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Innovation in air pollution control systems: A patent map analysis

Evaluating Innovation activity and Diffusion of innovation in Environmental management technologies at a major air pollution management company

Master of Science Thesis in the Master Degree Programme, Business Design

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Abstract

Air pollution has been a menace in recent years posing serious threats to environmental and social wellbeing. Government, authorities and industry have been at the forefront to tackle air pollution with the help of policy reformation and technological innovation. This research study concentrates on looking into the innovation activity in last decade to understand how industry has made technical breakthroughs and carried out its exploitation in the field of Air Quality Control Systems (AQCS) and Environmental Control Services (ECS). The aim is to understand the innovation activity in the technology domain and observe patterns in relation to diffusion of innovation in different jurisdictions. Innovation trends in the field of practice have been analyzed based upon the underlying principle that technology intensive companies perform research & development to innovate and thus patent it to obtain right of practice in different jurisdictions. The innovation trends in air pollution control technologies have only been investigated on a general level in reviewed literature whereas the research study evaluates specific trends in last decade therefore both academia and industry would benefit from an increased understanding of this field.

The study has been conducted at a prominent multinational company active in air pollution control technology business and R&D practices. Research study was the part of several practices performed at the company. A literature study was done to understand the technical area and to perform a thorough patent data search. Previous research studies and books have been used to form a holistic view for analysis of patent data and drawing conclusion from the trends. Research question has been answered using patent data from 5 innovative companies' practicing in AQCS technology domain.

The main findings of the research study include patent search keywords & IPC classes relevant to the technical area, related patent statistics, patenting trends, assessment of innovation activity using cumulative & individual patenting trends of 5 innovative companies and diffusion of innovation in different countries using patenting trends in top 10 jurisdictions. Report highlights various countries on the priority list of industry for protection and exploitation of developed technologies. Suggestions for future research and further investigation have also been made as a part of the research report.

Acknowledgement

I would like to thank the management of organization at which the study was conducted and especially the managers of AQCS technology domain for support, full cooperation and guidance, which has made this research work possible.

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I dedicate my research work and convey a special thanks to my family in India for their generous support. They have been a source of inspiration in accomplishment of my master studies with completion of this research work.

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Sumit Luthra

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Abbreviations and Definitions

These are the list of abbreviations that will be used throughout the report and several of the terms could have different meaning depending upon context when looked upon outside the report.

AQCS – The abbreviation expands to Air Quality Control Systems which relate of electrical & mechanical systems used in several industrial plants for control for mitigation of air pollution.

ECS – ECS expands to Environmental Control Systems which describe the spectrum of systems used for environmental management in pollution mitigation and control.

Absorption – The process by which a liquid or gas is taken into the filter media substance and held there

Air Filter – A device for removing particulate material from an airstream.

Baghouse – This includes a clean air plenum, tube sheet, dirty air housing, and hopper. It may or may not include legs. It is commonly used as a high airflow, low product loading, low pressure and low vacuum system unit.

Intellectual Property (IP) – Intangible property that is the result of creativity.

IPC - International Patent Classification which is a classification system formulated and used by WIPO for classification and managing the patent applications filed and granted.

WIPO - World Intellectual Property Organization. It is the organization responsible for the promotion of the protection of intellectual property throughout the world through cooperation among States.

The company – Refers to the studied organization practicing in Air Pollution control management, which has been the foundational source of information especially in relation to the identification of the technological information, patenting, domain knowledge & information about major player in the industry.

Patent Maps – Patent maps is the visual landscape of patent information of a target technology field which is thus processed and analyzed to give inputs to management of a company for its decision making.

1. Introduction

This introductory chapter presents the background problem, purpose, research question, methodology, delimitations method and limitations of methodology followed.

1.1.Background Problem

20th century has witnessed a seismic shift from the age of agriculture to industrialization which proved a boon to global economic climate and considerably changed the standards of living. The increased production and industrialization for major economies has brought its cons along with the benefits. It has led to many new problems much different from agricultural age. The problems have to be tackled well for a sustainable living. Air pollution is one of those few big problems that originated in the course of industrialization & urbanization. Increased emissions have been recognized as a threat to healthy living if not managed well. A major cause of air pollution is the emission of gases like carbon oxides, sulphur oxides, nitrous oxide etc. into atmosphere. Most of these gases are produced and emitted due to major industrial activities like power generation, fertilizer manufacturing, cement production, iron ore production, oil refining etc. Increased emissions are deteriorating global climate and human health thus challenging the sustainability of industrial activities carried out globally. Global warming, an after effect of increasing air pollution is one of the major issues which have attracted a huge attention lately by governments and authorities around the world leading to a bigger international dialogue, policy change and technological innovation.

1.2.Purpose

Growing problems due to air pollution has seen an acknowledgment with an effort to find solution to it. There have been major reforms in governmental regulations to promote innovation for control of air pollution. Governments around the world have come up with acts and regulations to cut emissions. With the help of governmental subsidies and regulations, few technology intensive organizations have made AQCS & ECS innovations and business as a part of their business models helping industry cut the emissions. Field of air pollution control management has seen a lot of research and development work in past few decades with considerable patenting and legal protection.

The intention of the study is to understand innovation activity in the field of air quality control systems and services by getting a grasp over patenting activities which happen to be an indicator of research and innovation activity in technology domain as understood by the existing theory. Idea is to observe interesting patent trends in AQCS practice domain by extracting the patent data related to technology area and analyze it to understand innovation activity and diffusion of innovation in different countries. The underlying logic behind is that the patenting activities are indicator of innovation in knowledge driven industrial economy today where patent is revenue driver then just being a way to protect idea. The scope of thesis research work is to identify general innovation trends along with the discussion about major jurisdictions of interest for key companies operating in the field of practice. Issues being targeted with reforms in policies & laws will also make it clear about how different organization have taken it as an opportunity to tackle problem by targeting markets & prioritizing innovation.

1.3. Research Question

Has there been an increase or decrease in innovation activity in the field of industrial air pollution control technologies with rising air pollution levels and how has the diffusion of technology taken place in top 10 jurisdictions important for patent filings in last decade?

1.4.Methodology

With an aim to understand the innovation activity in the industrial domain a methodology has been followed to gather the relevant patent data and analyze it to answer the research question.

To carry out the project work author started getting grasp over AQCS, ECS technology domain by getting in touch with practitioners and researchers at major environmental management company. Technology area understanding was developed by looking into the problems of Air pollution, sources, Techniques, Product & services to abate air pollution. Understanding of the technology domain has been given due consideration to lay the foundation for patent data search and its analysis. With profound understanding of technology area, techniques and products in the market keywords\catchwords were shortlisted forming a base for patent data search. The aim was to get hold of relevant classes since keywords tend to capture patent data relevant and irrelevant to technology domain where classes are capable of filtering out the irrelevant patents of disinterest in this context. The study has been conducted using the Thomson Innovation database. Patent data has been searched using keywords for innovative organizations active in the technical area pointed out by the industrial practitioners at firm where study was conducted.

List of relevant patent data fetched by carrying out the exercise of short listing keywords lead to patent data which was further filtered out by eliminating irrelevant classes in accordance to the subject matter in IPC classification dictionary at WIPO website. Shortlisted keywords and relevant IPC classes searched for major companies of interest in technology domain formed the base for collection of final patent data.

Patent data mining exercise followed patent data collection where various patenting trends by major actors and technology area were identified. Patent families and patents filed by major actors in last decade were relied upon to understand the interesting trends answering research question about their innovation activity. Cumulative and individual analysis of industry actors was conducted to get a grasp over overall behavior of firms in terms of innovation in technology field.

Diffusion of innovation being another part of research study was understood by looking into patenting in different jurisdictions. The trends pertaining to patenting by major companies in different countries were analyzed giving a clear idea how industry see world from the perspective of profit making and commercialization leading to protecting its technology in different countries to reap profits.

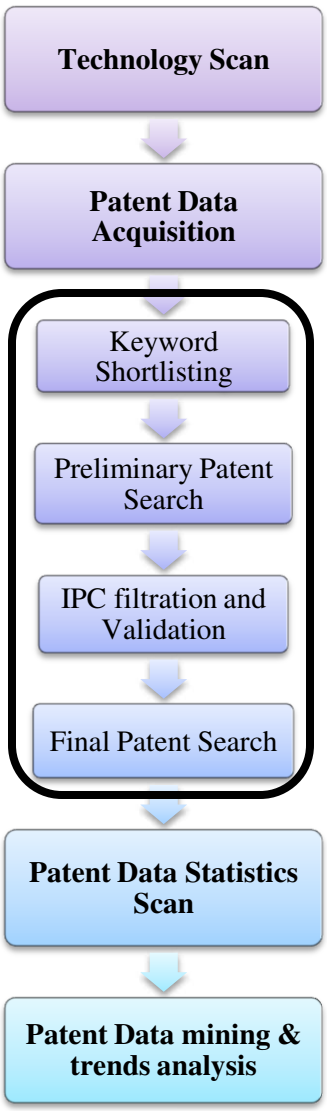

Fig1: Research Methodology

1.5. Delimitations Method

The scope of the research work limits itself to AQCS market for evaluation of innovative activity and diffusion of innovation in various countries. The patent data in the technology domain has been analyzed from year 2000 to 2009 in order to answer the research question. Goal of answering research question has been accomplished by understanding patenting activities at 5 innovative companies.

The research report doesn't reveal the names of 5 companies for which patent data analysis has been conducted. Names of companies have been kept anonymous as part work conducted at one of the companies abiding by the confidentiality issues. Relevant patent statistics and trends curve form the part this research report. The detailed patent data has not been published in the report.

1.6. Limitations of Methodology

The results of thesis limits to the trends that have been observed by analyzing innovation activity and patenting within only 5 companies. Patent search has been conducted using Thomson innovation where it should be noted that full patent data for year 2009 still might not have been published. Limitation of Thomson innovation to look into major jurisdictions and countries covered by its database should also be noted. The keywords used for preliminary and final patent search was collected by expert input and self technology scan where the some of the patents filed might have used synonyms of the search keywords used or alternate words in another language for patents in different jurisdictions. So leaving those patents out of the data used for analysis shouldn't be undermined. Patent data has been analyzed for top 10 jurisdictions only to understand diffusion of innovation in different geographies.

2. Theory

This chapter discusses the theoretical base built from literature study used for carrying out the research work. It covers the theoretical information about technology area, patent data search, data mining techniques and hypothesis about correlation between innovation activity and patenting to answer the research question about patenting as a measure of innovation in the industry.

2.1 Air Pollution

This chapter on Air pollution provides introduction to air pollution discussing technologies & products used in industry to control air pollution.

2.1.1 Introduction to Air pollution

The atmosphere in the present times is quite different from the atmosphere that existed before Industrial Revolution (circa 1760), in terms of chemical composition. If the natural atmosphere is considered to be "clean", then this means that clean air cannot be found anywhere in today's atmosphere. The contamination of atmosphere with the impurities and toxic substances has led to the term air pollution which can be described as such:

The term "air pollution" describes the substances that are artificially introduced into the air. Air pollution has its origin from gases and airborne particles which are harmful to human health, buildings and ecosystems in excess then the permissible value (Daly, A. and P. Zannetti, 2007)

Air pollution may be described as contamination of the atmosphere by gaseous, liquid, or solid wastes or by-products that can endanger human health and welfare of plants and animals. It can attack materials or produce undesirable odors. Although some pollutants are released by natural sources like volcanoes, coniferous forests, and hot springs, the effect of this pollution is very small when compared to that caused by emissions from industrial sources, power and heat generation, waste disposal, and the operation of internal combustion engines. Fuel combustion contributes maximum as air pollutant emissions, caused by man, with stationary and mobile sources.

2.1.2 Major Air Pollutants

Pollutants can be in the form of solid particles, liquid droplets, or gases. In addition, they may be natural or man-made (Science Daily July 23, 2009)

Pollutants can be classified as primary or secondary. Usually, primary pollutants are directly emitted from a process, such as ash from a volcanic eruption, the carbon monoxide gas from a motor vehicle exhaust or sulfur dioxide released from factories. Whereas the secondary pollutants are not emitted directly. Major primary pollutants produced by human activity include (PHYSorg.com. 17 Aug 2008):

- ✓ **Sulphur oxides (SO_x)**
- ✓ **Nitrogen oxides (NO_x)**
- ✓ **Carbon monoxide**

- ✓ **Carbon dioxide (CO_2)**
- ✓ **Volatile organic compounds**
- ✓ **Particulate matter**
- ✓ **Toxic metals**
- ✓ **Chlorofluorocarbons (CFCs)**
- ✓ **Ammonia (NH_3)**
- ✓ **Odors**
- ✓ **Radioactive pollutants**

Industrial practices contribute to the air pollution at large due to its operational emissions. The type of pollutants and the scale depends very much on the industry of practice. Major industries which contribute to the air pollution are power plants, fertilizer production centers, iron ore industry, cement production & petroleum refineries etc.

2.1.3 Techniques used in Air Pollutions Abatement

There are several techniques in practice to combat air pollution which are used in manufacturing air pollution equipments. Some of the techniques are discussed below (Infomil/Tauw, March 2000) (IPPC Reference document, February 2003):

- ❖ **Gravitation**
- ❖ **Dust scrubbing**
- ❖ **Filtration**
- ❖ **Condensation**
- ❖ **Adsorption**
- ❖ **Absorption**
- ❖ **Biological cleaning**
- ❖ **Thermal oxidation**
- ❖ **Cold oxidation**
- ❖ **Chemical reduction**

2.1.4 Air Pollution Control Devices

Various devices that have been developed and have been accepted in market to control air pollution. The following items are commonly used as pollution control devices by industry or transportation devices. They can destroy contaminants or remove them from an exhaust stream before it is emitted into the atmosphere (Dutch Association of Cost Engineers, November 2006).

Control Devices \ Pollutant abatement	Description	Types of Control devices
Mechanical Collectors	It can be regarded as a dust collector system or a system deployed to dust and other impurities from air or gas. It is designed to handle heavy dust loads, a dust collector system consists of a blower, dust filter, a filter-cleaning system, and a dust receptacle or dust removal system	
Electrostatic precipitators	An electrostatic precipitator (ESP), or electrostatic air cleaner is a particulate collection device that removes particles from a flowing gas (such as air) using the force of an induced electrostatic charge	
Baghouses	Baghouses are designed to handle heavy dust loads. A dust collector consists of several parts such as blower, dust filter, a filter-cleaning system, and a dust receptacle.	
Particulate scrubbers	Wet scrubber is a types of pollution control technology. The term describes varied devices that use pollutants from a furnace flue gas or from other gas streams. In a wet scrubber, the polluted gas stream gets into contact with the scrubbing liquid by spraying it with the liquid and then forced to go through a pool of liquid so that the pollutants can be removed.	
Scrubbers	Scrubbers are the diverse group of air pollution control devices that can be used to remove some particulates and/or gases from industrial exhaust streams. They are the pollution control devices that use liquid to wash unwanted pollutants from a gas stream.	✓Baffle spray scrubber ✓Cyclonic spray scrubber ✓Ejector venturi scrubber ✓Mechanically aided scrubber ✓Spray tower ✓Wet scrubber
NOx control	It's the types of devices used for controlling emission of nitrogen oxides.	✓Low NOx burners ✓Selective catalytic reduction (SCR) ✓Selective non-catalytic reduction (SNCR) ✓NOx scrubbers ✓Exhaust gas recirculation ✓Catalytic converter (also for VOC control)
VOC abatement	The type of devices deals with the control of volatile organic compounds.	✓Adsorption systems, such as activated carbon

		✓Flares ✓Thermal oxidizers ✓Catalytic converters ✓Biofilters ✓Absorption (scrubbing) ✓Cryogenic condensers ✓Vapor recovery systems
Acid gas/ SO_2 Control	The types of devices used for controlling emission of sulphur oxides.	✓Wet scrubbers ✓Dry scrubbers ✓Flue gas desulfurization
Mercury Control	The types of devices used for controlling mercury.	✓Sorbent Injection Technology ✓Electro-Catalytic Oxidation (ECO) ✓K-Fuel ✓Dioxin and furan control ✓Miscellaneous associated equipment ✓Source capturing systems ✓Continuous emissions monitoring systems (CEMS)

2.2 Technology Trends & Competitive Intelligence using patent information

There are several methods that have been developed to recognize progresses and development of technologies, and one of those several ways is by analyzing patent information. Methods used for analysis of patent maps and huge patent data related to a technology domain enables us to understand advances of emerging technologies and forecast its trend in the future. It has been a critical issue to understand technological trends not only to avoid unnecessary investment but also to gain the seeds for technological development. Its generally proves fruitful in helping top management make decision on its technology development investment and acquisitions inspired to make own patent portfolios strategically stronger.

As discussed by Professor Holger Ernst in his paper on Patent information for strategic technology management (Holger Ernst, 2003) Patent data has information stored in it which can be used for strategic planning purposes in core areas of technology management. Patent information can be used for competitor monitoring, technology assessment, R&D portfolio management, the identification and assessment of potential sources for the external generation of technological knowledge, especially by means of mergers and acquisitions, and human resource management. Indicators of patenting strategies and various portfolio concepts which can be used for these purposes are described. The strategic patent information can be of interest to different segments in an organization .i.e. (1) senior management who might use the information for decision-making in important areas of technology management and (2) external stakeholders of the firm, such as shareholders and analysts, who have an increasing interest in assessing a firms technological. The research responds to the needs of technology-driven business by exploiting their technological capabilities leading to new business opportunities. Patent information at the same time form the base for research agenda to be decided and managers to direct their technology

development investment. Patent data analyses is still a general term to quote and will be discussed later in the report with deeper focus on various techniques used by IP professionals such as data mining, trends analysis etc to discover meaningful implications from the patent data. (Holger Ernst, 1998)

As understood from the discussion above, patent data analyses form a strong platform to provide information for strategic decision making in the technology focused organization. Also it should be noticed that patent information is extremely technical and legal so it becomes difficult for regular organizational technical workforce to carry out the same in-house autonomously and thus requires special IP taskforce and skills (Brockhoff K., 1992)

2.3 Patent Maps

Patent mapping also referred to as patent landscaping at times is the art of visualization and a practice enabling companies to identify companies in a particular technological space where they are developing and competing. The exercise is performed with different aims and objectives since the process can help conclude varied results. On a general level the patent map is formed to help management understand and avoid unnecessary investment and exploit opportunities arising from technological development.

Patent map and its analysis assist organization look upon the technology area patent trends & thus providing it with input to make research, strategic decisions. Creation of a patent map involves gathering related patent information of a target technology field, processing, and analyzing it. Creation of patent map is a skilled task demanding a typical expertise for gathering the patent information relating to a technology area and thus analyzing it. At times it is out of the reach of technical or management work force in an organization to carry out this task without dedicated staff.

As understood and quoted in Guide Book for Practical Use of "Patent Map for Each Technology Field by Japan patent office (Patent Map for Each Technology Field, 2000) -- Patent maps are not produced to aim at just a specific use or application, but also serve as a general-purpose use. Thus, when using them, their contents can be read from various viewpoints. In particular, by combining multiple maps (figures and tables), it is possible to find a new matter that cannot be obtained from a single map.

As discussed above about the intentions of management for making a patent map and carrying out analysis, it can be used for different purposes for companies in mature R&D phase to companies eyeing to enter a technology market. Taking references of different patent maps in a particular technology area for different purposes I discuss what different technology maps can lead to and how it may help in ones business and technology endeavors. Classifications below discuss different maps based on the aim of user group and results one is aiming to fetch out of it.

1. Understanding Overall State of a Technology Field

(1) Maps Depicting an Overall Composition of a Technology Field

(2) Map Representing Expanses of Applications of a Technology Field

(3) Map Portraying Technology Fields Related to a Technology Field

(4) Map Describing a Technological Progress

2. To Find out Technological Changes

(1) Map Showing Changes of Relations between Activities of a Technology Development and Participating Companies

(2) Map Exposing the Degree of Maturity of a Technology Field

(3) Map Depicting Changes of Technical Contents

(4) Map Describing Trends of Problems in a Technological Development

(5) Map Describing Changes of Influential Industrial Field in Technological Development

(6) Map Portraying a Technological Development

3. To look for new Business Opportunities

(1) Map Portraying the Status Quo of Applications with Multiple Perspective of a Technology Field

(2) Maps Representing Problems in a Technological Development

(3) Map Depicting Correspondence between Problems and Technologies

4. To understand Properties of Applicants

(1) Map Portraying Applicants having Filed Many Applications

(2) Map Showing Types of Applicants (Individuals, Companies, Government Offices, etc.)

(3) Map Representing Numbers of Applications According to the Nationalities of Applicants

(4) Map Depicting Composition of Applications by Industry Type

5. To Deal with the Globalization of Business

(1) Map Depicting Structural Differences of Applications among the US, Europe and Japan

(2) Map Showing Upper Ranked Applicants (Right Holders) of Foreign Countries

(3) Map Portraying Expanses of a Technology Development in Foreign Countries

2.4 Patent search

Patent search is generally performed aiming at different requirements and results. World patent database consist of enormous information relating to various granted or pending patent documents. Each patent is related to variety of attributes by which it can be recognized. General patent search using patent databases of various patent offices around the world or professional patent search & analysis tools can be done by using these attributes and thus looking for interesting patent information. Patent information can be looked upon from different perspectives. It comprises of extensive information accumulated over a long period of time from around the world. When connected to R&D themes it can be recognized as the

technological information in relation to idea collection and research progress for huge portfolios. As a matter of fact it can be seen to maintain protection of exclusive right over specified period preventing the entrance of competitors, and as a right to receive royalties through license agreements creating management profits through royalty revenue (Patent information utilization manual, 1994)

In the scope of this thesis we aim to understand the innovation activity and diffusion of innovation by determining the technology & merchandizing trends of different corporations in the area of air pollution control management.

With reference to documentation by Korea Invention Promotion Association (Patent information search specialist process, 2003) on Patent information management different patent search methods are briefly discussed below:

A. Bibliographic Search: This type of search can be taken from the regard of fairly simple conducted on the base of patent number and the inventor's name. The point is to figure out what is protected by a particular patent number. Bibliographic search can be performed as personal background search, history search, and chronological search.

B. Patentability Search: It is one of the most general patent searches. This search is done to determine whether an invention under consideration can be patented, if it's valid and original. The purpose of this search is to determine whether a prior patent (prior technology) exists or not.

C. State of the Art Search: This type of search might involve extensive collection of information or it can be narrow one. This kind of specific technology field is used to perform a wider scope search & analysis of specific information relating to the R&D theme to conduct a more effective and strategic R&D process, and it can be divided into the following detailed research & analysis methods

(1) Basic information search: collection & extraction of related data
(2) Classification information search: technology classification
(3) Analysis information search: technology classification & analysis

D. Continuing Search: This type of search is mainly used to determine patent trends in the interested field or competitor trends. It also includes the monitoring search of legal status etc. in relation to a specific case.

E. Assignment Search: In case of a patent being assigned to another person or company this search is used to determine the legal owner of the relevant patent.

F. Infringement Search: The type of search is performed to determine actions that violate or are covered by a patent that has not been terminated. This search has a deep relationship with the non-terminated patent claim.

G. Validity Search: Validity search is conducted by an individual or a company with an aim to invalidate the patent possessed by someone else. Search is conducted to find public period knowledge used in an invention or technology defects which can warrant the invalidation of the patent. So, validity search assists to determine whether a non-terminated patent is valid or not.

H. Rights Termination Search: The particular search determines the potential legal outcomes of reproducing processes, products, and designs of other companies of which the exclusive rights have been terminated (Patent search guide using the internet, 2001)

Below we discuss the two types of parameters generally accepted and widely used for searching the patent information by short listing patents.

2.4.1 Key word based patent search

The type of search methodology is used to shortlist the patents by searching relevant keywords of interest to a particular technological innovation (T. S. Eisenschitz and J. A. Crane, 1986). There are several fields with which a patent can be associated. Most common and general method used is by referring a patent to a set of keywords which belong to a technological invention under question. A set of relevant keywords of specific nature can be shortlisted and be used to search in the title, abstract, claims or text body of whole patent document. The search is fairly simple in nature like general web search looking for patent in the database where specific keywords are encountered. Shortlisted patents thus as per the search criterion are shortlisted and displayed in the search results.

2.4.2 Classification based patent search

Patent classification system is a way patent examiners arrange patent documents, such as patent applications and invention disclosures. Documents are arranged using a patent classification so that they can be quickly found in case one is looking for a document disclosing the invention identical or similar to the invention for which a patent is claimed (Jon E Schakelford, 2005). It should be noted that the same document may be classified in several classes. Classification system is generally a norm agreed upon by a group of individuals coming together as an international government body or private organization. Discussing about different patent classification systems there are several widely used ones like **International Patent Classification (IPC)** which has been agreed internationally, **United States Patent Classification (USPC)** is fixed by the United States Patent and Trademark Office, **European Classification (ECLA)** is based on the IPC but adapted by the European Patent Office to its own requirements whereas the **Derwent classification system** is fixed by an enterprise named Thomson Innovation. A classification system is generally hierarchical with Sections consisting of different classes followed by subclasses, groups & subgroups. A classification for a particular patent is generally written in pattern of parent category in prefix to the child category making up a whole classification code with section followed by class, subclass, group and subgroup respectively.

As a patent can be associated with a multiple set of classifications codes. Thus if looked upon logically each patent has its relationship to different hierarchical categories in the whole classification chain and can be searched accordingly using the patent database. The patent information and set of patents can be called using the category under question.

2.4.2.1 IPC classifications

World Intellectual Property Organization (WIPO) is the founder of IPC system and it defines IPC system as below (Guide to the International Patent Classification (Version 2009), 2009):

The International Patent Classification (IPC), established by the Strasbourg Agreement 1971, provides a hierarchical system of language independent symbols for the classification of patents and utility models according to the different areas of technology to which they pertain.

The IPC classifies technology into eight sections with approx. 70,000 subdivisions. Each subdivision has a symbol consisting of Arabic numerals and letters of the Latin alphabet. The IPC symbols are allotted by the national or regional industrial property office that publishes the patent document. For PCT documents, IPC symbols are allotted by the International Searching Authority (ISA) (B. Stembridge, 1999)

IPC classification system is majorly used by all the active patenting authorities in the world thus generally patents can be searched using an IPC key. Finding the "right" IPC classification code at times is a difficult task. As referred to the learning on use of IPC(Guide to the International Patent Classification, 2009) it can be concluded that catchword\keyword index is good starting point but usually it doesn't catch the relevant patents in context of subject matter one is looking for. Thus later by getting hold of one or two relevant patents the related IPC codes can be indentified for its relation to subject matter, fetching all the relevant documents. There are tools on WIPO website helping user understand the subject matter a class or IPC code is associated with. User can look for subject matter explanation at any level of hierarchy and get information from the database to see if the explanation relate to what user has been looking for.

2.4.2.2 Other\National classification systems

There are several other classification systems developed, adopted and maintained by different authorities to manage different patent applications. Below are some of other national\other classification systems used:

ECLA: This is the classification scheme applied by the European Patent Office to its internal collection of search documentation and is based on the IPC, but is often more detailed (D. Dickens, 1994)

US Classification: This is the scheme used by the USPTO examiners as their primary classification tool.

British Classification: This is the scheme applied in parallel to the IPC to all published British patent applications by the examiners at the Patent Office.

2.5 Patent search strategies & methodologies

A robust search strategy is crucial to acquire patent data to be used for analysis of a technological area or a group of industry. It's cumbersome to come up with a search strategy in a particular technological area which can produce accurate search results for a part. Yet a strategy with improved accuracy can be still be worked out using the logical search methodologies. As discussed in article 2.4, patents can be searched using single\multiple parameters which are associated with a patent. Strategy should be followed to come up with a meaningful search string with appropriate checks to shortlist the relevant patents and leave out the ones that are irrelevant.

Taking the reference of a published research study (Young gil kim et al, 2008) patent search criteria is the most important part of whole lifecycle to gather right data which will form a base for further analysis. It is discussed in the framework of patent search strategy as follows:

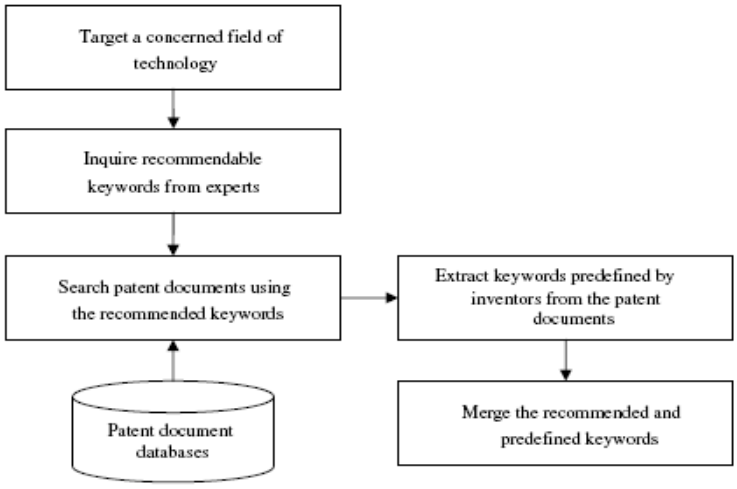

Fig 2: Patent data search strategy

Below we discuss the method to collect patent keywords as per the research report written by editor of research paper talked above (Fattori, M., Pedrazzi, G., & Turra, R., 2003):

Collecting keywords

Approach begins with looking into the technology domain of interest followed by collection of initial keywords from technology or industry experts to search related patent documents. After searching patent documents, keywords are collected from patent documents thus merging them with the initial keywords. As a result, the list of merged keywords is completed to be used for patent data collection.

Patent Keywords

As argued by Pipers Patent Attorneys (Editorial, Pipers Patent Attorneys) Terminologies and Keywords are important part of the initiation of patent data search. As said "Patent documents are described primarily by words. One needs to be familiar with the terminology applicable to the invention. Only the words that are used in a factory or work environment doesn't help, but one should know how the competitors locally, nationally and internationally might describe the invention and its component parts.

Patent search strings

The section on ***How to build up search strings*** by Pipers Patent Attorneys (Editorial, Pipers Patent Attorneys) discusses that while variations in terminology may encompass many combinations, one may find many documents that relate to other technical fields not relevant to the present search. Too general terms from a technology area may relate to many other unrelated areas of endeavor. Rather than scanning and filtering through irrelevant documents from such a text search, it's better to search for concepts rather than the keywords themselves. The patent search should involve internationally recognized categorical or classification system, usually in conjunction with a key word or key phrase search to make sure one comes up with relevant patent data of interest to a subject matter.

Patent Classification

Patent classification is very important attribute in patent data search. As argued by Pipers (Editorial, Pipers Patent Attorneys), it's an invaluable tool to limit the number of records (hits) returned by a search, it can be accomplished by comprising the relevant International Patent Class (IPC) & USPTO Classes (and possibly other classification schemes) or else screening the ones fetched by use of other attributes at first place. These Classification systems are complex hierarchical subject matter systems, which require a good deal of familiarity and expertise if they are used effectively. They are, however, logical in their makeup and thus can also be used by novice or a casual searcher.

2.6 Patent Data Mining and Analysis for effective IP strategy

Patent data and its analysis play a crucial role in keeping a watch over ones competitor activities. Knowing how to carry out analysis of the collected patent data helps in developing commercial patent management strategy. The power of one's patent portfolio is exposed by effectively managing it and exploiting it to capitalize the technology by tapping market opportunities around. On a broader level the aim of patent data analysis and data mining helps identify complementary technologies that can be licensed in to fill the gaps in own patent portfolio and identification of non core technology patents to license out or divest in them to gain financial returns on it. Accurate patent data coupled with data mining techniques provides with interesting results that assist management of an organization get a clear picture on such matters. Indicated by a major IP tools manufacturer and consulting firm "Thomson Reuters" (Stembridge and Corish, 2004) effective patent portfolio management task constitute of five key components:

- What do I have? (the IP audit)
- What do I need? (the gap analysis)
- Acquire what I need (the investment strategy)
- Divest what I don't need (the deployment strategy)
- Ongoing maintenance and monitoring for effective development of the IP strategy over time

As indicated by the IP consulting firm in its literature, graphical representation of how these activities might take place and briefing about major indicators of interest is described below:

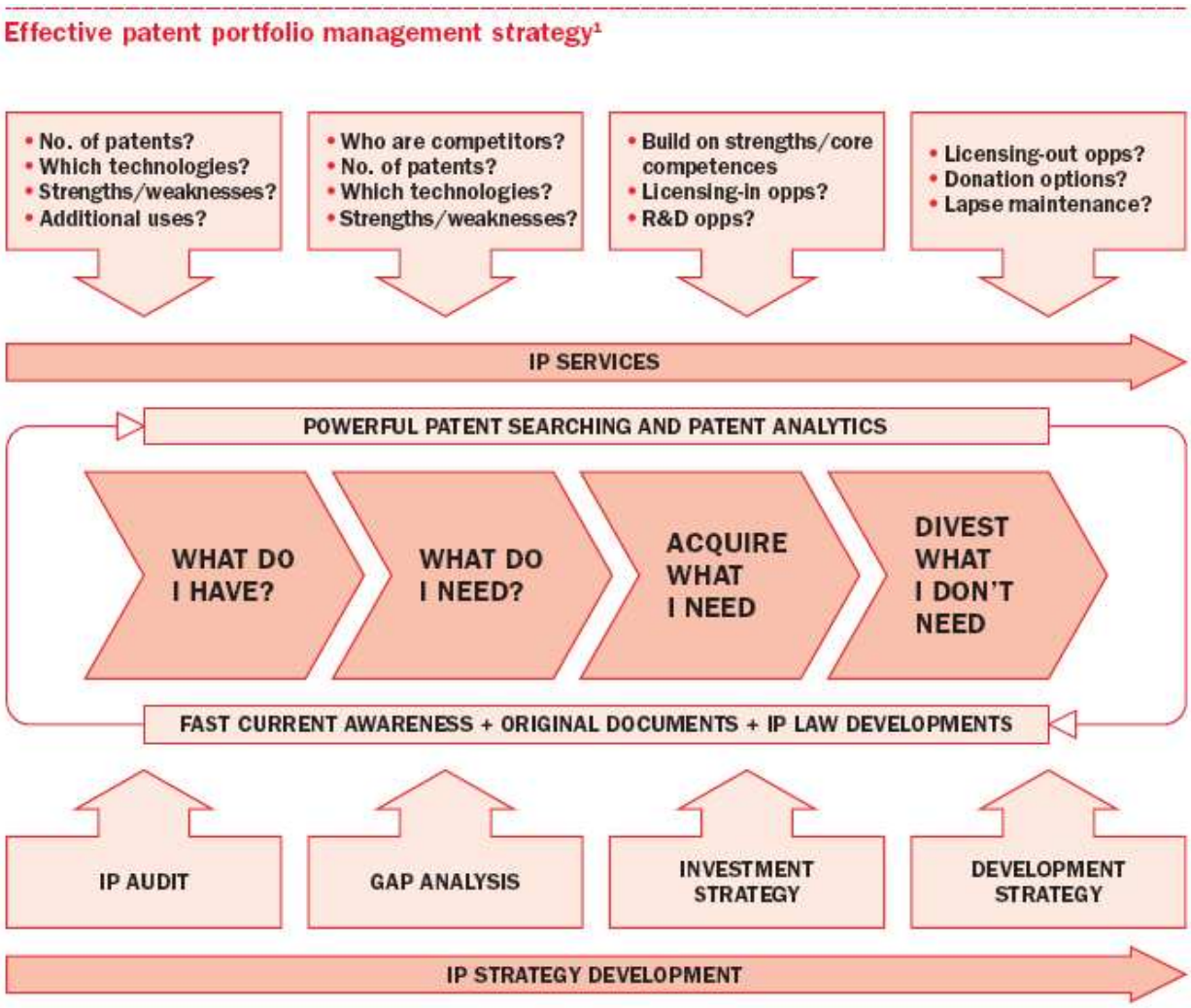

Fig 3: Effective patent portfolio management strategy (Stembridge and Corish, 2004)

We briefly discuss below the steps that are encountered in the process of data analysis:

1. **IP audit – what do I have?**

The IP audit process starts with closely analyzing own patent portfolio position by auditing the IP under organizations possession, analyzing collected data to come up with meaningful trends and graphs to answers some of the questions mentioned below(Stembridge and Corish, 2004):

- What patents do I have in my portfolio?
- What technologies do they belong to?
- What are my strengths and core competencies?
- How about any obvious weaknesses?

2. **Gap analysis – what do it need?**

The identification of own patent portfolio follows with getting a grasp over strengths and weaknesses compared to the competitors in technology domain (Stembridge and Corish, 2004). It can be

accomplished by looking at the interesting facts and trends using collected patent data. Some of the few parameters worth looking upon are as follows

- Identification of core competitors
- What are the patent portfolios of competitors in the technology or field of interest
- Technology areas they have been patenting
- What are competitors strengths which my pose threat

3. **Acquire what I need – the investment strategy?**

Having understood the IP position compared to other companies\competitors one needs to plan for fill the gaps and strengthens its position. Generally capital, people and intellectual property needs to be injected in organization in specific ways to strengthen its position and make up for the underlying gaps. Few parameters thus thought upon that help making up for the gaps and plan for investment are mentioned below (Stembridge and Corish, 2004):

- Where to increase R&D investment to build on strengths in coordination with market?
- Human resource hunting: Key inventors to head hunt to gain competitive advantage?
- Technologies to license in to compensate for areas of weakness?
- Competitor's strength and do these pose a threat?
- Possibilities to create an alliance and combining the IP portfolios

4. **Divest what I don't need – IP strategy development**

Licensing out a technology is on agenda for most of big conglomerates leading to new revenue streams. The uncertainty of research findings and noncore inventions during the course of work lead to some of the technologies which might not be of interest to the company in its product or service portfolio. Thus those technology lead to the path of licensing or spin outs. Some of the technologies and patents possessed by company might not fall in the interest of other companies either and thus are liability for them. Patent portfolio analysis, market research or citation analysis form the base for taking decision on disinvestment in them by stop paying the renewal fee or cutting the research budgets.

2.7 Patent data as a measure of Innovation

Since patents is the way to protect ones invention and research results ideally leading to commercialization in later stages of business driven innovation. Patent data speaks about innovation in an organization. There is quote by Schmookler J (Schmookler J. 1966). **"We have the choice of using patent statistics cautiously and learning what we can from them, or not using them and learning nothing about what they alone can teach us"**. The quote indicates use of patent data to understand the dynamics of innovation in a technology field by measuring different indicators of innovation. Keeping in mind the utility of use of patent data for measuring innovation lets discuss different indicators of innovation that can be measuring by using patent statistics (Xuan Li and Yogesh Pai, 2007).

1. **Innovative Activity:** Patent data is the measure of innovative activity in the technology area or a company. Patent applications are usually filed in the early stage of research process thus the number of patent applications cannot just be taken as a measure of innovative output, but also an indicator of the level of innovative activity itself. Cohen and al. (2000) indicates a mutual correlation between

R&D and patents, as argued patenting tends to stimulate R&D. Lanjouw and Mody found a strong positive correlation between patents and R&D in alternative energy for the US (Lanjouw and Mody, 1996).

2. **Technological Innovations by field:** When evaluating patenting activity at organization level, patent data can illustrate the types of innovation and technological competencies of organizations. Since a patent is classified and divided by authorities assigning to International Patent Classification with detailed description, which divides the area of technology into a hierarchal structure with a range of sections, classes, subclasses and groups. The description of the technology and the IPC codes can be used to distinguish between different types of technological innovations based on their technological field. Moreover, patents can provide the directions of research and of the technological competencies of organizations when huge portfolios are divided into classifications and thus analyzed.

3. **Technological Strength of Nations:** The patent data is the indicator of technological strengths of nations. For example, Marinova and McAlee (Marinova andMcAleer,2006) analyze the technological position of the top 12 foreign patenting countries/areas in the US in the area of nanotechnology using 4 technological strengths indicators based on patent data, which are: i) technological specialization index, ii) patent share, iii) citation rate and iv) rate of assigned patents. Thus with help of these parameters technological strength of different countries can be measured.

4. **Diffusion of Technology:** Patent data can be used to measure diffusion of technology by using the patent data from different countries to track patterns of diffusion(Popp, 2005).Filing of a patent application in a country is an indication of inventor's expectation of the invention to be potentially profitable in that country. Thus, the data on multiple filings of patents can be used to track diffusion of technology across countries (Lanjouw and Mody, 1996).

2.8 Patenting and Innovation correlation

R&D and patent data are seen as relevant indicators of the innovativeness of an economy. R&D expenditure is an input measure of the innovative activity, while patent data is considered to be the output indicator. Main advantage of patents is the public availability for a long time providing detailed technological information. The long time span make patents unique among innovation indicators. Using patent data, it is possible to collect data in highly disaggregated forms and subject it to statistical analysis. Patents measure inventive output and can be used as measure for innovation. As a measure of invention, patents have a close link to innovation. There are very few examples of major inventions that are not patented. Patents cover a broad range of techniques, extending now to biotechnology and software, with first extensions towards services-related inventions (Oltra, Kemp & Vries, 2008)

Griliches argues in his study “Patent statistics as economic indicators: A survey” that patent applications are usually filed early in the research process (Griliches, 1990). The filed patent applications give an idea about the early stage innovations in an organizations or a jurisdiction which eventually speaks about the R&D emphasis or its innovativeness. As discussed in section 2.7 quoting David Popp that they are not only a measure of innovative output, but also an indicator of the level of innovative activity itself. Quoting the study done by Lanjouw and Mody (Lanjouw and Mody, 1996) a positive correlation between patents and R&D in alternative energy for the US was found.

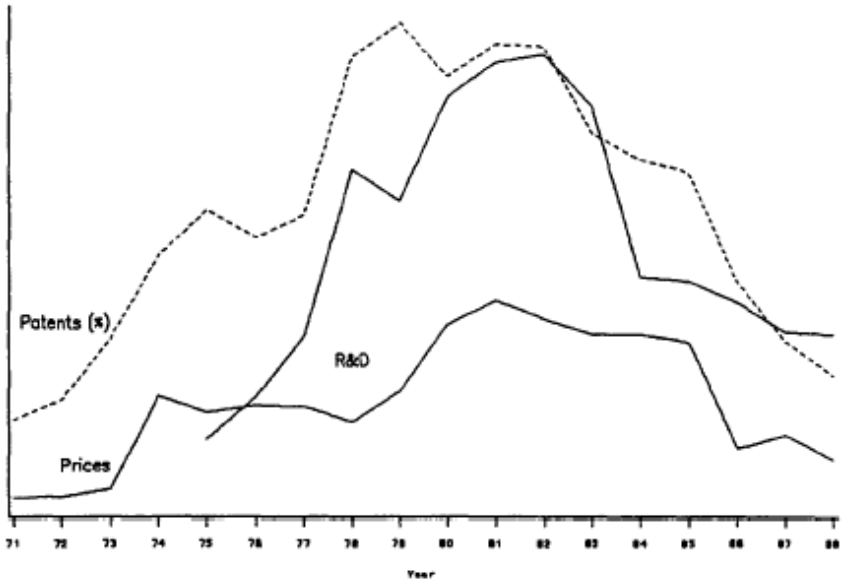

Fig. 4. Alternative energy. Patents, energy prices, R&D. Note: patents (%) is alternative energy patents / total U.S. patents. Sources: R&D funding. Chemical and Engineering News (various February issues).

Fig 4: Patents and R&D correlation alternate energy (Lanjouw and Mody, 1996)
Source Lanjouw and Mody (1996, p. 560)

From the figure above on the relation between R&D spending and patenting can be seen. There is a correlation between public R&D and patents for alternative energy but this is not always so since in this situation private R&D doesn't play that important role whereas in other technology areas private R&D is a major chunk of total R&D spending which makes it difficult to prove the correlation(Oltra, Kemp & Vries, 2008).

Patenting versus R&D spending

R&D spending being the input to innovation activity in an organization, its worth looking into the correlation of R&D budgets and patenting which eventually gives an idea on innovation & patenting correlation. Kammen and Nemet in their paper named *Reversing the incredible shrinking energy R&D budget* discuss the relationship of R&D spending in different technology fields to patenting. Looking into the patenting activities in several technology fields and public R&D spending it was concluded in the study that public R&D spending can be correlated to patenting in the field for the areas where public R&D plays an important role. Areas having influenced by private R&D don't seem to have a correlation since private organization choose to keep the data public. (Kammen and Nemet, 2005) Some of the figures described during the study performed are as such (Source: Kammen and Nemet (2005, p. 86)):

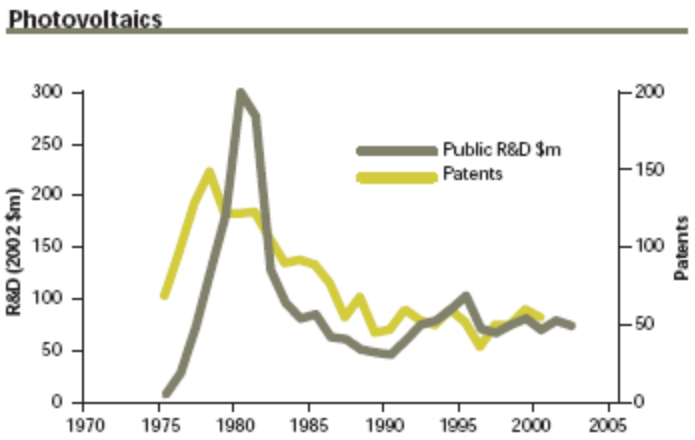

Fig 5: Patents and R&D correlation: Photovoltaic's (Kammen and Nemet, 2005)

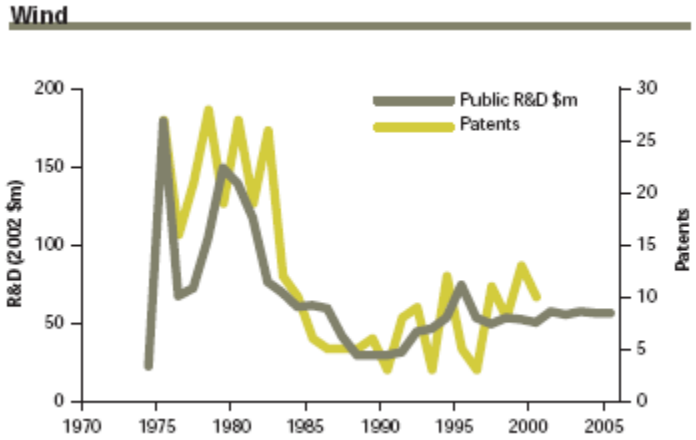

Fig 6: Patents and R&D correlation: Wind (Kammen and Nemet, 2005)

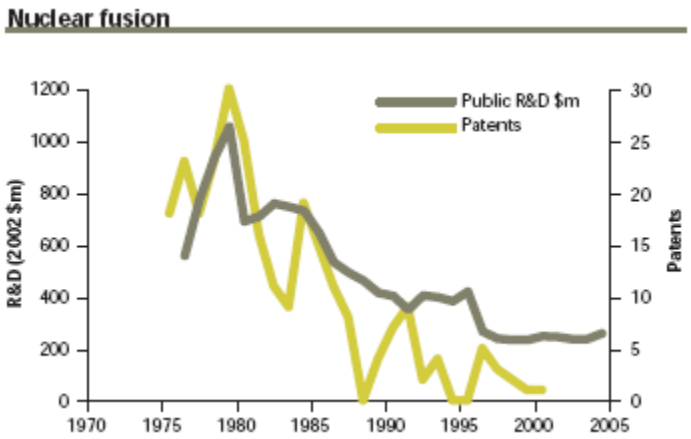

Fig 7: Patents and R&D correlation: Nuclear Fusion (Kammen and Nemet, 2005)

Looking at the plot between public R&D and patents for alternative energy technologies. Correlation between public R&D and patents is clearly visible but this is not always so which stands true looking at the next correlation plot for fuel cells below:

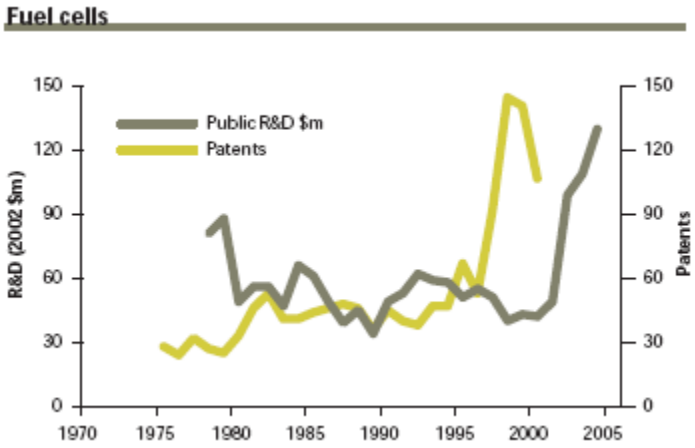

Fig 8: Patents and R&D correlation: Fuel Cells (Kammen and Nemet, 2005)

In the case of fuel cells there is no correlation between public research and patents; probably the reason for such an observation is that private R&D is very important in fuel cells R&D work.

It is argued in the paper (Oltra, Kemp & Vries, 2008) that patent data is correlated with R&D. The advantage of patent data is that it is available for analysis where the data for R&D is not available. Generally the public R&D data is still available for use whereas the private R&D data on technologies is usually not available as companies don't intend to do so and many of the statistical companies demand the same (Oltra, Kemp & Vries, 2008)

Diffusion of Innovation

Concerning the diffusion of innovation David Popp discusses that Patent data available from different jurisdictions can be used to track patterns of diffusion (Popp, 2005). Since the legal protections granted by a patent apply only in the country where patent is granted, inventors must file patent application in desired jurisdictions. Patent prosecution in a country is signal of commercial returns that inventors foresee by protecting the invention and then exploiting it commercially. In that sense, data on multiple filings of patents can be used to track diffusion of technology across countries (Lanjouw and Mody, 1996). Diffusion may be tracked for a technology field as a whole or subsets. It allows diffusion analysis at a high aggregate level and does not measure diffusion directly, but indirectly.

2.9 Measurement of Eco Innovations using patent data

Our focus is on air quality control systems and it falls under the umbrella of eco innovation as per the study that has already been conducted by Oltra, Kemp & Vries (Oltra, Kemp & Vries, 2008) to see the

application of patent data analysis in evaluation of innovation scenarios. It is discussed in paper that patent counts can be used as an indicator of the level of innovative activity in the environmental field. The study can be done in the same way as for innovation in general; patents of eco inventions can be used to measure research and invention activities. Patents can be used for studying eco-innovations – innovations that result, throughout its life cycle, in the reduction of environmental risk, pollution and other negative impacts of resources use. Eco-innovation may consist of a new or improved environmental technology, a production innovation, a service innovation, the introduction of a new business method or organizational measure, or a green system innovation. New business methods and organizational innovations are not patented since there is no clear invention underlying it. Patent analysis is not suited for this type of innovation. It is also not suited for analyzing service innovation as few services innovations are patented. Primarily technological innovations are the ones new to the worlds that are patented, and patent analysis may be used for these innovations. The paper concludes that eco-patents mainly measure inventions that underlie green product innovations and end of pipe technologies, whose environmental impacts are specific aims and motivations of the inventions. For these kinds of innovations it is suitable to use patent analysis. Eco-patents thus can provide indicators of environmental innovative activities in specific technological fields. (Oltra, Kemp & Vries, 2008). That can be accomplished by analyzing the patent data based upon its relevancy to the subject matter using IPC codes. Likewise for innovation in general, eco patents can be used to analyze the following features of environmental innovative activities:

1. The level of eco-innovation activities and the directions of research in certain environmental fields: Comparison of eco-patents in specific technological fields, Historical trends of evolution of eco-patents in specific fields, technological competition between environmental technologies.

2. The competencies of organizations in environmental technologies: Eco-patents can be used to evaluate technological competencies of private and public organizations in specific environmental fields by relating them to specific subject matters.

3. The diffusion of environmental technologies: International eco-patent data can be used to track patterns of diffusion by evaluating the patenting trends in different jurisdictions. Lanjouw and Mody calculated the share of foreign patenting as a proxy of technology transfer and diffusion (Lanjouw and Mody ,1996)

4. The sources of eco-innovations: The assignee's country of origin for eco-patents provide information on the sources of eco-innovation which can be very useful to study the relative role of private firms, universities and public laboratories. Data on co-patenting is quite useful to analyze collaborations in the field of eco-innovations and network of innovators.

5. Environmental technology strength of nations: The strength of nations in the various areas of environmental technology can be analyzed on the basis of patent data. Marinova and McAleer (2003c) argues that 4 technological strengths indicators based on patent data can be used to analyze which are: technological specialization index, patent share, citation rate and rate of assigned patents.

6. Technological spillovers and knowledge flows

3 Empirical study

This chapter of research report aim to analyze the patent data with a motive to understand innovation in the technology area. Empirical data collection and its analysis have been carried out by taking into consideration the theory and techniques. The patent search method thus used to collected patent data has been based on the understanding developed from scanning of research reports and case studies relevant to patent information collection. Research focused on collecting the patent data for major industrial players in technology area focusing on understanding their R&D activities. Collected patent data has thus been analyzed to understand the innovation trends with an intention to answer the research problem.

3.1 Technology Area Familiarization

With an aim of collecting relevant patent data technology area was scanned to get an in depth understanding of Air pollution, causes, abatement, products in market and services around. The study of technology domain was conducted by looking into the relevant literature (air pollution causes, sources, mitigation techniques, product portfolio of companies producing abatement equipments etc) and also part of information was fetched with the help of R&D department of a big company in same technology area. Following the scan of literature and information collection from company, we collected the relevant patent data and analyzed it to observe interesting trends in technology area research.

Acquisition of patent data collection required to come up with an appropriate search query containing constraints to limit the patent search to technology area keeping in view the constraints to be optimum enough, so that relevant patent entities are not left outside the search domain and at the same time ensuring not to include irrelevant patent data in the search result.

3.1.1 Keyword Short listing

Author began the work of search query building by scanning technology area to come up with relevant keywords. It was ensured that search keywords are not too general to build a query week enough to include patents from other technology areas and taking care to include ones which are controversial to belong to other technology fields and most often on the border lines. Keywords were looked upon to be from the sub fields of:

1. Pollutants and Sources of Air pollution
2. Air Quality control products
3. Environmental control technologies and techniques used
4. Important components of technology domain under continuous improvement and upgradation

The list of shortlisted keywords from the technology area scan is attached in the appendix section under section 6.1 .i.e. Table of collected Keywords.

3.1.2 Keywords from experts

In the collection of keywords, it's a high probability to miss most of the key-keywords during the exercise due to limitation of literature scan failing to cover all latest advancements and technology area research. Taking it into account the information from technology area experts was relied upon to fill the gaps in

keywords search. Author of the research work approached technology area experts in a major company producing equipments based upon air pollution control; the intention was to understand the technology area development with an aim of capturing the missed keywords. The innovation and research work in the technology domain was given due consideration to capture latest advancements that would have lead to increased patent in past. The task involved approaching in-house patent experts in the company to understand keywords under their watch list for keeping track of patenting activities in the technology field.

Author thus compiled a list of keywords under the watch list of a IP department at major AQCS company thus consulted and interviewed which will form as a validation and base to fill gaps in keyword list compiled as per previous section 3.1.1.

3.1.3 Keyword merge and filtration

With an intention of forming a preliminary search string trying to collect relevant patent data, as per the literature, keywords gathered from experts and literature scan were merged together. Exercise of merging the keyword list was carried out in parallel to filtration of keywords thus compiled in section 3.1.1 keeping in view the comments from experts in interviews and getting the more general keywords out having a tendency of pulling in more irrelevant patent data from other technology areas. Idea was to come up with the keyword list flexible enough not to leave relevant patent data out of search results and stringent enough not to pull in irrelevant set of patents in the search results. Several considerations taken care during the keyword merge and filter process are listed below:

1. Too general keywords like Dust, Carbon, Sulphur, Carbon dioxide, etc eliminated due to their tendency to pull in patent data from random technology fields of being of a general nature.
2. Few keywords like seawater flue gas desulfurization, Volatile Organic Compound and Wet Electrostatic Precipitators taken care to be included as a string instead of individual words due to their general usage in industry and patenting in technology area.
3. Abbreviations for keywords\strings like (PEP) for Performance Enhanced Plates, (RDE) for Rigid discharge electrode, (SCR) for selective Catalytic Reaction avoided due to their lesser usage possibility in the patent literature and professional patent writing.

3.1.4 Key Companies

Another important step in making a healthy patent search criteria comprised of including a constraint which still ensured collection of the relevant patent data. It was decided to focus the search on major companies doing business in the field of AQCS, ECS technologies with strong R&D and Innovation focus. Professional information from the experts of the company interviewed for thesis work and market study was relied upon to come up with a list of five major players active in R&D and patenting of technology in AQCS technology domain.

List of five companies was thus used to formalize the search string and analyze final data thus collected for shortlisted organization to observe the patenting and innovation trends.

Please note that under the scope of this thesis document the names of 5 organizations has been kept confidential and will be addressed as Firm 1, 2, 3, 4, 5 but the patent data statistics in real-time forming the base for analysis is published in later sections.

The organizations (Firm 1, 2, 3, 4, 5) selected for evaluation of technology area thus had varied technology businesses in international market with huge investments on R&D and Innovation. Patent portfolios of these firms vary individually from several thousands to hundred thousand patents per company so immense care was taken to filter out patents of disinterest.

3.2 Patent Search Methodology

With due consideration of the patent search methodology using literature from section 2.4 and 2.5 in theory section and logical analysis of forming a search string, a search strategy was followed to eliminate the irrelevant data for final patent data collection. Followed search methodology is described below in several steps

3.2.1 Patent Search String Formation

Discussion with experts, technology literature review for keywords\catchwords, list of companies active in technology domain formed the based for initial patent search string formation. The professional tool used for data collection was Thomson Innovation by Thomson Reuters. Different constraints in direct relation to patent data of interest thus formed a base for selection criteria.

3.2.2 Preliminary Search String

Thomson innovation imposes the use of syntax for making up a valid search string. The data thus generated in exercise carried out in section 3.1 was modified using this syntax and valid search string was formed with an intention of further restricting the search criteria for data collection. The preliminary search string thus generated for collection of firm time data is mentioned in Appendix Section 6.2 named Preliminary Search criteria:

Patent data was thus searched for multiple jurisdictions for patent data to be searched in US Granted, British Applications, US Applications, French Applications, WIPO Applications, German Utility Models, European Granted, German Granted, European Applications, German Applications, Japanese Applications, Korean Granted/Examined, Korean Applications, Other Authorities.

3.2.3 Search Results

Search results thus generated 6794 Derwent patent families which comprised of 11,308 patent records out of 79,292,185 records thus filed in different jurisdictions searched.

Analysis of Results done during the random check of patent data confirmed that their relevancy to our target technology field was still questionable for some patents where keywords used were also closely related to other technology domains which still didn't fall into our search interest.

3.2.4 Search Filtration & Validation

Diverse businesses of the organizations ((Firm 1) OR (Firm 2) OR (Firm 3) OR (Firm 4) OR (Firm 5)) when searched upon led to inclusion of irrelevant patent data even after using technology specific keywords. The need for further strong constraint from the list of different attributes attached to a patent

document was felt and with deep analysis & literature review (reference section 2.4.2 on Classification based patent search and 2.5 on Patent search methodologies) it was decided to look into the IPC classification which formed the part of patent attributes and classified patents based upon subject matter.

Since the IPC classification is made up of hierarchical components such as section, class, sub class, group and subgroups thus decision on level of filtration to relevant values was taken after reviewing the number of different section, class, sub class, group and subgroups thus generated from preliminary search. The results of uniqueness index and short listing of relevant IPCs is thus discussed below:

Data Uniqueness Index

6794 Derwent patent families which comprised to 11,308 patent records when analyzed for different unique IPC components resulted to the observations below:

Classification level	No. of unique
Section	8
Class	105
Subclass	391
Group	2026
Subgroup	7435

Table 1: Data Uniqueness Index

IPC classification short listing

Considering patent data uniqueness index and reviewing the description of same using WIPO database explaining the subject matter related to different classes. It was decided to filter out the irrelevant classes by looking at description of each using WIPO service for IPC classification definition at < http://www.wipo.int/ipcpub/#refresh=page > The version of IPC used to thus carry out the filtration process was 2011.01. Patent class was thus pasted in the symbol section to see its definition and manually evaluate its relevancy to AQCS technology.

Following points were considered during the class filtration process to come up with relevant classification in order to make up final search criteria:

- Classes found fully relevant with subclasses also falling under the domain of technology area of interest were retained for final search criteria formation.
- Classes found fully irrelevant with no subclasses even forming a base for having patents related to AQCS were filtered out and did not include in the list of final search criteria.
- On evaluation of subject matter from IPC definition for a particular class, where ever there was confusion of full relevancy of class further deep evaluation of looking into subclasses was conducted to come up with relevant subclasses in relation to technology area. It should be noted that questionable subclasses also dealt with going further down to analysis of IPC groups instead.

The list of filtration process is thus attached in Appendix section 6.3 Table named Relevant IPC classes

Results of the IPC's thus shortlisted

B01 , B02 , B03 , B04 , B05 , B06 , B07 , B08 , B09 , C01 , C02 , F15 , F17 , F23 , F26 , A62D , B24C , B65G , C10K , C23F , C23G , C25F , F01N , F16J , F16G , F16H , F16L , F25J , F28B , F28D , G05B , G05D , G06D , G06F , G06Q , G07G

3.2.5 Final Patent Search String

Shortlisted classes along with used keywords and companies were compiled (refer section 6.4, criteria for final search string) together to make up a final search query for collection of relevant patent data.

3.2.6 Final Patent Data Acquisition

Patent data was thus collected using the finalized criteria in Thomson innovation and statistics related to patent data acquisitioned are discussed below in section 3.3 and analyzed further to answer the research question.

3.3 Patent Data Statistics

Patent data fetched using the final selection criteria in different jurisdictions resulted to a pool of 1284 patent families comprising of 2590 patent documents when searched upon for 5 firms. The patent applications made for a decade (2000-2009) in 5 organizations collectively are thus mentioned below:

Patent Families Filed	
Application Year	**No. of Families**
2000	170
2001	151
2002	133
2003	113
2004	82
2005	98
2006	108
2007	133
2008	135
2009	161
Grand Total	**1284**

Table 2: Cumulative patent families filed

Patents Filed	
Application Year	**No. of Patents**
2000	340
2001	289
2002	231
2003	228
2004	177
2005	224
2006	199
2007	255
2008	324
2009	323
Grand Total	**2590**

Table 3: Cumulative patents filed

As observed, table above describes the applications made for patent families and patents in last decade. Further breakdown of the company specific data is mentioned below with information about families and patents filed by each company:

Year	Firm 1		Firm 2		Firm 3		Firm 4		Firm 5	
	Families	Patents	Families	Patents	Families	Patents	Families	Patents	Families	Patents
2000	30	55	2	5	61	122	12	33	65	125
2001	39	64	2	2	47	87	17	39	46	97
2002	20	42	1	10	42	67	15	27	55	85
2003	22	53	10	17	31	61	10	22	40	75
2004	26	59	1	1	28	68	5	9	22	40
2005	19	53	3	9	36	72	11	28	29	62
2006	17	48	0	1	47	70	9	23	36	57
2007	22	80	3	6	68	103	6	20	34	46
2008	30	108	2	5	65	126	11	29	27	56
2009	59	143	6	7	54	90	7	25	30	50

Table 4: Individual patent families and patents filed

The data about the patent filings with emphasis on different geographies\countries with corresponding filings in each year is mentioned in appendix section 6.5 .i.e. Table: Jurisdiction based patent data statistics.

3.4 Patent Data mining and analysis

The chapter deals with the analysis of collected patent data. Patent data mining & analysis has been done with reference of the literature under section 2.7 on Patent data as a measure of Innovation. Fetched data has been analyzed to observe interesting patenting trends and thus analysis has been used to answer research question. Trends in filing patent applications internationally & frequency of patenting has been identified below to understand the innovation activity in different firms and innovation diffusion in different jurisdictions has been analyzed.

3.4.1 Patenting trends and Innovative activity

Under the head cumulative and individual patent data for 5 innovative companies practicing in the technology area has been analyzed & discussed. Increase and decrease in patent filings with years have been understood to point out growing or diminishing innovation activity.

Cumulative Company Analysis

The figure below describes the trends in patenting individual patents and patent families by the 5 companies under consideration. Number of patent family applications are the measure of different inventions filed whereas the individual patents give idea about number of patent filings in different jurisdictions.

Patent families filed each year are the measure of innovation activity since each patent family can be regarded as unique invention or part of a bigger invention. As observed from figure below, patenting in Air Quality control systems has seen a mixed behavior. The group of 5 companies when analyzed collectively have seen a slump in innovation activity between years 2000 & 2004 with decreasing no. of patent families each year compared to the previous year, whereas the same has recovered post year 2004 with more patent families being filed each consecutive year. The innovation activity overall has thus seen a downside in first 4 years (2000-2004) & thus recovering to grow in next years of decade with the pace of recovery witnessing a slower growth in year 2007-2008 and thus getting to speed again in 2008-2009.

Trends about no. of patents filed each year collectively speak a story of optimism in terms of commercial expectations when patent filings increased whereas the decrease in individual patent filings in comparison to the patent families raise doubts about emphasis on international scope per filing.

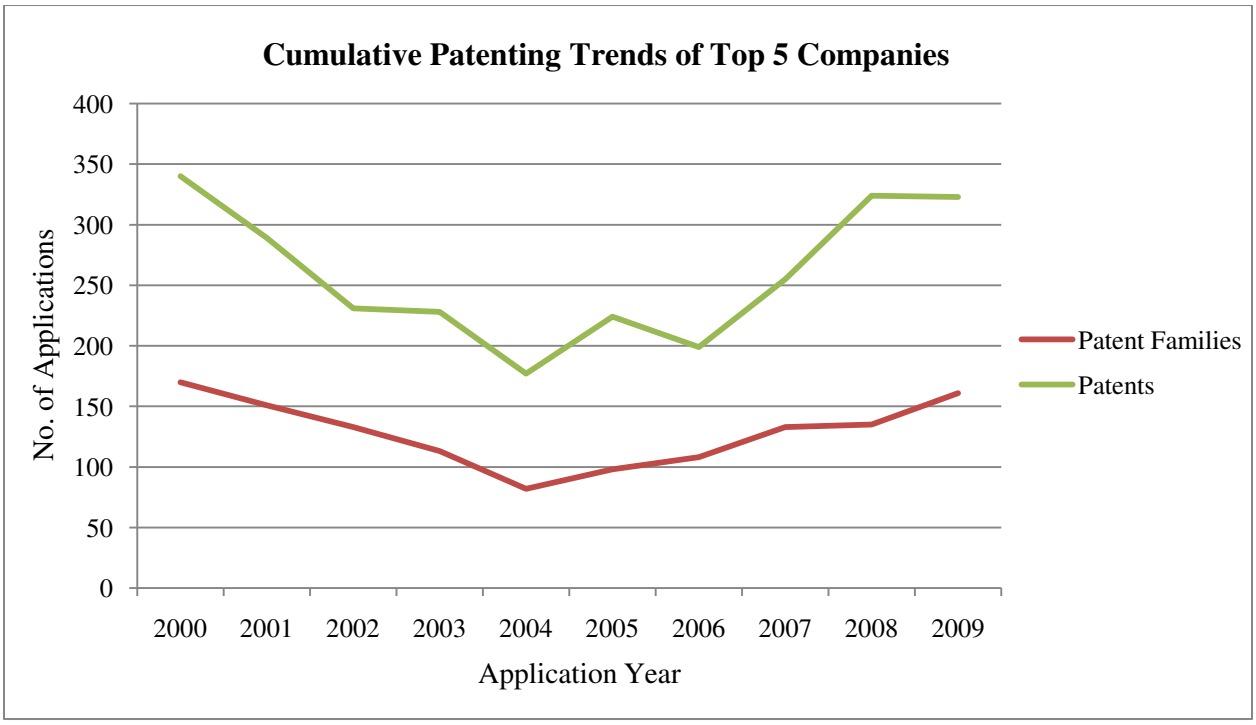

Fig 9: Cumulative trends in Patent filing (2000-2009)

Discussed below is the year by year analysis of patents & patent families filed to understand the emphasis on different jurisdictions which speaks about level of optimism and pessimism about returns on investment.

- Year 2001 and 2002 witnessed a decrease in the patent families filed with a further slump in total number of patent applications made which speaks about non confidence of companies in different market with steep decrease in total applications compared to that of patent families. It can be observed as pessimism in stake holders to go ahead with multiple filings due to dilemma about return on investments.

- Year 2003 observed the opposite with a decrease in patent family' applications made whereas international filings and multiple applications remained almost constant. The year thus speaks about optimism of industry in protecting their inventions internationally.
- Year 2004 witnessed a slump in inventions filed which affected the no. of patent applications as well with slight pessimism in multiple filings in different jurisdictions observed.
- Year 2005 saw a rise in the no. of inventions patented with an increased interest in multiple filings by the applicants which certainly speak about their belief in international markets.
- Though innovation activity continues to see a rise with increased patenting in year 2006 but faith in multiple filings and international market did slip to be on same lines as of year 2005.
- In addition to increased patent family filings year 2007 and 2008 has witnessed inflated enthusiasm as far as multiple filings are concerned. The no. of multiple filings has seen steep increase which definitely speaks about more focus on international markets and globalization.
- Year 2009 has seen increased patent family filings whereas the international application/multiple applications have decreased but it should be noted that more data for 2009 year might still come in next week\months to when this thesis study was conducted so analysis of year 2009 still cannot be relied upon.

Individual Company Analysis

The analysis below discusses patenting and innovation activity in the 5 firms of interest by analyzing their individual patenting trends. Patent data from last decade (2000-2009) has been analyzed. The patenting trend charts for individual firms are in the appendix section 6.6. Individual patent data analysis charts

Firm 1

Patenting Families & Innovation Activity: The patenting history of firm has seen a sudden rise after years of calm and uniform patenting. Observing ups and downs in patenting activities for first 6 years with a good start in the 2001 and then observing a sudden decrease in 2002 thus lead to rise again in 2002 -2004. The innovation activity at Firm 1 actually took a lead from year 2006 after which it has been inclining with increased patent filing each year post 2006 with more focus on multiple filings in different jurisdictions in year 2008-2009.

Firm 2

Patenting Families & Innovation Activity: Firm 2 has a small patent portfolio with less patent filings each year on an average. Patenting and innovation activity in the firm has been irregular with increased and decreased patenting year by year. Start of decade 2000-2009 witnessed a slump in year 2001 leading to rise between 2001-2003. Patenting activity has been irregular with ups and downs till year 2006 thus on a rise thereafter with a small decrease in year 2008 & hence increasing again.

Firm 3

Patenting Families & Innovation Activity: Innovation activity at firm 3 has rather been uniform with decrease in average patenting for first few years till 2003 thus leading to a rise in innovation by patenting more families and individual patents. The patenting increased year by year till 2008 witnessing a small decrease in year 2009.

Firm 4

Patenting Families & Innovation Activity: Firm 4 witnessed first 4 years of decreased innovation in the firm with lesser patent filings in terms of total no. of ideas as well as individual applications around. Post 2004 firm 4 had an increase in patenting with more ideas in the firm for patenting but still struggling to maintain a rise, witnessing increase and decrease between years post 2004.

Firm 5

Patenting Families & Innovation Activity: Firm 5 has been observed to decrease its innovation activity with a steep fall in year 2000-2004 and after that unable to pick up considerably yet small ups and downs. The innovation activity and patenting post 2004 has been rather a bit uniform for nearly same no. of patent family and patents filed each year.

3.4.2 Diffusion of Innovation

With reference to the literature review under section 2.7 diffusion of innovation in a country can be measured by using the patent data from different countries to track patterns of diffusion. Thus similarly the patent data collected for AQCS technology domain has been analyzed to understand innovation diffusion in different jurisdictions. Patent filings each year in different countries speak about development of markets and commercial scope that different organizations foresee. Top 10 jurisdictions from the point of view of no. of patents filed in last decade have been analyzed. Data in appendix section 6.5 has been analyzed by plotting the trends for top 10 jurisdictions in the figure below.

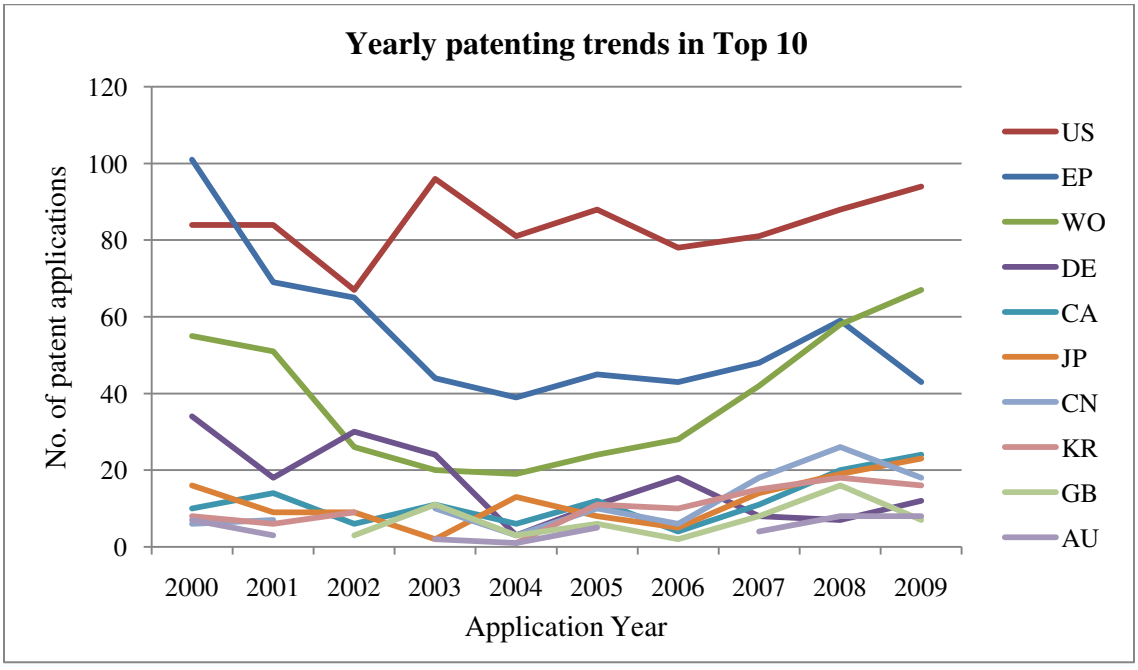

Fig 10: Cumulative patenting trends in Top 10 Jurisdictions for 5 innovative companies

Patenting in US tops the list for innovation in AQCS technologies. US have seen most filings in last decade (2000-2009) with ups and downs in each consecutive year till 2006. There after 2006, the

patenting has been on a rise with continuous growth and increased focus on innovation. The diffusion of innovation has been the highest in US witnessing most no. of filings. Although the start of patenting after year 2000 has been a bit shaky for US with declining patents per year till 2002, thereafter rise and fall, the innovation activity got onto the track from 2006 with a rise each year.

EU has seen a strong decline in patent application filings each year post 2000. The patenting has been declining year by year after 2000 till 2004, after which the efforts to get patenting on track have been made thus succeeding to support till year 2008 witnessing a fall again in 2009. Thus it can be concluded that diffusion of technology in EU has been quite slow with an overall decline during last decade where second half has still seen a recovery.

Countries like UK, Canada, China, Japan and Korea have seen mixed patenting and technology diffusion if analyzed year by year but the overall diffusion has been on the rise. Post 2006 all the countries have seen an increased patenting with companies having an optimistic approach towards all. Innovation activity has resulted in increase IP protection among these jurisdictions companies expecting returns may be due to amended policies or enforcement of environmental laws.

The use of PCT applications for patent filings have increased post 2004 which speaks about companies being more international focus for immediate or future filings. Global technology protection approach and developing markets can be regarded as a motivational factor for such a move. The PCT applications have decreased till 2004 thus rising again continuously thereafter with more and more filings each year. Analysis of trends reveal the situation of Germany in terms of patent filing and diffusion technology not being good in whole decade. The no. of patent filings has seen an overall decrease across whole decade. Patents filed each year decreased from year 2000 to 2004 and thus struggling thereafter to catch up with previous years. The patenting has been on its high in year 2004 decreasing thereafter to be among its low in year 2009. Germany can be concluded to have seen a deep fall in diffusion of new innovations and technology developed globally.

4 Conclusion and Discussions

This chapter concludes the analysis of the innovation activity in technology domain and describes how diffusion of innovation has taken place. It further points out the direction for further research.

4.1 Conclusion

With the main purpose of thesis to evaluate the innovation activity in technology domain and understanding diffusion of innovation in several countries, literature proved to be a crucial source in facilitating techniques to carry out patent search and analyze trends in answering research problem. Interesting results were observed from the patent data mining and statistical analysis. Discussed below is the conclusion of research work.

Innovation Activity

The analysis of cumulative and individual patent data of technology field reveals mixed trends of innovation activity. The cumulative trends analysis answers the research problem on a broad level where individual behaviors of companies still varies due to organizational priorities, strategic issues or many other factors. Overall the innovation activity has been high at the start of decade with a strong emphasis on multiple patent filings in varied jurisdictions. Initial years have seen more patent families being filed compared to the later 2-3 years. The inventions filed in initial years decreased consecutively. Years 2004, 2005, 2006 have been at the all time low after an overall slump in innovation activity. Increased patent protection and application filing was observed post year 2006. Companies got really active with increased innovation and patenting later to 2006. Multiple patenting has been on the lists for most of the individual companies and cumulative results reveal the same. Thus, it can be concluded that there is an increased innovation activity in AQCS technology domain with improved patenting and additional no. of inventions being protected by companies for further exploitation.

Diffusion of Innovation

Patent data mining carried out for different jurisdictions revealed interesting results after understanding the patters of innovation diffusion. Top 10 jurisdictions from the point of view of no. of patents filed in last decade were identified and they happen to be US, EU, Germany, Canada, Japan, China, Australia, UK, Korea and WIPO application. United States of America has top patent filings in the world with continuous technological growth and a focal point for innovating firms. With a shaky start in first half of decade US has seen increased innovation and technology diffusion in later years. Increased filing of PCT application is good news on a broad level with companies more interested in multiple filings and exploitation of their technology in varied geographies. It was observed that EU has seen a decreased technology patenting leading to slower technology diffusion rates, whereas, the jurisdictions like UK, Canada, China, Japan and Korea have had a optimistic viewpoint from investors and organizations patenting more with higher expectation on returns. Thus it can be concluded that organizations are patenting in diverse jurisdictions expecting high returns with overall increased technology diffusion due to increased patenting of inventions and filing of multiple applications.

4.2 Suggestions for future research

The scope of this research project has been limited to evaluation of innovation activity and diffusion of innovation. However the identification of technology areas being research focus for most of the companies has still not been identified and is a natural continuation of this research study.

Suggested research area is the evaluation of patenting activity and collected patent data with an aim to identify the types of innovation and technological competencies of organizations. It can be accomplished by analyzing the Patent data classified and divided into different International Patent Classifications with detailed description. Data divided into hierarchal structure with a range of sections, classes, subclasses and groups can be analyzed to observe different types of technological innovations based on their technological field identified by referring to subject matter associated with IPC codes. The particular research suggestion can provide information about focus of R&D by understanding technological competencies of organizations with huge patent portfolios. The result of such a research work would be interesting for academia and industry. It would help management of big organizations in their strategic decision making & research agenda preparation while at the same time academic world would be benefited by knowing the research direction of organizations for its research prioritization and competence facilitation.

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6 Appendix

6.1 Table: 5 Table of collected Keywords

Keywords	Keywords
Air Pollution control	Insulated Gate Bipolar Transistor (IGBT)
Pollution Abatement	lime
Environment control	limestone
Environmental control	mist eliminator
Sulfur	mixer
Nitrogen	multi peak electrode
Carbon	nid
Sulfur oxide	NOx
Nitrogen oxide	N_2O
Hydrochloric acid	NO_2
Nitrogen oxide	Performance Enhanced Plates (PEP)
Hydrochloric fluoride	power electronics
Dust	power supply
Particulate matter	rectifier
Ammonia	resonant converter
Carbon dioxide	rigid discharge electrode (RDE)
Carbon Monoxide	Selective Catalytic Reaction (SCR)
Mercury	scrubber
Trace metals	seawater flue gas desulfurization (SWFGD)
Chlorides	semi pulse
Permanent Organic Compounds	spark over control
POC	spiral discharge
Volatile Organic Compounds	spray dryer
VOC	spray tower
Absorber	spray nozzle
Ammonia injection	SO_2
Atomizer	SO_3
Baghouse	SOx
Bottom Rapping	Sulfur injection
Clean Air	Switch Integrated Rectifier (SIR)
Collecting electrode	top rapping
Electrode	transformer
Converter	transformer / rectifier (T/R)
Demister	tray

Desulphurization	tumbling hammer
Discharge electrode	Turbulent-bed reactor
Dry electrostatic precipitator	Volatile Organic Compound (VOC)
Dry flue gas desulfurization	Wet Electrostatic Precipitators (WESP)
Dust dispersion	wet FGD
Dust layer	Exhaust gas
Electrostatic Precipitator	Selective catalytic reduction
ESP	Scrubbing
Elpac	Gas flare
Emission reduction	Electrostatic precipitator
Emissions	Biofilter
Emissions control	Wet Scrubber
Emitting electrode	Baffle spray scrubbers
Fabric Filter (ff)	catalytic converter
Flue gas conditioning	Cyclonic separation
Flue gas	Cyclonic spray scrubbers
Flue Gas Desulfurization (FGD)	ejector or venturi scrubber
Flowpac	Flue-gas desulphurization
Filter	Regenerative thermal oxidizer
Gypsum production	Wet sulfuric acid process
High frequency transformer	Fabric filters
High Voltage (HV)	Denitrification
High voltage converter	Dust collector
Hybrid filters	

6.2 Preliminary Search Criterion

Keywords to be searched in <*Abstract/Title/Claims*>**:**

(Air Pollution control) OR (Ammonia injection) OR (Atomizer) OR (Baffle spray scrubbers) OR (Baghouse) OR (Biofilter) OR (Bottom Rapping) OR (Carbon dioxide) OR (Carbon Monoxide) OR (catalytic converter) OR (Chlorides) OR (Collecting electrode) OR (Cyclonic separation) OR (Cyclonic spray scrubbers) OR (Demister) OR (Denitrification) OR (Desulphurization) OR (Dry electrostatic precipitator) OR (Dry flue gas desulfurization) OR (Dust collector) OR (Dust dispersion) OR (venturi scrubber) OR (Electrostatic precipitator) OR (Elpac) OR (Emission reduction) OR (Emissions control) OR (ESP) OR (Exhaust gas) OR (Fabric filters) OR (Flowpac) OR (Flue gas) OR (Flue gas conditioning) OR (Flue Gas Desulfurization) OR (Gas flare) OR (Gypsum production) OR (Hybrid filters) OR (Hydrochloric acid) OR (Hydrochloric fluoride) OR (Insulated Gate Bipolar Transistor) OR (mist eliminator) OR (multi peak electrode) OR (N_2O) OR (nid) OR (Nitrogen oxide) OR (NO_2) OR (NOx) OR (Particulate matter) OR (Performance Enhanced Plates) OR (Permanent Organic

Compounds) OR (Pollution Abatement) OR (RDE) OR (Regenerative thermal oxidizer) OR (resonant converter) OR (rigid discharge electrode) OR (scrubber) OR (Scrubbing) OR (seawater flue gas desulfurization) OR (Selective Catalytic Reaction) OR (Selective catalytic reduction) OR (SO_2) OR (SO_3) OR (SOx) OR (spiral discharge) OR (spray dryer) OR (spray nozzle) OR (spray tower) OR (Sulfur injection) OR (Sulfur oxide) OR (seawater flue gas desulfurization) OR (Switch Integrated Rectifier) OR (top rapping) OR (Trace metals) OR (tumbling hammer) OR (Turbulent bed reactor) OR (Volatile Organic Compound) OR (Wet Electrostatic Precipitators) OR (Wet FGD) OR (Wet Scrubber) OR (Wet sulfuric acid process)

Companies to be searched in < Assignee/Applicant>

(Firm 1) OR (Firm 2) OR (Firm 3) OR (Firm 4) OR (Firm 5)

Formal Search Query:

CTB=((Air ADJ Pollution ADJ control) OR (Ammonia ADJ injection) OR (Atomizer) OR (Baffle ADJ spray ADJ scrubbers) OR (Baghouse) OR (Biofilter) OR (Bottom ADJ Rapping) OR (Carbon ADJ dioxide) OR (Carbon ADJ Monoxide) OR (catalytic ADJ converter) OR (Chlorides) OR (Collecting ADJ electrode) OR (Cyclonic ADJ separation) OR (Cyclonic ADJ spray ADJ scrubbers) OR (Demister) OR (Denitrification) OR (Desulphurization) OR (Dry ADJ electrostatic ADJ precipitator) OR (Dry ADJ flue ADJ gas ADJ desulfurization) OR (Dust ADJ collector) OR (Dust ADJ dispersion) OR (venturi ADJ scrubber) OR (Electrostatic ADJ precipitator) OR (Elpac) OR (Emission ADJ reduction) OR (Emissions ADJ control) OR (ESP) OR (Exhaust ADJ gas) OR (Fabric ADJ filters) OR (Flowpac) OR (Flue ADJ gas) OR (Flue ADJ gas ADJ conditioning) OR (Flue ADJ Gas ADJ Desulfurization) OR (Gas ADJ flare) OR (Gypsum ADJ production) OR (Hybrid ADJ filters) OR (Hydrochloric ADJ acid) OR (Hydrochloric ADJ fluoride) OR (Insulated ADJ Gate ADJ Bipolar ADJ Transistor) OR (mist ADJ eliminator) OR (multi ADJ peak ADJ electrode) OR (N2O) OR (nid) OR (Nitrogen ADJ oxide) OR (NO2) OR (NOx) OR (Particulate ADJ matter) OR (Performance ADJ Enhanced ADJ Plates) OR (Permanent ADJ Organic ADJ Compounds) OR (Pollution ADJ Abatement) OR (RDE) OR (Regenerative ADJ thermal ADJ oxidizer) OR (resonant ADJ converter) OR (rigid ADJ discharge ADJ electrode) OR (scrubber) OR (Scrubbing) OR (seawater ADJ flue ADJ gas ADJ desulfurization) OR (Selective ADJ Catalytic ADJ Reaction) OR (Selective ADJ catalytic ADJ reduction) OR (SO2) OR (SO3) OR (SOx) OR (spiral ADJ discharge) OR (spray ADJ dryer) OR (spray ADJ nozzle) OR (spray ADJ tower) OR (Sulfur ADJ injection) OR (Sulfur ADJ oxide) OR (seawater ADJ flue ADJ gas ADJ desulfurization) OR (Switch ADJ Integrated ADJ Rectifier) OR (top ADJ rapping) OR (Trace ADJ metals) OR (tumbling ADJ hammer) OR (Turbulent ADJ bed ADJ reactor) OR (Volatile ADJ Organic ADJ Compound) OR (Wet ADJ Electrostatic ADJ Precipitators) OR (Wet ADJ FGD) OR (Wet ADJ Scrubber) OR (Wet ADJ sulfuric ADJ acid ADJ process)) AND PA=((Firm 1) OR (Firm 2) OR (Firm 3) OR (Firm 4) OR (Firm 5));

6.3 Table: 6 Relevant IPC classes

IPC Class	Sub classification
A01	
A21	
A23	
A24	
A41	
A47	
A61	
A62	A62D
A63	
B01	
B02	
B03	
B04	
B05	
B06	
B07	
B08	
B09	
B21	
B22	
B23	
B24	B24C
B25	
B26	
B27	
B28	
B29	
B30	
B32	
B41	
B43	
B44	
B60	
B61	
B62	
B63	
B64	
B65	B65G

IPC Class	Sub classification
C11	
C12	
C21	
C22	
C23	C23F, C23G
C25	C25F
C30	
C40	
D01	
D02	
D04	
D06	
D07	
D21	
E01	
E02	
E04	
E05	
E06	
E21	
F01	F01N
F02	
F03	
F04	
F15	
F16	F16J,F16G,F16H,F16L
F17	
F21	
F22	
F23	
F24	
F25	F25J
F26	
F27	
F28	F28B, F28D
G01	
G02	
G03	

B66	
B67	
B81	
B82	
C01	
C02	
C03	
C04	
C05	
C07	
C08	
C09	
C10	C10K

G04	
G05	G05B, G05D
G06	G06D, G06F, G06Q
G07	G07G
G08	
G09	
G10	
G11	
G21	
H01	
H02	
H03	
H04	
H05	

Legends:

Relevant Class	
Irrelevant Class	
Not fully relevant	

6.4 Criteria for Final Search String

Keyword Search query:

(Air Pollution control) OR (Ammonia injection) OR (Atomizer) OR (Baffle spray scrubbers) OR (Baghouse) OR (Biofilter) OR (Bottom Rapping) OR (Carbon dioxide) OR (Carbon Monoxide) OR (catalytic converter) OR (Chlorides) OR (Collecting electrode) OR (Cyclonic separation) OR (Cyclonic spray scrubbers) OR (Demister) OR (Denitrification) OR (Desulphurization) OR (Dry electrostatic precipitator) OR (Dry flue gas desulfurization) OR (Dust collector) OR (Dust dispersion) OR (venturi scrubber) OR (Electrostatic precipitator) OR (Elpac) OR (Emission reduction) OR (Emissions control) OR (ESP) OR (Exhaust gas) OR (Fabric filters) OR (Flowpac) OR (Flue gas) OR (Flue gas conditioning) OR (Flue Gas Desulfurization) OR (Gas flare) OR (Gypsum production) OR (Hybrid filters) OR (Hydrochloric acid) OR (Hydrochloric fluoride) OR (Insulated Gate Bipolar Transistor) OR (mist eliminator) OR (multi peak electrode) OR (N_2O) OR (nid) OR (Nitrogen oxide) OR (NO_2) OR (NOx) OR (Particulate matter) OR (Performance Enhanced Plates) OR (Permanent Organic Compounds) OR (Pollution Abatement) OR (RDE) OR (Regenerative thermal oxidizer) OR (resonant converter) OR (rigid discharge electrode) OR (scrubber) OR (Scrubbing) OR (seawater flue gas desulfurization) OR (Selective Catalytic Reaction) OR (Selective catalytic reduction) OR (SO_2) OR (SO_3) OR (SOx) OR (spiral discharge) OR (spray dryer) OR (spray nozzle) OR (spray tower) OR (Sulfur injection) OR (Sulfur oxide) OR (seawater flue gas desulfurization) OR (Switch Integrated Rectifier) OR (top rapping) OR (Trace metals) OR (tumbling hammer) OR (Turbulent bed reactor)

OR (Volatile Organic Compound) OR (Wet Electrostatic Precipitators) OR (Wet FGD) OR (Wet Scrubber) OR (Wet sulfuric acid process)

Companies:

(Firm 1) OR (Firm 2) OR (Firm 3) OR (Firm 4) OR (Firm 5)

IPC

(B01) OR (B02) OR (B03) OR (B04) OR (B05) OR (B06) OR (B07) OR (B08) OR (B09) OR (C01) OR (C02) OR (F15) OR (F17) OR (F23) OR (F26) OR (A62D) OR (B24C) OR (B65G) OR (C10K) OR (C23F) OR (C23G) OR (C25F) OR (F01N) OR (F16J) OR (F16G) OR (F16H) OR (F16L) OR (F25J) OR (F28B) OR (F28D) OR (G05B) OR (G05D) OR (G06D) OR (G06F) OR (G06Q) OR (G07G)

Formal Search Query (Final):

CTB=((Air Pollution control) OR (Ammonia injection) OR (Atomizer) OR (Baffle spray scrubbers) OR (Baghouse) OR (Biofilter) OR (Bottom Rapping) OR (Carbon dioxide) OR (Carbon Monoxide) OR (catalytic converter) OR (Chlorides) OR (Collecting electrode) OR (Cyclonic separation) OR (Cyclonic spray scrubbers) OR (Demister) OR (Denitrification) OR (Desulphurization) OR (Dry electrostatic precipitator) OR (Dry flue gas desulfurization) OR (Dust collector) OR (Dust dispersion) OR (venturi scrubber) OR (Electrostatic precipitator) OR (Elpac) OR (Emission reduction) OR (Emissions control) OR (ESP) OR (Exhaust gas) OR (Fabric filters) OR (Flowpac) OR (Flue gas) OR (Flue gas conditioning) OR (Flue Gas Desulfurization) OR (Gas flare) OR (Gypsum production) OR (Hybrid filters) OR (Hydrochloric acid) OR (Hydrochloric fluoride) OR (Insulated Gate Bipolar Transistor) OR (mist eliminator) OR (multi peak electrode) OR (N2O) OR (nid) OR (Nitrogen oxide) OR (NO2) OR (NOx) OR (Particulate matter) OR (Performance Enhanced Plates) OR (Permanent Organic Compounds) OR (Pollution Abatement) OR (RDE) OR (Regenerative thermal oxidizer) OR (resonant converter) OR (rigid discharge electrode) OR (scrubber) OR (Scrubbing) OR (seawater flue gas desulfurization) OR (Selective Catalytic Reaction) OR (Selective catalytic reduction) OR (SO2) OR (SO3) OR (SOx) OR (spiral discharge) OR (spray dryer) OR (spray nozzle) OR (spray tower) OR (Sulfur injection) OR (Sulfur oxide) OR (seawater flue gas desulfurization) OR (Switch Integrated Rectifier) OR (top rapping) OR (Trace metals) OR (tumbling hammer) OR (Turbulent bed reactor) OR (Volatile Organic Compound) OR (Wet Electrostatic Precipitators) OR (Wet FGD) OR (Wet Scrubber) OR (Wet sulfuric acid process)) AND PA=((Firm 1) OR (Firm 2) OR (Firm 3) OR (Firm 4) OR (Firm 5)) AND IC=((B01) OR (B02) OR (B03) OR (B04) OR (B05) OR (B06) OR (B07) OR (B08) OR (B09) OR (C01) OR (C02) OR (F15) OR (F17) OR (F23) OR (F26) OR (A62D) OR (B24C) OR (B65G) OR (C10K) OR (C23F) OR (C23G) OR (C25F) OR (F01N) OR (F16J) OR (F16G) OR (F16H) OR (F16L) OR (F25J) OR (F28B) OR (F28D) OR (G05B) OR (G05D) OR (G06D) OR (G06F) OR (G06Q) OR (G07G));

6.5 Table 7: Jurisdiction based patent data statistics

Country\Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total
AR										2	2
AT				1			2			2	5
AU	7	3		2	1	5		4	8	8	38
BG		2	3								5
BR									1		1
CA	10	14	6	11	6	12	4	11	20	24	118
CN	6	7		10	3	10	6	18	26	18	104
CZ		1									1
DE	34	18	30	24	3	11	18	8	7	12	165
DK					1		1				2
EP	101	69	65	44	39	45	43	48	59	43	556
ES		2									2
FR	4	4	3	4	4				2		21
GB	8		3	11	3	6	2	8	16	7	64
GR	1	2									3
IL										2	2
IT			2								2
JP	16	9	9	2	13	8	5	14	19	23	118
KR	8	6	9		1	11	10	15	18	16	94
MX	1	4	2				2	5	1	2	17
NZ			1			2				1	4
PL		4									4
PT			1	1							2
TW	5	8	3	2	2	2					22
UA		1	1		1						3
US	84	84	67	96	81	88	78	81	88	94	841
WO	55	51	26	20	19	24	28	42	58	67	390
ZA								1	1	2	4
Grand Total	**340**	**289**	**231**	**228**	**177**	**224**	**199**	**255**	**324**	**323**	**2590**

6.6 Individual Patent Data Analysis Charts

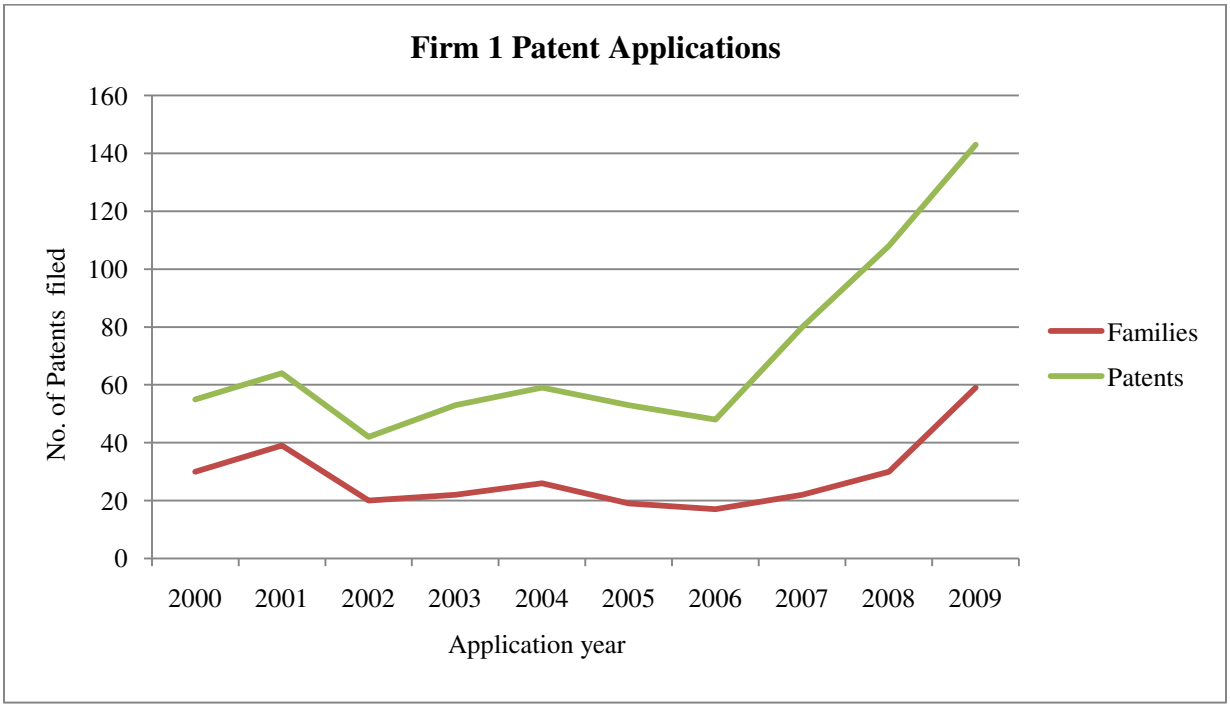

Fig 11: Patenting trends Firm 1 (2000-2009)

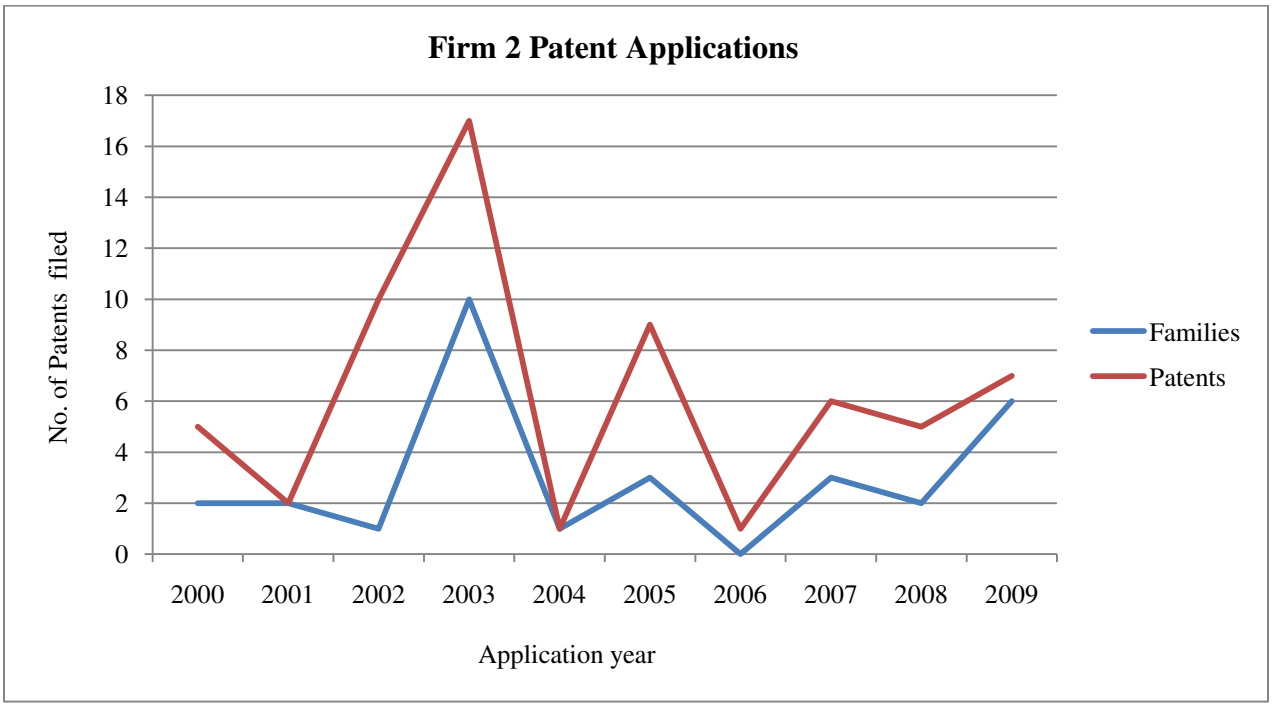

Fig 12: Patenting trends Firm 2 (2000-2009)

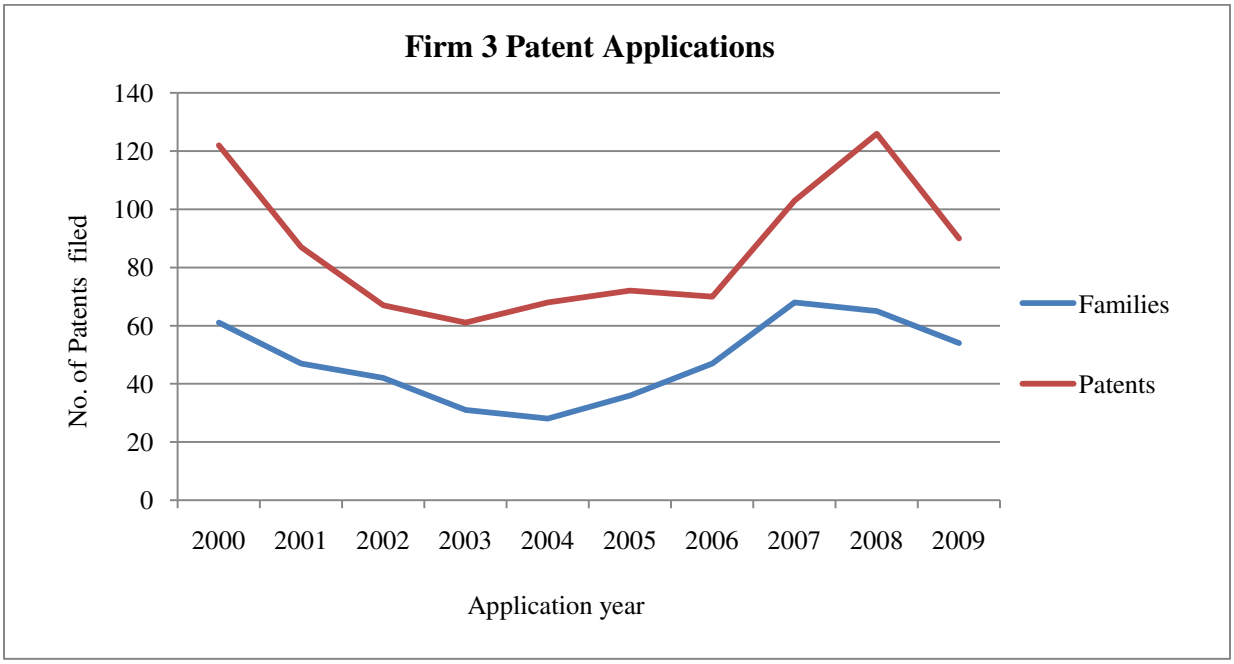

Fig 13: Patenting trends Firm 3 (2000-2009)

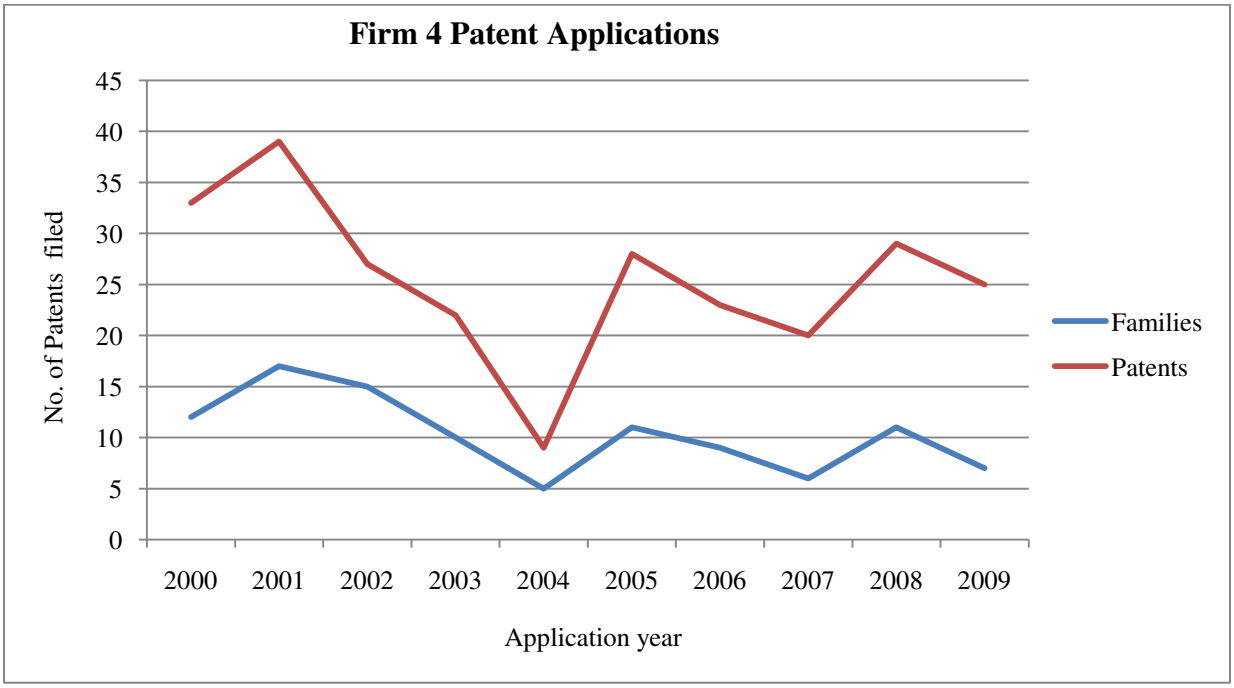

Fig 14: Patenting trends Firm 4 (2000-2009)

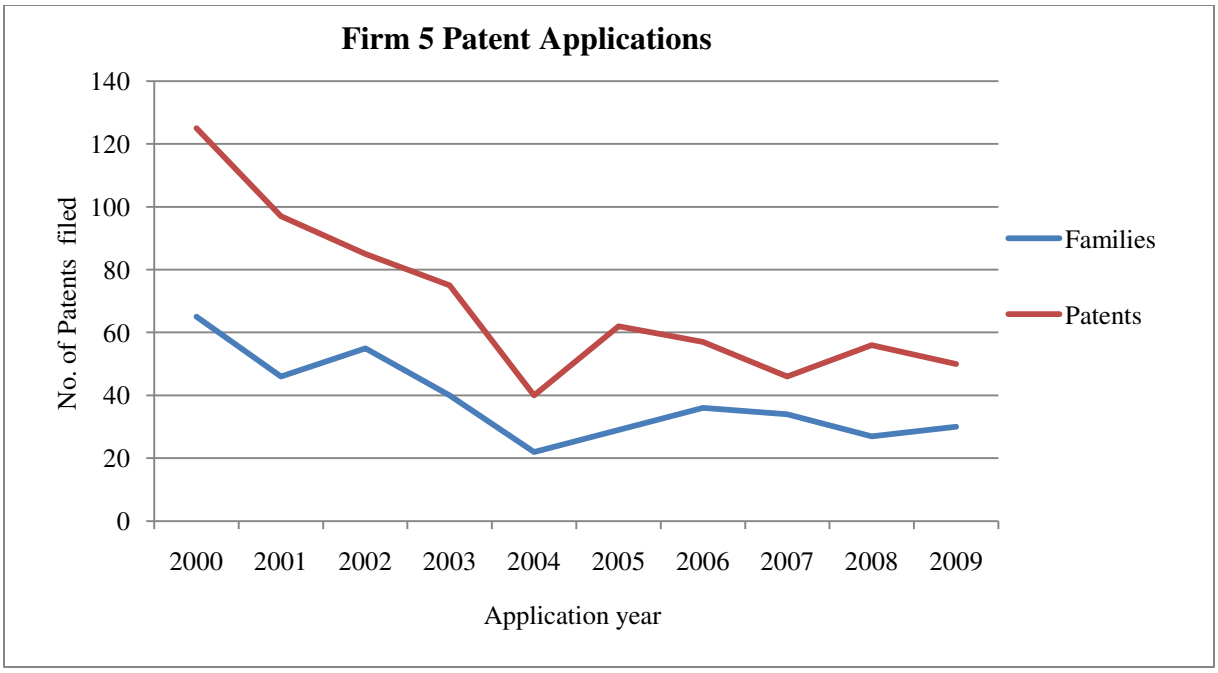

Fig 15: Patenting trends Firm 5 (2000-2009)