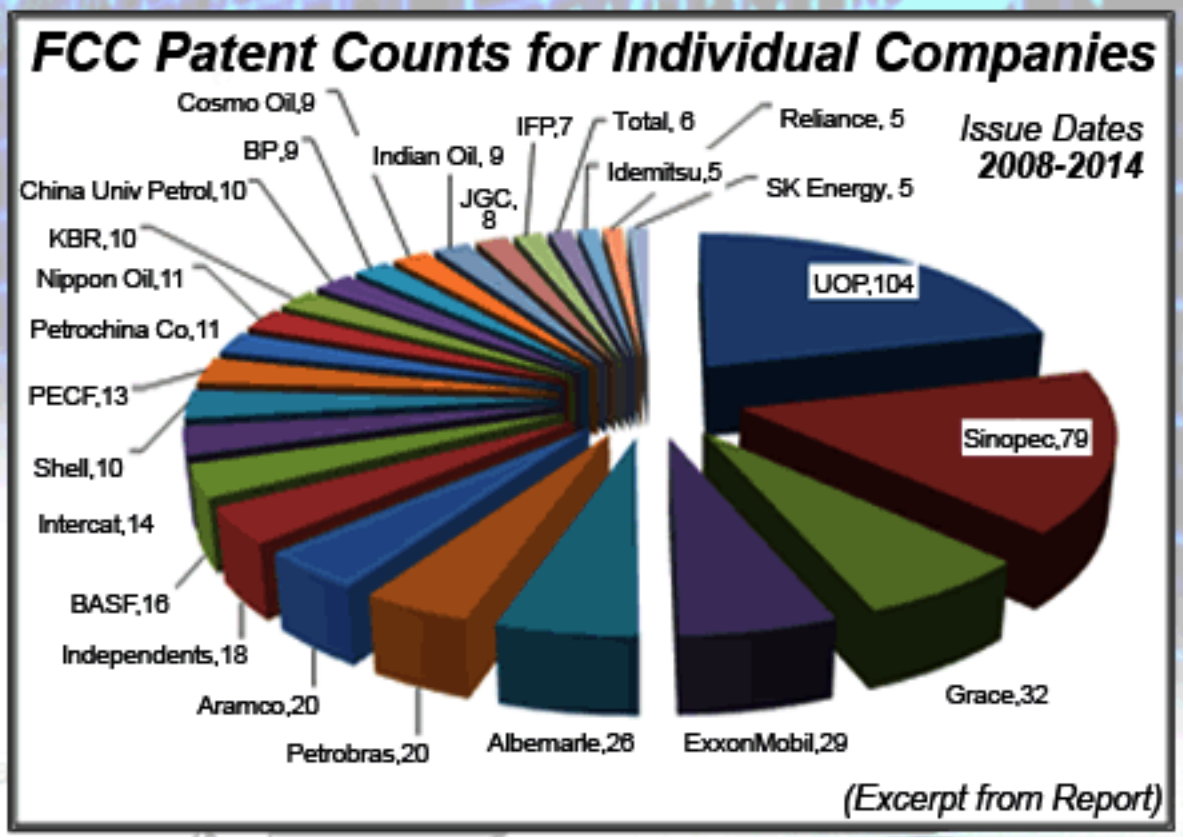
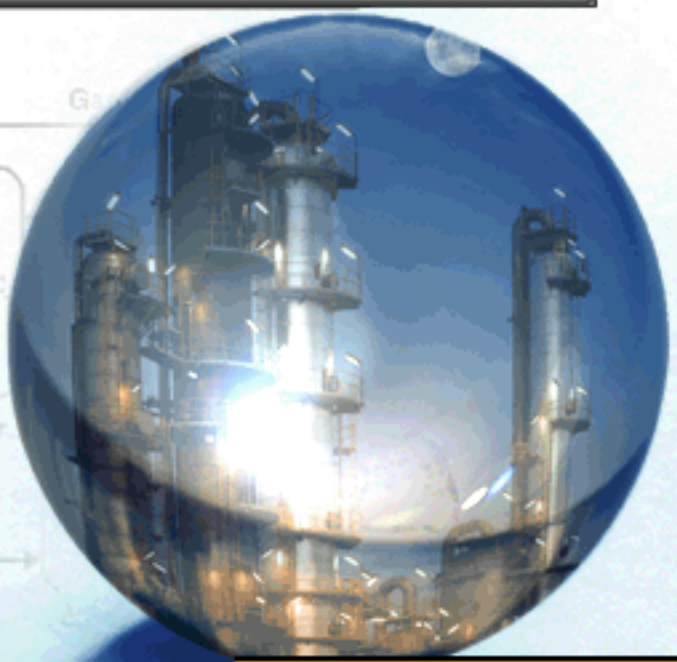
SPECIAL REPORT

STRATEGIC ROLES OF FLUID CATALYTIC CRACKING IN REFINERY OPERATIONS



- **PATENT** *ANALYSIS*
- **GAP** *ANALYSIS*
- **SWOT** *ANALYSIS*



Multi-CLIENT STRATEGIC REPORT

PREVIEW REPORT ▸

Predictions of Emerging Technology Trends

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INTRODUCTION

American writer Mark Twain's famous misquotation, "Reports of my death have been greatly exaggerated" may well be applied to the current status of refinery fluid catalytic cracking technology and certain gasoline-centric FCCUs operated in parts of the world. Declining gasoline demand caused by bio-ethanol mandates and improving vehicle fuel efficiency, poor fuel demand because of of weak economies in some regions of the world, rising shale/tight oil processing in the US resulting in growing production of gasoline and naphtha, and diminishing outlets for naphtha as more steam crackers source cheaper ethane and propane feedstock are considered detrimental to the sustainability of the catalytic crackers.

On the other hand, robust gasoline demand since the beginning of 2015 to the time of publication (July 2015) has defied expectations. In spite of on-going talks of "dieselization" in the transportation fuel market, gasoline consumption in the world's two biggest oil consumers (the US and China) is going strong, supporting refining margins across the globe. According to the API, US gasoline demand was at its highest in nearly eight years in June 2015, rising 3.5% on the year to more than 9.3MM b/d—the most gasoline demand the country has seen since Aug. 2007. In China, fuel consumption has been steadily shifting from diesel toward gasoline over the past few years, and total June gasoline consumption was higher than in May—when gasoline demand grew by nearly 14% on the year. European refiners—longtime producers of a surplus of gasoline—are the first in line to benefit. Thanks to higher gasoline exports and lower crude costs, Total S.A. has reported that its European refining margins indicator (ERMI) rose to $54.10/mt ($7.38/bbl) during 2Q 2015, a record high since ERMI was first tracked in 2003.

Will the good times roll for forever? It all depends, as the nature of the refining business is cyclical and the FCCU—the centerpiece of many refineries—also has its ups and downs. Therefore, it is important for refiners to prepare for the next cycle by taking advantage of the flexibility of the FCCU. With constant technology innovations, this refinery workhorse has been continuing to perform "miracles" for refiners in light of increasingly stringent fuel standards, changing market conditions, and competing technologies. Over the years, its role has expanded from a gasoline machine to an olefins maker, a sulfur remover, a residue upgrader, and a ULSD feedstock contributor by maximizing LCO output. Furthermore, it is lending itself to two additional roles—biofeeds user and refinery CO2 emissions reducer—to alleviate growing concerns over energy security and global warming.

So, the question is "What is the future of FCC operations?" One way to predict is by looking at where technology companies have been investing in research and development, especially patent applications. This report analyzes the patenting trends of the FCC technology around the world, reviews the significance of the data, and explains how the analytics can be used to predict the future business opportunities and challenges for refiners and technology developers alike.

REPORT METHODOLOGY

Primary sources of information include extensive literature searches and evaluations, in-depth patent analyses and reviews, and insightful technology and business strategy assessments by a team of analysts and consultants. The information is supplemented by Hydrocarbon Publishing Co.'s quarterly technology newsletter called *Worldwide Refinery Processing Review* and previously published FCC reports. The latter information includes direct communications with technology providers and catalyst/additive producers.

REPORT SCOPE AND FOCUS

Key discussions begin in **Section 3** by looking at the business and regulatory environs and trends. **Section 4** details FCC patent analytics in terms of global patent activities and applications (2008-2014) covered by patents of specific companies. **Section 5** identifies and examines the five patent technology themes (2008-2014). **Section 6** concentrates on the GAP analysis to reveal market opportunities that demand technology solutions not currently available. **Section 7** looks at internal and external factors impacting the FCC technology in the future through SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis. **Section 8** predicts FCC technology trends and identifies R&D opportunities based on patents from 2000 to 2014. **Section 9** concludes with comprehensive analyses and recommendations for global refiners operating FCCUs and FCC technology providers.

Why Analytics—Mining of BIG DATA ?

Analytics, which is a term referring to the search for and use of patterns in vast quantity of data, has been applied in a variety of industries to help businesses gain a competitive edge. Marketing agencies, sales companies, and even sports teams have turned to analytics.

In the case of analyzing patent data, the authors of a management handbook entitled Strategic and Competitive Analysis: Methods and Techniques for Analyzing Business Competition said, "Patent analysis is a unique management tool for addressing the strategic management of the firm's technology and product or service development process. Translating patent data into competitive intelligence allows the firm to gauge its current competitiveness, to forecast technology trends, and to plan for potential competition based on new technologies."[i]

Analytics has become a powerful management tool for refiners and vendors to establish a competitive edge. A generalized combination of external and internal patent analysis can help companies assess their technology portfolios and directions in the context of the marketplace and enable them to strategically position their technologies, particularly at the time of changing crude slates and shift in product demand. Also, it is possible to identify areas that are not profitable and focus R&D investment elsewhere.

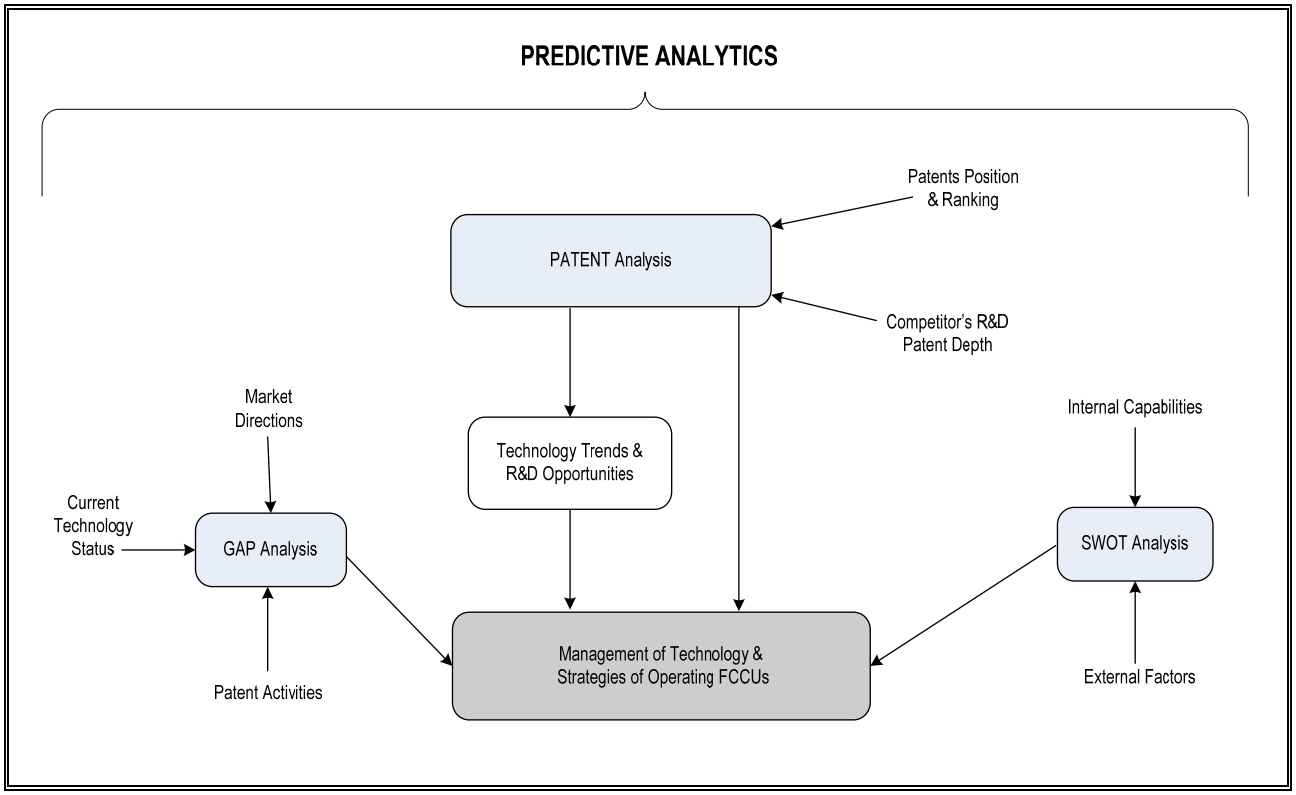
People have looked at spending for R&D as being similar to playing a slot machine in a casino. If you continued to put money into the machine, sooner or later there would be a payout; and one could even try to

increase the odds by putting money into multiple machines. It seems wasteful and foolish. Also, there is an opportunity cost of making the wrong R&D investment in terms of wasting financial resources and valuable time. **Can a technology company afford to go down to the wrong research path in a highly competitive market?** We believe the most cost-effective and efficient approach to find the next technology winner(s)—which deserve research funding—is to conduct predictive analytics.

Predictive Analytics

The 550+page study deploys the latest novel management tool—**Predictive Analytics** comprising **Patent Analysis** (Sections 4 and 5), **Gap Analysis** (Section 6), and **SWOT** (Strengths, Weaknesses, Opportunities and Threats) **Analysis** (Section 7) as well portrayed in the following diagram. Furthermore, a separate section (Section 8) is devoted to predicting technology trends and identifying R&D opportunities. The goal is to provide our clients a proactive technology-driven business strategy based on R&D investments in order to stay ahead of the competition in the very dynamic market as highlighted in **Figure 1**.

FIGURE 1: INTERWORKING OF PATENT, GAP, AND SWOT ANALYSES FOR FUTURE FCC OPERATIONS



Patent Analysis

In the intellectual property business, Patent Analysis (PS)—or patent analytics when statistical techniques are used to quantify the observations—is also referred to as Landscape Studies. PS is very valuable

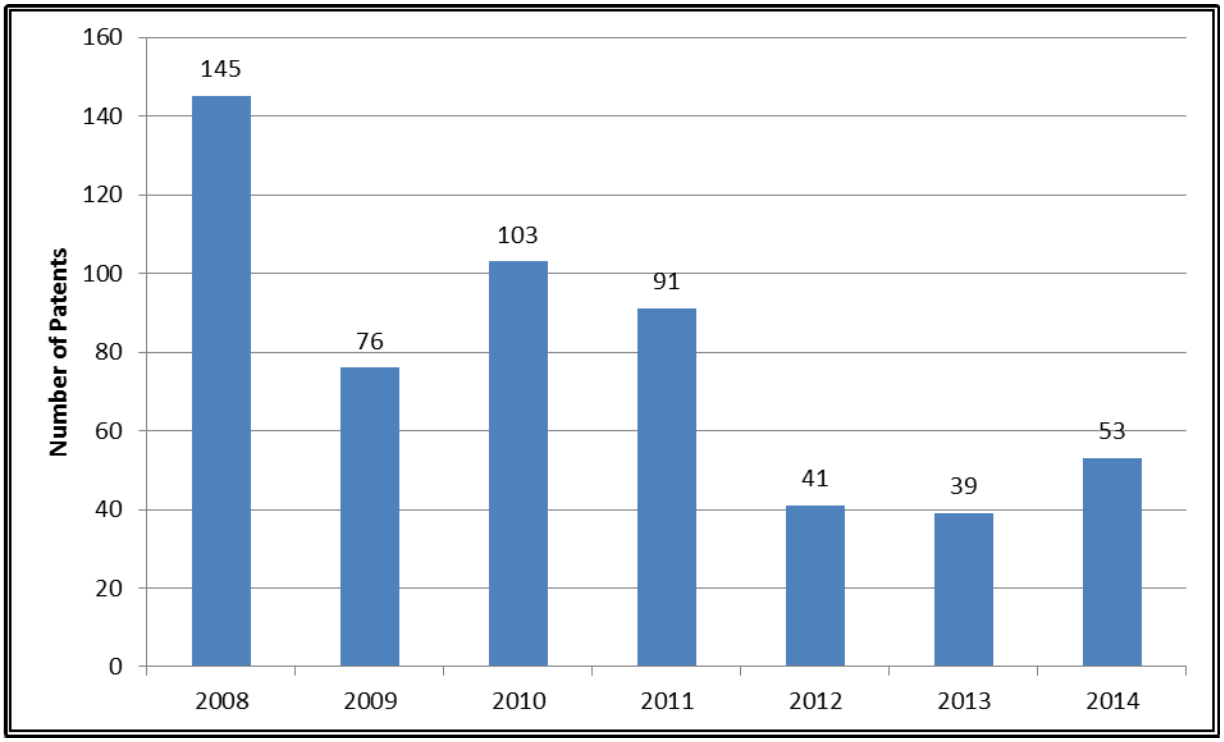
for companies to identify several technology domain areas: technology trends, R&D profiling, key players in the market, R&D focus of the competitors, seed and derivative patents of commercial and emerging technologies, and technology evolution. Furthermore, PS can assist companies in managing the R&D portfolio including patent filing strategies, R&D investment decisions, evaluating the potential market opportunity for product development, and sharpening their technology strategies as well as corporate planning and strategic development. One of many benefits is to explore licensing opportunities.

Generally, a comprehensive Patent Analysis involves a search of relevant patents and published patent applications, classification into groups based on applications and specific companies, and evaluations of the technology themes to pinpoint patent novelties. R&D profiling can be used to predict likely development paths and capture early signals of commercialization intents. Time slices can be used to show evolution of topical emphasis.

Annual Global Patent Counts

Figure 2 displays how the global count breaks down for each year of this period. What appears here is a general downward trend in the number of patents for FCC technology that were issued each year between 2008 and 2014. This report intentionally excludes certain patents—such as those focusing on composition of matter, general process inventions, and generic devices without specific disclosures or claims for FCC or catalytic cracking application. These non-FCC specific patents are considered "noise" in our patent analysis.

FIGURE 2: ANNUAL GLOBAL COUNTS OF ISSUED FCC PATENTS, 2008-2014

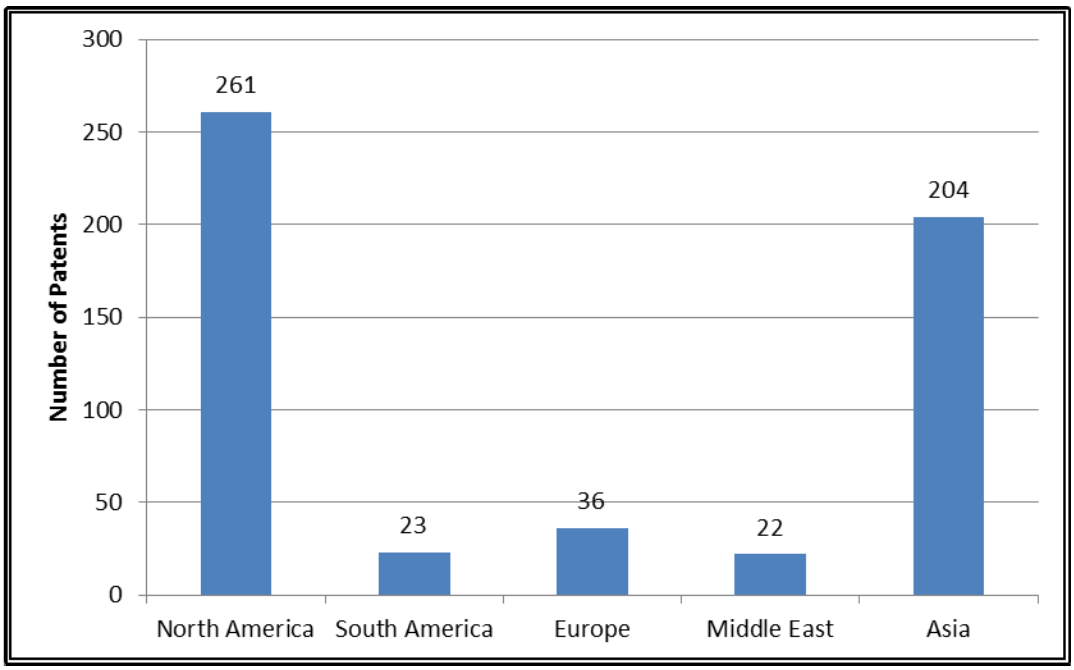


Regional Differences

Figure 3 shows the distribution by regions of the companies to which the patents in our set were issued. The five regions cover 546 of the 548 FCC patents that we found were issued during the period. Two patents had insufficient information to establish their origins. Also, the European count includes one patent from Russia. Based on these data, North American companies had 48% of the issued patents, and Asian companies were somewhat lower at 37%. European, South American and Middle Eastern companies contributed 7%, 4% and 4%, respectively.

With the exception of Europe and Asia, one country accounts for nearly all of the patents issued for each region: North America (United States); South America (Brazil); Europe (Netherlands and France); Middle East (Saudi Arabia); Asia (China and Japan).

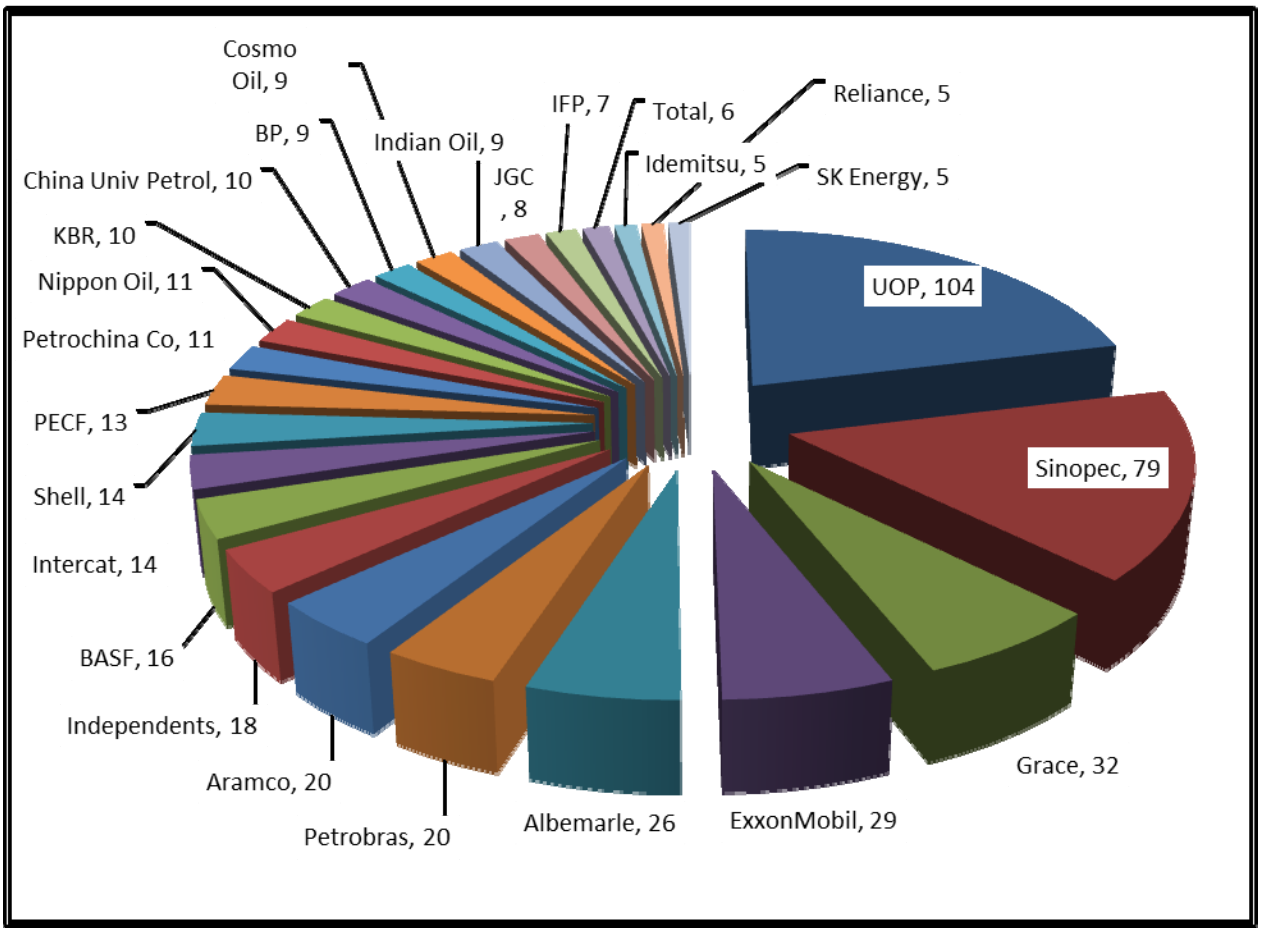
FIGURE 3: REGIONAL COUNTS OF ISSUED FCC PATENTS, 2008-2014



Patent Counts on Individual Companies

Our data on patents for FCC technologies issued during 2008-2014 shows that these were issued to 73 companies in all. **Figure 4** displays the identities and the counts for those companies that received five or more patents. Twenty five companies are in this group, and it is easily seen that two of these – UOP and Sinopec – readily stand out from the rest in terms of the number of patents awarded. Clearly, these two companies by themselves contribute heavily to the regional counts for North America and Asia that are shown in **Figure 4**. Also, their combined total of 183 patents is one-third of the global total of 548.

FIGURE 4: COMPANY COUNTS OF ISSUED FCC PATENTS, 2008-2014

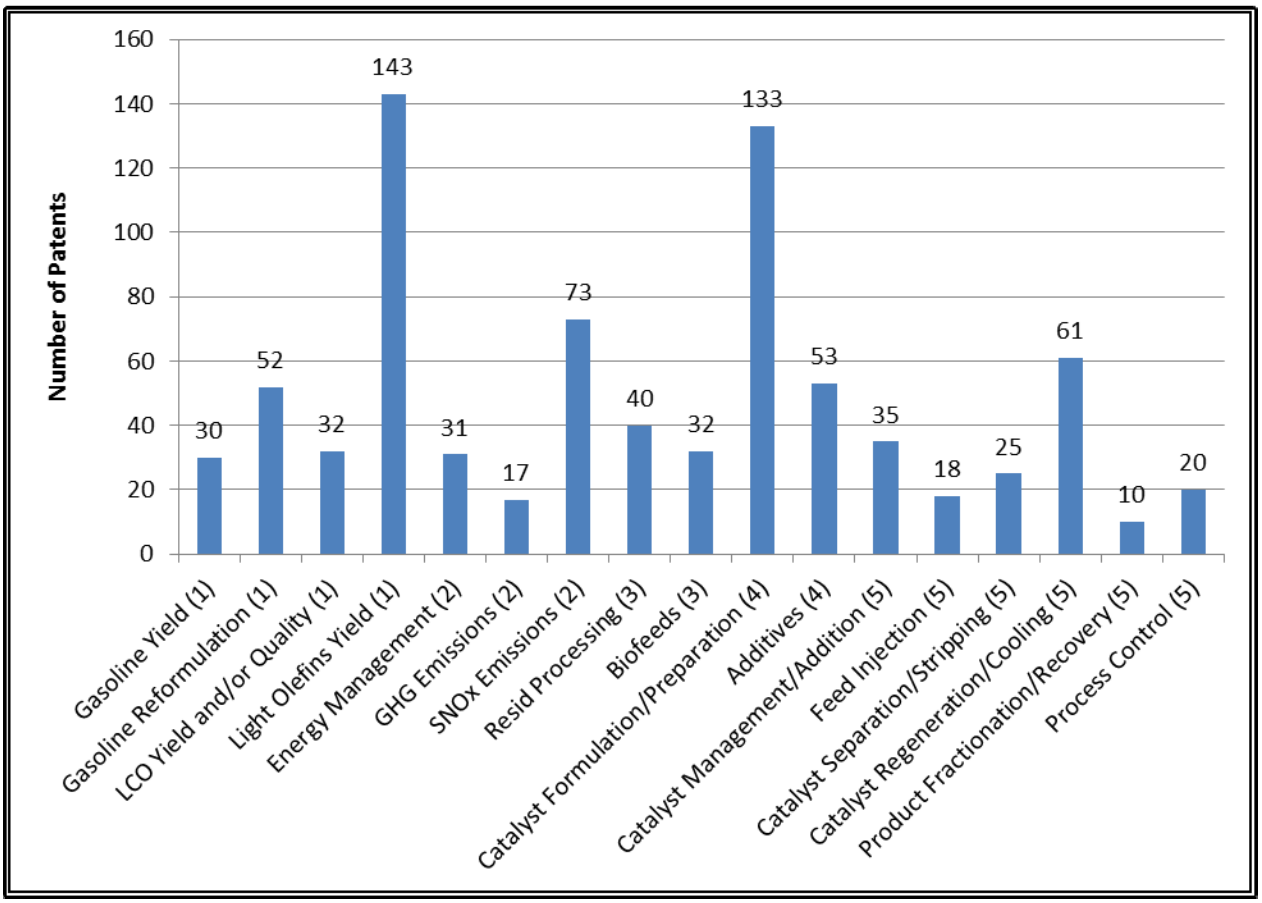


Specific Applications

Figure 5 shows the number of global FCC patents with issue dates during 2008-2014 that are found in each of 17 application Categories. These Categories include almost all of the subjects to which FCC patents apply. It must be noted that a patent may fall into more than one of these Categories. Consequently, the sum of the numbers shown at the tops of the columns in the figure is greater than the actual number of patents that are represented. The Categories can be sorted into five general Groups. The Group identification for a Category is indicated by the number in parenthesis at the end of the Category name as follows:

- Group 1: FCC Product Yields and Qualities;
- Group 2: Energy and the Environment;
- Group 3: FCC Alternative Feeds;
- Group 4: Catalysts and Additives; and
- Group 5: FCC Operations.

FIGURE 5: APPLICATIONS FOR 2008-2014 ISSUE DATES



There are many ways to delve into the materials and use different metrics to bring out the intrinsic values for the research works. For illustration purposes, here are three of several metrics (or so-called levels of mining) that have been explored.

First metric explores technology competition. One can uncover competitor's strategies and future technology deployment by looking at where a company is applying its patent efforts. Oftentimes, R&D funding is allocated to experimental works that satisfy customers' needs (e.g. iron trap to reduce catalyst poisoning when processing shale/tight oil in the US), capitalize business potentials recognized by market development executives (e.g. increasing benzene yield in FCC product to anticipate benzene supply shortfall), and complete the company's product portfolio (e.g. cracking biomass).

Second metric goes further into innovation concentration. The goal is to find out development trends and which companies are involved.

Third metric breaks down the applications into the specific technology areas or themes where patent coverage is being pursued. The purpose of the analysis here is twofold: (1) providing an overview of

technology innovations in individual applications and (2) identifying potential areas of patent infringement or collaboration opportunities. For illustration purposes, **Table 1** summarizes the technology themes that appear in the four applications from Group 1 Application – FCC Product Yields and Qualities.

TABLE 1: SPECIFIC RESEARCH AREAS IN GROUP 1 APPLICTATIONS – FCC PRODUCT YIELDS AND QUALITIES

Application		Technology theme	Patent assignees*
Gasoline yield	Process	Short contact time	ExxonMobil, UOP
		Dual riser or multiple reaction zones	China Univ. of Petroleum (CUP), KBR, Nippon Oil, PetroChina, Sinopec, UOP
	Catalysts	Composition can reduce coke yield or reduce dry gas and LPG	Grace, JGC Catalysts and Chemicals, Nanjing Petrochemical, Petroleum Energy Center Japan (PECJ)/Cosmo Oil, Reliance Industries
Gasoline reformulation	Process	Various innovations to improve octane, increase propylene and BTX yield, and reduce gasoline	CDTECH, Indian Oil, KBR, Nippon Oil, PetroChina, Saudi Aramco, Sinopec, SK Energy, UOP
		Converting and/or removing undesirable components from cracked naphtha	ExxonMobil, Sinopec
	Catalyst	Reducing gasoline sulfur	CUP, ExxonMobil, Grace, Idemitsu Kosan, Sinopec/RIPP
		Improve gasoline octane	PECJ/Cosmo
		Sulfur-reducing additives	Bharat Petroleum, Grace, Saudi Aramco
LCO yield and quality	Process	Multi-stage or multi-reactor process configurations	ExxonMobil, Petrobras, Stone & Webster
		Integrated process to boost yield	Eni, Sinopec/RIPP
		Using pre-coked catalyst to raise output	Total
	Catalyst	LCO with low aromaticity	Albemarle, Petrobras
		Yield of LCO > HCO	Eni
Light olefins yield	Process and hardware	Multi-stage, multi-reactor or downstream reactor	CUP, Indian Oil, KBR, Nippon Oil, Petrobras, Reliance Industries, Saudi Aramco, Shell, Sinopec/RIPP, Total, UOP
		Co-processing heavier olefins	IFP, Sinopec, UOP
		Unconventional approaches to make olefins and BTX	Indian Oil, Petrobras, Saudi Aramco, Sinopec/RIPP, SK Innovation, UOP
		Catalyst management	UOP
		Feed injection scheme	Slavneft, UOP
		Enhanced recovery	Lummus Technology, Reliance Industries, SK Energy/Korea Energy Research Institute, UOP
	Catalysts and additives	Modified ZSM-5 zeolite	CUP, Petrobras, Reliance Industries, Sinopec/RIPP, Total,
		Catalyst mixture	Asahi Chemical, BASF, Grace, Petrobras, Saudi Aramco, Sinopec-RIPP, UOP
		New zeolite materials	Grace, Petrobras, Sinopec-RIPP, UOP
*Partial list			

Gap Analysis

In business management, Gap Analysis (GA) is also referred to as White Space Analysis, which is undertaken to identify the unexpected gaps or white spaces in an application/business area that is unmet or underserved by current technologies. Therefore, results of GA could offer an opportunity for R&D works to come up with an innovation for companies to gain a competitive edge in a crowded playing field. Furthermore, GA presents a roadmap for companies to address new opportunities or threats as discussed in the third step: SWOT Analysis in Section 7.

There are three primary reasons why a company should conduct the Gap Analysis. First, the GA is a prerequisite to find out where an invention may be generated for an unchartered market. If there are "perceived" technology deficiencies, a R&D program could be initiated to bridge the gap. Second, the GA offers a valuable tool to gauge the competitors in terms of their speed in technology development in potential applications so that a company can devise a proactive plan for further R&D to gain competitive advantage and even develop a 'niche' product or service that could block the competitors. Third, the GA findings can provide a communication platform that enables business development executives and research professionals to review the current and future business opportunities, state-of-the-art commercial technologies, and latest patents awarded. This joint effort is believed to be the best way in bringing everybody on board. It is noted that non-patent literature must be explored as part of GA because many institutions have developed technologies for academic interest, but do publish their findings in various scientific and trade journals. Their publications oftentimes present insights into future technology directions that are very valuable for complete Gap Analysis. Therefore, any analysis not taken account of non-patent papers is considered incomplete. Furthermore, human expertise is essential for efficient or productive patent analysis, otherwise, the results could lead to unprofitable product development.

SWOT Analysis

Along with the results from the Patent Analysis in Sections 4 and 5 and Gap Analysis in Section 6, the Strengths, Weaknesses, Opportunities, and Threats (SWOT) Analysis is used to examine and predict the strategic roles of the FCC technology and units in future refinery operations based on internal and external factors. The analysis begins with the competitive advantages (or internal strengths and weaknesses) of FCC technology compared to other refinery processes, and is then followed by impacting external drivers (or threats and opportunities from outside).

The recommendations in the subsequent parts of the analysis are derived from matching internal and external factors to either capture opportunities based on the strengths or avoid the threats because of the weaknesses. On the other hand, weaknesses or threats can be converted into strengths or opportunities using a "flipping" strategy. And then, the results are used to make recommendations to refiners/FCC operators and

suppliers who provide technologies, products, and services to the FCC plants in Section 9: Strategic Analysis and Recommendations.

Predicting FCC Technology Trends and Identifying R&D Opportunities

Can one look at the past to predict the future? The answer is yes and no. Since most events are connected and in continuation by inertia, searching the past patent data and spotting the trends often give a good indication what will happen next, at least in the near future. In the other words, we are looking for "patterns of patents." On the other hand, the external factors are changing rapidly, what in the past may not be relevant in the future. Also, there may be a herd-mentality of many inventors following the wrong ideas; though the probability of this happening is small since most researchers' works are critically tested and reviewed amongst their peers. The R&D undertakings must be economically justified as resources are limited within organizations.

In order to successfully forecast promising research works that have very high probability of being commercialized, there are five criteria used to judge the innovations: (1) considerable research volume—both patent and non-patent—by one company or several companies in particular areas, (2) increasing numbers of patents being filed over time, (3) research works independently done in different parts of the world, (4) credibility and worthiness of the patents, and finally and most importantly (5) upcoming market demand as identified in Section 6: Gap Analysis. The latter addresses the evolving technical challenges and business opportunities facing FCC technology because of changing business conditions and environmental regulations. The objective of this section is to identify the promising technologies that are worthwhile enough to be continuously monitored for either individual companies' R&D strategies or potential licensing opportunities. Of course, the economics and competitiveness of the technologies in offering environmentally acceptable products at reasonable costs will be the ultimate winners.

In addition to findings discussed in the latest R&D works (from 2008 to 2014) in Sections 4 (Patent Analysis) and 5 (Patent Technology Themes), this report also brings in FCC patent works as far back as 2000 as examined and analyzed in previous reports by Hydrocarbon Publishing Co.: Advanced FCC Technology to Improve Refinery Profitability (published in March 2005), Future Roles of FCC and Hydroprocessing Units in Modern Refineries (published in March 2009), Opportunity Crudes Report II: Technologies & Strategies for Meeting Evolving Market & Environmental Challenges (published in June 2011).

Who Can Benefit From This Report?

For refiners, this could provide something of a deeper level of analysis beyond what will come from the licensing companies. A broad knowledge of patent directions and activities helps refiners understand

technology trends, availability, and details in order to make better decisions in selecting the right technologies for their operations.

As for technology providers, this could be another way to track competition. For example, Company X is the leading commercial provider of dual riser FCC technology, but Company Y with no market position in the technology has been issued a number of patents in this area over the past several years. As part of competition analysis, one can correlate R&D work with commercial offerings and product developments to monitor and predict the readiness of Company Y for entering the market. Patent analytics on a global basis allows technology companies to focus on competitors located within the same regional market but also with an eye on external market competition.

Most importantly, R&D personnel can track research trends based on big data analytics, size up competition, compare technology developments, and spot opportunities of potential collaborations. This report can also provide a common forum for business management and research professionals to communicate and prepare future research directions and strategies.

Finally, one can identify emerging trends to see where commercial practices line up with recent R&D undertakings. Furthermore, incorporating some recent market fundamentals in terms of fuel and petrochemical feedstock supply/demand trends and also future business opportunities could provide guidance to companies in formulating future strategies.

PRICING INFORMATION

Order this publication at Hydrocarbon Publishing Co.'s online store at: http://www.hydrocarbonpublishing.com/fccanalytics

[i] Fleischer, C.S.; Bensoussan, B. *Strategic and Competitive Analysis. Methods and Techniques for Analyzing Business Competition*; Prentice Hall: Upper Saddle River, US, 2002.