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Nishad Deshpande^a, Shabib Ahmed^a and Alok Khode^a

^aCSIR Unit for Research and Development of Information Products (CSIR URDIP), Pune, India

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Business intelligence through patinformatics: A study of energy efficient data centres using patent data

Nishad Deshpande^{a*}, Shabib Ahmed^a and Alok Khode^a

^a*CSIR Unit for Research and Development of Information Products (CSIR URDIP), Pune, India*

**Corresponding author: nishad@urdip.res.in*

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ABSTRACT The advent of cloud computing has nurtured an unprecedented growth of data centres. With its growth, the main concern for service providers and data centre owners is to efficiently manage the energy of the data centres without compromising their computing capabilities. This concern is genuine as data centres utilise 10-30 times more energy than office spaces and also generate immense heat. As cooling accounts for half of the total power consumption in data centres, efficient cooling systems have become a vital need for data centres. This has resulted in increased research and innovation in the field of efficient cooling of data centres, which in turn has led to growth in filing of patents in this domain. Patents are techno-legal documents that contain different kinds of information that is accessible to all. In the present study, patents are used as source of information for competitive/business intelligence to highlight the technological trends in the field of energy efficient cooling of data centres. The study reveals that IBM, HP, Schneider and Hon Hai Industries are the major players working in this technological area. Contrary to the notion that air conditioning would be the most researched area for cooling data centres, the study reveals that there is also interest in the hardware of the servers and racks to produce less heat or to have built-in cooling mechanisms. The main technologies for which patents are being filed include ventilation using gaseous coolant, technologies related to rack design as well as liquid cooling. Original equipment manufacturers and other vendors have increased filings, along with cloud service providers. Most of these technologies originate from Asia-Pacific and this region is a strong market, following the USA.

KEYWORDS Cooling, data centres, energy efficiency, green data centres, patents, patinformatics

1. INTRODUCTION

To survive in the dynamic business environment, it is imperative for organisations to have relevant and timely business information for decision making. This has led to the emergence of business intelligence as a vital decision support system. Business intelligence is a tool that helps organisations to refine business related information for making effective business decisions (Ghoshal and Kim, 1986). Business intelligence provides information that can be used for actionable

assessments in a timely manner. By means of discovery, analysis and querying, business intelligence provides the ability to reason and understand the meaning behind business information (Azoff and Charlesworth, 2004). Business intelligence is also referred to as competitive intelligence, market Intelligence, customer intelligence, competitor intelligence, strategic intelligence or technical intelligence (Lönnqvist and Pirttimäki, 2006). Business intelligence or competitive intelligence is considered to be an interdisciplinary field

(Walker, 1994). According to Solberg-Søilen (2010) competitive intelligence is a subset of marketing management. However, studies also suggest that competitive intelligence is associated with strategic management and knowledge management (Gabriel and Adiele, 2012; Calof and Viviers 2001). Kahaner (1998) defines competitive intelligence as the process of “gathering and analysing information about your competitors’ activities and general business trends to further your own company’s goals”. Toit (2015) observed that successful enterprises have a formal competitive intelligence functioning unit, which may follow a competitive intelligence cycle consisting of the following activities (Viviers et al., 2005):

- Planning for the collection of information;
- Collecting information from relevant sources;
- Analysing information using analytical tools; and
- Preparing reports for management

In addition to publicly available financial statements for gathering competitive information (Ditter et al, 2011), studies suggest that patent data is also a valuable source of competitive intelligence from which to derive a strategic advantage (Rouach and Santi, 2001; Dou et al., 2005; Grandjean et al., 2005; Shih et al., 2010). In the present study, patents are used as a source of information for competitive/business intelligence and highlight the technological trends in the field of energy efficient cooling of data centres.

Traditionally, the development of computing systems has been focused on performance improvement, which was driven by a demand for applications from consumer, scientific and business domains (Beloglazov et al., 2011). This resulted in rapid growth in the demand for computational power and this in turn led to the creation of large-scale data centres (Beloglazov and Buyya, 2010). Moreover, due to the advent of cloud computing environments, data centres have experienced unprecedented growth in their size and population (Judge, 2015; Jones Lang LaSalle, 2016). These densely populated data centres dissipate heat and needs large cooling units to keep temperatures within the functional levels, thereby increasing the demand for power (Suja et al., 2012).

Data centres use nearly 10-30 times more energy per square foot than office spaces

(Caldow, 2008). Like energy costs, the energy used in data centres is also increasing two-fold every five years (Uddin and Rahman, 2010). If we assume that data centre energy costs continue to double every five years, they will increase by 1,600 percent between 2005 and 2025 (Emma, 2008).

The ever-increasing energy consumption of data centres has started to limit their growth due to overwhelming electricity bills and large-scale carbon dioxide (CO₂) emissions (Beloglazov et al., 2011). Cooling accounts for half of the total power consumption in data centres (Brown, 2008). Therefore, the focus of recent data centre technologies and computer system designs has shifted to power and energy efficient cooling systems for data centres without compromising computing capabilities (Daim et al., 2009)

Patent data available from the patent offices of different nations are a huge resource of techno-legal information. If this patent data is properly analysed, it can provide various business intelligence insights focusing on technological trends and their patent filings, the newly emerging technologies and products in a particular domain and also competitors’ intellectual property strategies (Deshpande et al., 2014; Ahmed et al., 2013).

Of the various approaches used in data centre cooling, the technologies using cold aisle containment pod deployment are expected to become the future standard in data centre design (Hawkin, 2015). This is also reflected in the patent data available, revealing that patents relating to aisle cooling technology have been already granted or filed. Table 1 lists examples of a few related patents and applications in this field.

Table 1 List of a sample of patent numbers and their assignees for aisle based cooling systems.

<i>Assignee</i>	<i>Patent Number</i>	<i>Assignee (cont)</i>	<i>Patent Number</i>
Facebook	US9144181	HP	US8984906
Amazon	US9152191	Hon Hai	US8405977
Bripco	US20150305208	Schneider	EP1882402
IBM	US9072196		

2. METHODOLOGY

The Thomson Innovation Database (www.thomsoninnovation.com) was used for extracting the data. The text mining and visualization tool VantagePoint (www.thevantagepoint.com) was used to clean,

normalise and analyse the patent data. The methodology involved the two major steps outlined below.

2.1 Information gathering

In order to find patents and applications in the data centre cooling field, a search strategy was prepared and a search was executed on the commercially available database, Thomson Innovation. Patents published through November 15th 2016 were considered in the study. The search strategy consisted of a combination of keywords and International Patent Classification (IPC; WIPO, 2016) and Cooperative Patent Classification (CPC; European Patent Office, 2016) classification codes relevant to the topic, as they are considered to be a proxy technology indicator based on hierarchical assignment and the categories to which every patent may belong (Pulate et al., 2015).

The keywords used for the search were datacenter, data center, server room, datacentre, and data centre and were combined with the terms cool* and ventilat*.

The following IPC and CPC codes specific to cooling in data centres listed in Table 2 were used in the search in combination with the keywords.

Table 2 International Patent Classification (IPC) and Cooperative Patent Classification (CPC) codes and their descriptions.

IPC / CPC Code	Description
H05K00071485	Mounting supporting structure in casing or on frame or rack used/placed in servers; data centre rooms
H05K000720	Modifications to facilitate cooling, ventilating, or heating.

The keywords were searched in the title, abstract and claims. The actual search query that was executed in Thomson Innovation was: CTB=(datacenter OR data ADJ center OR server ADJ room OR datacentre OR data ADJ centre) AND (cool* OR ventilat*) OR AIC=(H05K00071485 AND H05K000720) AND DP>=(18000101).

This search strategy resulted in 7640 hits. Patents are territorial in nature so the same invention may be duplicated by way of multiple filings in different countries, known as patent families (European Patent Office, 2016). To reduce this form of duplication, one representative for each patent family was retained to obtain a dataset of 3036 records. The bibliographic details such as the title,

abstract, priority date, assignee name, inventor names, and INPADOC family members were collected and stored in a spreadsheet for further processing and analysis.

2.2 Data cleaning

While looking for competitive Intelligence, there was a need to take into consideration variations in the spellings of names, typographical errors, corporate hierarchies and mergers or acquisitions of various organizations. Thus data was normalized for assignee names by replacing name variants with a standard name. For example, there were many different companies such as Consolidation Coal Co, Entek Corp and Du Pont Iberica SL all listed under Du Pont (E.I.) de Nemours & Co. Assignee normalization replaced all these variants with Du Pont (E.I.) de Nemours & Co. Assignee normalization was also carried out using the assignee clean up feature tool VantagePoint. Similarly, the inventor list was also cleaned using the VantagePoint inventor clean-up list tool.

3. ANALYSIS AND VISUALISATION

3.1 Patenting activity in the field of energy efficient cooling of data centres

Patenting activity related to energy efficient cooling of data centres and server rooms can be seen from 1995. This patenting activity, however, gained momentum from the year 2008 and has been on the rise since 2010. This can be seen from the overall patenting activity graph shown in Figure 1.

From Figure 1, it can be seen that less activity was performed in the domain of energy efficient cooling of data centres before 2010.

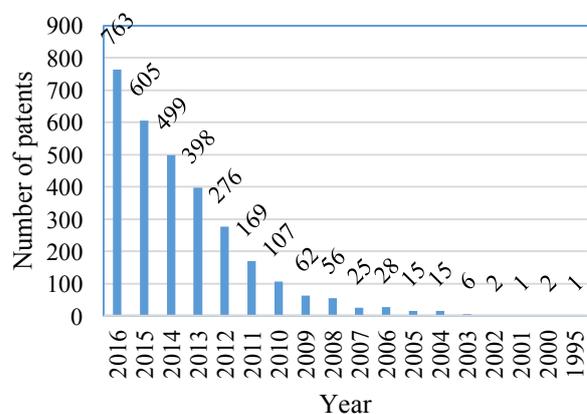


Figure 1 Patenting activity in energy efficient data centre cooling from 1995-2016.

The cloud environment came into dominance from 2008 (Columbus, 2015), and there was a need for energy efficient cooling of data centres, thereby leading to more R&D output in this field from 2008 onwards. As is evident from Figure 1, there is a seven-fold increase in patent filings from year 2010 to year 2016.

3.2 Top assignees in the area of energy efficient cooling of data centres:

IT Companies like IBM, HP, Amazon, Google, Amazon, Yahoo Dell, Microsoft and Oracle, which are active in cloud computing and data centre services are amongst the major assignees in the patenting area of efficient cooling of data centres, as is evident from Figure 2. While Amazon Web Services (AWS) is the leader in the public cloud computing space, companies like IBM, HP, Microsoft, Dell, Oracle, Baidu and Google are the obvious players in this domain as IBM, Dell, Oracle and HP are traditionally involved in hardware related products and services while Google has its own data centres across the globe (Kepes, 2015; Weinberge, 2015) and Baidu has its presence in China and is slowly moving to a global position. Hence these companies are interested in improving and protecting technologies that are energy efficient.

Companies such as Schneider Corp. and Hon Hai Precision Industry Co. Ltd. are

amongst the leaders in the patent assignee group, even though they do not have data centres of their own. For example, Hon Hai is an electronics contract manufacturing company also known as Foxconn Technology Group and Hongfujin Precision Industry Co., a subsidiary of Foxconn. Its clients include major American, European, Japanese, and Canadian electronics and information technology companies, which might be the reason behind their interest in the energy efficient cooling data centres' patent portfolio. On the other hand, Schneider Electric develops technologies and solutions to make energy safe, reliable, efficient, productive and green. NEC Corporation is a Japanese multinational provider of information technology (IT) services and products involving innovative technology development to enable data centres to reduce air conditioning power consumption. Hence it can be said that the consumers of data centres as well as the suppliers for data centres are both actively pursuing research in the field of energy efficient data centres. What is striking in this data is the presence of Xi'an Polytechnic University, the only academic institution amongst the top twenty patent filing applicants for energy efficient cooling of data centres.

While normalizing the data, Emerson and Liebert were merged together. Motorola Mobility was merged with Google. Further, the same was applied for merging Sun and Oracle, VMWare, EMC and Dell.

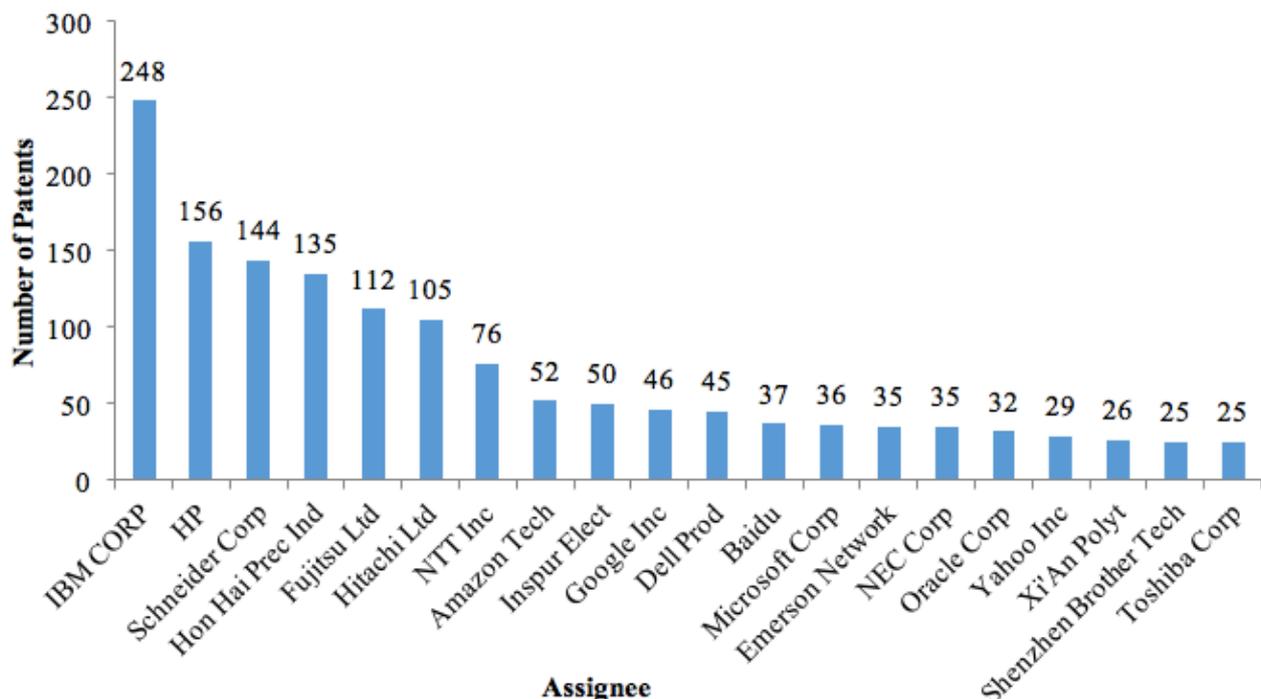


Figure 2 Top patent assignees in energy efficient data centre cooling, listed by company.

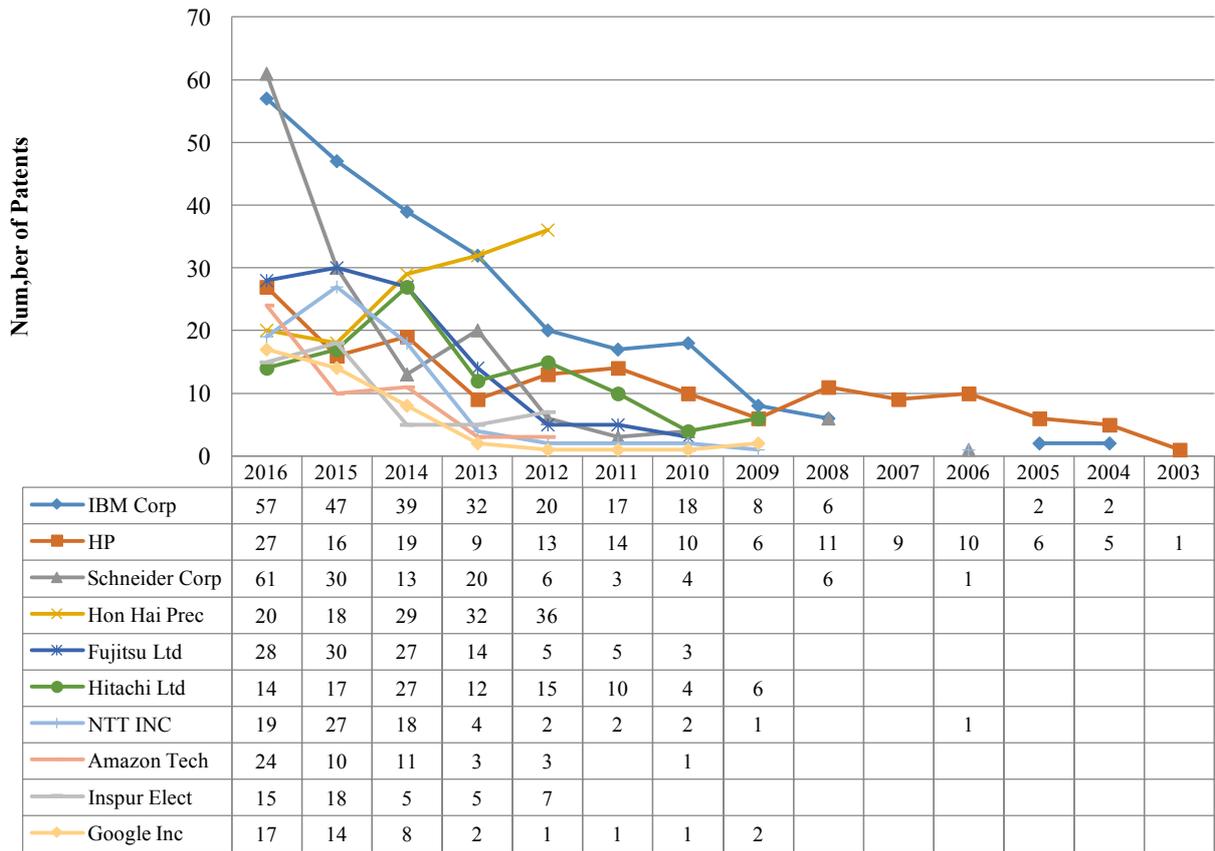


Figure 3 Yearwise assignee trends

3.3 Top assignee for each year

Year by year technology advancement based on patent filings by individual companies reveals that HP was in the field from the beginning. They were followed by IBM. Figure 3 shows that product based companies such as Hon Hai Precision Industry, Schneider and Fujitsu have increased their filings at a constant rate since 2012, while cloud based service providers such as Google and Amazon entered the field later and have only been active during the last five

years. Surprisingly, Inspur Electricals started filing many patents in the domain of energy efficient cooling of data centres only in the last 2 years. Inspur is a Chinese multinational information technology company focusing in server hardware and also acts as a software developer providing outsourcing for USA and Japan.

3.4 Origin of invention

The origin of inventions can be found using patent data. The priority filing country shown in the patent document is considered to be an

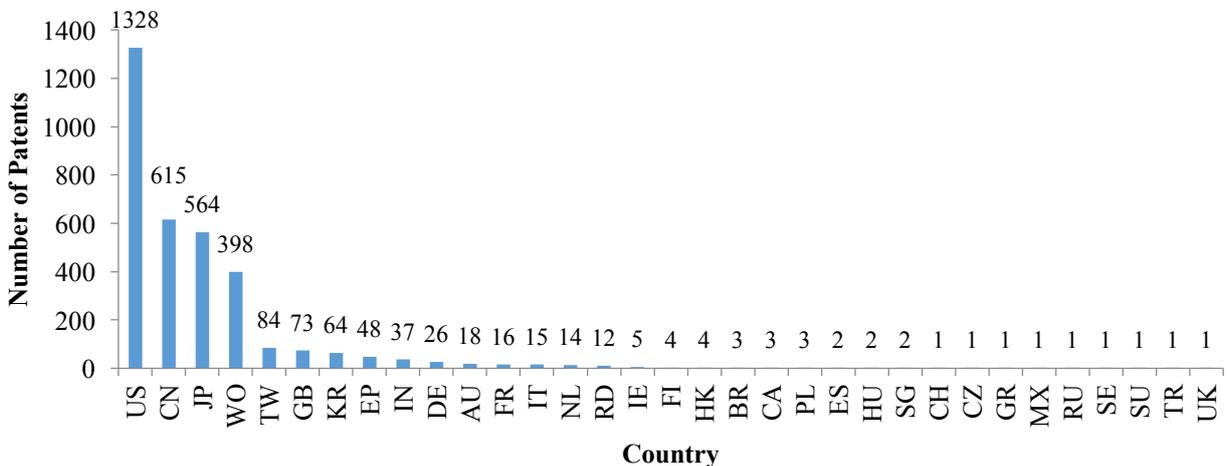


Figure 4 Origin of inventions by country

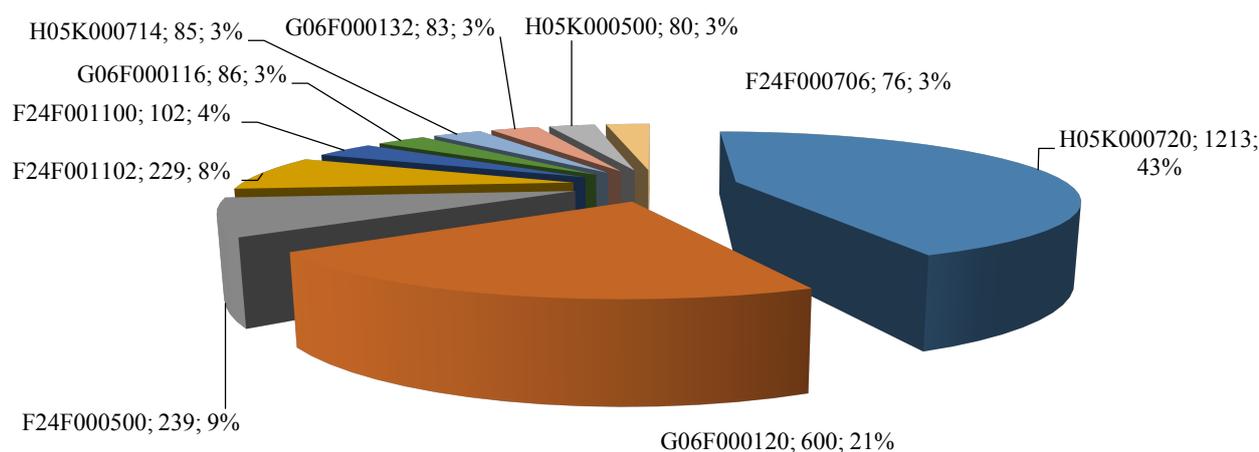


Figure 5 Distribution of top ten IPCs

indicator for the origin of a particular invention (UK Intellectual Property Office, 2014) as companies normally prefer to first file for a patent in the same country in which it is invented (Figure 4).

It can be seen from Figure 4 that the USA is leading with the most patents relating to energy efficient cooling for data centres, followed by China and Japan. However, it is interesting to see that countries from the Asian continent, and Asia Pacific in general, are ahead in the innovation of efficient cooling of data centres, as almost 50% of the technology patents originate from this region. China leads Asia, followed by Japan and Taiwan. European companies also have a presence but are minor when compared to the US and Asia.

3.5 Technological Trends

Figure 5 depicts the top 10 international patent code (IPC) classes revealed from an analysis based on the IPCs assigned to patents and applications related to energy efficient cooling in data centres. It is observed that most of the inventions are focused on the construction detail or modifications related to cooling, ventilating or heating. About 60 % of the patents are related to cooling through ventilation whereas 30 % of the patents focus on constructional aspects for facilitating the cooling of data centres. A short description of the top 10 IPC classes is given in Table 3.

Figure 6 highlights the year-wise IPC trends. It shows that patents with code H05K7/20 (indicating modifications to facilitate cooling, ventilating, or heating) are the most sought after and researched technology, having a huge surge in the last

couple of years. The IPC G06F1/20 (indicating constructional details or arrangements for cooling means) also shows a higher growth in the last couple of years compared to other technologies. Figure 6 also shows that companies are not only focusing on the basic research in cooling but also giving priority to the constructional changes and modifications that enable efficient cooling of data centres.

Table 3 IPC classes and their descriptions

IPC design.	Description
H05K000720	Modifications to facilitate cooling, ventilating, or heating.
G06F000120	Constructional details or arrangements for cooling means.
F24F000500	Air conditioning systems
F24F001102	Arrangements or mounting of control or safety devices related to air conditioning or air humidification or ventilation
F24F001100	Control or safety systems or apparatuses for air conditioning or air humidification or ventilation
G06F000116	Constructional details or arrangements of data processing equipment
H05K000714	Constructional details related to mounting supporting structures in casing or on frames or racks
G06F000132	Power saving means
H05K000500	Casings cabinets or drawers for electric apparatuses
F24F000706	Ventilation with ducting systems using forced air circulation

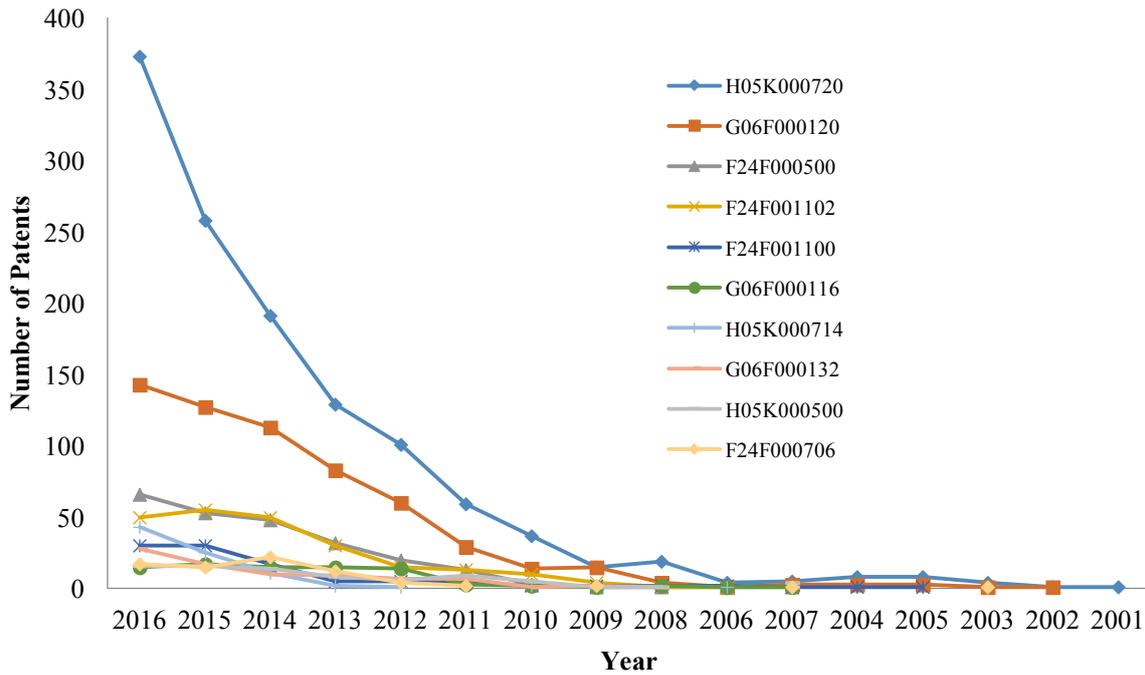


Figure 6 Yearwise IPC trends

Figure 7 highlights the distribution of core technologies derived from the patent analysis. The figure shows that approaches focusing on thermal management and gaseous cooling are the preferred approaches for energy efficient cooling of data centres.

A further analysis of patents reveals that the above mentioned technologies existed for more than a decade, with a surge in technological advancements after 2010, except for approaches focusing on resource allocation (Figure 8). Figure 9 illustrates in-depth technology breakup. It is observed that technologies using forced ventilation with gaseous coolants and thermal management of racks are gradually on the rise when compared with other technologies.

Figure 10 illustrates the top assignees for the top 10 CPCs available in the area of

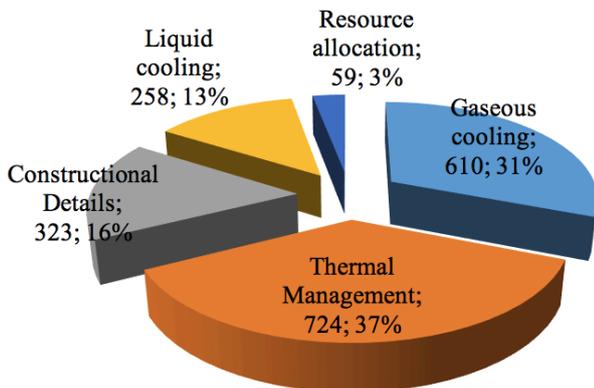


Figure 7 Distribution of core technology

efficient cooling of data centres. The data reveals that there are about 251 patents in CPC H05K000720836, which is related to thermal management for server racks or cabinets. IBM is leading in patents in this technology, followed by HP and Fujitsu. These three companies deal with server and rack products. CPC class H05K0007200745 deals with forced ventilation using gaseous coolant within rooms for removing heat from cabinets. IBM again leads in this technology, followed by Hon Hai Precision and HP. IBM leads with most patents in the CPC H05K00072079, which is related to thermal management for server racks or cabinets and liquid cooling within rooms for removing heat from cabinets. It is important to note IBM has about 38 patents in the technological area of liquid cooling within rooms, whereas Hon Hai, with the second most patents in this field, has only 9. Hon Hai is very active in the CPC H05K00071497, which deals with the construction of mounting structures in data centre rooms, and they have half of all the patents, while Amazon and Google follow with 7 and 5 patents in this area, respectively. The data also reveal that IBM leads in the CPC class H05K000720781, with about 75% of all the patents available in this field that deals with liquid cooling within cabinets for removing heat from server blades. This is logical, as IBM is involved in the sale of blade servers. What is surprising is that the patents

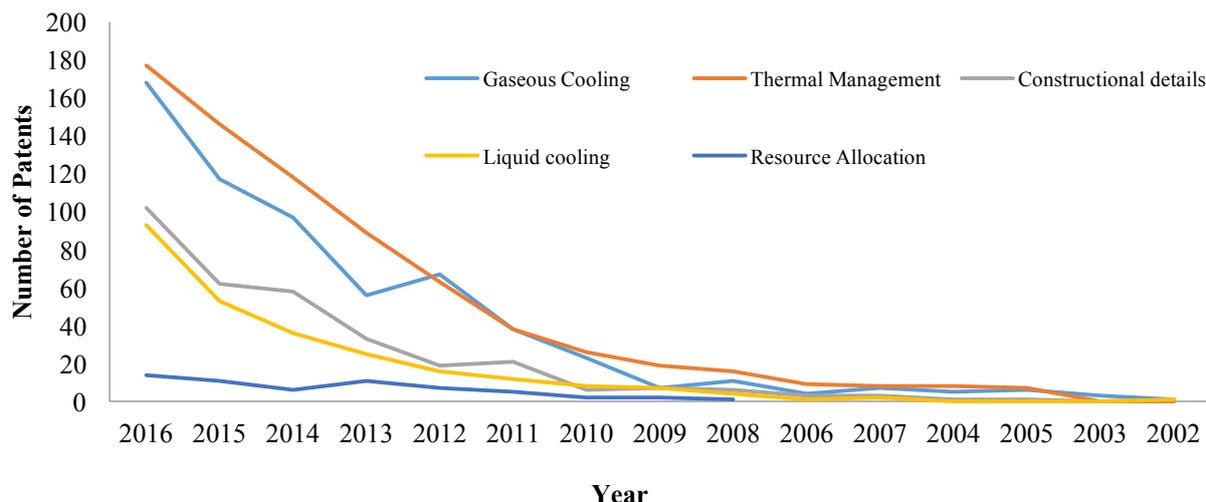


Figure 8 Yearwise core technology trends

for this CPC class are very low for HP even though they are leaders in the supply of blade servers (Gartner, 2016; International Data Corporation, 2016). This same is again true for CPC class H05K000720736, which deals with gaseous cooling within cabinets for removing heat from server blades, where IBM has one third of all patents and HP's presence is low.

Figure 11 displays the similarity between technologies used by the top 10 assignees in the field of energy efficient cooling of data centres.

It is observed that companies such as Inspur and NTT are patenting in technologies that are different from other players based on CPC codes. On the other hand, companies such as HP, Schneider, and Fujitsu are working in similar technological areas.

As patents rights are territorial in nature, they need to be protected in various jurisdictions. As such, inventions remain the same but are protected in different regions are called "patent family members". Further, the

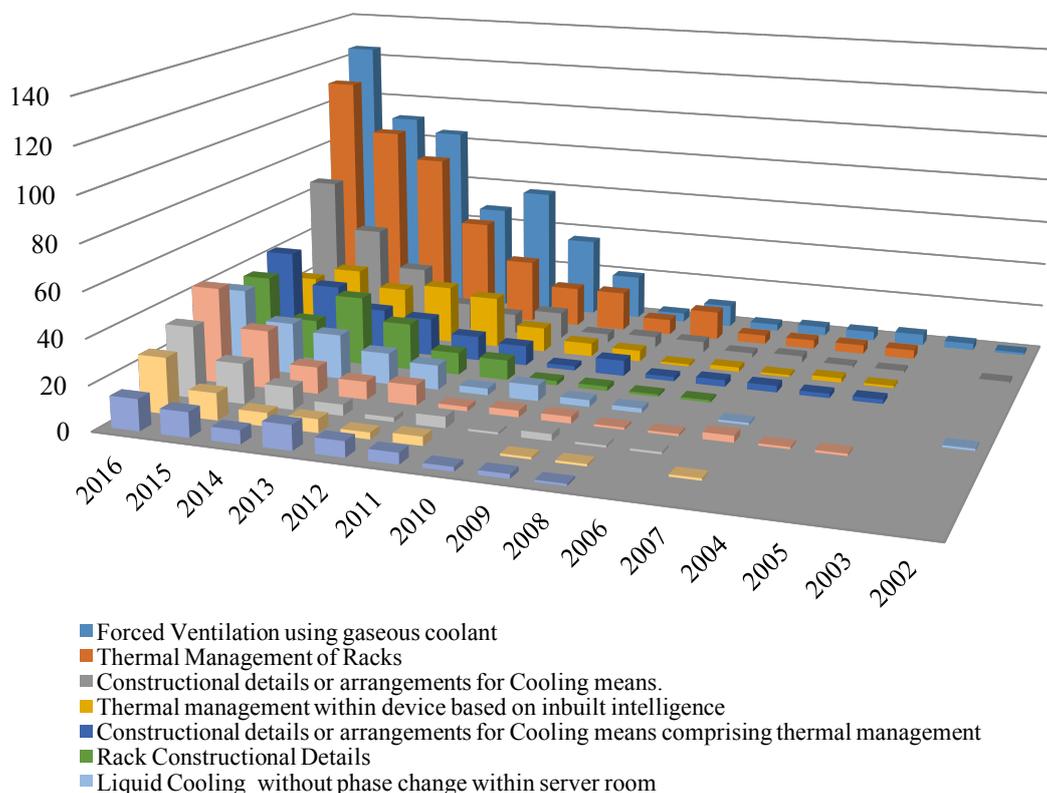


Figure 9 Yearwise technology breakup

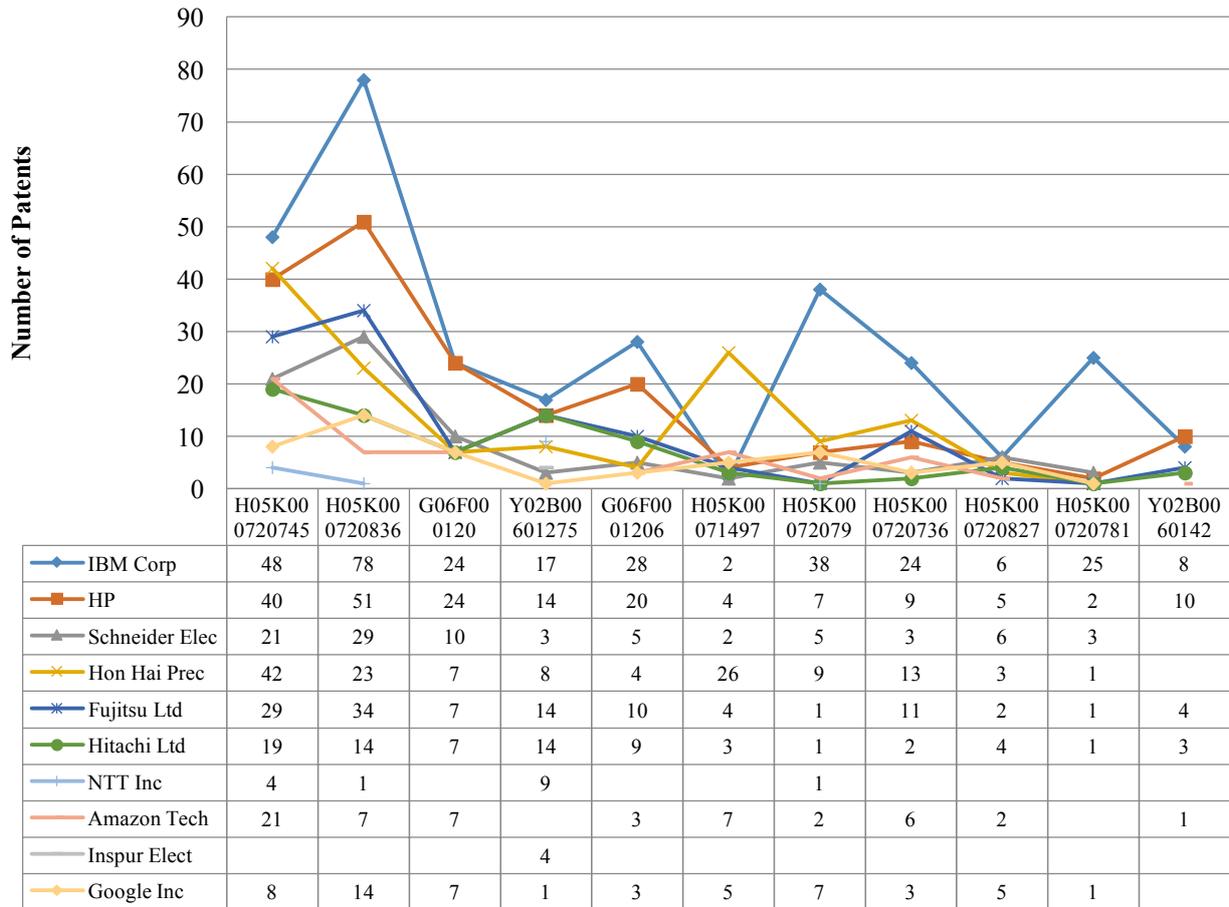


Figure 10 Top assignee-wise CPC distribution

protection is generally sought in countries where markets exist. Figure 12 illustrates the top 10 markets for energy efficient cooling of data centres represented by family patent filing coverage. USA seems to be the major market. However, more than one third of the market is concentrated in Asia Pacific, which includes China, Japan, Korea and Taiwan.

Figure 13 illustrates the market focus of the top 10 assignees based on family patent filings because companies file patents only in the regions where there is a potential market for such technologies. IBM and HP consider the USA to be their major market, while Schnider has its presence in Europe and China along with the USA. Hon Hai has filed patents in the USA, Taiwan and China indicating these to be their markets. Fujitsu, Hitachi and NTT have more patents in Japan. However, Inspur has filed patents only in China indicating it is focussing only on the national level for its products. Further analysis of this data reveals that about 40% of the technology market lies in Asia. This is contrary to the belief that the USA is the major market for data centres. This is also illustrated in Figure 14.

Figure 14 shows that 13 percent of patents for efficient cooling of data centres are filed through the Patent Cooperation Treaty (PCT, WIPO). The PCT assists applicants in seeking patent protection internationally for their inventions, helps patent offices with their patent granting decisions, and facilitates public access to a wealth of technical information relating to those inventions.

Figure 15 illustrates the patent filings for energy efficient cooling of data centres in Europe. It is observed that more than 60 percent of the filings in this region are through the European Patent Office, which offers inventors a uniform application procedure that enables them to seek patent protection in up to 40 European countries.

4. CONCLUSIONS

The growth of data centres, and their consumption of power along with the heat generated from them has led to a call for energy efficient cooling technologies for data centres. Using patent data as a business intelligence indicator to highlight the technological advancements and trends in this domain found that cooling in data centres is not limited to air

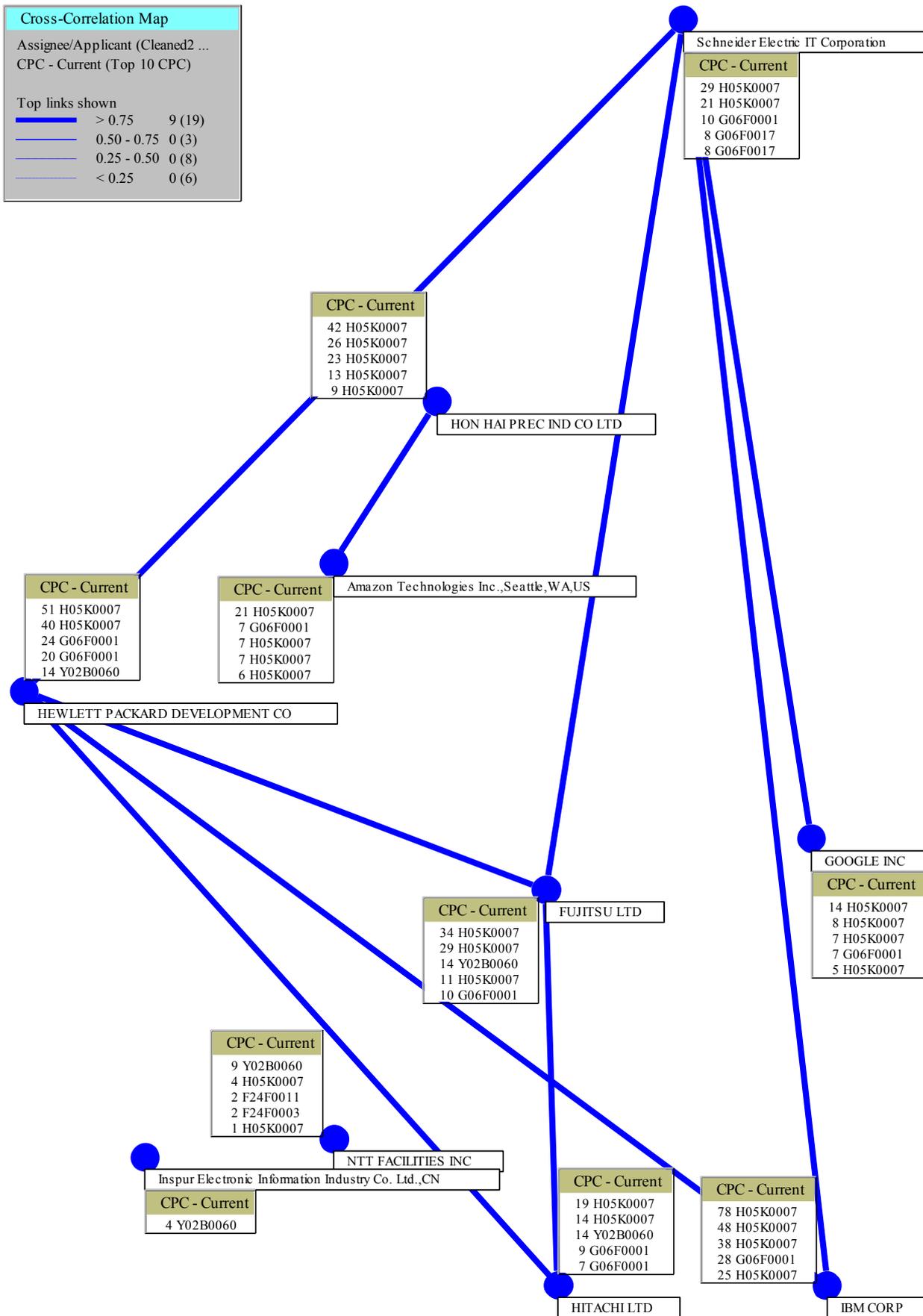


Figure 11 Top assignee technology similarity network

conditioners but also includes the design of the servers and racks to produce minimum heat as well as to have mechanism to cool the devices.

This study highlights that apart from traditional cooling device manufacturers, other players such as data centre owners, IT service

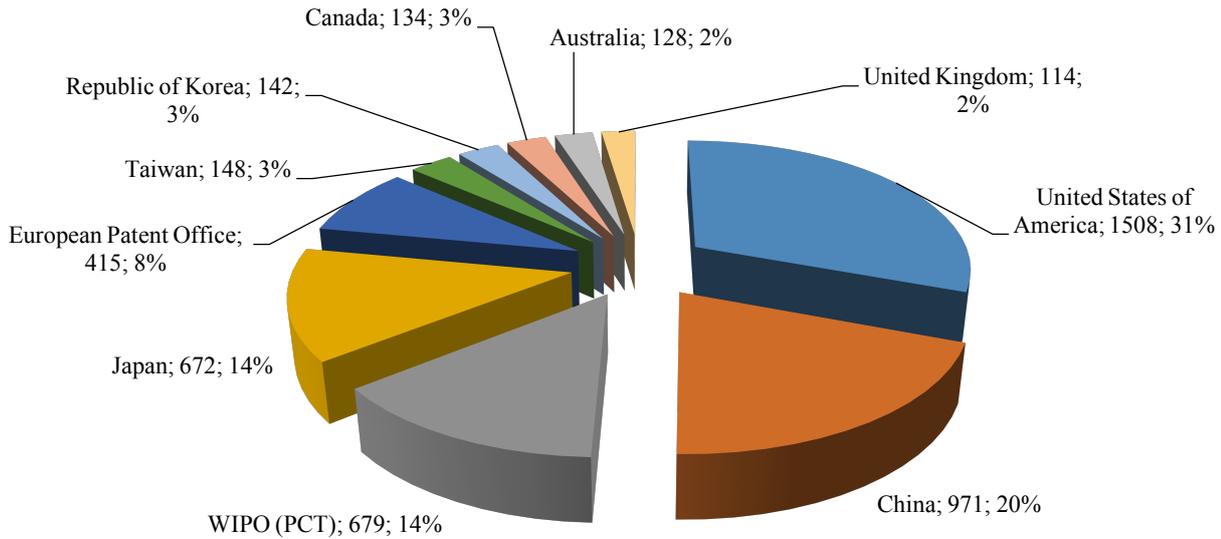


Figure 12 Top ten markets

providers, and hardware vendors, as well as electronics manufacturing companies, are also active in innovating and protecting their inventions. The dominance of cloud computing has led to more research and development in the field of energy efficient data centres from 2008 onwards. Electronic manufacturing companies and hardware vendors have increased their number of filings since 2012, whereas cloud based service providers and owners have entered the field relatively late. Although the USA is the major filing country

for energy efficient cooling for data centres, it is found that half of the technologies originated from the Asia Pacific region with Japan, China and Taiwan at the forefront. Modifications to facilitate cooling, ventilating, or heating is the most researched technology, with a non-linear increase in patents in the last several years. Thermal management and gaseous and liquid cooling, as well as technology related to rack design, are the major technological topics for energy efficient cooling and their patent filing increase can be seen post-2010. Companies

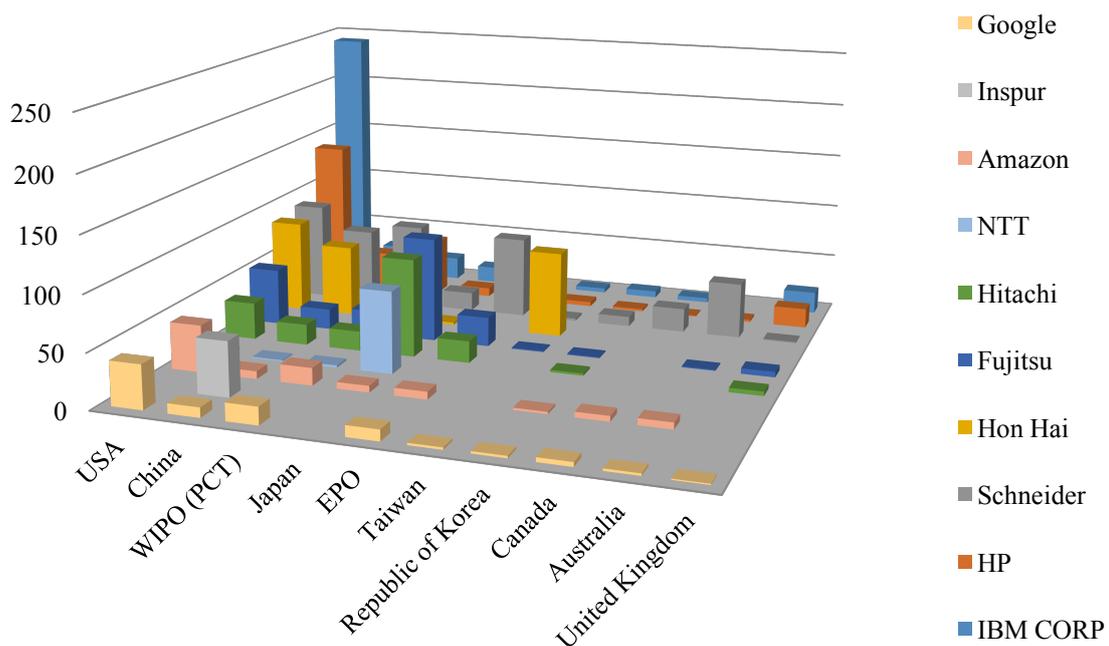


Figure 13 Assignee-wise market focus

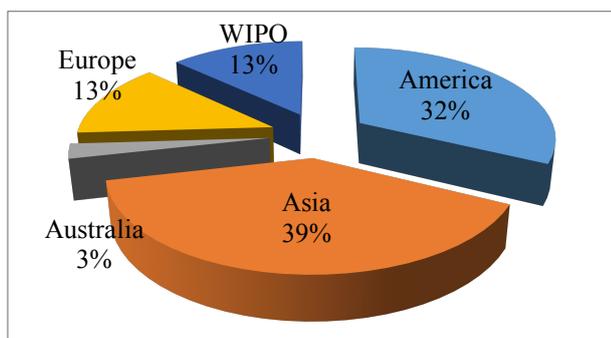


Figure 13 Continent-wise market distribution

dealing with server racks and cabinets are leaders in the area of thermal management for the cooling of data centres and in this area, IBM leads followed by HP and Fujitsu. Hon Hai is very active in the area relating to the construction of mounting structures in data centre rooms, with half of all the patents. IBM has about 75% of all patents available in the field that deals with liquid cooling within cabinets for removing heat from server blades. IBM also leads for gaseous cooling within cabinets for removing heat from server blades where IBM has one third of all patents. IBM's dominance in this area is expected, as it is involved in the sale of blade servers. Analyses show that IBM is an active player in protecting its inventions in thermal management for server racks or cabinets and liquid cooling, whereas despite HP's global leadership in the blade server market they are not an active innovator in this technology. Companies that deal with energy efficient cooling for data

centres look at the USA and Asia Pacific as the major markets for technology deployment.

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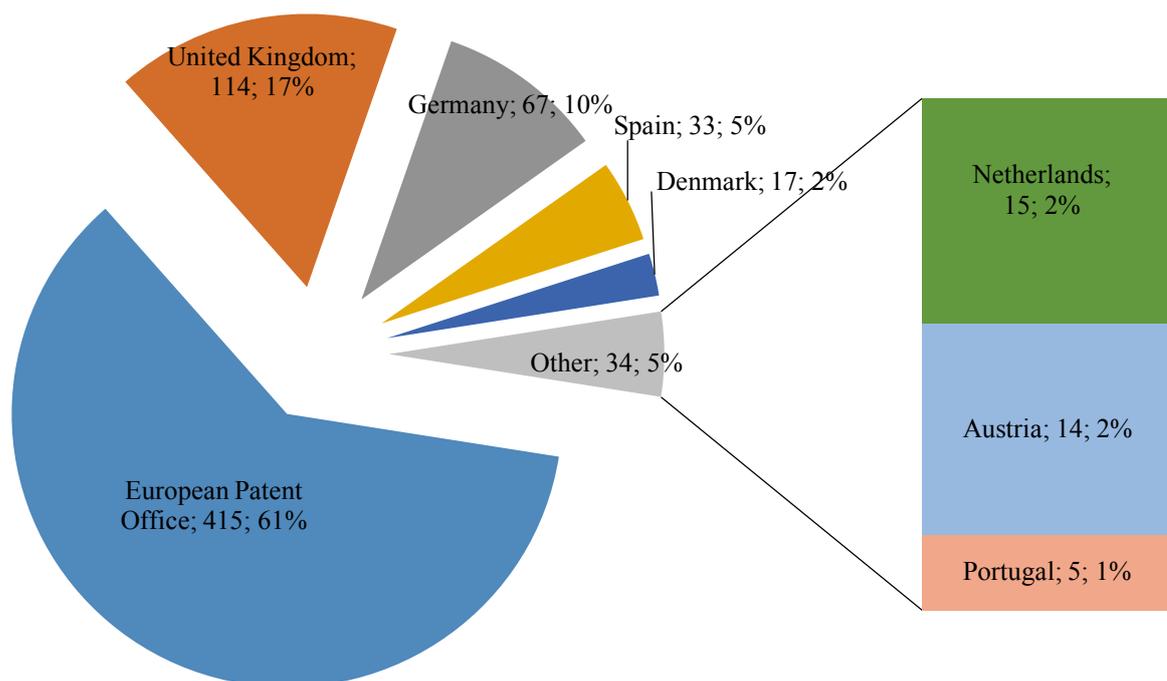


Figure 14 Country-wise patent filing in Europe

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