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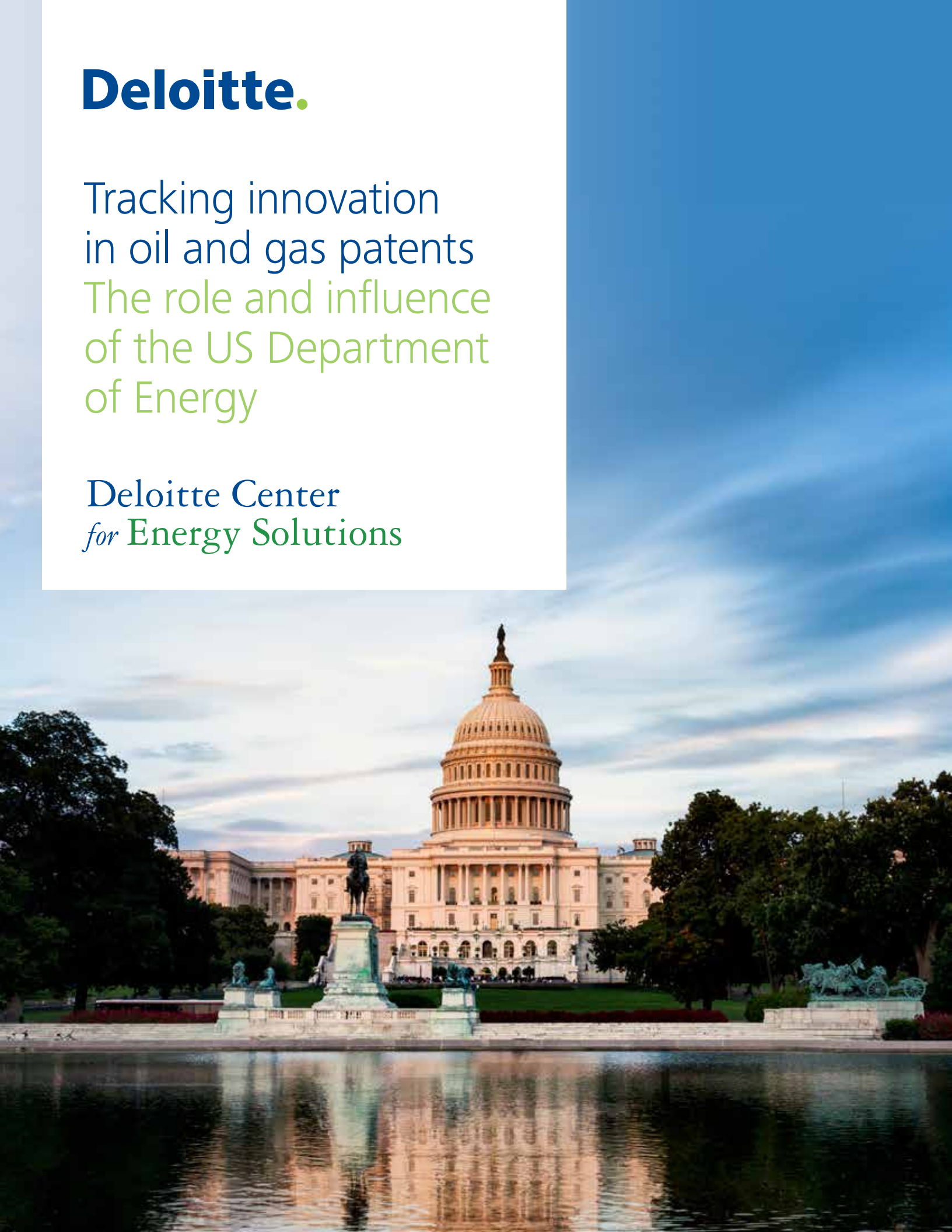
Tracking innovation in oil and gas patents

The role and influence of the US Department of Energy

Deloitte Center *for* Energy Solutions



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Executive summary

There is an ongoing, often partisan, debate about the efficacy of government investment in the creation of new technologies. Given the importance of intellectual property (IP) to the health and growth of technological progress, this debate is important and warranted. This study sets out to quantify the influence that the US Department of Energy (DOE) has had on the state of innovation within the oil and gas sector, based on patents generated[1] by the DOE. This is the first paper in a series which analyses a large database of patent filings and citations to discover and analyze trends in the sources and focus of innovation in oil and gas from 2006–2014.

Oil and gas technology incubation has been one important role of the DOE since its inception in 1977.[2] Over the years, DOE's research focus has evolved from reducing the country's foreign energy dependence to also include undertaking research into growing domestic energy resources.

This study provides quantitative data to assess the role and contribution of the DOE in advancing innovation and new technology for oil and gas. Specifically, the report assesses the influence that DOE has had on oil and gas innovation by evaluating the extent to which patents that were generated or funded by the DOE have fed into further research and innovation pursued directly by the oil and gas sector. This study is based on patent data furnished directly by the DOE as well as a larger Deloitte database that contains patents filed between 2006 and 2014. Cross-walking DOE's non-public data set of 8,003 patents with Deloitte's proprietary database of 2.1 million patents and over 75 million patent citations, enabled the assessment of DOE's influence on oil and gas patents. The analysis revealed the following key findings:

- 8.6 percent of all patents from major oil and gas firms cite at least one DOE funded patent.
- 55.8 percent of all DOE patents produced prior to 2006 were cited by at least one oil and gas firm.
- DOE patents have staying power, with a median shelf life of 16.5 years.

- In 2012–2014, there were six non-oil and gas areas which cited oil and gas patents at least 100 times.
- 62 percent of DOE oil and gas innovations were created by academic and non-profit entities while 5 percent were created by private oil and gas focused firms. The remainder were created by non-oil and gas firms.

DOE and the federal government are placing greater emphasis on measurable returns related to innovation. Meeting the mid-century challenges of global energy-use doubling, and electricity demand tripling, will require a coordinated effort among those that occupy the energy innovation ecosystem. The data presented in this study serves to inform conversations regarding innovation so that entities can maximize their impact within an ecosystem in a way that aligns with national priorities and also addresses global challenges.

Introduction

The DOE's mission is to "enhance US security and economic growth through transformative science, technology innovation, and market solutions to meet our energy, nuclear security, and environmental challenges."[3] In pursuit of this mission, the DOE funds a wide variety of initiatives designed to further technology in key areas related to energy production. These efforts can be fully funded by DOE or funded in collaboration with non-DOE entities. The extent to which DOE research contributes to subsequent innovations within an industry can be explored using information from the US Patent and Trademark Office (USPTO). By conferring these patents publicly, as well as documenting when other patents cite them, the USPTO data allows the creation of a functional map of how innovations feed one another over time. By using this information, this study seeks to assess the influence of DOE's patents and to allow all innovators in the oil and gas sector to gain a better understanding of the intricacies of the oil and gas innovation ecosystem.

To assist us with quantifying DOE's influence on the oil and gas space, DOE furnished a list of 8,003 patent numbers[4] that they had supported. To improve the depth of our analysis, the DOE list was used in conjunction with a Deloitte database containing all 2.1 million US patents granted from 2006–2014 and their 64.9 million citations. In order to tie patents to commercial oil and gas entities, 42 key oil and gas firms (including majors, service companies, and independents) were identified.[5] The analysis was extended by examining not only what DOE patented but also tracing where those patents were eventually cited by private oil and gas companies. The analysis presented here is in line with much of the emerging academic literature on patents which treats patent data as a knowledge network. Viewing the data in this way enables our assessment of DOE's role in the growth of oil and gas technology and to pursue answers to the following questions:

- Has DOE research and innovation influenced industry IP?
- What is the shelf life of innovation?
- What is the path of innovation from conception to application?
- What is the reach of DOE research?
- What organizations are involved in similar research?

Such questions are important to all entities that have engaged research and development (R&D), but particularly for the public sector entities, as they are continually asked to rationalize their budget based on the extent to which their activities have contributed to the public good. In the case of DOE, quantifying such contributions is difficult, yet this study offers a means for evaluating innovation impact. In the following sections, this study answers the above questions in relation to the role that DOE played in the oil and gas innovation ecosystem.

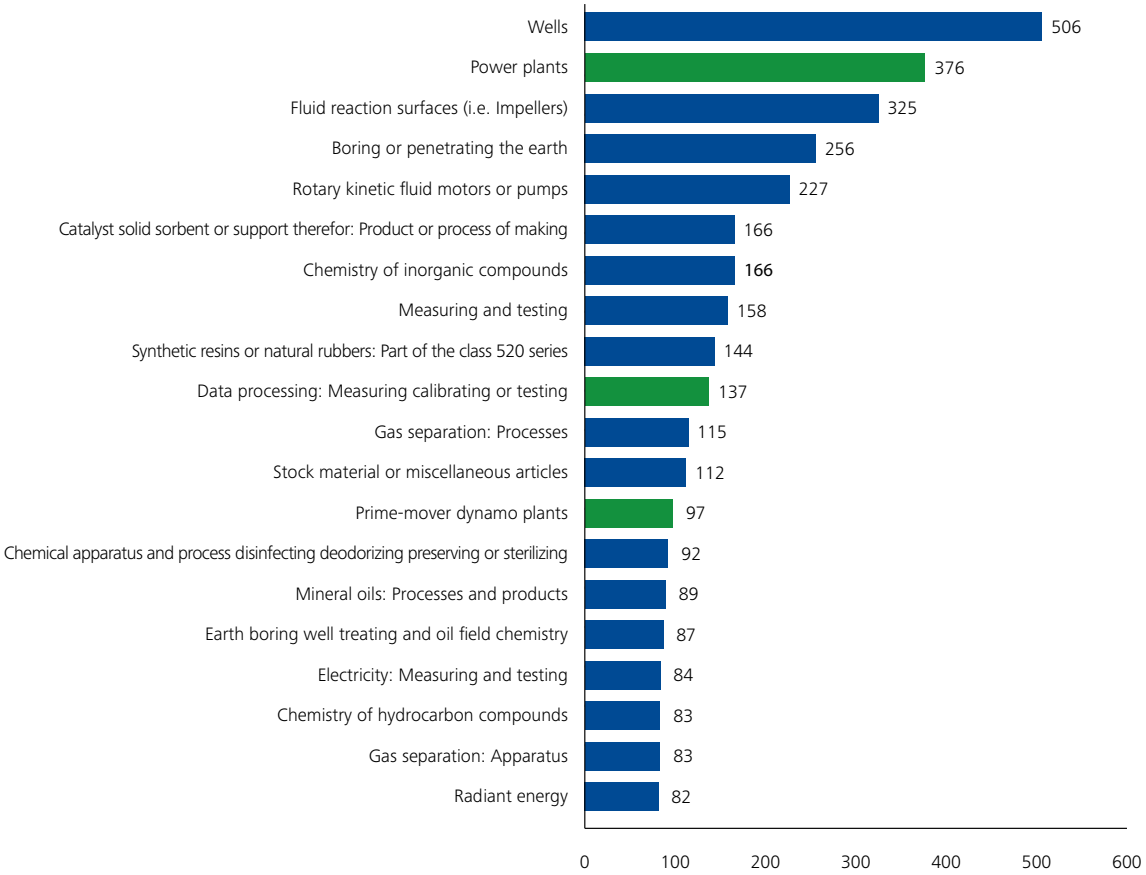
What influence has DOE patent activity had on industry IP?

Deloitte's analysis of patents filed by 42 key oil and gas organizations during 2006–2014 reveals that 8.6 percent of their patents were either funded by DOE or, more commonly, cited a patent produced by DOE.[6] If analyzed from DOE's perspective, 55.8 percent of DOE patents produced prior to 2006 (which were old enough to ensure opportunity to have been cited by other patents) at some point were cited in a patent by the oil and gas firms. Had our sample of 42 firms stretched beyond the oil and gas space or been a larger oil and gas set, this 55.8 percent may have been higher.

The 8.6 percent of patents that were generated by DOE were primarily focused on traditional oil and gas technologies as shown in Figure 1, which identifies the top 20 technology areas that oil and gas companies patented when citing a DOE patent. The list below features three exceptions (highlighted in blue) that are adjacent technologies, rather than core, to oil and gas operations. This supports the thesis that firms beyond the oil and gas sector are extracting direct commercial value from some of DOE's oil and gas patents.

According to Figure 1, the highest number of DOE patents were cited in the "Wells" classification, one of the most critical areas of ongoing innovation for the oil and gas sector to improve the efficiency and effectiveness of hydrocarbon production in both conventional and unconventional resource plays.

Figure 1. Uses of DOE patents in key areas of oil and gas firms

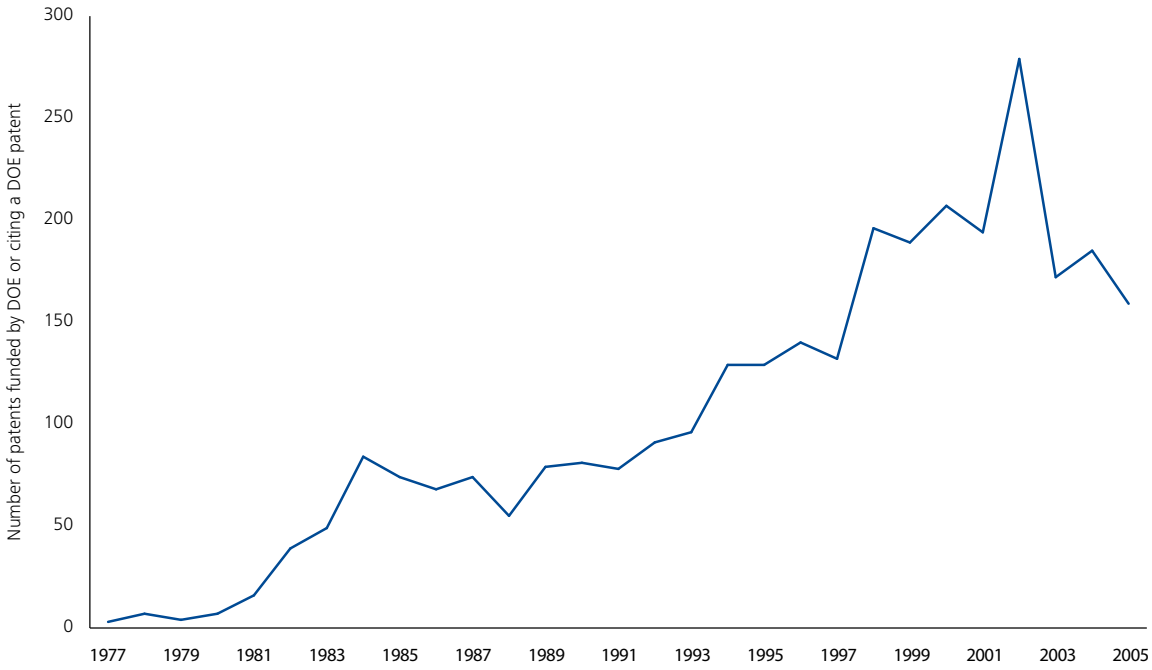


What is the shelf-life of DOE patents?

The goal of DOE's research is often to lay the pre-commercial foundation for industry to build upon by advancing technology to a state such that industry is capable of continuing development and deployment when commerciality thresholds are closer. The patents generated during such activity will be cited by industry as the technology is advanced to a state of commercialization. Given the extended timeline for technology development and deployment, it is expected that a compelling patent will see a decade or two of citations as the technology reaches its market potential.

The shelf life of a patent can be thought of as the length of time from when it is first granted until its last citation. While increasing citations do not impact a patent's legal standing, it does directly speak to how frequently other innovations build upon it. Figure 2 uses citation data to calculate the number of patents that were funded by DOE and subsequently cited by a patent that was granted in 2006–2014. This removes patents which were funded by DOE but then fell into disuse in the private sector. The gradual increase shown in the chart is a function of modern era patents being more relevant and a general growth rate in patenting activity in the US over time.

Figure 2. Frequency of DOE oil and gas patents still making an impact on innovation



Drilling down into the top 10 areas commercial oil and gas firms are currently researching, there are a wide range of "patent shelf lives" present in the data. The boxplot below (in the gray box) shows the citation shelf life of the central 50 percent of patents associated with a given category. The dotted red line shows the average age (as dated from the end of 2014) of the patents in this group. Each blue dot represents one patent citation produced by the DOE in an oil and gas area. Reading this graph for Wells, we see the dotted red line indicates the DOE Wells patents were produced relatively recently (14 years ago) and that Wells patents have the shortest shelf life, meaning that commercial oil and gas firms tend to only reach back eight years for innovations in Wells. In contrast, "Stock Material" patents had a median citation shelf life of 14 years, meaning that the typical DOE patent in this area continues to receive citations for 14 years after its publication.

Notably, a few patents filed by DOE during the 1970's are still receiving citations over 30 years after their publication, showing their historical importance in the process of generating innovation in the oil and gas space. This means that even though these research activities occurred long ago, modern patents are still citing them. Further boosting the credibility of these patents is the fact that, overall, DOE patents are cited an average of 10 times while the average patent that was not supported by DOE's oil and gas efforts is cited a total of three times.

While the figures above demonstrates the utility of DOE patents, there are some that stand out as being more widely cited within the private sector oil and gas industry. Figure 3 lists the names of those patents along with their dates of publication. Unsurprisingly, some of them are older (early 2000's) but some are quite old (such as the drilling patent from the 1970's).

Figure 3. DOE oil and gas patent lifespan in years

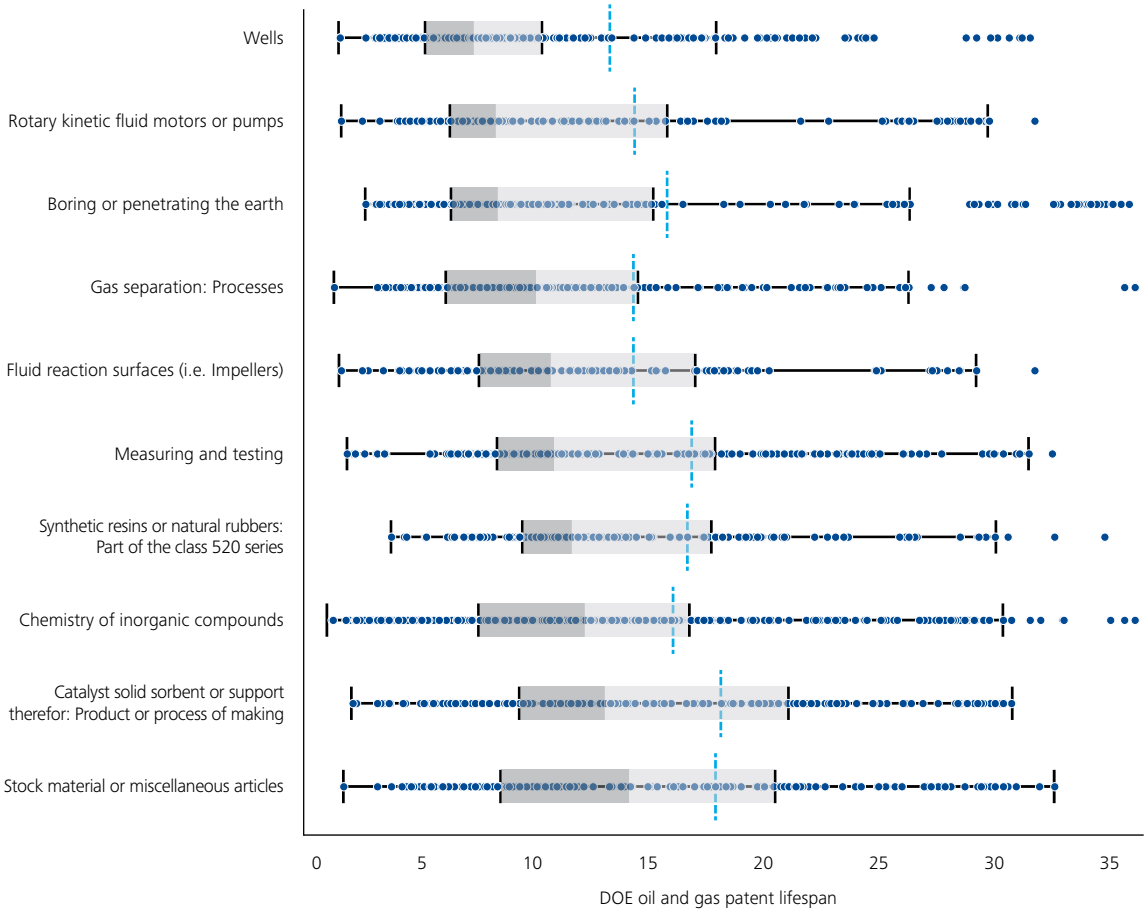


Figure 4. Top 10 DOE oil and gas patents by citation from private oil and gas firms

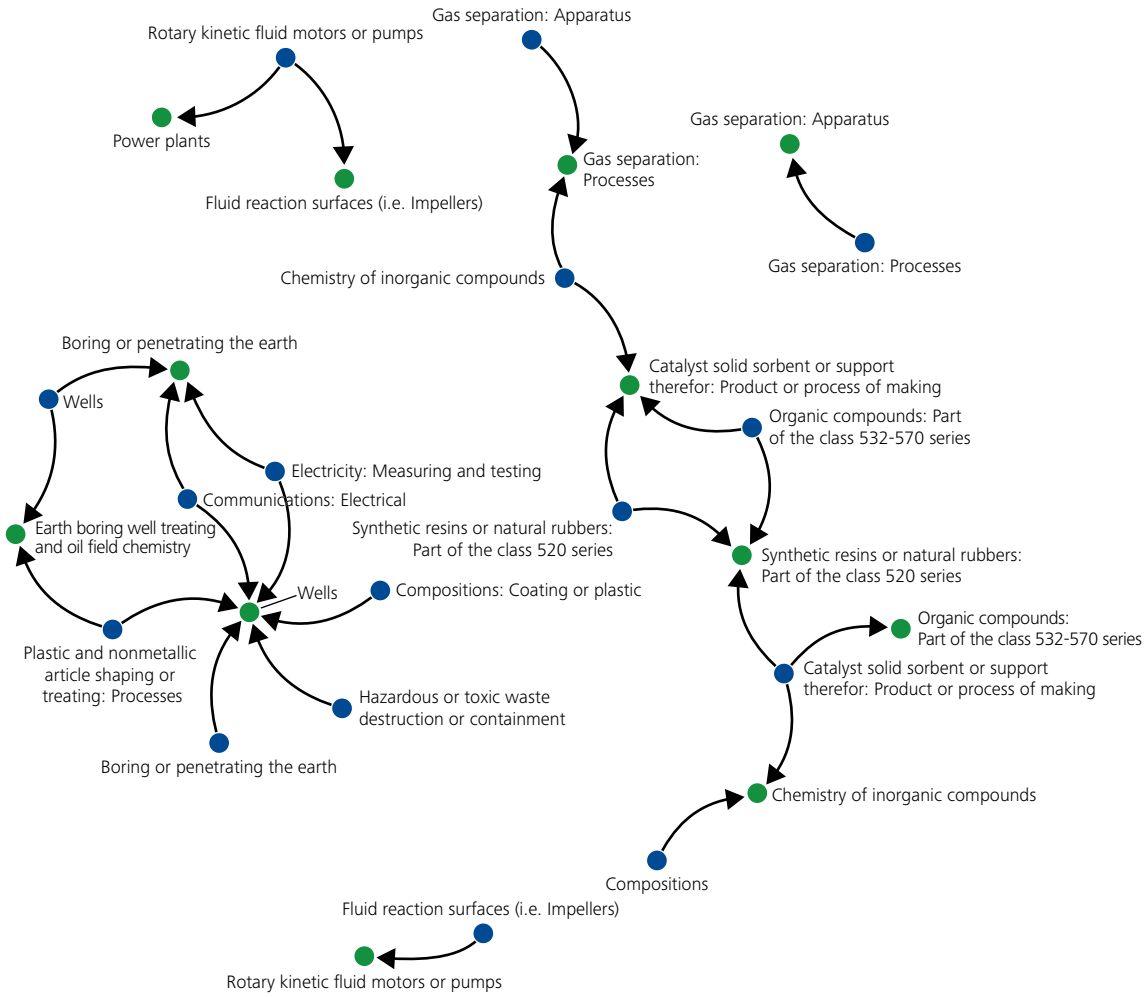
Title	Publication date	Number of citations from within the oil and gas industry
Downhole data transmission system	Dec 30, 2003	78
Annular wire harness for use in drill pipe	May 21, 2002	77
Real-time reservoir fracturing process	Aug 27, 2002	77
Canister, sealing method, and composition for sealing a borehole	Jun 28, 2005	71
System for improving coalbed gas production	Jun 12, 2001	59
Composition and process for the encapsulation and stabilization of radioactive, hazardous, and mixed wastes	Mar 24, 1998	58
Methods and apparatus to produce stick-slip motion of logging tool attached to a wireline drawn upward by a continuously rotating wireline drum	Feb 10, 1998	54
Swozzle-based burner tube premixer including inlet air conditioner for low emissions combustion	Aug 27, 2002	49
Method for inverting reflection trace data from 3-D and 4-D seismic surveys and identifying subsurface fluid and pathways in and among hydrocarbon reservoirs based on impedance models	Aug 25, 1998	49
Hydromechanical drilling device	Aug 15, 1978	40

What is the path of innovation from conception to application?

While DOE is not driven by profit, there has always been an economic aspect to its mission, as it is charged with improving the global competitiveness of the US and its companies. The manner in which industry applies DOE's innovations varies with some technologies finding fertile commercial ground in areas beyond that for which it was conceived. The following analysis drills into the specifics of how innovations formed within DOE flow into commercial innovations. In general, when DOE innovates in a certain technological area, such as inorganic chemistry, the most common area to reuse that knowledge within the industry is other patents creating knowledge about inorganic chemistry. However, the knowledge created in an area often grows into other areas beyond the initial area of patenting.

To illustrate this, a link diagram was constructed which shows what DOE invested in (in blue) and what private industry actually ended up using the technology for (in green). The diagram below illustrates where each of these DOE technologies feeds other technologies in the private sector. The top 25 strongest connections between technologies were included in the diagram. Connections from a technology to itself (for example Wells contributing to Wells) are excluded from the diagram below.

Figure 5. The flow of DOE oil and gas innovations to applications within industry[7]

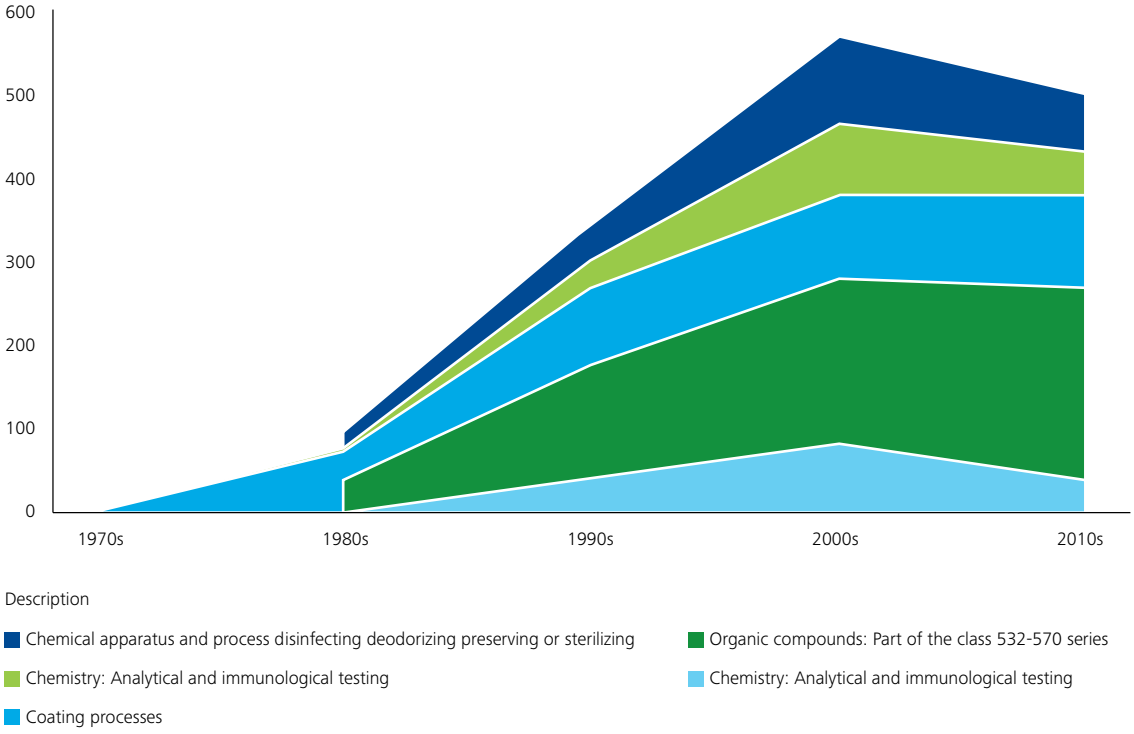


Unsurprisingly, the single largest area for which oil and gas firms used DOE patents was in Wells technologies. This reinforces our finding that oil and gas firms are using DOE patents to improve technologies which are core to their business. This analysis doesn't prove or disprove the notion that DOE is "ahead of the curve" of oil and gas firms. What it does show is that DOE's innovations are regularly used in areas that go beyond the initial area of DOE's innovation. That being said, many patents remained consistent with their original application. Those technology areas that tend to show the single strongest connections between the original area of the DOE research and differentiated application are:

- Organic compounds
- Chemistry: Analytical and immunological testing
- Coating processes
- Rotary kinetic fluid motors or pumps
- Chemical apparatus and process disinfecting deodorizing preserving or sterilizing

Interestingly, Figure 6 shows that many of the inventions cited in the modern era date back to the 1980s and 1990s, showing that these investments are still inspiring technological innovation. Of the examined technologies, "coating processes technology" has the patent with the earliest citations. However, beginning in the 1980s, all of the five technologies in question begin to make an impact. By the 2010s, organic compounds stand out as the patenting areas which have the highest rate of patenting and/or citation. In practice, almost all of the impact of the DOE in the last few years is captured solely based on its funding of new patent acquisitions. Innovations published in 2011–2014 simply haven't been around long enough to receive many citations by other patents and so almost exclusively draw their impact from DOE having directly funded them. Also, as this data only goes through 2014, the "2010s" portion below likely understates any future trends in patenting in these areas. It is reasonable to believe these patterns will further intensify compared to their historical baselines.

Figure 6. Number of DOE oil and gas patents by technology area over time (in highest volume areas)



What is the reach of DOE's oil and gas research?

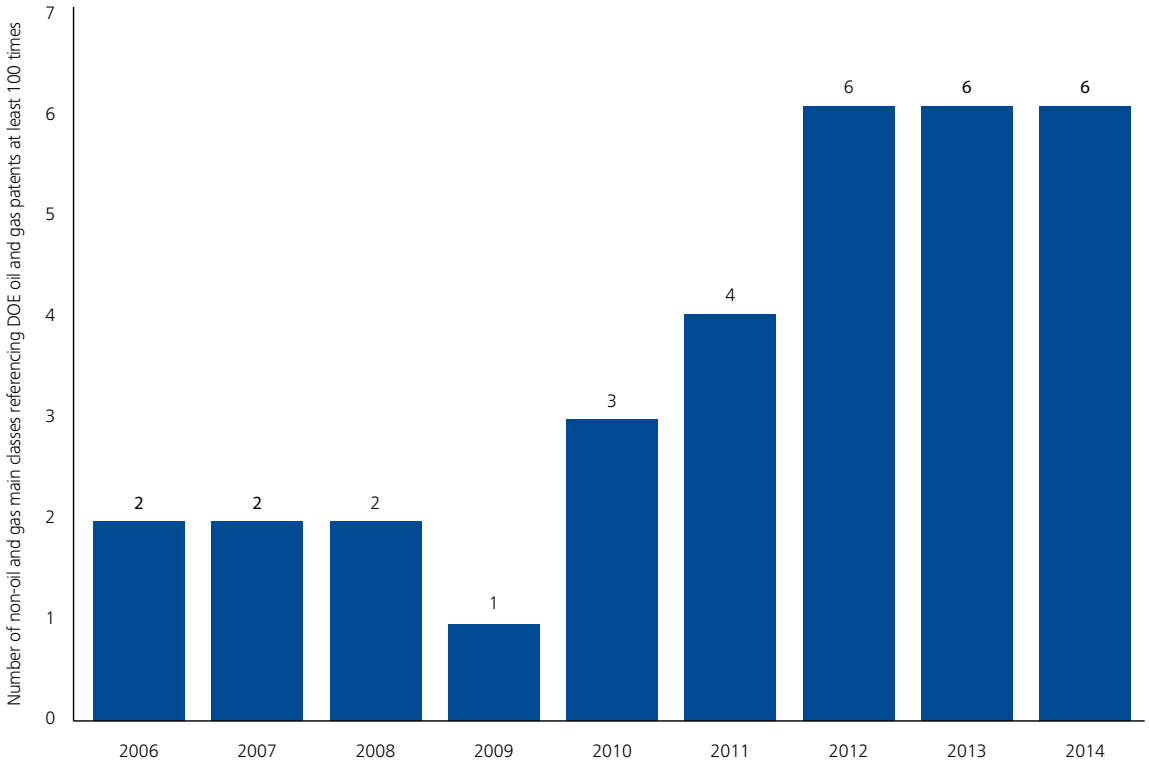
In an organization as diverse as DOE, opportunities abound for collaboration and cross-pollination. Such interaction among researchers, both internal and external to DOE, often leads to the identification of new applications for novel technology. However, in addition to actively seeking synergies, there is a passive element to knowledge diffusion that is correlated with increased innovation and prolific patent activity. That is as researchers are informed (actively or passively) of technological breakthroughs, many consider the possible implications within their focal area. As a result, DOE's oil and gas research has the potential to influence and inspire areas beyond the oil and gas mission space. One way to quantify this effect (i.e. DOE's reach into adjacent markets) is to measure the number of different kinds of technologies that reference patents that DOE funded.

To accomplish this, Deloitte categorized 99 of the USPTO's 475 primary classifications based on whether they substantially related to the oil and gas space.

Deloitte found that DOE's oil and gas patents are used in a relatively narrow subset of patents outside of the traditional oil and gas space. It is crucial to note that this analysis solely focuses on the oil and gas patents that DOE provided. DOE's overall reach, especially in areas like renewable and nuclear power, is likely much wider, but that reach is out of scope for this particular study.

Figure 7 shows the number of main classes that had at least 100 patents that cited a DOE patent but was not itself a core oil and gas area. As the chart below shows, only recently have there been very many areas outside of core oil and gas areas which have used DOE oil and gas patents. This change should not be over-interpreted since the number of total patents granted per year and the number of citations per patent have both grown over time. As a result, this increase may be the result of the overall growth in the complexity of the patent universe rather than a fundamental shift in the use of oil and gas technologies.

Figure 7. DOE's oil and gas patents reach into few non-oil and gas technology areas

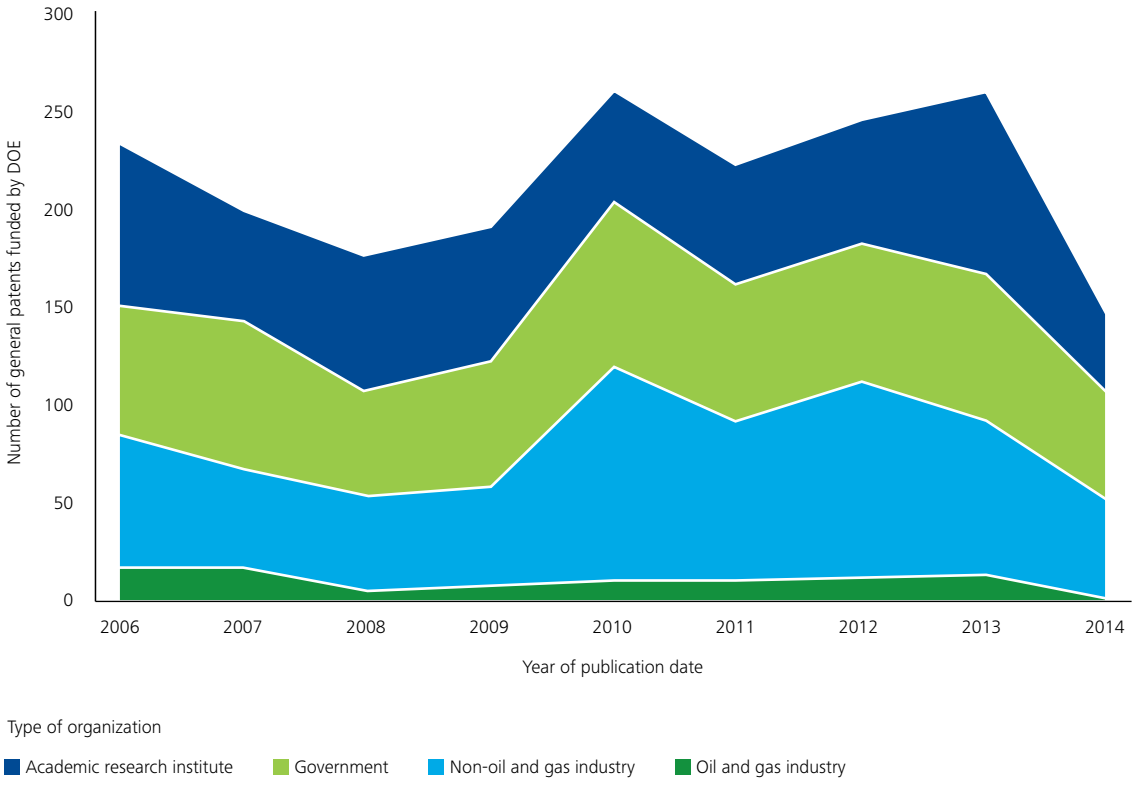


What organizations are involved in DOE's oil and gas patents?

DOE and its national laboratories often serve as the focal point for innovation. The knowledge that is generated during research is disseminated through partnerships with academia and industry, with the latter including the entities that ultimately take the technology to market. Collaborations and interactions with external parties are essential if DOE's impact is to extend beyond its borders.

Deloitte investigated patents that were generated since 2006 in an effort to better understand the entities that contributed to their creation. Unsurprisingly, DOE's research is primarily performed by academia and national laboratories. What is interesting in this set of patents is that few oil and gas companies were involved in the creation of the patents, yet industry often uses these innovations as source material for their own patents. This disparity could potentially be attributed to the IP concerns that many industries have with respect to collaborative research. Oil and gas companies have historically chosen to conduct development efforts in-house, yet many have recently begun to show an interest in open innovation, which could lead to more partnerships with DOE and its national laboratories.

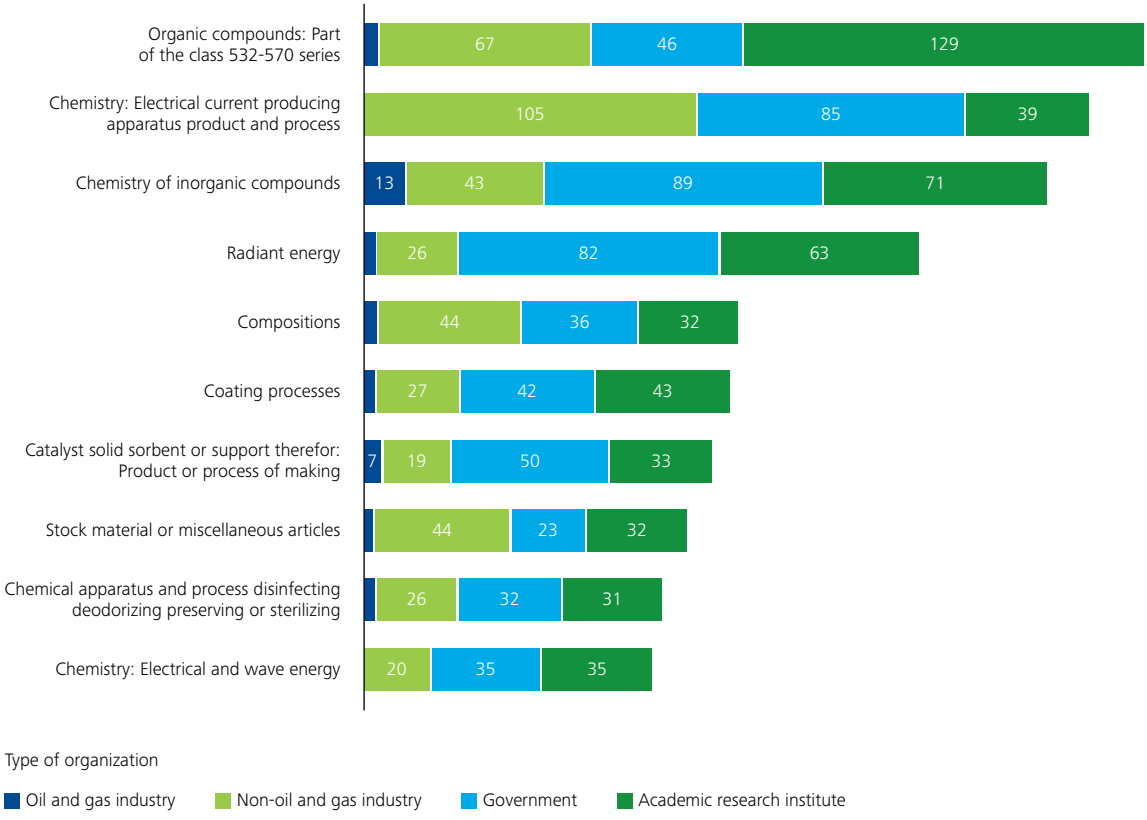
Figure 8. Types of organizations creating DOE patents in traditional oil and gas categories from 2006–2014



Each type of institution contributed in markedly different ways to DOE's oil and gas patent portfolio. Below are the number of oil and gas patents funded by DOE that each organization created from 2006–2014. As the chart below illustrates, the closer the researching institution is to actual oil production, the more the technologies listed converge towards being used in day-to-day oil and gas operations. Each type of organization focused on different kinds of technologies.

Academic institutions focused on organic compounds, inorganic compounds, and radiant energy. Non-academic government contributors focused on inorganic chemistry, electrical current, and radiant energy. Non-oil and gas industry participants focused on electrical current chemistry, organic compounds, and fluid reaction surfaces. While small, the contributions of traditional oil and gas firms were markedly different and focused on core areas of operations including wells, communications, and gas separation processes.

Figure 9. Types of organizations creating DOE patents by technology type



Conclusion

Over its 40 year history, the DOE has sustained ongoing contributions to oil and gas research and innovation. Overall, DOE has had a measurable impact on the oil and gas patent landscape, especially considering it contributes substantially to the United States' energy R&D expenditures and often focuses its efforts in areas that experience less patent activity. Going forward, opportunities exist to increase DOE's influence and there are many ongoing initiatives that are seeking to identify ways for DOE to improve the effectiveness of its research. Data, such as that presented here, provides insight into the United States' innovation infrastructure and informs conversations as to how government agencies like DOE can maximize their impact within an ecosystem in a way that aligns with national priorities and can also lead to commercial application.

The methods presented in this paper demonstrate how entities can begin to track their influence within specific innovation ecosystems. Despite the patent universe's immense size and technical complexity, tools such as the databases described here, can reveal opportunities for federal agencies to better engage stakeholders, and for the private sector to secure a competitive position.

This study is the first of a multi-part series. To receive the rest of the series and other Deloitte Oil & Gas reports, subscribe at www.deloitte.com/us/subscriptions.

Appendix

This study exclusively focused on patents that were granted between January 1, 2006 and December 31, 2014. This timeframe was selected on the basis that it would capture patents that had an impact in the recent past without digressing into academic pursuits. Additionally, all citation counts are from patents in that period. As a result, a theoretical patent that was cited by a patent granted in 2005 and another one grated in 2007 would show only one citation in our results above. This was intentional and this selection ensures that all results give credit to recent innovations and avoid giving credit to patents which were, for example, crucial in the 1960s but have long since lost their relevancy.

Additionally, our study benefitted significantly from the database of 8,003 patents that Deloitte was given access to by DOE. This list of patents should include the "bulk" of DOE investments in the oil and gas space. Of these 8,003 patents, Deloitte could match 7,230 patents DOE directly funded to our database. Patents were matched either by showing that the patent was directly funded by DOE or that a patent cited (and therefore, was influenced or benefitted from) a DOE funded patent. While over 3,036 of these patents were granted in the modern era where it was unsurprising that they were active (due to being directly funded,) 5,887 more could be traced to a direct citation from a modern patent (2006–2014.) These numbers total to over 7,230 because some patents were both funded during the study period and then cited by other patents later on in the study period. To further isolate the impact of oil and gas investments, Deloitte primarily investigated patents funded by DOE in a set of 99 "traditional" oil and gas innovation areas.

These patents are only a subset of DOE's overall portfolio of energy investments. This set was selected because it excluded developments like solar and wind energy which major oil and gas firms might take advantage of but which would not be relevant to the oil and gas industry. The inclusion of a broader set would only serve to artificially inflate many statistics in the study including the number of DOE patents "still in use" and the percentage of industry patents which are currently in use by the oil and gas subset of firms. This may be a topic for future research either by the DOE or Deloitte.

Additionally, this study defined "in use in the private sector" by using a representative cross-section of 42 unique entities including all four major US oil producing firms, multiple joint ventures, and other representative major players in the oil and gas space. Crucially, our analysis not only included the parent company but all major subsidiaries of those firms as identified in FactSet. This makes our list of patents those that are functionally accessible to the parent firms of these large organizations. Our totals for patents for each firm were validated against a major commercial patent search technology and universally our totals were higher due to our inclusion of not wholly owned subsidiaries. This helps solidify our representative set as truly encompassing a wide range of firms and all the tools they have at their disposal. After completing this process, Deloitte then pruned out non-oil and gas specific subsidiaries to further distill our results to represent oil and gas activities.

Data source:

Data was acquired from a variety of sources including Enigma.io, Google Patents, and Reed Tech. All calculations shown were performed by Deloitte and not a third party.

Endnotes

1. "Generated" is inclusive of patents that the DOE was granted and/or funded.
2. In 1975, the Energy Research and Development Administration was created and served as the predecessor to what is now known as the Department of Energy.
3. DOE Strategic Plan, http://energy.gov/sites/prod/files/2014/04/f14/2014_dept_energy_strategic_plan.pdf.
4. A patent number is a unique identifying number for each granted patent. This number allows patent users to consistently and reliably refer to the same patent as patents can share the same titles, etc.
5. As organization names are not standardized on patents, over 900 misspellings and/or relevant subsidiaries were identified and rolled up to their parent company.
6. If the analysis is limited to the 99 main classes that Deloitte identified as being relevant to the oil and gas space, the rate of usage of DOE patents in those same areas actually rises to 9.5 percent of all industry patents being influenced by DOE.
7. Many of the technology names supplied by the patent office are long and would cloud the diagram.

Contacts

Andrew Slaughter
Executive Director
Deloitte Center for Energy Solutions
Deloitte Services LP
anslaughter@deloitte.com
+1 713 982 3526

Daniel Byler
Manager, Lead Data Scientist
Deloitte Services LP
dbyler@deloitte.com
+1 571 814 7166

Vamsi Krishna
Senior Analyst, Data Scientist
Deloitte Support Services India Pvt. Ltd.
vamsikrishna5@deloitte.com

Anshu Mittal
Executive Manager
Deloitte Support Services India Pvt. Ltd.
ansmittal@deloitte.com

Alok Ranjan
Manager, Data Scientist
Deloitte Support Services India Pvt. Ltd.
alokranjan@deloitte.com

Budd Shaffer
Manager, Deloitte Advisory
Deloitte Transactions and
Business Analytics LLP
bshaffer@deloitte.com

Contributors

Noah Lang
Assistant General Counsel
Deloitte LLP

Ashish Kumar
Senior Analyst
Deloitte Support Services India Pvt. Ltd.

Michael R. Petrillo
Specialist Leader
Deloitte Consulting LLP

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