determination of the presence of other material types in the dataset
- Detailed analysis of a particular material type e.g. PET
- Detailed analysis of a particular composite material e.g. glass-reinforced plastic
- Detailed analysis of a particular technology area e.g. recycling of compact discs
- Analysis of recent British companies

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