INTELLECTUAL PROPERTY OFFICE

A Patent Informatics Study of Energy from Waste

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(revised May 2009)

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IPO Patent Informatics Project Report: Energy from Waste

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Executive summary

Worldwide patent data was studied to identify historical developments in different Energy from Waste sectors, key applicants, inventors and patents. A second phase studied UK innovation data and contrasted this with worldwide activity as well as interrogating the UK landscape to mine UK expertise and specialisms. Commentary on the pattern of historical Energy from Waste innovation is provided in light of oil price trends.

Energy from Waste:

- Is dominated by Japanese patent activity, with UK activity 6th internationally
- Is historically well-established but continues to develop through new entrants and new technologies
- Is moving from an established position, particularly in incineration, to include pretreatment, recuperation of heat and biological treatment of waste including generating biogas
- Comprises non-corporate activity dominated by individuals, some of whom patent prolifically for periods of time and obtain key patents
- Shows signs of emergence in sectors such as pyrolysis and hydrogen production

Technologies in the field of Energy from Waste are well established and the evidence of the patent records is that activity stretches back to the early twentieth century. 2001 is the peak year on record for Energy from Waste patents, followed by an apparent decline.

Energy from Waste is a broad term which in fact comprises a large number of different technologies which are developing all the time. Technologies relating to incineration in general dominated the field from the late 1960s to the early 1980s and have been less significant since. Instead, the focus has moved towards perfecting technologies, such as pretreatment, recuperation of heat, or secondary combustion in incinerators, or towards other technologies, such as anaerobic treatment to form gases, or solid fuels.

Japan is the world's leader by a large margin in Energy from Waste patent filings. The UK is the sixth country overall, but activity has been apparent in the UK from an early stage. Of the top ten organisations for patent filings, all but one are Japanese companies, the exception being a German company.

The pattern of activity in the UK differs from other countries, with technologies relating to incineration being under-represented, whereas technologies relating to the treatment of solid waste, the production of solid fuels, and the anaerobic treatment of waste water and sewage are well-represented. The UK has seen periods of significant activity in the 1970s, the 1990s, and the 2000s. However, it appears that different companies and individuals are responsible during each period.

A "GB Dataset", obtained by extracting all records from the worldwide dataset which contain either of a GB applicant, a GB inventor, or a GB priority application, produced 430 documents. The year range for this dataset was 1909 to 2007.

There is patchy activity in the dataset until the end of the 1960s, from when the activity is generally greater, apart from a dip to zero in 1986. The most prolific patent applicants in the dataset were Rees and Stubbing. Individuals make significant contributions to patent filings in the UK, although these tend to be concentrated into short time periods. Therefore they influence the overall trends significantly, dominating certain periods entirely (1995-1996 and 1999-2002).

Over the last ten years, significant applicants have been Tetronics Ltd., Accentus Plc., and Stubbing, Bird, and Dunne. Although topics relating to incineration and the preparation of waste ready for incineration appear to be the most active field in the UK, there is also a notable level of activity in fields relating to biological treatment.

There is a very low, and perhaps insignificant, level of activity from academia and government/public sector applicants in the UK in energy from waste topics. However, a significant proportion (36%) of records have named individuals as applicants, rather than organisations, and organisations account for 59% of records. The remaining 5% are accounted for by academic, public sector, and government applicants. For certain topics (treatment/pretreatment; treatment of water, waste water, sludge, and sewage; production of gas) the level of activity of individuals closely matches that of organisations, and therefore perhaps these are sectors in which small companies can influentially contribute. Other topics, such as incineration, seem to offer less opportunity for small companies.

Pyrolysis and hydrogen production yield interesting patterns of clustering in the landscape which may indicate emerging fields.

Recommendations for further work include:

- Identify further sectors which exhibit emergence and disruptive potential
- Identify specific UK portfolios and understand their impact on worldwide Energy from Waste technology
- Identify the effects of specific legislation on patent trends e.g. the Japanese Basic Environment Law[1]
- Study collaborations to understand knowledge transfer
- Rigorously analyse academic patent activity to potentially uncover activity masked by collaboration or commercialisation
- Understand specific strengths and opportunities in e.g. biological treatment of waste and biomass conversion
- Deep analysis of a specific sub-sector e.g. anaerobic digestion, pyrolysis

[1] http://www.env.go.jp/en/laws/policy/basic/index.html

Contents

1. Introduction

1.1 Basis for report

Reference to 'patents' relates to both patent applications and granted patents unless otherwise indicated.

For this project the European Patent Office (EPO) database EPODOC 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), EPO and the African Regional Industry Property Organisation (ARIPO). It should be noted that since by convention patents are classified and published within eighteen months after filing, the patent record set cannot be complete for the last eighteen months. In addition, delays in records arriving on the databases must be considered. This should be borne in mind when considering recent patent trends, and particularly within the last eighteen months.

Phase I of this project sought to provide a broad overview of all energy from waste topics in a dataset with worldwide coverage. Some comparisons were drawn between activity in the UK and the rest of the world.

Phase II of this project paid closer attention to innovation in the UK. A "GB dataset" was derived for this purpose, which comprised patents having a GB inventor, a GB applicant, or a GB priority patent application (that is, a patent application from part of a patent family with the earliest filing in the UK). Foreign patents which originate from UK innovation were therefore included in the dataset. GB publications originating from foreign priorities and having only foreign inventors and applicants, on the other hand, were not included and were not classed as UK innovation.

1.2 Patent documents analysed

Where dates are attributed to patent documents, this is the priority date of the patent. Priority dates are the earliest attributable indication of inventive activity. In certain cases a patent comprises more than one priority date (for example for different aspects of the invention). This should be borne in mind when interpreting the data.

Prior to analysis, the applicant and inventor field data was cleaned to remove duplicate entries for different forms of the same name, for example arising from spelling error, international variation (such as Ltd, Pty, GmbH) or equivalence (such as Ltd., Limited).

Below is a summary table of the patent documents analysed in the phase I worldwide dataset:

Total Number of Records:	11,743
Years Range From:	1909 - 2008
Peak Year	2001 [739 Records]
Top Country:	JP
Top Company Name:	EBARA CORP

Field Choices	Field Name	Number of entries	Field Coverage
People	Inventors (Cleaned)	11,293	86%
Companies	Patent Assignees (Cleaned)	5,512	89%
Countries	Priority Countries	78	99%
Years	Priority Year	96	99%
Technology	International Classifications (All)	2844	87%

28 records have no priority year associated with them.
The 'narrow' IPC classification database field used reflects the inventive concept at the time of classification but does not necessarily reflect other or subsequent family member inventions. However all family members should be included in the dataset and their classifications represented accordingly.

Summary data representing the GB dataset is as follows:

Total Number of Records:	430
Years Range From:	1909 - 2007
Peak Year	1995 [48 Records]
Top Country:	GB
Top Company Name:	REES WILLIAM GERAINT

Field Choices	Field Name	Number of entries	Field Coverage
People	Inventors (Cleaned)	240	81%
Companies	Patent Assignees (Cleaned)	257	94%
Countries	Priority Countries	18	100%
Years	Priority Year	60	100%
Technology	International Classifications	17	100%

The GB dataset uses a custom collection of consolidated groups of classification terms, hence "17" represents 17 consolidated groups (see Appendix). Both 'narrow' and 'broad' IPC classification database fields were used. The latter ensures up-to-date accuracy as it is based on an updated IPC classification database field which does reflect family member inventions. Because these fields were consolidated, the effect of potential dilution of inventive classification relevance is reduced and macroscopic relevance is enhanced. Usage of each of the 'narrow' and 'broad' consolidated terms is discussed below.

1.3 Objectives

The objectives as defined in the original project proposal are as follows:

- Provide an overall patent landscape analysis in the technology area of Energy from Waste.
- Provide analysis of the level of UK research in comparison to the rest of Europe and rest of the world.
- Identify key active companies and key patent applications.

The objectives for Phase II were designed to focus on the UK energy from waste patent landscape, covering:

- Specific technology fields: biogas / biohydrogen from waste
- Emergent technologies
- UK patent applicant types: commercial, academic, or government
- The activities of individual patent applicants and the extent to which they influence the overall patterns in the UK
- Consolidated IPC classifications to form larger groups and produce more focused results
- Producing and interrogating a UK patent landscape map

2 Results and Discussion

2.1 Worldwide Patent Trends

Figure 1 shows the global picture of patent activity in Energy from Waste.

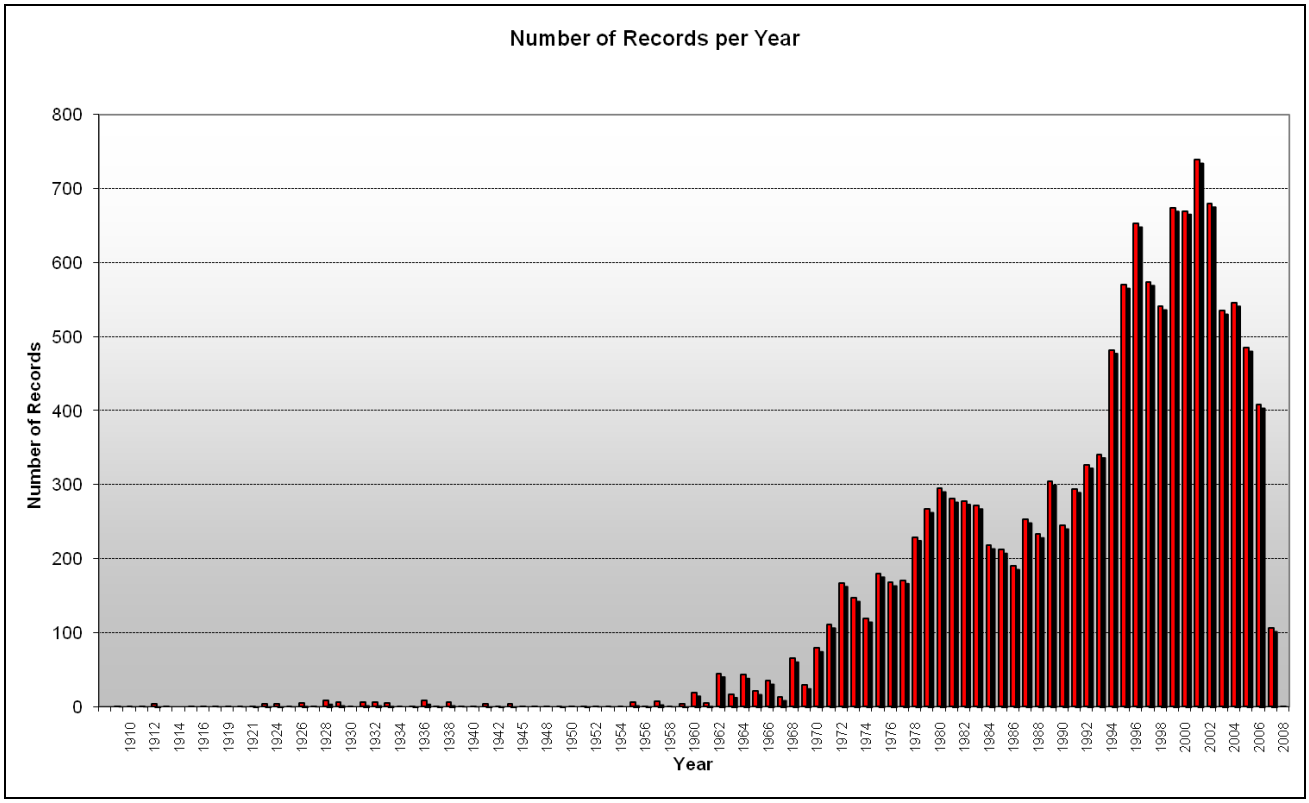


Figure 1 *Worldwide patent filings by priority year 1909-2008*

The earliest patent filings have a priority date in 1909 (2 records) and these are followed in subsequent years by a low but consistent level of filing activity up until 1959. All records in this range were viewed to verify that they were truly relevant and not false inclusions; every document was indeed deemed relevant. This demonstrates that Energy from Waste is well established in various forms. In 1960 there is a significant leap to 19 documents filed, which is more than twice the highest number of filings in any prior year (8 in 1928 and in 1936). Although there are only 5 records for 1961, there are 45 in 1962, and 1968 shows 65 records. Thereon the trend is generally upwards, albeit in bursts and with localised peaks around 1972 (167 records), 1980 (295 records), 1996 (653 records), and 2001 (739 records and the overall peak to date).

Between 2004 (546 records) and 2008 (1 record) the number of records filed annually trails off. This is because patent applications having a priority year anything up to five years prior to the time of search may still be unpublished, or be awaiting classification. The time taken for a patent to be published and to then appear in the databases varies according to differences in backlogs and publication systems between patent offices around the world. It is therefore difficult to draw conclusions for the most recent years.

However, Energy from Waste is a somewhat broad term which encompasses many different fields of technology, whose different trends are masked by Figure 1. It is therefore more informative to view the patenting activity split out according to the type of technology. Figure 2 shows activity according to technology for the ten technologies with the greatest number of records overall. "Technology" is determined by the classification marks applied to each record from the International Patent Classification, which has 87% coverage in the dataset according to the summary table. Since the numbers of records for years earlier than 1960 are so small, these are not shown in Figure 2. Most of the records not appearing in Figure 2 are classified in C10L5/48 (Solid fuels based on industrial residues and waste material) or F23G5/46 (Recuperation of heat from the incineration of waste).

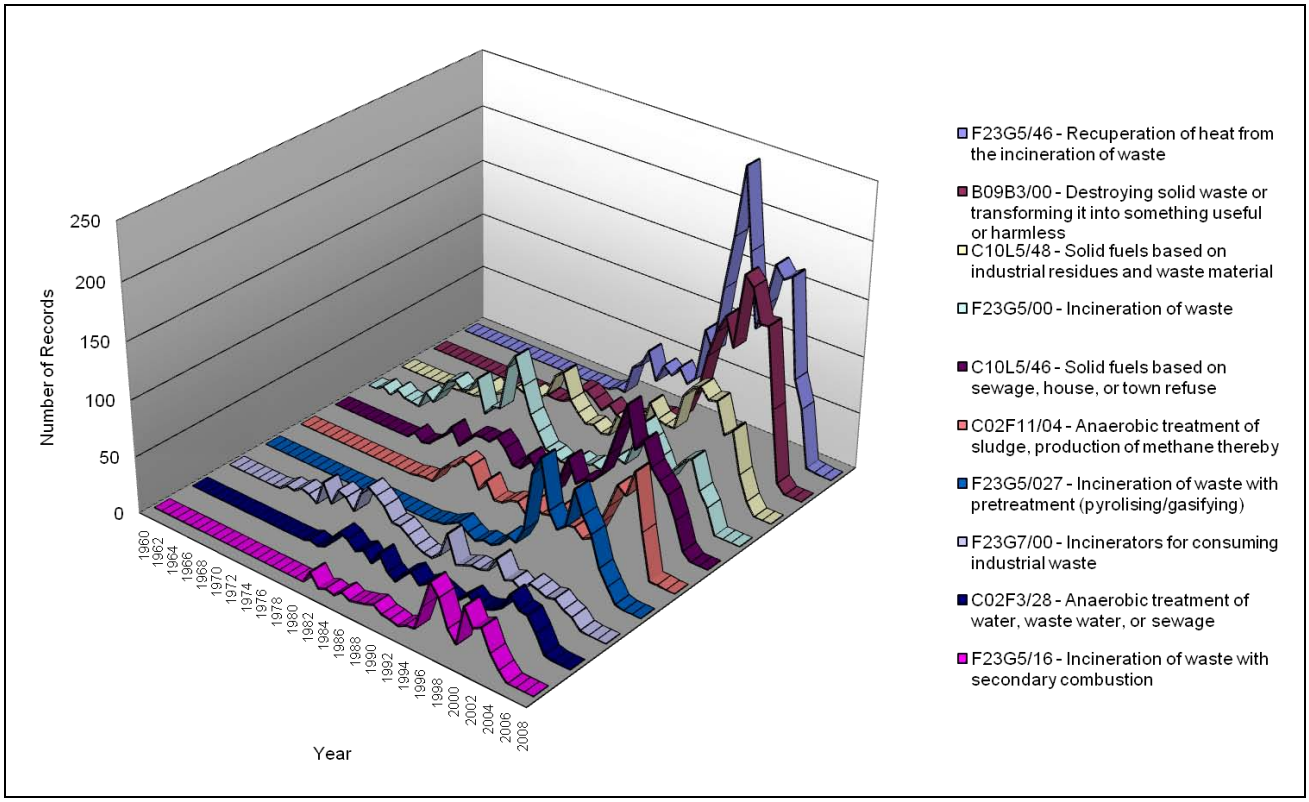


Figure 2 *Worldwide patent filings by technology and priority year 1960-2008*

The differing profiles of each technology are clear, and it can be seen that the various localised peaks referred to earlier are each due to different technologies peaking at different points in time. This demonstrates the evolution of the technology and the various phases over time. All the profiles tail off to zero because of classification and publication delays as explained above.

The earliest significant activity is in "Incineration of waste" from around 1960 and this technology exhibits a high level of activity from the late 1960s, through the 1970s, and into the early 1980s, with an overall peak in 1980 (85 records). It declines soon after, however, until the 1990s when there are further peaks in 1996 (72 records) and also in 2002 (59 records), although these peaks do not match the one in 1980. Early activity is also apparent in "Incinerators for consuming industrial waste" beginning in the late

1960s and thereafter roughly mirroring “Incineration of waste” with increasing activity leading to an overall peak in 1979 (40 records). There is again a decline soon after this but “Incinerators for consuming industrial waste” is thereafter distinct from “Incineration of waste” with a recovery in 1989 (31 records) and a further, smaller peak in 1995 (29 records). This is followed by a flat period and gradual decline during the late 1990s and into the 2000s.

A different pattern is seen in fields of technology which are subsets of incineration generally. “Recuperation of heat from the incineration of waste”, which is the most active area of technology of all those considered, emerges with a single record in 1978, but there is little more activity until into the 1980s. Activity grows and reaches a peak in 1996 (243 records) which dwarfs every other area of technology in the scope of this study. “Incineration of waste with secondary combustion” emerges in 1981 (12 records), and shows a lower level of activity throughout the 1980s and early 1990s. Interest resumes in 1995 (31 records) and peaks overall in 1996 (55 records), with a lesser peak in 2000 (48 records). “Incineration of waste with pretreatment (pyrolising/gasifying)” first appears in 1983 (2 records) and there is activity throughout the rest of 1980s and 1990s through to an overall peak in 1996 (99 records), and a further peak in 2000 (85 records). These fields exhibit more activity in recent years, as the technology advances from a broader level to a more detailed and refined level.

The remaining fields of technology in Figure 2, which are not connected to incineration in any way, also follow this latter trend of increased activity in later years. The greatest of these is “Destroying solid waste or transforming it into something useful or harmless”, in which activity has been seen since the late 1970s, but in which the most activity is seen in the late 1990s onwards, with the peak in 2000 (177 records). This is a rather unspecific title, however and may consequently reflect miscellaneous or unforeseen technologies. “Solid fuels based on industrial residues and waste material” is active from an early stage (one record in 1966), and steadily builds to a peak in 1982 (58 records) which almost coincides with the peak of activity in “Incineration of waste”. However the greater level of activity is seen, following a dip in the 1980s, from around 1990 to the present day. Similarly, “Anaerobic treatment of sludge, production of methane thereby” and “Anaerobic treatment of water, waste water, or sewage” see activity at an earlier stage (although not as early as incineration or solid fuels) and greater activity in more recent years, but with a less pronounced dip in between. Peaks for these two technology areas occur in 2001 and 2003 respectively.

As well as masking different trends between the different technologies, however, Figure 1 also masks different trends between different countries. Figure 3 shows the total number of records for each priority country. The world leader is immediately clear and is Japan (4979 records). The US is some distance behind with 1755 records. The UK features as sixth place as a priority country (neglecting patents obtaining priority through the PCT route) with 366 records. Figure 4 shows this information in more detail with the profiles of each country over time. Each country has its own profile. The earliest ripples of activity are seen in the US, Germany, and the UK, and although Japan demonstrates the greatest level of activity overall, has zero records until 1964 (2 records), with major activity not commencing until into the 1970s. It is now also clear that the pattern of activity in Figure 1 is greatly skewed by Japan alone. China emerges in the 1980s. Activity in France and Switzerland also commences much later than in the UK.

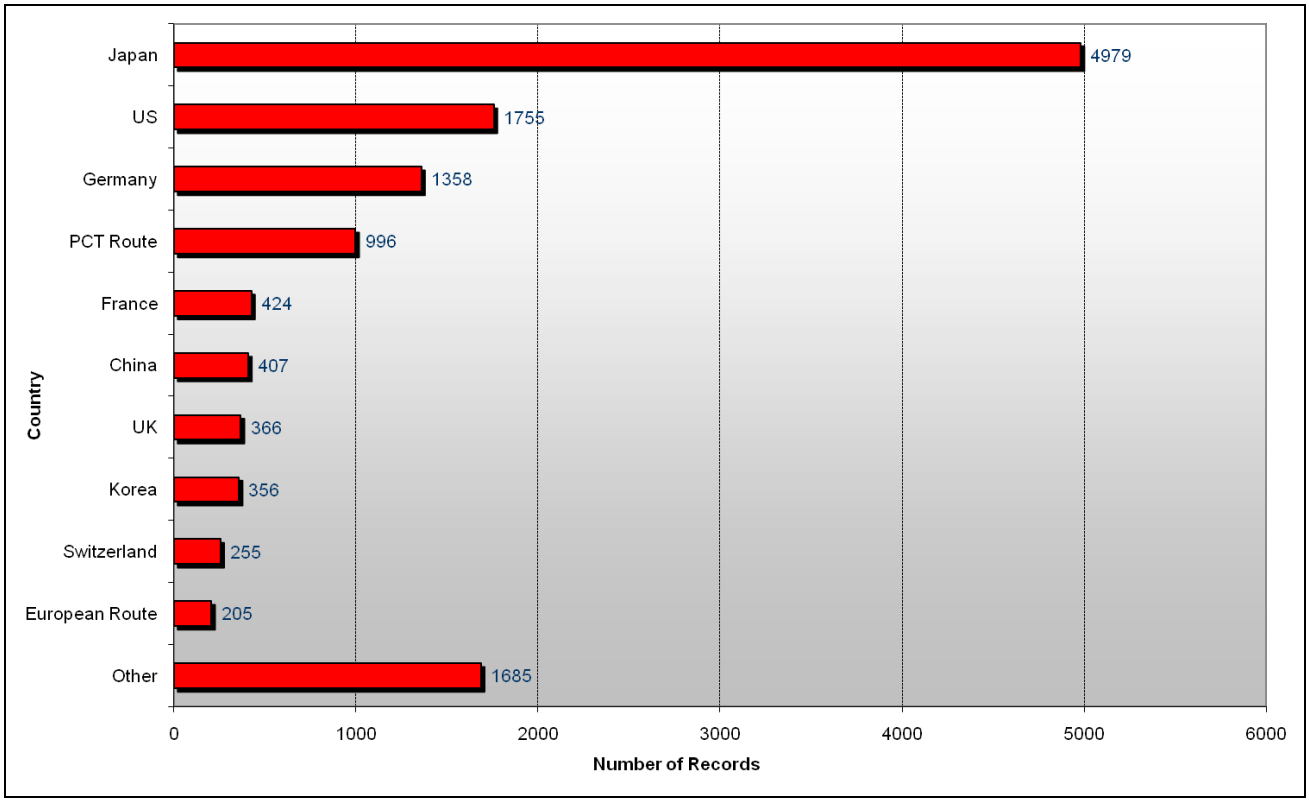


Figure 3 *Total number of records by priority country*

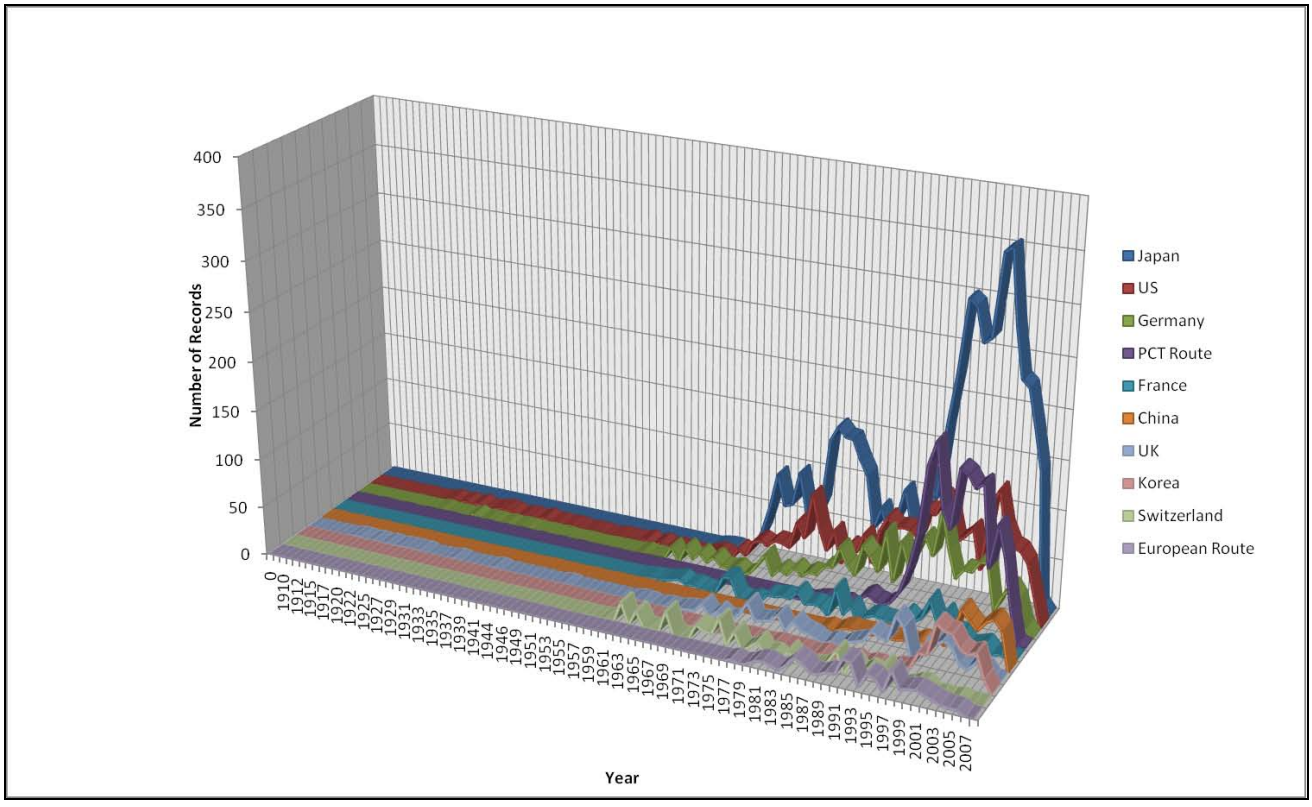


Figure 4 *Patent filings by priority country and year*

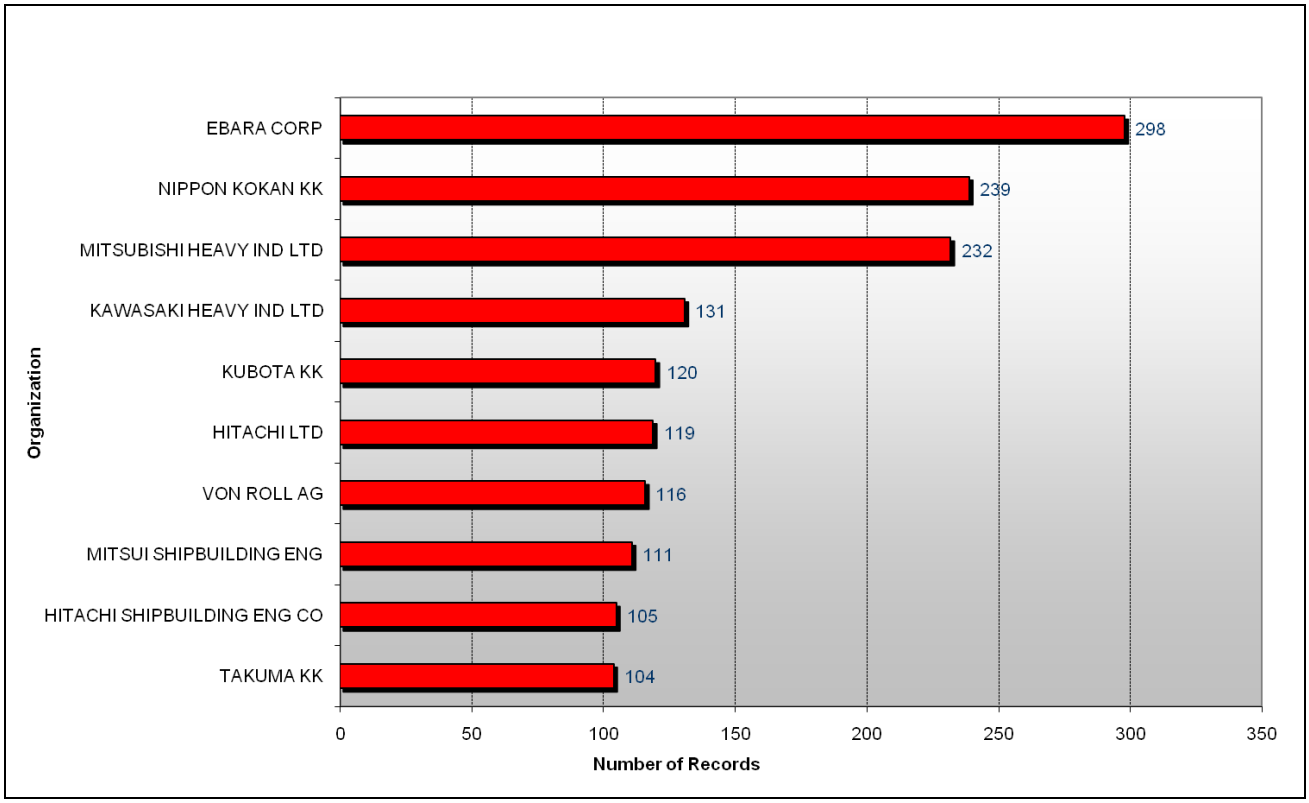


Figure 5 *Top organisations*

Figure 5 shows the most patent prolific organisations. There are 5512 organisations in total, with all except those in Figure 5 holding fewer than 100 patents. All the companies appearing in Figure 5 are Japanese, except for Von Roll, which is a German company. The highest UK entries, Thomas John Stubbing[2] and William Geraint Rees, would appear in joint seventy-third place.

[2] At least two records appear to be family members of Stubbing patents but carry no assignee field value. Patent family analysis for each joint applicant may reveal that such unassigned records resolve the 'tie' but this is outside the scope of this study.

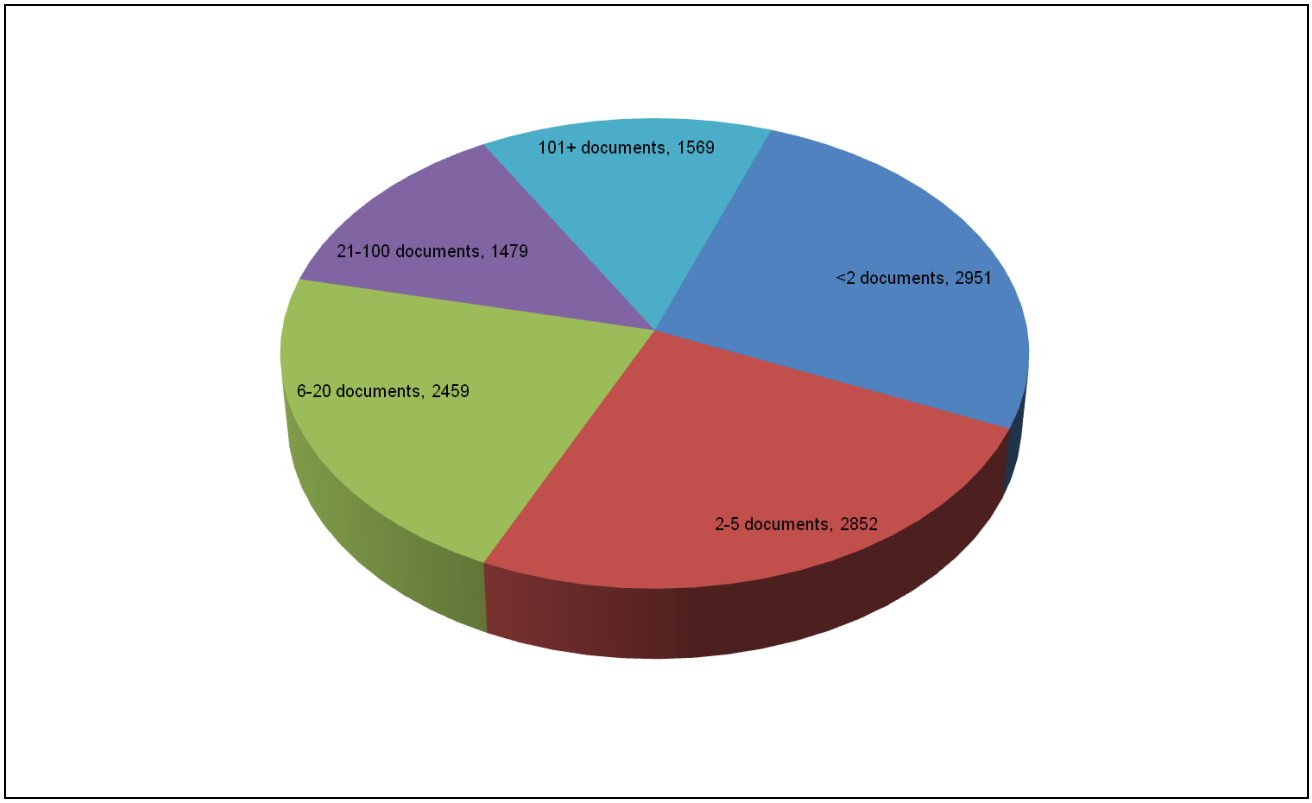


Figure 6 *Distribution of records by organisation activity*

Figure 6 shows a breakdown of patent portfolios by portfolio size. 2951 patents are assigned to applicants who have only one patent in their portfolio (that is, a low level of activity): 1589 patents are assigned to applicants who have over 100 patents in their portfolio (the highest levels of activity). This particular distribution of patents, showing a significant proportion of records with applicants who exhibit a low level of patenting activity, is characteristic of an area of technology that is still developing. As technology develops and matures, the proportion of patents held by the most active applicants is expected to increase. However, since the dataset contains a wide variety of different technologies, as mentioned earlier, this overall view could be hiding varied trends amongst the different components. For example, the evidence of Figure 2 is that certain technologies relating to incineration of waste have “cooled off” and so have passed through to maturity, whereas later technologies are still emerging or developing.

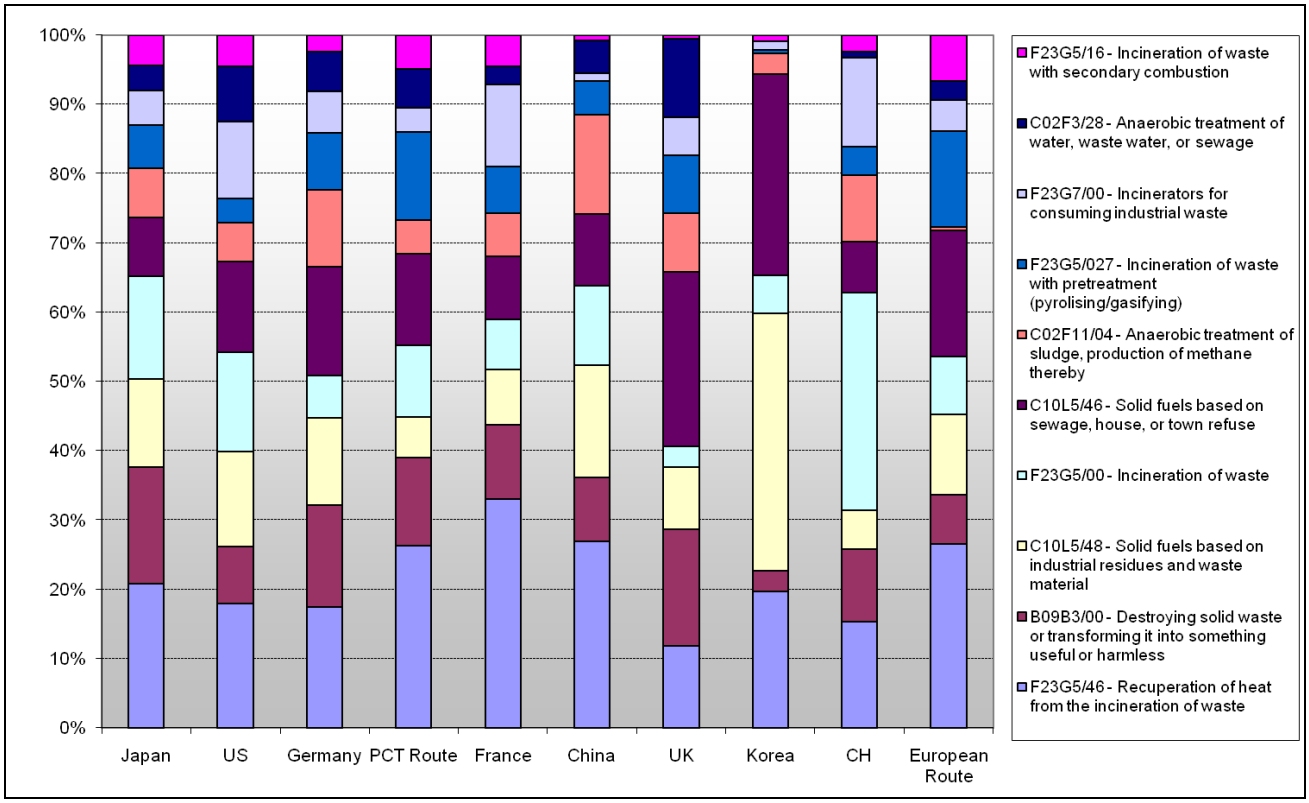


Figure 7 *Percentage of technologies by country*

Figure 7 shows the relative balance of activity in each priority country for the ten areas of technology having the most activity overall. The pattern in the UK differs from many other countries. It is immediately apparent that incineration is under-represented in the UK, because all of the incineration areas are lower relative to elsewhere, with the exception of “Incineration of waste with pretreatment (pyrolysis/gasifying)”, which shows a more moderate proportion of activity. “Destroying solid waste or transforming it into something useful or harmless” and “Solid fuels based on sewage, house, or town refuse” are well represented in the UK relative to elsewhere, although “Solid fuels based on industrial residues and waste material” is less so. “Anaerobic treatment of water, waste water, or sewage” is also particularly well represented in the UK.

2.2 UK Patent Trends

Figure 8 illustrates the filing trend for the whole GB dataset.

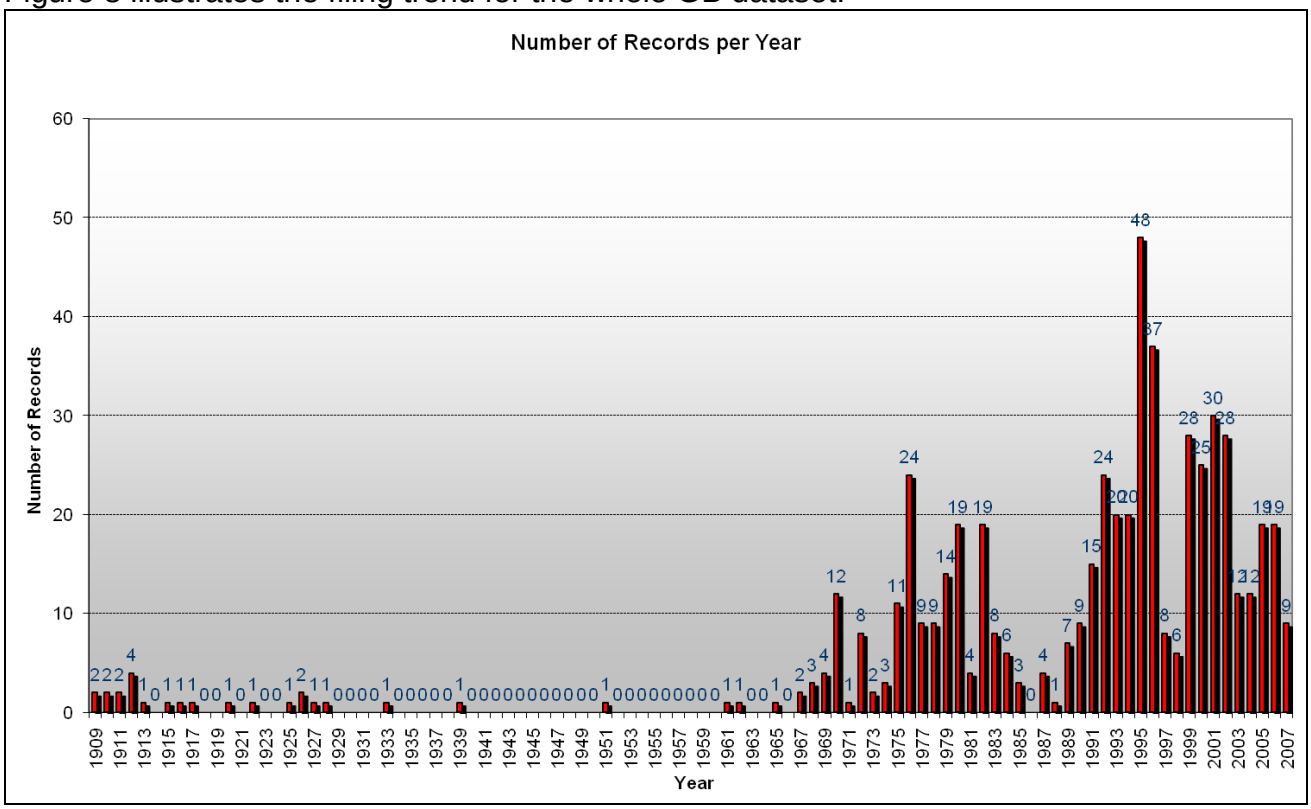


Figure 8 *Energy from Waste patents in the GB dataset*

Since the total number of documents in this dataset is only 430 (compared with 11,743 for the worldwide dataset), the patterns are much noisier. The most frequently occurring patent applicants over the whole dataset are given in Table 1 below:

Number of Records	Patent Applicant
15	REES WILLIAM GERAINT
15	STUBBING THOMAS JOHN
14	ICI PLC
14	WASTE GAS TECHNOLOGY LTD
13	BIRD GRAHAM
12	DUNNE TERENCE PATRICK
11	TETRONICS LTD
10	JAMES ENGINEERING TURBINES LTD
10	CARRIER ENGINEERING CO LTD
10	CHRISTOPHER PAUL REYNELL
9	REFUSE DERIVED FUELS LTD
8	BIOMASS RECYCLING LTD

Table 1

However, turning only to recent activity, Table 2 shows the most frequently occurring patent applicants over the last ten years and the number of records for those applicants:

Year	Patent Applicant	Number of Records
2007	STERECYCLE LTD ENVIRO CONTROL LTD	5 2
2006	TETRONICS LTD ITT MFG ENTERPRISES INC GASREC LTD	8 2 2
2005	TETRONICS LTD ENVIKRAFT A S GOSSOP JOHN	11 2 2
2004	ACCENTUS PLC ITT MFG ENTERPRISES INC AEA TECHNOLOGY PLC	4 4 2
2003	ACCENTUS PLC DB FIBRES LTD TASS ENVIRONMENTAL TECHNOLOGY	3 2 2
2002	STUBBING THOMAS JOHN BIRD GRAHAM DUNNE TERENCE PATRICK	9 8 7
2001	STUBBING THOMAS JOHN BIRD GRAHAM DUNNE TERENCE PATRICK	15 13 12
2000	JAMES ENGINEERING TURBINES LTD GREEN ISLAND ENVIRONMENTAL TEC FINCH INTERNAT LTD	7 7 4
1999	JAMES ENGINEERING TURBINES LTD FINCH INTERNAT LTD AMEC CIVIL ENG LTD	10 6 5
1998	AMEC CIVIL ENG LTD	2

Table 2

Amongst this recent activity, certain applicants are notable because they produce a significant amount of activity within a very limited period. Specifically, Rees (the joint top applicant in the GB dataset, from Table 1) was only active over the years 1995-1996. Similarly, Stubbing was only active in years 2001-2002, Tetronics were only

active from 2005-2006, James Engineering Turbines were only active from 1999-2000, and Refuse Derived Fuels were only active from 1975-1976. These concentrated bursts of activity influence the filing trend seen in Figure 8 significantly.

2.3 UK Technology Trends

A large number (297) of unconsolidated classification codes are applied to the GB dataset documents in all. Different classification fields in the database represent narrow and broad (reflecting e.g. family member inventions) characteristics. These generally classify to a level which is too detailed for providing a general overview and in fact may obscure larger-scale trends. Simpler and clearer results may therefore be obtained by grouping the classification codes into categories. All the codes that appear on any of the documents in the dataset were grouped. All codes relating to energy from waste subjects are grouped into a manageable number of categories, yet each having meaningful numbers of documents. The "other" category contains any codes applied which classify aspects of the inventions which are not specifically of interest to energy from waste. Since each document may have several codes applied to it and may include subject matter falling into more than one category, the categories are not mutually exclusive and it may be assumed that for any category, all documents containing, *inter alia*, relevant matter are included.

The list of categories and some description of the subject matter contained is as follows:

- Fuel from solid waste – transforming solid waste into something useful or harmless; solid fuels from sewage, town, house, and industrial refuse.
- Treatment, pretreatment – transforming solid waste into something useful or harmless; pretreatment of waste for incineration; gasifying and pyrolising waste for incineration; drying
- Incineration
- Treatment of water, waste water, sludge, sewage – all aspects
- Biological treatment – aerobic and anaerobic plus other processes
- Physical processes – separation and filtering; purification of gases; mixing and dissolving
- Anaerobic digestion processes
- Recuperation of heat – in incinerators
- Enzymology, microbiology, microorganisms – details of processes, types of organisms
- Chemical compounds and processes – codes relating to types of compounds and processes used
- Pyrolysis
- Production of gas – methane in particular; producer gas, water gas, synthesis gas

- Aerobic processes
- Thermal treatment – destructive distillation of carbonaceous materials for production of gas, coke, tar, or similar substances
- Briquetting
- Materials – terms relating to types of cement in particular
- Other – codes unrelated to energy from waste topics

A full inventory of classification codes in each category may be found in the Appendix.

On this basis, a full technology profile can be created as in Figure 9.

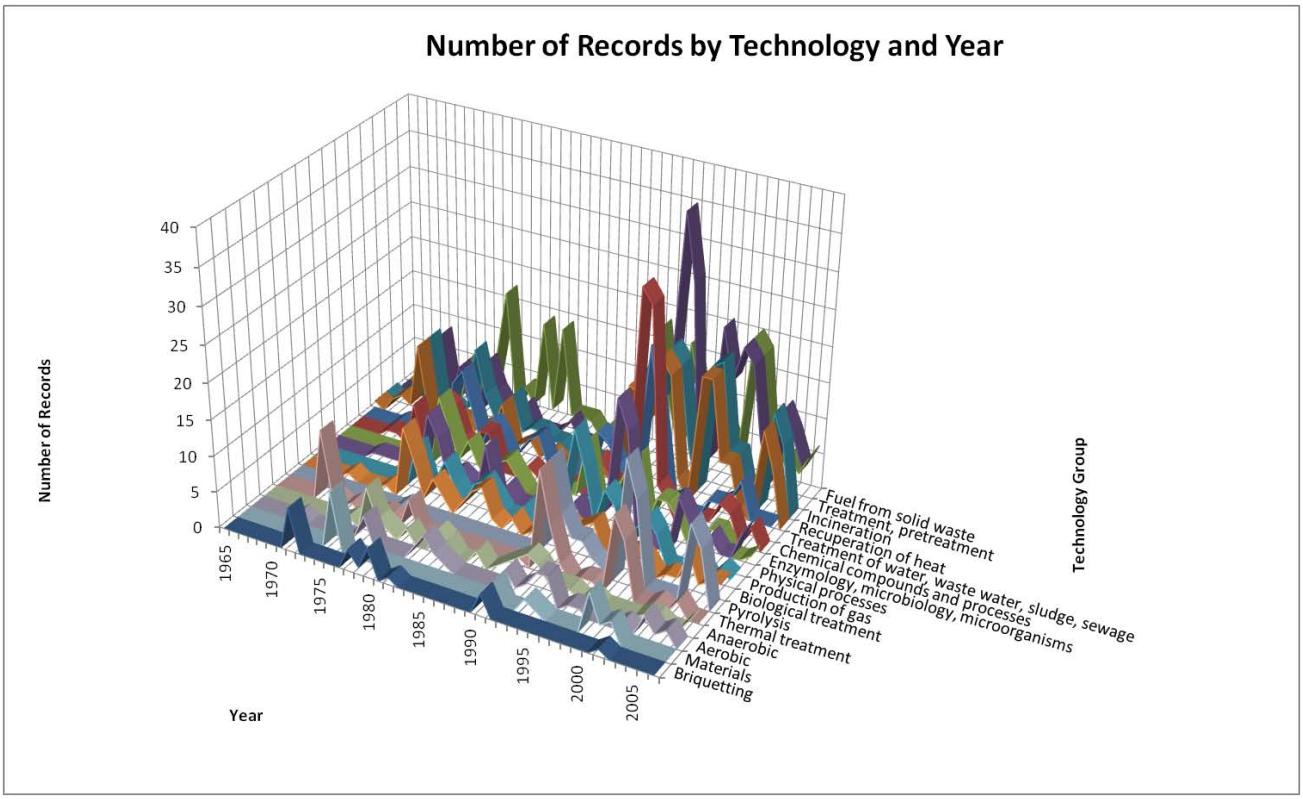


Figure 9 *Technology profile of patents in the GB dataset*

This graph gives a good overview of all the relevant topics using the broader classification field to reflect all patent family member influence. It can be seen from Figure 9 that most activity begins in the 1970s. Incineration and recuperation of heat have early presence, at the beginning of the available records, and then more activity is seen in the 1960s and 1970s, with a dip during the 1980s (including a zero point at 1986, consistent with Figure 8). Further activity to the present day is then seen from the 1990s onwards. Fuel from solid waste shows a similar pattern, and so does treatment, pretreatment, although with notably more activity recently. It may also be noted that briquetting, biological treatment, and anaerobic show less interest today than in the past. However, anaerobic demonstrates a recent upturn at the end of the dataset. Pyrolysis makes a sudden appearance in the early 1990s and is thereon a significant category.

It can be seen that the significant peak around 1995-1996 is in large part due to the fields of treatment/pretreatment and chemical compounds and processes. This period is examined more closely in Figure 10. Figures 10-12 are based on the narrow classification field as otherwise the occurrence of related family member classification terms obscures specific assignee-technology characteristics.

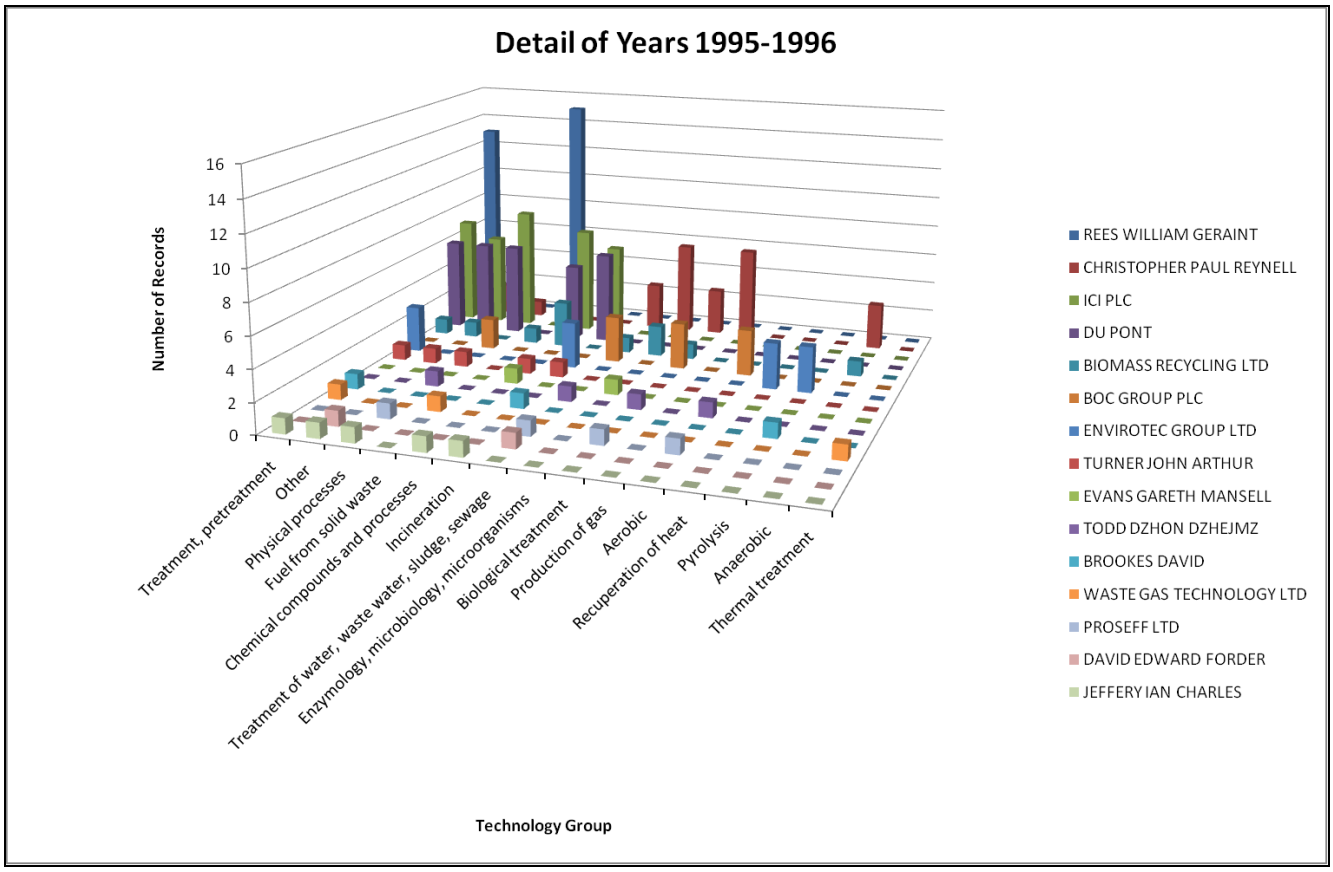


Figure 10 *Detail of patents filed in years 1995-1996*

A significant level of activity in this period is from Rees in the fields of treatment/pretreatment and fuel from solid waste, with a broader range of activity on the part of Reynell, ICI, and Du Pont also contributing. Of the 48 records in 1995, 15 are "William Geraint Rees", 8 are "ICI plc", and 8 are "Christopher Paul Reynell". Of the 37 records in 1996, 9 are "Rees", 8 ICI, 6 DuPont, and 6 Reynell.

Other peak periods, from Figure 8, may also be examined in further detail. For example, 1975-1976 is illustrated in Figure 11.

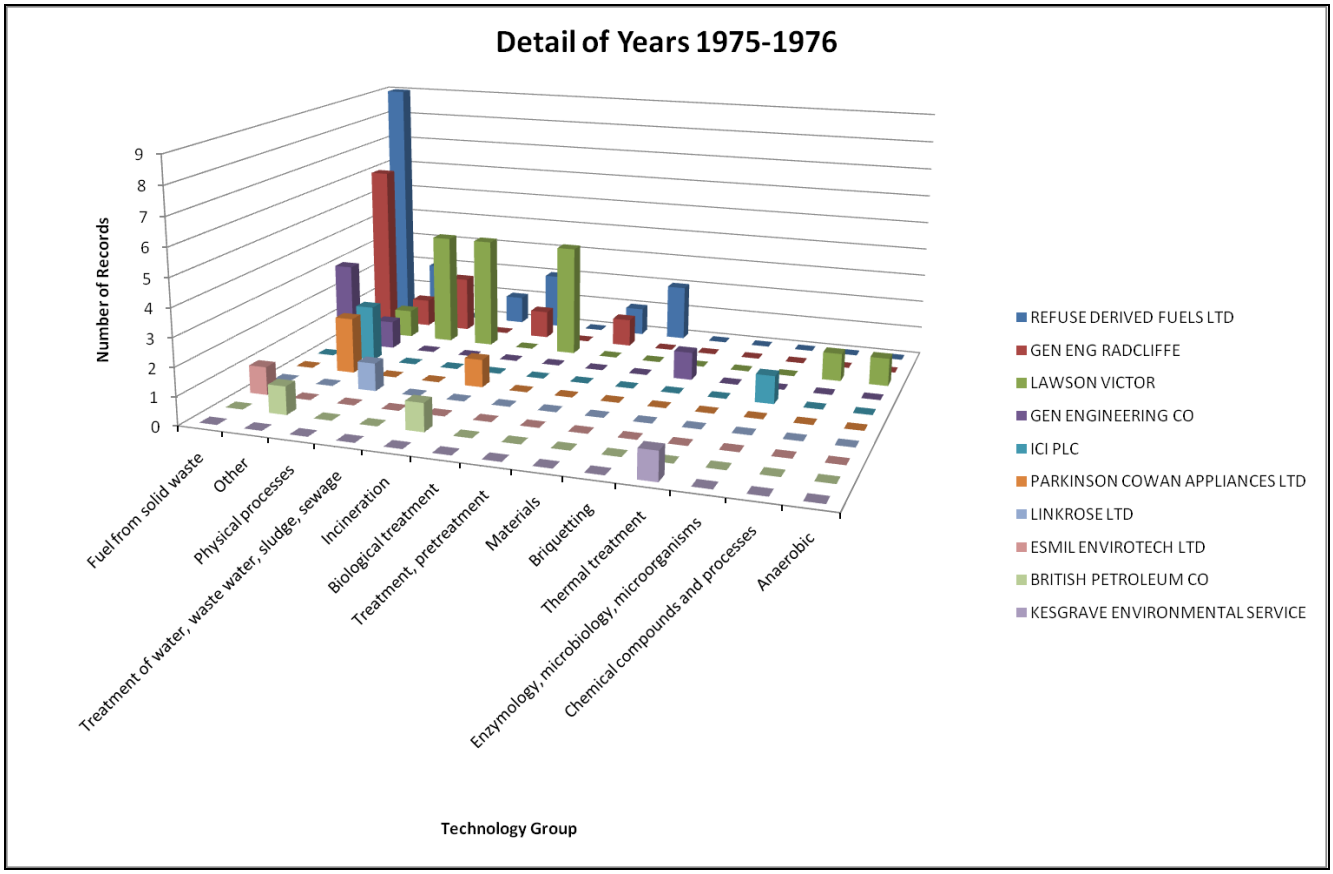


Figure 11 *Detail of patent filed in years 1975-1976*

During 1975-1976 the largest amount of activity is by Refuse Derived Fuels and Gen Eng Radcliffe in the field of fuel from solid waste.

Similarly, the years 1999-2002 are illustrated in Figure 12.

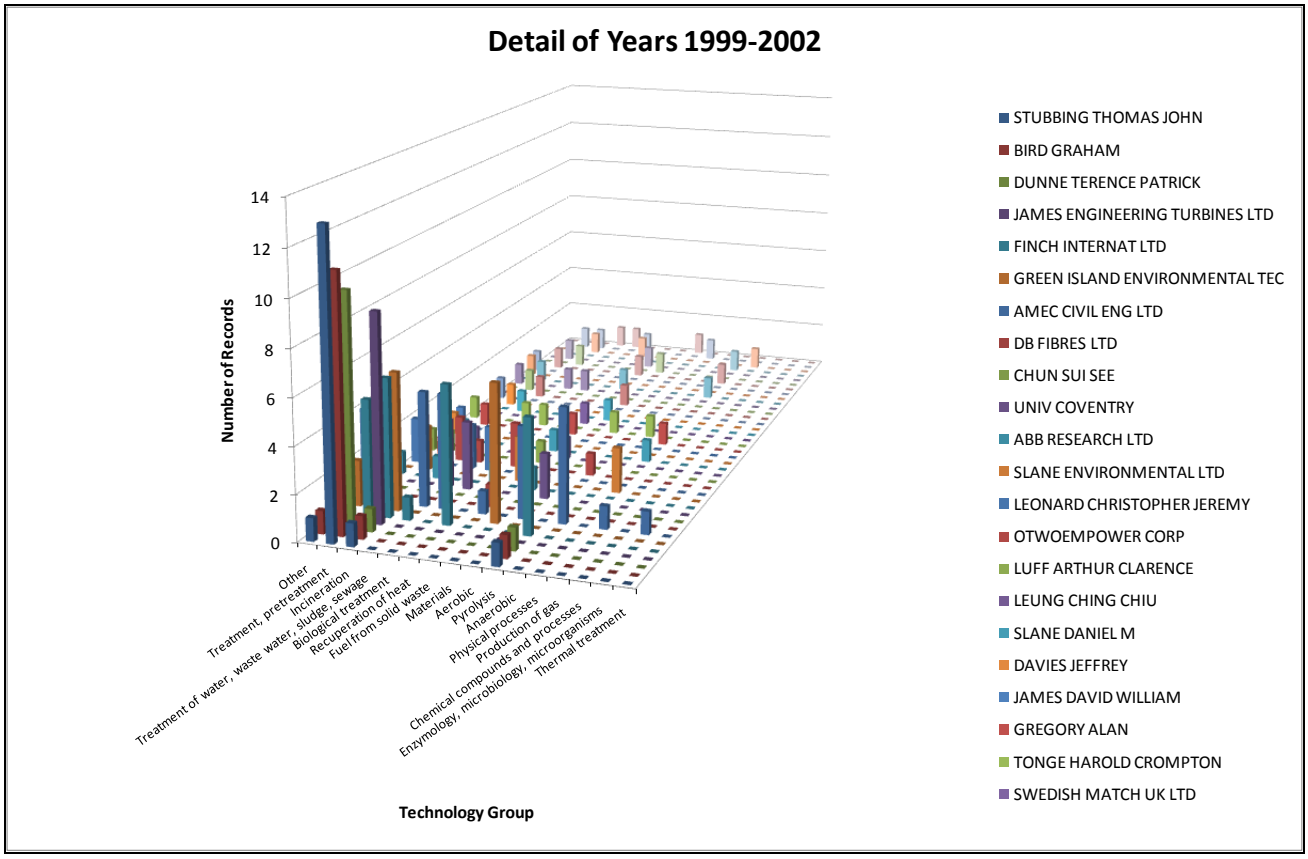


Figure 12 *Detail of patents filed in years 1999-2002*

Stubbing, Bird, and Dunne (who are generally co-assignees) are active in the field of treatment and pretreatment, and account for a lot of activity in this period. James Engineering Turbines was active in incineration. Finch International is also notable, in the fields of incineration, recuperation of heat, and pyrolysis.

Note that there are different applicants leading the fields in the different periods of time.

2.4 UK Applicant Types

Each applicant in the GB dataset was assigned to one of the following groups:

Commercial – organisations
Commercial – individuals
Academic
Public Sector
Government

The balance of activity by applicant type is given in Figure 13.

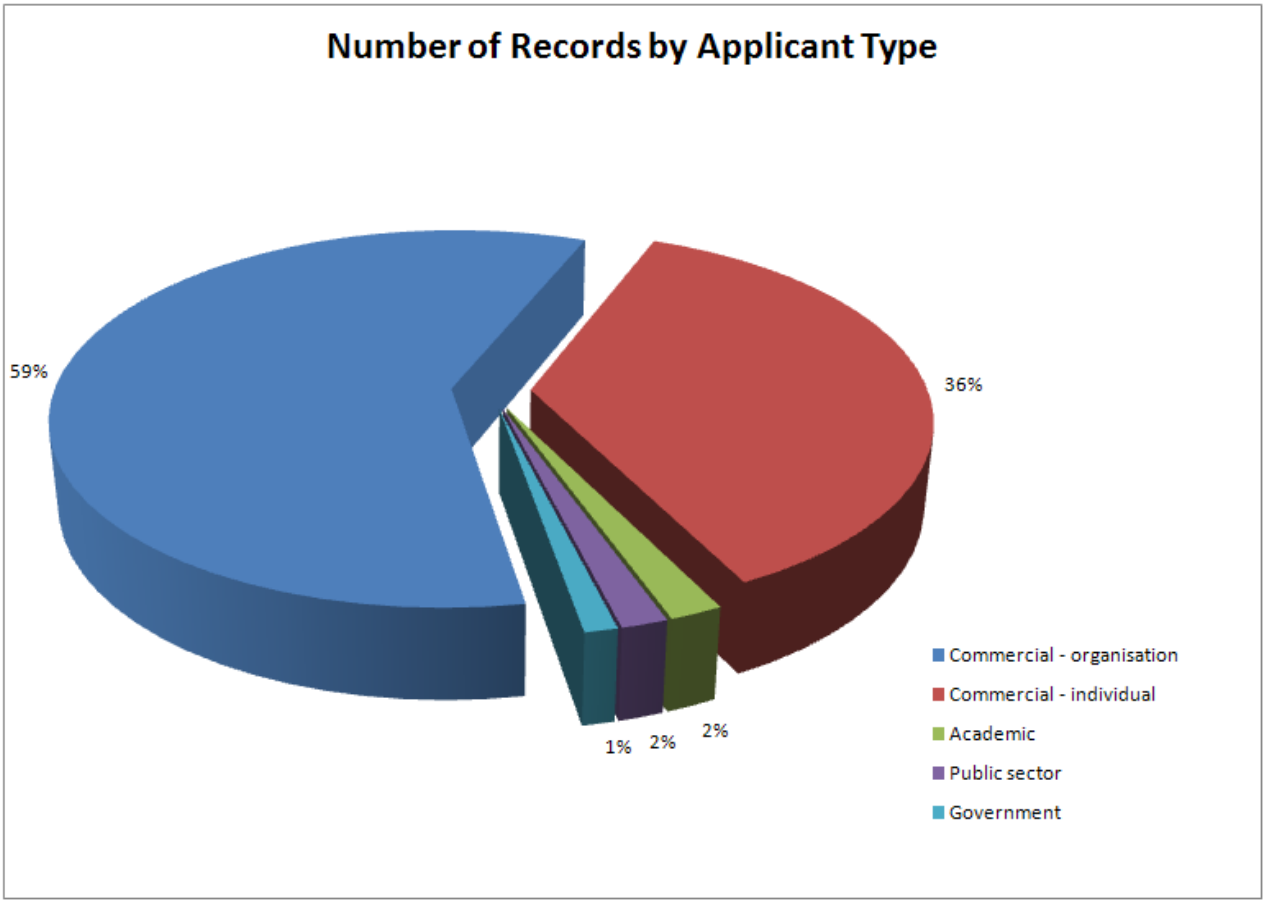


Figure 13 *Types of applicants in the GB dataset*

Commercial activity clearly dominates in the UK, suggesting sector maturity, although it is interesting that 36% of the sector is attributed to individuals.

Figure 14 shows the distribution of applicant types by technology type.

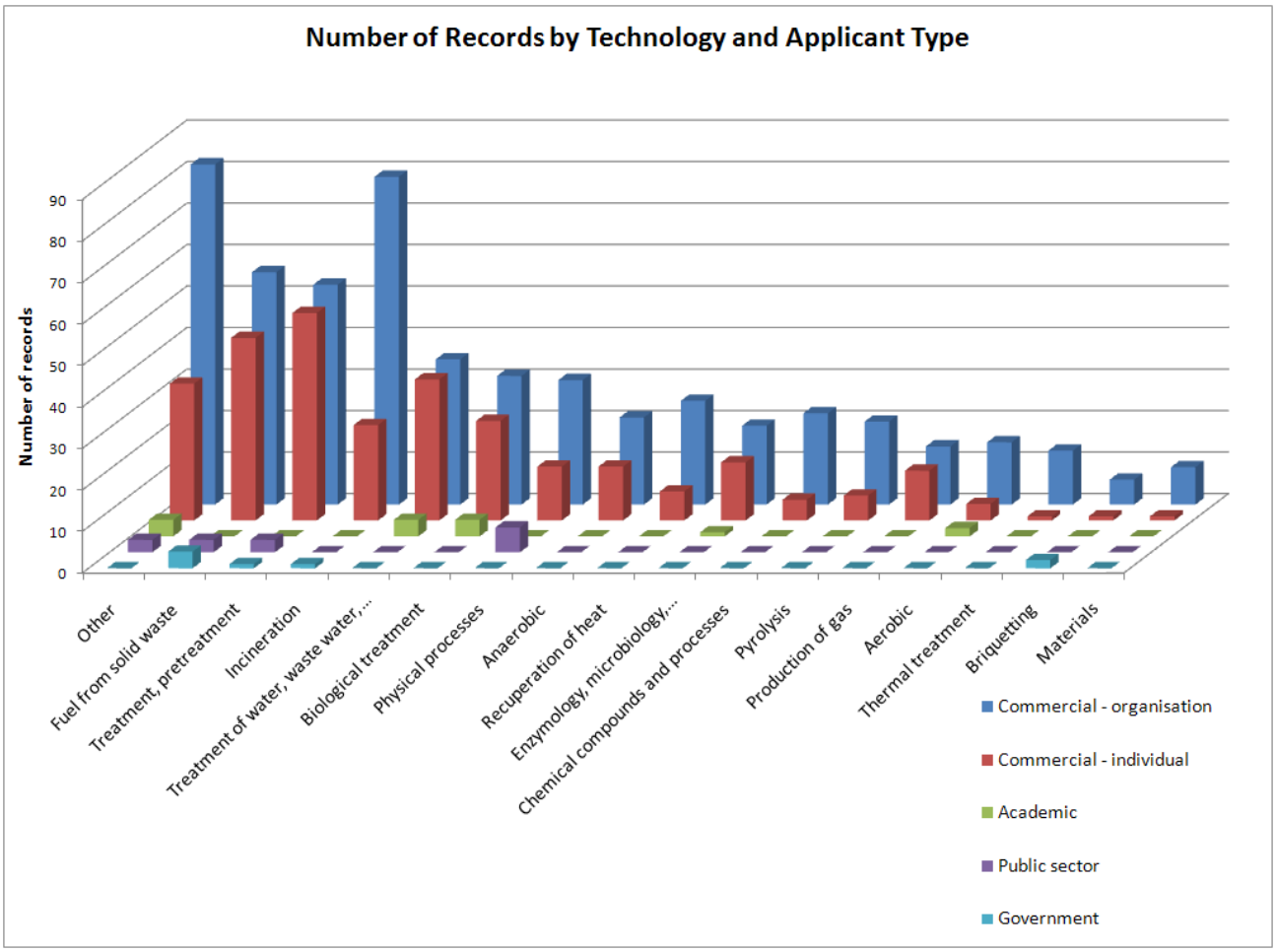


Figure 14 *Technology profile of the applicant types in the GB dataset*

Incineration can be seen to be a largely commercial organisation interest, whereas individuals tend to be more interested in treatment and pretreatment, almost matching organisations in this category. There is a very low level of academic interest and it is found exclusively in areas relating to biological treatments: aerobic; enzymology, microbiology, and microorganisms; biological treatment; treatment of water, waste water, sludge, and sewage, but notably absent from anaerobic. There were in fact only two academic assignees in the GB dataset: University of Coventry, and University of Waterloo. The Government assignees were the Environment secretary and the Defence secretary. Other Public sector applicants were Greater Manchester Council and the Thames Water Authority.

Figure 15 illustrates the pattern over time.

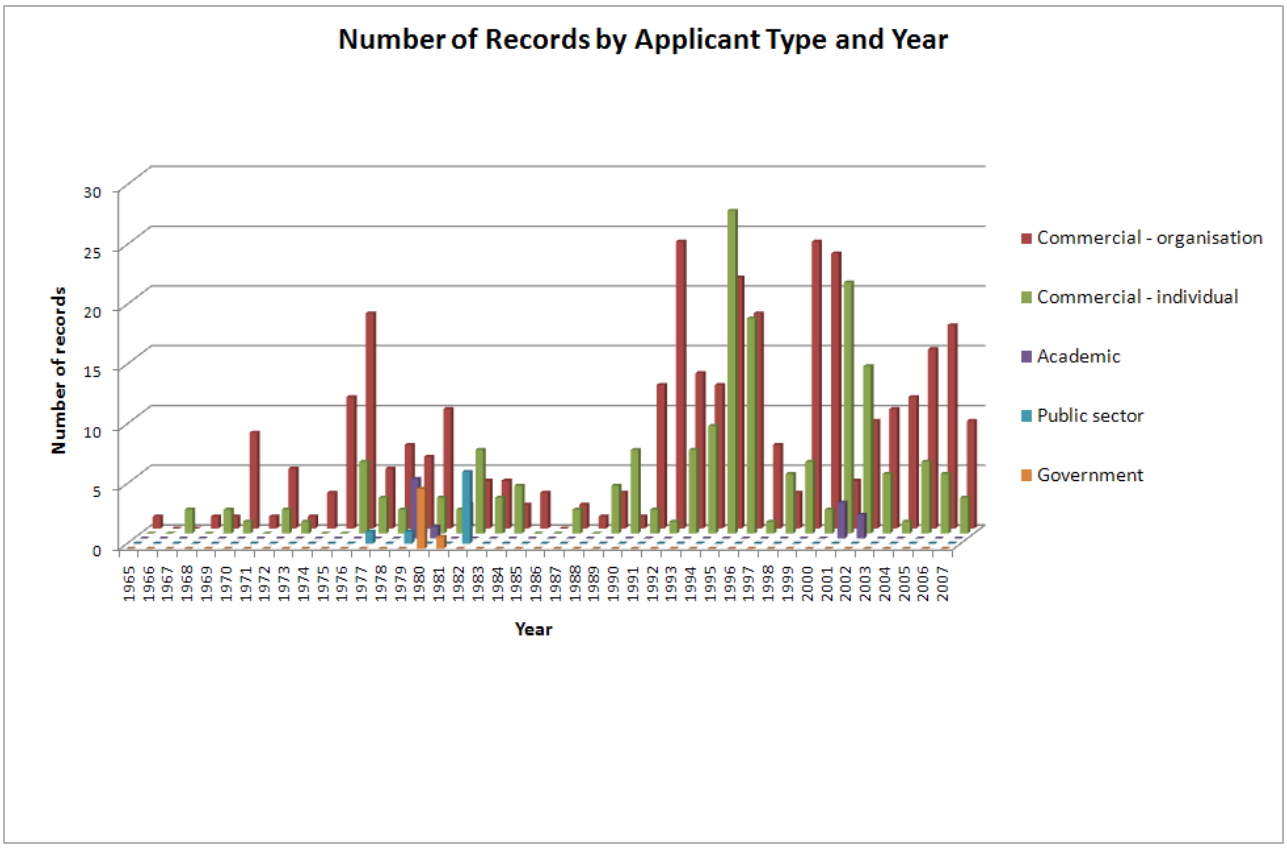


Figure 15 *Filing trends of applicant types in the GB dataset*

Periods of particular interest are where the number of records for individual inventors outnumbers those of organisations. For example, the years 95-96 and 01-02 show a substantial number of individual applications equalling or numbering more than organisations. These periods coincide with the overall peak periods examined in detail above, when individuals were very active for a short period of time. The year 1986 stands out as a year with no patents in any energy from waste field, and occurs during a generally quiet period from 1985-1988. In 1986 there were no records from commercial organisations, and in both 1985 and 1986 there were no records from commercial individuals. However, this result is not statistically significant[3].

[3] Given the "noisiness" of the distribution in the chart of Figure 15, from the mean and standard deviation, the zero is not a significant deviation and may be considered pure chance

2.5 Landscape Maps

A number of landscape maps were processed and refined. A list of stopwords is user-editable and this allows commonly-occurring words, or words that are not of interest, to be excluded from consideration when processing a map. The list of stopwords was refined to ensure that the maps are based on relevant detail. The same stopword list was used for all maps.

The entire map for energy from waste worldwide dataset is as follows in Figure 16.

Figure 16 *Landscape map of the worldwide dataset © Thomson Reuters*

Looking in more detail at the map, areas of interest and even individual patents of interest may be identified. For example, the white peak at the top of the map is shown in more detail in Figure 17.

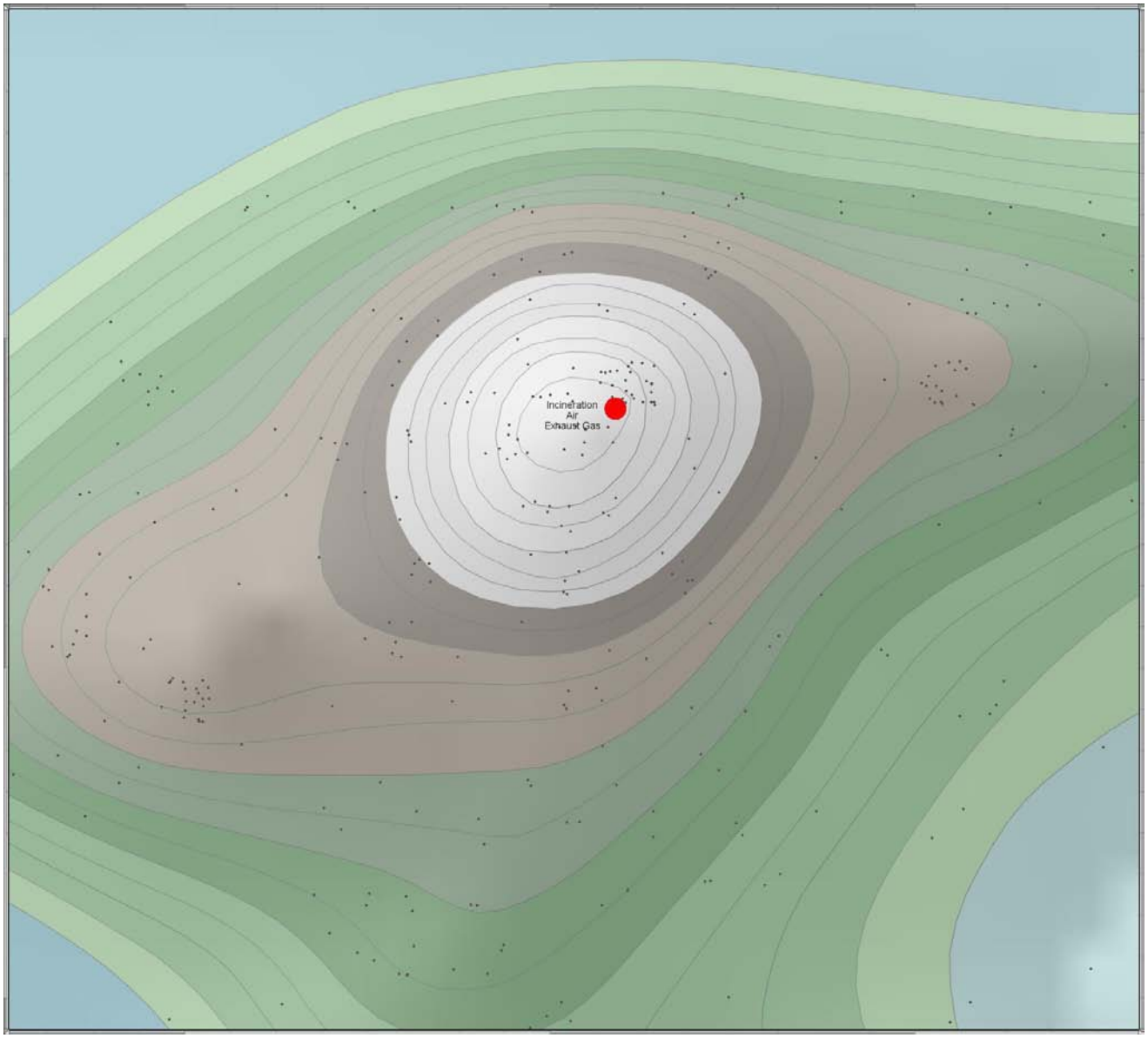


Figure 17 *Detail of the worldwide landscape map © Thomson Reuters*

Individual documents are represented by black dots. The document highlighted in red is an early document appearing in the peak. This is a significant document as it has no documents cited against it and it appears early in an area of the map which is subsequently heavily populated. This document is GB 944480, assigned to Thomas McDowell Ltd., relating to the combustion efficiency of an incinerator.

Similarly, GB 1451398 (again, highlighted in red) appears as an early document in a peak towards the lower left of the whole map, as shown in Figure 18. This document was assigned to Biomechanics Ltd. and it concerns an anaerobic digestion plant.

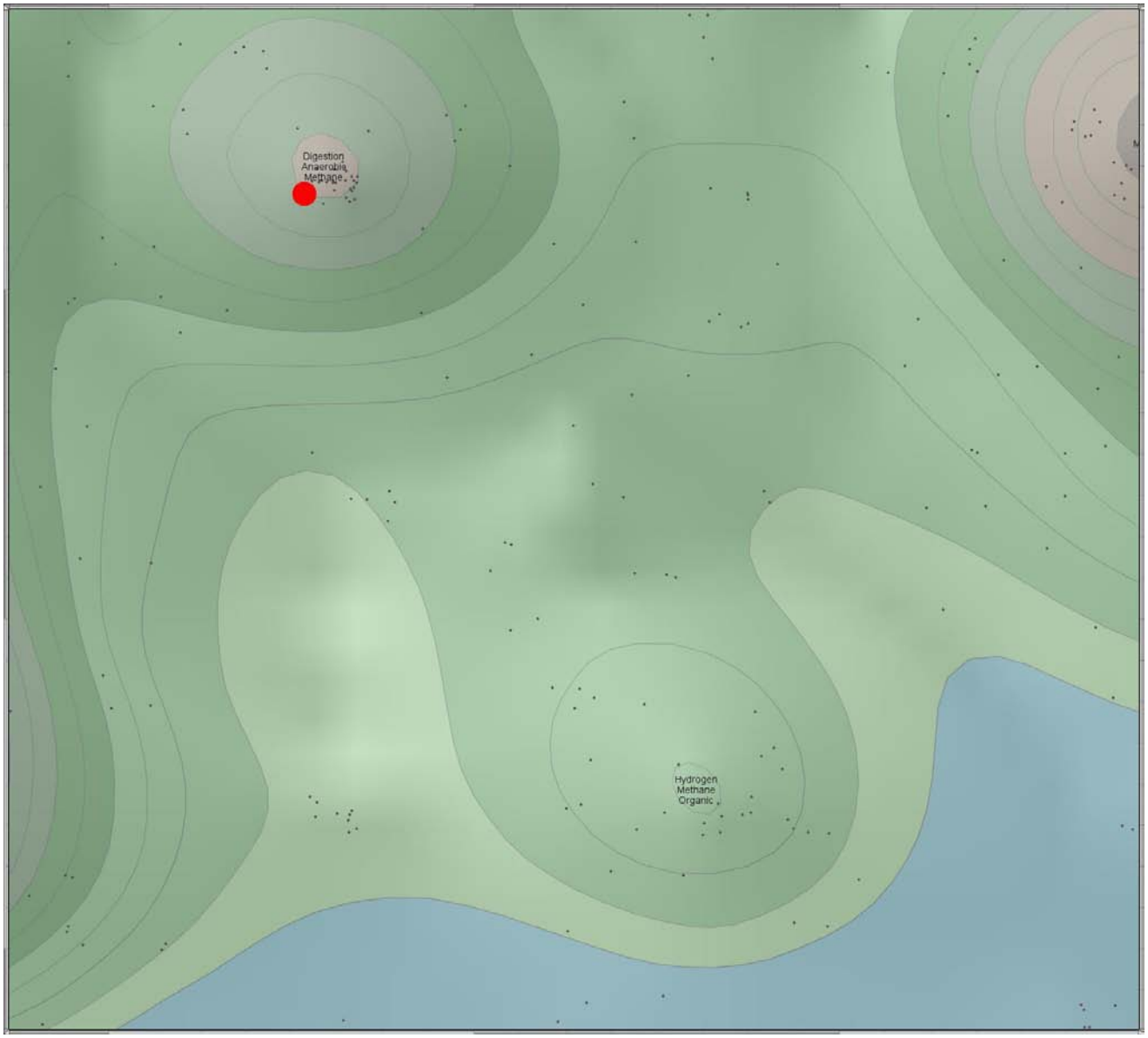


Figure 18 *Detail of the worldwide landscape map © Thomson Reuters*

Documents containing particular key words may be highlighted in the map. Pyrolysis shows a particularly interesting pattern, shown in Figure 19.

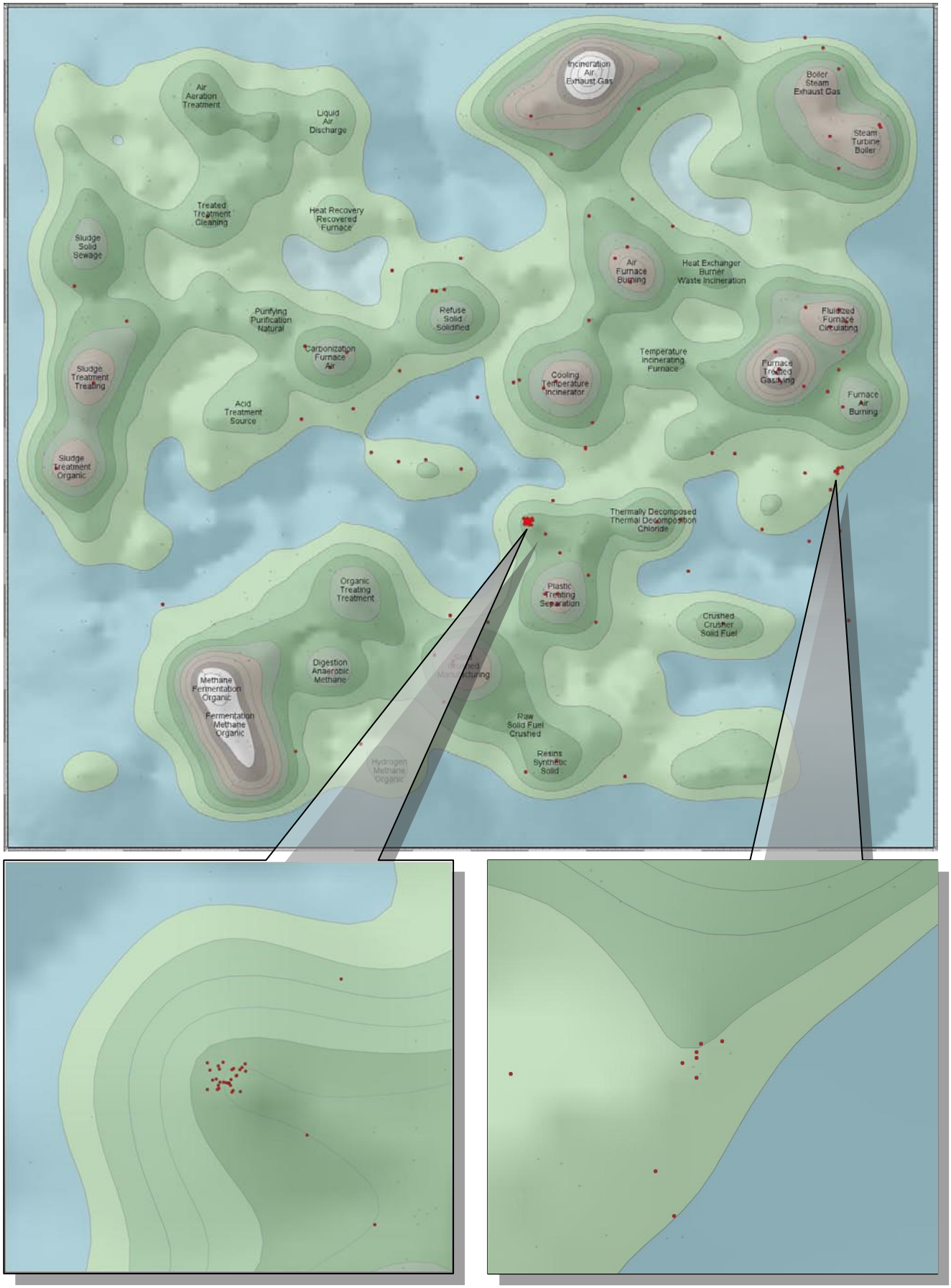


Figure 19 *Pyrolysis in the worldwide map (detail 1, lower left; detail 2, lower right) © Thomson Reuters*

There is some spread of the documents, but there is an exceptionally tight cluster shown in detail 1 (left), and a second cluster in detail 2 (right). These clusters appear to lack particular affinity for other topics, forming clusters by themselves. In detail 1 the keywords pyrolysis/pyrolization appear as most frequently occurring keywords. The earliest document in this cluster is GB 1531106, which is part of a large family (of 25 patents altogether), and is referenced 105 times. Therefore it appears to be a significant document, yet this document is the only one from this assignee (Lampl) in the dataset. Organic and plastic keywords also appear in this cluster, but furnace only appears in 24% of the documents. This cluster may indicate an emerging field or specialism, particularly since it is remote from the furnace region of the map. A full list of documents in this cluster is provided in the Appendix for further study. The second cluster has more affinity for furnaces, with furnace appearing as a keyword in 95% of the documents, and it is therefore perhaps of less interest. However this is a 'coastal' area and as such may indicate emergent potential.

Further study reveals that the term biohydrogen is not significantly used, but if biogas is highlighted, the pattern in Figure 20 is seen.

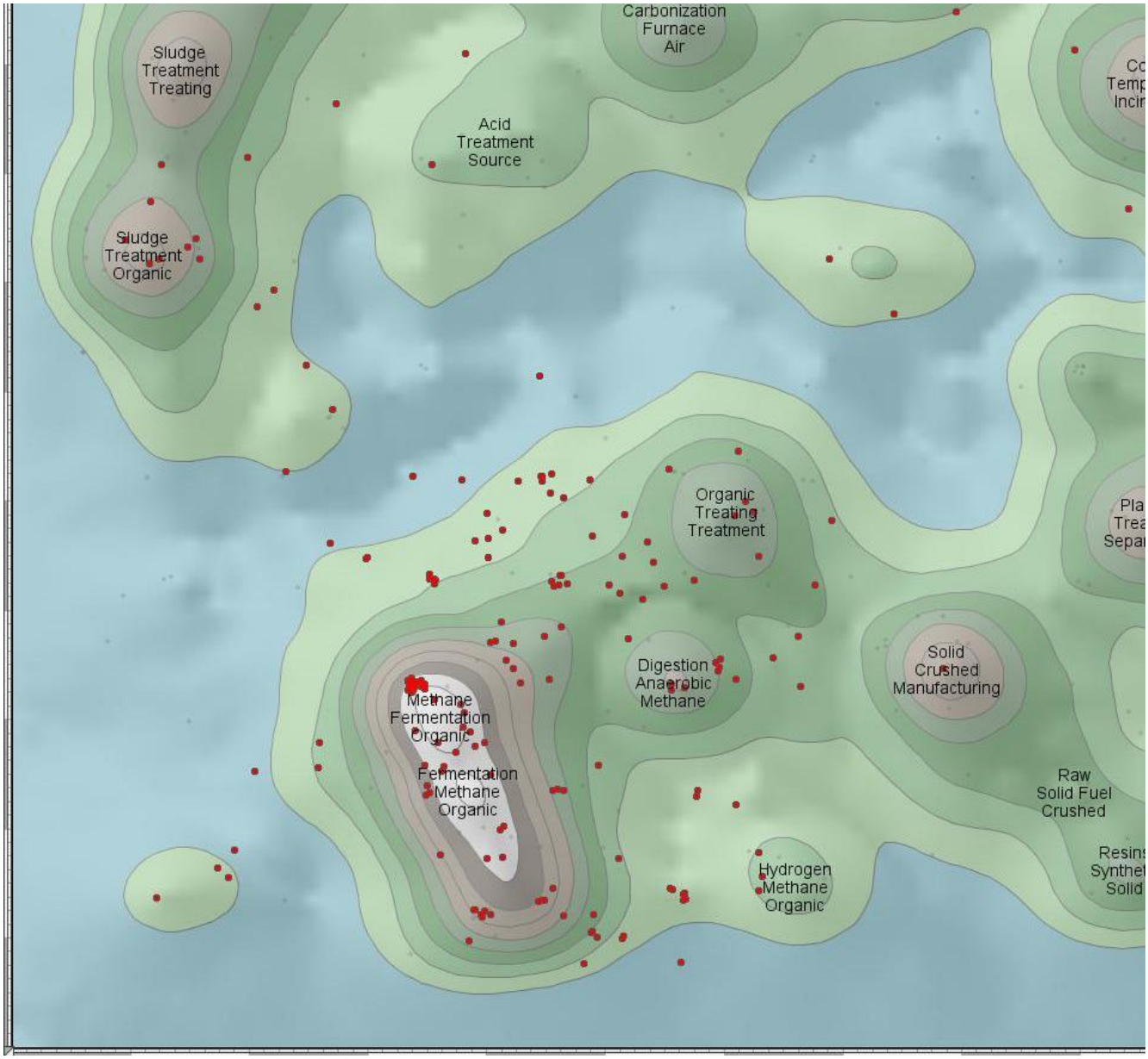


Figure 20 *Detail of the worldwide landscape map showing biogas © Thomson Reuters*

Most activity appears around the bottom left region of the map, unsurprisingly, alongside organic and biological topics. Hydrogen appears as follows, in Figure 21.

EP162545A2	EP1134194B1
EP414957A1	JP3137994A
EP415160A1	EP400837B1
EP1756013A1	JP61234989A
GB1604948A	JP4190900A
JP61205492A	JP2001149983A
JP2035993A	GB2439647A
JP4277097A	JP11046754A
JP5096294A	JP11046753A
JP6277446A	JP6000493A
JP2004057874A	JP62050000A
US5714058A	JP2000167523A
US6887692B2	
US7166211B1	

Figure 21 *Worldwide landscape map showing hydrogen © Thomson Reuters*

There is again a small cluster in an unexpected region in this map, as highlighted. This cluster is interesting because it occupies 'shallow water' unsurrounded by other patents. The documents range in time from 1978 to 2006 so there is ongoing, and possibly emerging, activity. The list of document numbers is supplied for further investigation.

GB 2230004 may be found as one of the earlier documents in the peak "furnace, treated, gasifying". This document was assigned to Pallett and is granted and presently in force in its nineteenth year of renewal. It has ten forward citations, and is the top forward-cited GB patent. The inventor is Reynell, who is also in the top ten of applicants in the GB dataset. All of these are good indicators that this is a particularly high value patent.

The map for the GB dataset is as follows in Figure 22. GB 2230004 is highlighted in red, and in this map has an affinity with "solid, consists, pulverized". This reflects the different relative levels of activity in the UK.

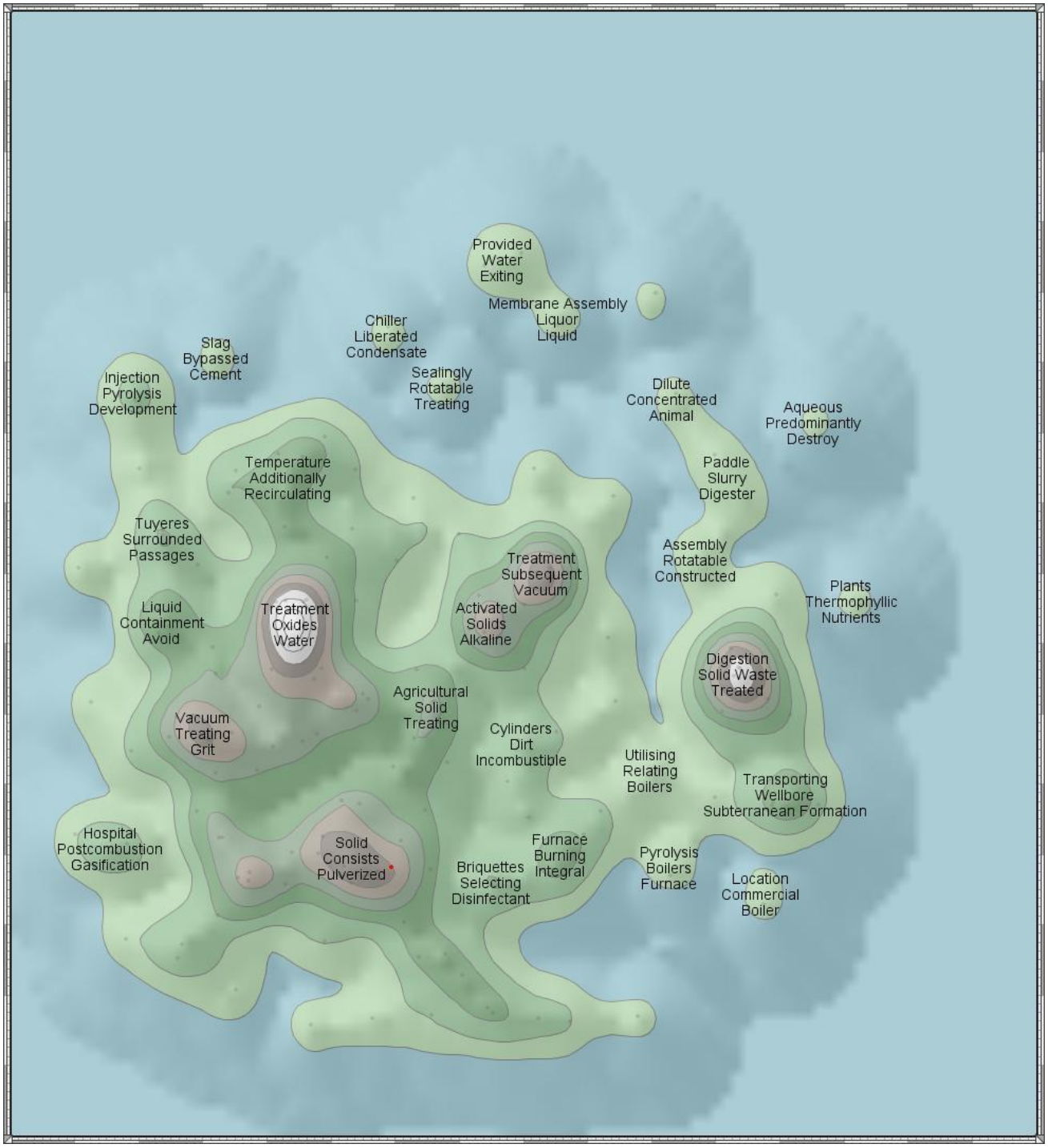


Figure 22 *Landscape map for the GB dataset © Thomson Reuters*

Because of the smaller numbers in the GB dataset, fewer conclusions can be drawn about this landscape map. However, the major peaks in this map appear around "treatment, oxides, water" towards the left hand side, and "digestion, solid waste, treated" towards the right hand side. The most frequently occurring terms in this landscape include: treatment, water, solid, liquid, and digestion. Document GB 1451398 occurs in the "digestion, solid waste, treated" peak on this landscape, as might expected. However, the other "significant" documents pointed out above in the worldwide landscape do not occur within populous regions on the GB landscape,

reflecting the different balance of activity within the UK. Note that the small islands around the top and right of the map contain only one document each, so although they are outlying areas, they cannot be considered to represent emerging technologies as of yet.

Similar analysis to above may be used to identify early occurrences within peaks on the landscape. GB 2082628 (assigned to Motherwell Mechanical and Electrical) is the earliest document within the main “treatment, oxides, water” peak. It relates to the production of a fuel from heterogeneous waste materials, and no documents were cited against it during examination. This was granted in 1984 and was renewed until 1988.

GB 2431155, assigned to IWI, granted in 2009, claims a method for treating organic waste. This patent is of interest because it occurs in the “digestion, solid waste, treated” peak on the landscape, and also because it was recently granted.

2.6 Legislative, Social, and Other Influences

A number of factors are likely influences on the patenting trends seen in the data. Attitudes towards incineration, for example, differ between countries; Figure 7 demonstrates that incineration is much more popular in Switzerland than in the UK. Legislative influences such as the Landfill Directive may encourage development of Energy from Waste technologies, although a detailed study of these external influences is not within the scope of Patent Informatics per se. Growing awareness and concern over human-induced climate change and diminishing fossil fuels is also likely to encourage development of these technologies. In particular, Figure 23 shows the relationship between patents for Energy from Waste technologies and oil prices.

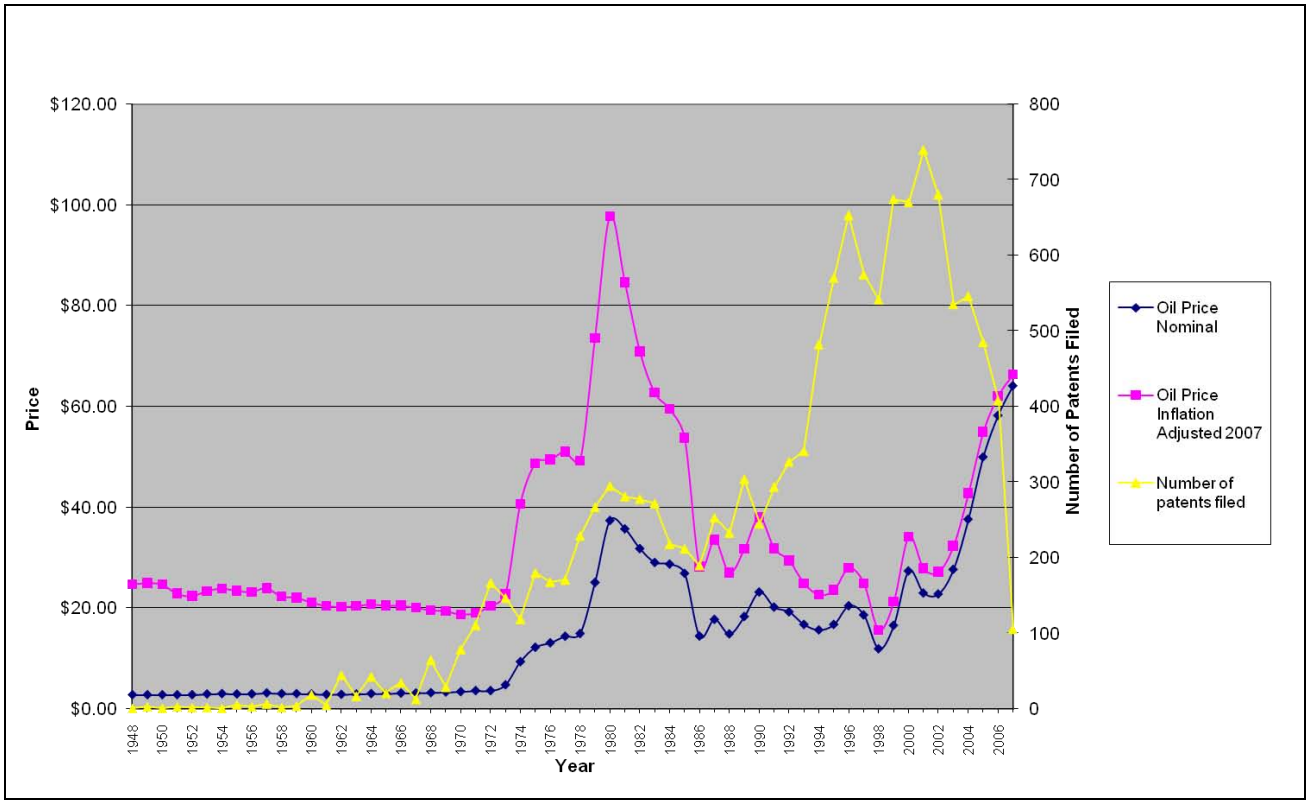


Figure 23 *Energy from Waste patents and oil prices*

There is a notable degree of tracking overall and several coincident peaks and troughs (for example in 1980, 1986, 1987, 1988, 1996, and 1998). Note that Figure 23 shows oil prices up until 2007 only, and that with further increases since, the technology may be expected to follow suit. For comparison, Figure 24 shows the total number of patents filed across all areas of technology through the PCT (worldwide) patent route. This acts as a barometer to indicate overall patenting activity throughout the world. No clear trend is apparent in this data, which supports the hypothesis that Energy from Waste patenting reflects global oil prices as noted above.

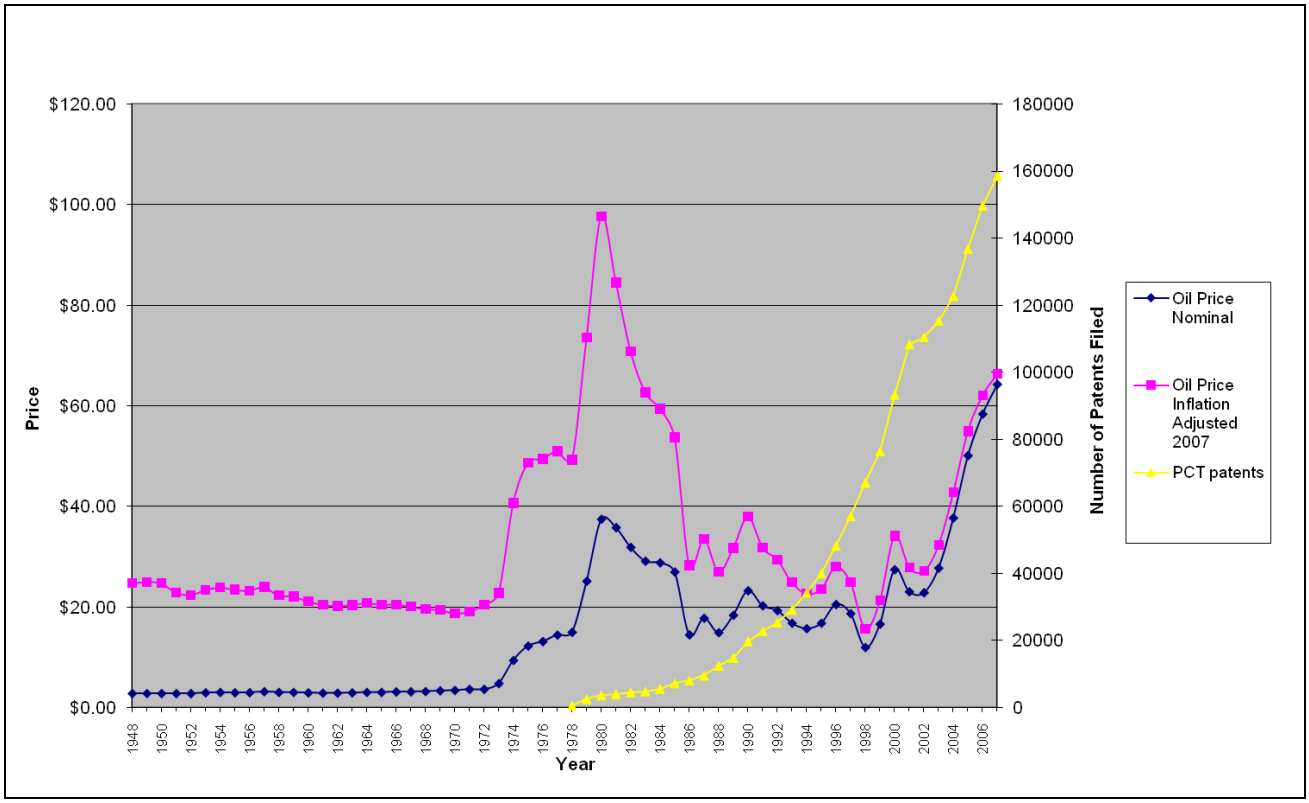


Figure 24 *Number of PCT patents and oil prices*

3 Conclusions

Technologies in the field of Energy from Waste are well established and the evidence of the patent records is that activity stretches back to the early twentieth century. 2001 is the peak year on record for Energy from Waste patents, followed by an apparent decline. However, it is a characteristic of patent data that the date at which patent records appear in published databases lags the priority year by up to five years.

Energy from Waste is a broad term which in fact comprises a large number of different technologies which are developing all the time. Technologies relating to incineration in general dominated the field from the late 1960s to the early 1980s and have been less significant since. Instead, the focus has moved towards perfecting technologies, such as pretreatment, recuperation of heat, or secondary combustion in incinerators, or towards other technologies, such as anaerobic treatment to form gases, or solid fuels.

Japan is the world's leader by a large margin in Energy from Waste patent filings. The UK is the sixth country overall, but activity has been apparent in the UK from an early stage. Of the top ten organisations for patent filings, all but one are Japanese companies, the exception being a German company.

The pattern of activity in the UK differs from other countries, with technologies relating to incineration being under-represented, whereas technologies relating to the treatment of solid waste, the production of solid fuels, and the anaerobic treatment of waste water and sewage are well-represented. The UK has seen periods of significant activity in the 1970s, the 1990s, and the 2000s. However, it appears that different companies and individuals are responsible during each period.

There are many external factors which may influence the patenting trends seen in the data. In particular, there is some correlation between Energy from Waste patent filings and the price of oil.

A "GB Dataset", obtained by extracting all records from the worldwide dataset which contain either of a GB applicant, a GB inventor, or a GB priority application, produced 430 documents. The year range for this dataset was 1909 to 2007.

There is patchy activity in the dataset until the end of the 1960s, from when the activity is generally greater, apart from a dip to zero in 1986. The most prolific patent applicants in the dataset were Rees and Stubbing. Individuals make significant contributions to patent filings in the UK, although these tend to be concentrated into short time periods. Therefore they influence the overall trends significantly, dominating certain periods entirely (1995-1996 and 1999-2002).

Over the last ten years, significant applicants have been Tetronics Ltd., Accentus Plc., and Stubbing, Bird, and Dunne. Although topics relating to incineration and the preparation of waste ready for incineration appear to be the most active field in the UK, there is also a notable level of activity in fields relating to biological treatment.

There is a very low, and perhaps insignificant, level of activity from academia and government/public sector applicants in the UK in energy from waste topics. However, a significant proportion (36%) of records have named individuals as applicants, rather than organisations, and organisations account for 59% of records. The remaining 5% are accounted for by academic, public sector, and government applicants. For certain topics (treatment/pretreatment; treatment of water, waste water, sludge, and sewage; production of gas) the level of activity of individuals closely matches that of organisations, and therefore perhaps these are sectors in which small companies can influentially contribute. Other topics, such as incineration, seem to offer less opportunity for small companies.

Pyrolysis and hydrogen production yield interesting patterns of clustering in the landscape which may indicate emerging fields. Specific patents may also be identified: GB 1531106, GB 944480, GB 1451398, GB 2431155, and GB 2230004 appear to be significant patents.

4 Recommendations

The project conducted research into global patent activity in Energy from Waste with a UK focus and in particular studied sector trends, identifying key applicants and patents.

Recommendations for further work include:

- Identify further sectors which exhibit emergence and disruptive potential
- Identify specific UK portfolios and understand their impact on worldwide Energy from Waste technology
- Identify the effects of specific legislation on patent trends e.g. the Japanese Basic Environment Law[4]
- Study collaborations to understand knowledge transfer
- Rigorously analyse academic patent activity to potentially uncover activity masked by collaboration or commercialisation
- Understand specific strengths and opportunities in e.g. biological treatment of waste and biomass conversion
- Deep analysis of a specific sub-sector e.g. anaerobic digestion, pyrolysis

[4] http://www.env.go.jp/en/laws/policy/basic/index.html

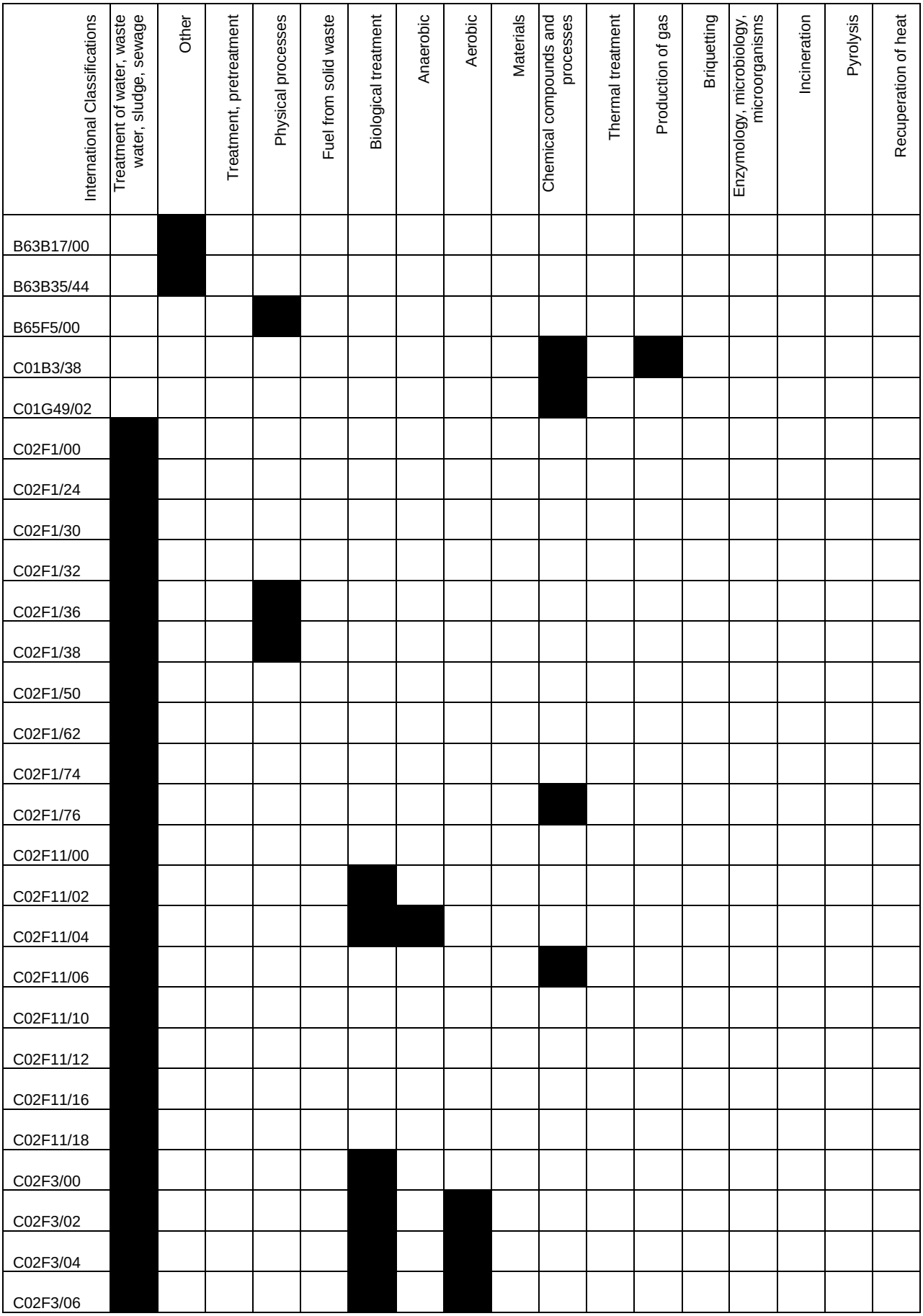
5 Appendix

5.1 Groupings of Classification Codes

International Classifications	Treatment of water, waste water, sludge, sewage	Other	Treatment, pretreatment	Physical processes	Fuel from solid waste	Biological treatment	Anaerobic	Aerobic	Materials	Chemical compounds and processes	Thermal treatment	Production of gas	Briquetting	Enzymology, microbiology, microorganisms	Incineration	Pyrolysis	Recuperation of heat
A01C3/02	■																
A01D41/00		■															
A01D91/00		■															
A01D91/04		■															
A01F15/04		■															
A01F15/08		■															
A01K61/00		■															
A01K67/033		■															
A01N63/00		■															
A01N63/02						■											
A23K1/00		■															
A23K1/10		■															
A23K1/12		■															
A23K1/16		■															
A23K1/18		■															
A23L1/30		■															
A61K35/12		■															
A61K35/64		■															
A61L11/00			■														
A61L2/07		■															
A61L2/12		■															
A61P31/12		■															
A61P35/00		■															

International Classifications	Treatment of water, waste water, sludge, sewage	Other	Treatment, pretreatment	Physical processes	Fuel from solid waste	Biological treatment	Anaerobic	Aerobic	Materials	Chemical compounds and processes	Thermal treatment	Production of gas	Briquetting	Enzymology, microbiology, microorganisms	Incineration	Pyrolysis	Recuperation of heat
A61P37/00		■															
A62D3/19		■															
A62D3/40																■	
B01D19/00				■													
B01D19/02				■													
B01D24/36				■													
B01D24/38				■													
B01D3/14				■													
B01D3/16				■													
B01D33/11				■													
B01D33/70				■													
B01D35/18				■													
B01D47/00				■													
B01D53/18				■													
B01D53/40				■													
B01D53/62				■													
B01D53/68										■							
B01D53/77				■													
B01D53/86			■	■													
B01D61/18				■													
B01F1/00				■													
B01F15/00				■													
B01F3/04				■													
B01F3/08				■													
B01F3/12				■													
B01F5/02				■													
B01F5/04				■													

International Classifications	Treatment of water, waste water, sludge, sewage	Other	Treatment, pretreatment	Physical processes	Fuel from solid waste	Biological treatment	Anaerobic	Aerobic	Materials	Chemical compounds and processes	Thermal treatment	Production of gas	Briquetting	Enzymology, microbiology, microorganisms	Incineration	Pyrolysis	Recuperation of heat
B01F5/10				■													
B01J10/00										■							
B01J19/10				■													
B01J19/24				■													
B01J19/28				■													
B01J2/00				■													
B01J3/00				■													
B01J6/00				■													
B01J8/02				■													
B01J8/18				■													
B01J8/22				■													
B02C18/00				■													
B02C19/06				■													
B02C21/00				■													
B02C23/10				■													
B03B1/02				■													
B03B9/06				■													
B07B9/00				■													
B09B1/00					■												
B09B3/00			■		■												
B09B5/00					■												
B27N3/04		■															
B29B17/00			■														
B29B17/02				■													
B30B11/22				■													
B30B9/12				■													
B60K3/04				■													


International Classifications
Treatment of water, waste water, sludge, sewage
Other
Treatment, pretreatment
Physical processes
Fuel from solid waste
Biological treatment
Anaerobic
Aerobic
Materials
Chemical compounds and processes
Thermal treatment
Production of gas
Briquetting
Enzymology, microbiology, microorganisms
Incineration
Pyrolysis
Recuperation of heat
B63B17/00
B63B35/44
B65F5/00
C01B3/38
C01G49/02
C02F1/00
C02F1/24
C02F1/30
C02F1/32
C02F1/36
C02F1/38
C02F1/50
C02F1/62
C02F1/74
C02F1/76
C02F11/00
C02F11/02
C02F11/04
C02F11/06
C02F11/10
C02F11/12
C02F11/16
C02F11/18
C02F3/00
C02F3/02
C02F3/04
C02F3/06

International Classifications	Treatment of water, waste water, sludge, sewage	Other	Treatment, pretreatment	Physical processes	Fuel from solid waste	Biological treatment	Anaerobic	Aerobic	Materials	Chemical compounds and processes	Thermal treatment	Production of gas	Briquetting	Enzymology, microbiology, microorganisms	Incineration	Pyrolysis	Recuperation of heat
C02F3/08	■					■		■									
C02F3/10	■					■		■									
C02F3/12	■					■		■									
C02F3/16	■					■		■									
C02F3/20	■					■		■									
C02F3/22	■					■		■									
C02F3/24	■					■		■									
C02F3/26	■					■		■									
C02F3/28	■					■	■										
C02F3/30	■					■											
C02F3/34	■					■								■			
C02F7/00	■																
C02F9/00	■																
C04B2/10									■								
C04B7/36									■								
C04B7/43									■								
C04B7/44									■								
C05D9/00										■							
C05F15/00		■															
C05F17/00		■															
C05F17/02		■															
C05F3/00	■									■							
C05F3/06	■	■								■							
C05F7/00	■	■								■							
C05F9/00		■								■							
C05F9/02		■								■							
C07C1/04										■							

International Classifications	Treatment of water, waste water, sludge, sewage	Other	Treatment, pretreatment	Physical processes	Fuel from solid waste	Biological treatment	Anaerobic	Aerobic	Materials	Chemical compounds and processes	Thermal treatment	Production of gas	Briquetting	Enzymology, microbiology, microorganisms	Incineration	Pyrolysis	Recuperation of heat
C07C29/151										■							
C07C51/265										■							
C07C63/26										■							
C07C7/00										■							
C08J11/00			■														
C08J11/06			■														
C08L97/02										■							
C10B1/10											■						
C10B47/30											■						
C10B47/44											■						
C10B49/00											■						
C10B53/00											■						
C10B53/07											■						
C10B53/08											■		■				
C10B57/02											■						
C10G2/00										■							
C10G21/00										■							
C10G32/00										■							
C10G7/00										■							
C10J3/00												■					
C10L1/02										■							
C10L1/14										■							
C10L10/02										■							
C10L11/04										■							
C10L3/00												■					
C10L3/08												■					
C10L3/10												■					

International Classifications	Treatment of water, waste water, sludge, sewage	Other	Treatment, pretreatment	Physical processes	Fuel from solid waste	Biological treatment	Anaerobic	Aerobic	Materials	Chemical compounds and processes	Thermal treatment	Production of gas	Briquetting	Enzymology, microbiology, microorganisms	Incineration	Pyrolysis	Recuperation of heat
C10L5/00													■				
C10L5/02													■				
C10L5/04													■				
C10L5/10													■				
C10L5/12													■				
C10L5/14													■				
C10L5/40					■												
C10L5/44					■												
C10L5/46					■												
C10L5/48					■												
C10L7/00													■				
C10L7/02													■				
C10L9/00										■			■				
C10L9/10										■			■				
C12M1/00														■			
C12M1/02														■			
C12M1/04														■			
C12M1/08														■			
C12M1/107												■		■			
C12M1/36														■			
C12M1/40														■			
C12N1/00														■			
C12N1/16														■			
C12N1/20														■			
C12N1/22														■			
C12N1/32														■			
C12P1/00														■			

International Classifications	Treatment of water, waste water, sludge, sewage	Other	Treatment, pretreatment	Physical processes	Fuel from solid waste	Biological treatment	Anaerobic	Aerobic	Materials	Chemical compounds and processes	Thermal treatment	Production of gas	Briquetting	Enzymology, microbiology, microorganisms	Incineration	Pyrolysis	Recuperation of heat
C12P5/02										■							
C12P7/08										■							
C12P7/10										■							
C12S13/00														■			
C22B1/16			■														
C22B1/245			■														
C22B1/248													■				
C22B21/00			■						■								
C22B7/02			■														
C22B7/04			■														
D21B1/00			■														
D21B1/02			■														
D21B1/32			■														
D21C11/00		■															
D21C11/04		■															
D21D5/00		■															
E02D31/00		■															
E03F1/00	■																
E04C2/16									■								
E04G9/10		■															
E21B43/00		■															
E21B43/25		■															
E21B43/40		■															
F01K23/10		■															
F01K25/14		■															
F02B45/02		■															
F02B47/06		■															

International Classifications	Treatment of water, waste water, sludge, sewage	Other	Treatment, pretreatment	Physical processes	Fuel from solid waste	Biological treatment	Anaerobic	Aerobic	Materials	Chemical compounds and processes	Thermal treatment	Production of gas	Briquetting	Enzymology, microbiology, microorganisms	Incineration	Pyrolysis	Recuperation of heat
F02B51/02		■															
F02C3/20		■															
F02C3/26		■															
F02C3/28											■						
F02C6/10		■															
F02C7/08		■															
F02C7/26		■															
F02C9/40		■															
F03D9/00		■															
F16J15/40		■															
F22B1/02		■															
F22B21/34		■															
F22B31/00		■															
F22B31/04		■															
F22B37/14		■															
F22B7/12		■															
F23C1/00															■		
F23C1/08															■		
F23C10/00															■		
F23C10/14															■		
F23C10/18															■		
F23C10/22															■		
F23C6/00															■		
F23G1/00															■		
F23G5/00															■		
F23G5/02			■												■		
F23G5/027			■												■	■	

International Classifications	Treatment of water, waste water, sludge, sewage	Other	Treatment, pretreatment	Physical processes	Fuel from solid waste	Biological treatment	Anaerobic	Aerobic	Materials	Chemical compounds and processes	Thermal treatment	Production of gas	Briquetting	Enzymology, microbiology, microorganisms	Incineration	Pyrolysis	Recuperation of heat
F23G5/033			■												■		
F23G5/04			■												■		
F23G5/08															■		
F23G5/10															■		
F23G5/12															■		
F23G5/16															■		
F23G5/20															■		
F23G5/24															■		
F23G5/30															■		
F23G5/32															■		
F23G5/34															■		
F23G5/40															■		
F23G5/44															■		
F23G5/46															■		■
F23G5/50															■		
F23G7/00															■		
F23G7/05															■		
F23G7/06															■		
F23G7/07															■		
F23G7/10															■		
F23G7/12															■		
F23H13/06															■		
F23H7/00															■		
F23J11/00															■		
F23J15/02															■		
F23J15/04															■		
F23K3/02															■		

International Classifications	Treatment of water, waste water, sludge, sewage	Other	Treatment, pretreatment	Physical processes	Fuel from solid waste	Biological treatment	Anaerobic	Aerobic	Materials	Chemical compounds and processes	Thermal treatment	Production of gas	Briquetting	Enzymology, microbiology, microorganisms	Incineration	Pyrolysis	Recuperation of heat
F23K5/10			■												■		
F23L1/02															■		
F23L15/04															■		
F23L17/16															■		
F23L7/00															■		
F23L9/02															■		
F23M5/00															■		
F23M5/08															■		
F23N1/00															■		
F23R3/36															■		
F23R3/42															■		
F23R3/58															■		
F23R5/00															■		
F24J1/00		■															
F26B1/00			■														
F26B21/04			■														
F26B21/06			■														
F26B21/08			■														
F26B21/10			■														
F26B21/14			■														
F26B23/02			■								■						
F26B3/04			■														
F26B3/20			■														
F26B3/32			■														
F26B7/00			■														
F26B9/06			■														
F27B15/00		■															

International Classifications	Treatment of water, waste water, sludge, sewage	Other	Treatment, pretreatment	Physical processes	Fuel from solid waste	Biological treatment	Anaerobic	Aerobic	Materials	Chemical compounds and processes	Thermal treatment	Production of gas	Briquetting	Enzymology, microbiology, microorganisms	Incineration	Pyrolysis	Recuperation of heat
F27D19/00																	
F28F13/12																	
H01M8/06																	
H05H1/00																	

5.2 Full List of Documents from Cluster in Figure 12

EP28021B1
EP126407B1
EP815393B1
EP819233B1
EP1231433A2
EP1371713A1
EP1464713A1
GB1531106A
GB2018283A
JP60036506A
JP60036507A
JP10103636A
JP10292178A
JP10311515A
JP11005984A
JP2000198988A
JP2001098282A
JP2001208308A
JP2002037919A
JP2002161282A
JP2003231886A
JP2004156863A
JP2005126524A
JP2005133038A
JP2006266604A
JP2007138033A
US6807916B2
US7169197B2
US20070289507A1
WO2005068908A1

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