

Buying a Green Image or Investing in a Green Future?

A thesis in Business Economics

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ABSTRACT

This paper examines the business motives of integrated oil and gas firms with regard to investing in renewable energy research and development. In doing so, five distinct methodologies are employed in examining five distinct facets of the topic. Precedent research is reviewed to determine if consumers are drawn to renewables. Oil industry advertisements are reviewed to ascertain whether renewables are a specific focus. Industry research is used to determine the expected points at which various technologies would reach commercial viability. Annual reports of integrated oil and gas companies are searched for mentions of renewables and related technologies. Finally, patent data is analyzed for patent quality specifically as it relates to renewable energy patents. This paper finds that there is evidence to support the conclusion that integrated oil and gas companies invest in renewable energy on the basis of developing their offerings and maintaining their viability in an increasingly green future.

Keywords: Renewable Energy, Oil and Gas, Business Strategy, Greenwashing

INTRODUCTION

Perhaps no other industry in history has had as much impact on the ways in which humanity secures energy to fuel the world economy as the petroleum industry. That said, such impact comes with negatives and positives. Many of the largest players in this field have well publicized research into renewable energy, but what is the motivation behind that? No prior research has examined this specific question, one that is of critical importance to understand. Policymakers who regulate firms in the oil and gas industry and who will over time impose increasingly strict environmental protections on them must have an idea of how the companies will respond. Consumers should know the drivers of an industry that has a constant impact on their lives and will continue to have influence on them and their descendants for decades to come. Businesses in the industry need to recognize the long term need for change and critically examine how they do, and will, respond to that need. This paper seeks to answer the questions that all of these stakeholders may have about the motives behind renewable energy development.

Such a complex question demands a multifaceted approach to finding an answer. The question has been broken down into five parts, which are the following:

- Are everyday consumers drawn to renewables, such that advertisements focused on them would be economically efficient for a business to produce?
- Do firms in the oil and gas industry specifically advertise their renewable energy research efforts in addition to their general environmental responsibility advertising?
- Are oil and gas companies investing in renewable energy technologies that are relatively close to commercial viability or just those that are “flashy”?
- Do the annual reports of integrated oil and gas firms demonstrate a commitment to renewable energy sources?

- Do the patents filed by oil and gas firms on renewable energy technology suggest that they are completing high value research?

It also should be noted that for the purposes of this paper the research is focused on seven major companies operating in this space, which are ExxonMobil, BP, Shell, Chevron, ConocoPhillips, Phillips Petroleum (now part of ConocoPhillips), and Valero. Each of these questions is addressed with a distinct testing method. At a high level, the methods used in these tests are as follows:

- Review precedent research on consumer preferences for indications of whether they would be drawn to renewables-focused advertising specifically.
- Review advertisements of the selected firms on their websites, youtube, and third party websites.
- Research the commercial viability of major renewable energy technologies by finding their market share, cost relative to non-renewables, rate of cost decline, etc.
- Search the annual reports of the firms included in the research for mentions of keywords relating to renewable energy sources.
- Aggregate citation data on renewable energy patents filed by the firms included in the research in order to ascertain the quality of such patents.

Each of these tests yield intriguing results that point to a conclusion on the topic. Many studies indicate that consumers do indeed value renewable energy and proprietary research indicates that the companies included in the analysis respond to that by frequently focusing their advertisements explicitly on renewables. Review of market research indicates that many of the most popular technologies in this space are fast approaching (or have reached) cost parity with existing energy sources, to the point that very soon renewables will make up a majority of net

power generation capacity added worldwide (Cuming et al.). In response to this, renewables (and in particular biofuels) show a strong presence in financial statements of the companies examined. Furthermore, review of patent citation data shows a clear skew towards those with higher numbers of citations (and thus greater value/quality). Given these factors, it is more likely than not that investment in renewable energy sources is part of a real long-term business strategy to remain relevant in a green energy future.

LITERATURE REVIEW

Existing literature has a few points to state regarding the drivers of renewable energy investment in the oil and gas industry: First, that this industry spends vast sums advertising commitments to renewable energy and environmental responsibility (Motyka and Clinton, 2016). Second, even oil companies do recognize that in the long term the trend is away from petroleum. Third, there is much research that suggests businesses in this space use corporate social responsibility (CSR)¹ as a form of reputational insurance. As such, the current literature seems to indicate that investment in clean energy by petroleum companies is primarily driven by the need to project a positive and “clean” image to the public. This report seeks to find evidence of the true motivation through careful research (with a focus on the United States’s oil industry in order to simplify the research).

It must first be noted that there is little to no research explicitly examining this question. While there is much research on the influence of green advertising in the oil industry, no reports known to the author answer the root question of motivation. There is little doubt that firms in the petroleum industry spend large amounts of money on advertising their green energy investments

¹ For the purposes of this report, CSR will be defined as a self-regulatory mechanism whereby a business monitors and ensures its active compliance with the spirit of the law, ethical standards and national or international norms. (“Corporate Social Responsibility.” Wikipedia. Accessed November 13, 2015. https://en.wikipedia.org/wiki/Corporate_social_responsibility.)

and environmental stewardship efforts. This goes back to at least the 1960s, when the ascension of environmentalism in the U.S. first motivated firms to advertise their commitments (Hoffman 1995). In recent years concerns surrounding global warming have made this a much larger part of petroleum advertising budgets. A well known recent example is BP's "Beyond Petroleum" advertising campaign, which ran from 2002 - 2008 and sought to publicize the firm's emphasis on environmental stewardship (both green energy and environmentally safe operations). The campaign launched with a budget of \$200 million and involved a full rebrand of the company, including a brand new "Helios" motif for their logo (Barrage and Chyn 2014). Most other oil majors (Exxon, Shell, etc.) also have at least some level of advertising focused on environmental responsibility.

This is not without good reason. There are a number of studies available that show consumers are increasingly valuing renewable energy at a premium to conventional sources. Mozumder, Marathe, and Vasquez find that consumers in the southwest U.S. (which has some of the most abundant access to solar energy of anywhere in the country) are willing to pay on average 35% more for electricity per month when the share of that power that is from renewables is raised from 10% to 20%. We see a similar phenomenon in auto fuels. A recent study found that the consumer demand for E-85 auto fuel (85% bio-ethanol and 15% gasoline) is significantly more price inelastic than demand for E-10 (10% bio-ethanol and 90% gasoline) largely due to strong preferences for E-85 but little to no preference for E-10 over straight gasoline (Petrolia 2009). Recognizing these trends, firms in the energy industry must respond to consumer preferences in their products and advertising.

That said, this drive goes beyond consumers alone. As fossil fuel reserves become increasingly difficult to extract and the environmental regulatory climate becomes more

restrictive, renewables and other alternative sources of energy will become more important in the future (BP Energy Outlook 2030, 2013). As any prudent business would, these firms are constantly looking for the latest trends with the objective of determining which ones make the best investments (Douglass 2005). That said, they are also very aware of the limitations of these new technologies. Most projections agree that the majority of growth in energy use over the next 15 years will still come from fossil fuels, limiting the motivation to invest in this space (Global Trends 2025: A Transformed World, AICPA 2008). Besides being as yet often unproven on a large scale, expensive, unreliable, etc. there are substantial structural barriers to the growth of alternative energy sources in a world built for the status quo (Energy Vision 2013 - Energy Transitions: Past and Future, 2013). Oil majors are well aware of this. At this point, the share of energy industry R&D and Capex spent on renewable and/or alternative energy sources is only about .7% (Cuming, Mills, Strahan, Boyle, Stopforth, Latimer, Becker 2015) (Ro 2014). Clearly we have not reached a point in history where this industry is ready to embrace investment in renewables.

However, based on advertising you might not realize that is the case. Studies have shown that people often expect the companies they transact with to be involved in some level of CSR (Rethinking Corporate Social Responsibility, 2007). There are clear benefits to this. In the case of the “Beyond Petroleum” campaign described above, it has been shown that areas where the campaign was more intensive saw significantly less negative of an impact on the company from the Deepwater Horizon oil spill and the subsequent ecological crisis in the gulf (Barrage et al. 2014). This benefit can even be pursued and realized ex post facto, as evidenced by the conclusion of study that found that in the aftermath of a negative publicity event businesses tend to raise their investment in CSR (Kotchen, Moon 2012).

All this said, the businesses in question cannot really be blamed. As described by Cherry and Sneirson in their own case study of the Deepwater Horizon disaster, corporate law (particularly in the United States) dictates that CSR can move beyond purely utilitarian goals in only limited ways. There is a substantial body of case precedent in U.S. courts that establishes the primacy of fiduciary duty of the managers of a business as their guiding directive. As such, it is by nature that businesses must pursue profit and growth above all else (Cherry, Snierson 2011). While we know with the benefit of hindsight that the decision of BP to cut corners in their operations (letting worker safety, environmental protection, and caution in drilling fall by the wayside) was a mistake, it is also true that at the time their rebranding as a “green” company while pursuing successful wells and taking great risks was profitable. Minor and Morgan even lay out a specific model for how effectively deployed and publicized CSR can function as reputational insurance, and this is exactly what BP accomplished (Minor, Morgan).

In sum, the present literature on this subject suggests a number of key ideas. First, that much effort is spent by the petroleum industry on advertising commitments to renewable energy and environmental responsibility. No other industry puts so much effort and capital to work here. Second, that these firms understand that the world is in the midst of a gradual shift towards a greater role for renewable energy sources. Leadership in this space will require substantial research and development over many years. However, there is a broad array of research that points to CSR in this industry as being largely a way of insuring the firm against the risk of negative impacts on public image stemming from industrial accidents. As such, the current literature seems to indicate that investment in clean energy by petroleum companies is primarily driven by the need to project a positive and “clean” image to the public.

SIGNIFICANCE

Energy and in particular oil and gas are by their very nature worldwide industries that have huge impacts (social, economic, environmental, etc.) everywhere they operate. This is particularly true here in the United States, where we have the luxury of considering not only whether there is gas in our cars and electricity in our homes but also the implications of the industry that provides these services (among others). The focus on the motivations of the businesses that operate in this field in their investments in renewable energy stands at the intersection of the country's energy future and the industry (and societal) dynamics that will get us there. As such, the applicability is fairly broad. That said, the value of this research is not so much in changing the way oil and gas firms do business but more in examining how they prefer to present themselves to the world and what this says about the true drivers of the industry.

At this point there is very little literature that addresses the specific question addressed by this report; rather the precedent literature tends to examine tangential topics that are related to the question of motivations more broadly. As such, this report is uniquely positioned to provide useful input on this discussion. By adding new thoughts and research to the body of knowledge already existing it should be possible to stimulate thought on both academic and industrial sides as to what truly drives the industry.

METHODOLOGY

Part 1

The first key aspect examined is on the consumer side: are consumers drawn to renewable energy in particular, or just a general “green” image? In order to answer this question, precedent research on consumer preferences for renewable energy as they relate to general attitudes, willingness to pay, etc. is reviewed. If it can be shown that the consumers are fairly indifferent, it would not make sense that petroleum companies would pursue R&D in renewables instead of

simpler/cheaper “green” efforts, like cleaning up waterways or reducing environmental impact of existing oil drilling and distribution.

Part 2

The second key point to examine is whether petroleum companies advertising their environmental stewardship are seeking to be known as “green” in general or if they explicitly focus on renewable energy. The lack of a complete database of all advertisement put out by these companies makes a truly quantitative study here difficult if not impossible. Instead, a qualitative assessment of the frequency of such ads was conducted via web searches, YouTube searches, and browsing both the company sites and third party sites featuring their advertising copy. This test is relatively rudimentary, though it fills the purpose of determining if explicit advertisements of these types are common.

Part 3

Third, market research on major renewable energy technologies (solar, geothermal, wind, biofuels, etc.) is reviewed to determine the expected length of time to commercial viability and the degree to which each technology is favored by integrated oil and gas firms for their own investments. This shows if the ones that are closer to commercial viability get more investment. If they do, then that would suggest that petroleum companies are indeed trying to invest in these technologies for the purposes of strengthening their business in the future. Otherwise, they may just be selecting the technologies that are relatively more “flashy” to get better returns in terms of building a green image.

Part 4

Fourth, annual and quarterly reports of the largest oil companies are examined for mentions of their renewable energy strategy by searching for the terms “wind”, “solar”,

“biofuel”, or “renewable energy” (and derivatives thereof). This provides insight in terms of what has driven the initiation and growth of renewable energy investment policies. In addition to the terms themselves, the statements are examined for any details regarding the renewables strategies of these firms in order to potentially illuminate motivations. Such research is useful in determining if the stated strategy and foci of the company match with what they advertise. This serves essentially as a check on the objectives of the business by seeing if they have a fully formed renewables strategy and if that makes sense in context of what they invest in (“Are they putting their money where their mouths are?”).

Part 5

The final test concerned data on renewable energy patents filed by the companies studied. Data sets containing all citations of U.S. patents, all assignees of U.S. patents, all U.S. patent numbers, and all patent classification codes of U.S. patents were obtained. The citation files were used to count the number of citations of each individual patent. The file containing the number of citations was then truncated to include only patents relating to renewable energy (the US Patent Classification codes used in this step are shown in figure 10). Finally, that file was truncated to include only patents listing one of the integrated oil and gas companies examined in this research. This resulted in an end product of a spreadsheet listing the number of citations for every patent filed by one of the included firms that related to renewable energy, in addition to a spreadsheet listing every other patent filed by these firms for the purpose of comparison. Using precedent research on the relationship between number of citations and patent quality, this data could then be employed to measure the quality of each listed patent. This enabled the determination of the quality of renewable energy patents filed by oil and gas firms relative to patents they filed on non-renewable technologies.

RESULTS

There is very wide swath of precedent research that suggests that consumers do indeed care about the proportion of their energy that comes from renewable sources (Murakami, Ida, Tanaka, Friedman, 2015). Particularly in recent years as concerns regarding climate change have become more widespread and consumers have become better informed about where their energy comes from, renewables as an issue have come to the forefront in terms of energy concerns. In a recent national survey conducted by the National Renewable Energy Laboratory, 80 percent of those surveyed stated that they cared about renewable energy (Bird, Sumner 2011). This result is all the more striking when one considers that another recent poll found only 70% of Americans believe the Earth's climate is changing and only 27% believe humans are responsible for such changes. Caring about renewable energy has gone beyond the realm of the environmentally concerned and conscious; it is, in fact, fashionable to be renewable. This is further supported by other studies suggesting that in certain cases consumers are willing to pay more for energy that is sourced from renewables. A study conducted in the southwest US found that power consumers would pay 35% more for electricity when the share of renewable energy, such as solar, was raised from 10% to 20% (Mozumder et al., 2011). A second study found that there is a statistically significant difference in elasticity of demand for E-10 (standard gasoline that is 10% ethanol) and E-85 (gasoline that is 85% ethanol), with E-85 being much more price inelastic due to preference for it (Petrolia, Bhattacharjee, Hudson, Herndon 2009). As such, it clearly is in the interest of integrated oil and gas companies to tailor their advertising to these preferences in order to appeal to their customers.

With that in mind, it should come as no surprise that these firms do just that. While the lack of a unified database of all advertising published by these firms makes quantifying the total

spending on a given type of ad (ex. renewables-focused) difficult if not impossible, it is very easy to find examples of renewable energy advertising from the firms included in this study. A few such examples are shown in figures 1 - 5. All of these (and many others besides) show a clear focus on the renewable energy sides to these businesses, be that in terms of research and development or the actual products produced by the firms today. It is clear from these advertisements that these companies are actively seeking to be known for their commitments to renewables, whether or not such technologies are actually a core part of the business. As previously established, consumers care about these issues so it is entirely sensible for firms to play to those preferences as a factor in efforts to gain market share. Furthermore, studies have shown that regularly undertaking CSR efforts and making them known to the public can be a highly effective method of mitigating reputational damage in the case of an accident (ex. An oil spill) (Kotchen, Moon 2012). Perhaps the most extreme example of this is BP. From 2000 - 2008 the company undertook a \$200MM advertising campaign entitled “Beyond Petroleum”, which sought to rebrand the company as green. The campaign was a great success, though shortly after it was completed the Deepwater Horizon oil rig (contracted by BP at the time) exploded and sank in the Gulf of Mexico in 2010. This resulted in the largest accidental oil spill in history and massive reputational damage for BP. Despite this, a study found that after the spill there was a significant reduction in the loss of revenue for BP gasoline stations in areas that saw more “Beyond Petroleum” advertising (Cherry and Snierson, 2011). Even after one of the most severe disasters ever to face an oil company, simple advertising was able to block some of the damage. Given consumer preferences and the insurance to reputational damage this advertising supplies, it is no surprise that large oil and gas firms would seek to look environmentally conscious in the

eyes of consumers (a practice generally referred to as “green-washing”). However, is that the only motivation?

It can be shown that the cost of renewable energy sources is an increasingly insignificant reason not to pursue them. As such, the argument that large oil and gas firms would not pursue R&D in this area for reasons other than green-washing due to the costs of such alternative energy sources is weak and weakening. At the utility level, renewables made up 48% of net capacity added in the past year (this statistic refers to power generation capacity added beyond that needed to replace retired capacity). Economically, this is to be expected. The cost of building wind power onshore has fallen 11% in the past five and a half years and is now on par with coal and nuclear in locations with favorable weather. Solar remains about 50% more costly than any of those sources, though in that same 5.5 year period the cost of utility scale solar has fallen by 59%. It thus seems likely that the cost of solar will fall to parity with conventional power sources in the next few years (Cuming et al. 2015). The story is even more striking for biofuels. As of now, 13.825 billion gallons of ethanol are produced every year in the U.S. alone at a cost of about 78 cents per gallon. This is substantially below the retail price of gasoline, thus suggesting that such production earns healthy profits for the companies involved. Shell, for example, produces nine billion liters of ethanol for blending into gasoline every year. As a result of these strong economics, while transportation fuel use is expected to grow 1.1% per year through 2040, use of biofuels is expected to grow by 3.7% per year over the same period (Gokianluy 2014). Based on all these factors, it can be reasonably stated that is not uneconomic for businesses in the oil and gas industries to pursue expertise in these areas (or at least it will cease to be in the near future).

Given that it can make economic sense to pursue these technologies, it must next be established that firms operating in this space do in fact seek to build a presence in renewables and that their activities directed at that goal are effective in generating valuable expertise. That these firms are actively involved in these technologies was determined based on mentions in annual financial statements, as described in the methodology section. The results of this examination are shown in figures 6 - 9 for selection of firms that showed interesting results (BP, Shell, Chevron, and Valero). There are a number of points to note here. Most notably, all of the firms except Valero have shifted emphasis away from efforts relating to solar power (Valero never mentioned it at all). This suggests that if anything the drivers of investment in renewables by these firms have become more purely economic over time. None of them have any real competency in solar power, but they are well-equipped to handle liquid fuels. As such, the shift of emphasis towards biofuels makes perfect sense in the context of these businesses. This is particularly the case for Valero, which as a purely downstream (refining and retailing) firm must work with biofuels as a major part of their business due to the Renewable Fuels Mandate (a US program that requires a certain proportion of ethanol be mixed into gasoline). A further underscore to the hypothesis that the shift away from solar represents more realistic business choices based on economics is that in order to pay for the *Deepwater Horizon* settlement BP sold off their solar power operation. It was a non-core business in which they have no pre-existing competencies; the same is not true of the biofuels operation. Based on this analysis the emphases in the financial statements of the businesses examined suggest that there are real business motivations behind renewables investments rather than simple concerns of green-washing.

This conclusion is further underscored by the portfolios of renewable energy patents filed by the firms included in this research. The plot shown in figure 13 was generated by calculating

what proportion of a firm's patents fell in each "bucket" of citations on a histogram and then finding the differences between those proportions as calculated for renewables-related patents and patents not related to renewables. As shown, there is a very clear skew towards renewable energy patents filed by these firms having relatively more citations than patents not relating to renewables. This is very important result. In a study conducted at UC Berkeley it was found that on average each additional citation represented an increase in the value of the patent by 3% (Hall, Jaffe, Trajtenberg 2005). As such, this analysis that suggests the renewables-related patents of large oil and gas firms generally have a larger number of citations indicates these patents are generally of greater value. If research and development efforts in this area were focused on generating expertise and intellectual property that would help these businesses remain relevant in a green future, one would expect that the research pursued would be in depth, high value, and patentable. Indeed, this is exactly what is suggested by the data presented.

CONCLUSION

Understanding the business motives that drive some of the largest and most influential companies of the modern era is clearly important. That said, it is even more critical when considering the motives that direct their commitments to the green energy future that the peoples of the world generally agree must be reached for the good of mankind. Anyone from the highest policymaker to the smallest consumer should know the forces that direct these businesses. Through a series of interconnected analyses, this paper finds that the investments of large oil and gas companies in renewable energy sources are likely driven by motivations more core to the business than simple greenwashing. Instead, they are driven by a real recognition that the world of the future will be driven by rising costs and regulation to be increasingly reliant on renewable sources of energy. While oil and gas companies do advertise their commitments to renewables to

gain public goodwill today, the commitments themselves are real. This is clear from the prominence of such programs in annual reports and particularly from the relatively high value of the patents filed in this space. Without building expertise in renewables now, these companies will fade into history as their fossil fuel products are regulated out of existence (similar to the phenomenon taking place with coal today). As was stated by the President of Shell US at a recent talk delivered at Penn's Kleinman Center for Energy Policy, Shell (and likely other large oil and gas firms) recognizes that today it is an oil and gas company, and that in order to stay relevant it must become an energy company providing not only fossil fuels specifically but rather providing energy for a new world. Renewables are the future and even the largest players in oil and gas know that is the case. With such influential players on board, the world can be confident that such a future will be reached.

AREAS FOR FURTHER STUDY

There are a few expansions of this research that could yield intriguing results. First, this paper generally focused on examining the states of these businesses as they are today, rather than considering how their motives changed over time (with the exception of the review of financial statements). As such, expanding this analysis to prior years could illuminate how the degree to which investment in renewables is a decision based on the need to remain relevant in a green future has changed over time. It is worth noting that the analysis of financial statements did find that these firms have shifted away from emphasis on solar energy in recent years, which may indicate a shift away from investments that were not expected to have long term value to the firm other than in terms of improved image. Therefore, it could be hypothesized that greenwashing was a more prevalent motive in the past.

Another potential area for deeper examination could be what exactly drives the choice of field of renewables in which to focus. In general, it is easier for oil and gas firms to integrate biofuels into their existing business since the addition of ethanol to gasoline is simply one extra step in gasoline production. Even so, there is evidence for some variation among the companies examined in terms of how this decision is made. The financial statement analysis showed that Valero has only ever emphasized biofuels, while Shell, BP, and Chevron have all at some point invested in other fields such as solar energy. Finding out in greater detail what exactly drives these differences could add some interesting color to the analysis presented in this paper.

TABLES AND FIGURES

Biofuels, solar,
hydrogen, natural
gas. We think it's
important to
diversify, too.

Building a diverse portfolio is one way we're investing in the new energy future. Over the last 5 years, we've invested \$30 billion in U.S. energy supplies, like cleaner burning natural gas. We're investing up to \$8 billion over ten years in solar, wind, natural gas and hydrogen to provide low carbon electricity. And, we're expanding our longtime involvement in biofuels, investing \$500 million to bring the next generation of biofuels to market. It's a start.



beyond petroleum®

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bp.com

Figure 1: BP renewable energy advertisement



Figure 2: Shell biofuels-focused advertisement

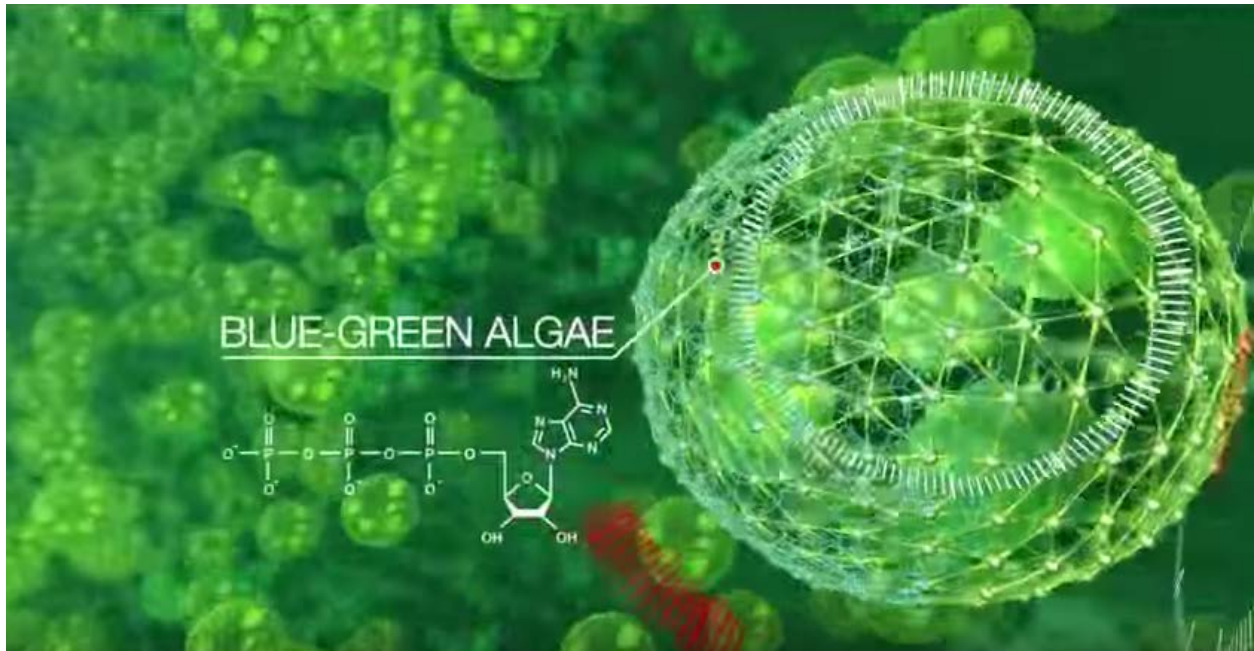


Figure 3: Screenshot from ExxonMobil algal biofuels advertisement



Figure 4: Valero biofuels-focused advertisement

Friday, October 4, 2013 The Bakersfield Californian 21



OIL AND AGRICULTURE --- CAN GROW --- TOGETHER.

WE AGREE.

Ronald C. Phillips
Ronald C. Phillips, CEO
Chevron Energy Services International

Donald E. Meyer
Donald E. Meyer, Chairman
California Farm Bureau Federation


We've been proving it right here in Kern County. For years, Chevron has been recycling the water that's produced during our oil recovery process to provide area farmers with a reliable source of clean, local water. Every day we deliver around 20 million gallons to Kern County's farms, which helps them grow produce that's exported all around the globe. We're helping our agriculture industry thrive. And showing how much we can accomplish when we work together. Watch the video at chevron.com/EnergyAndOranges



Figure 5: Chevron biofuels-focused advertisement

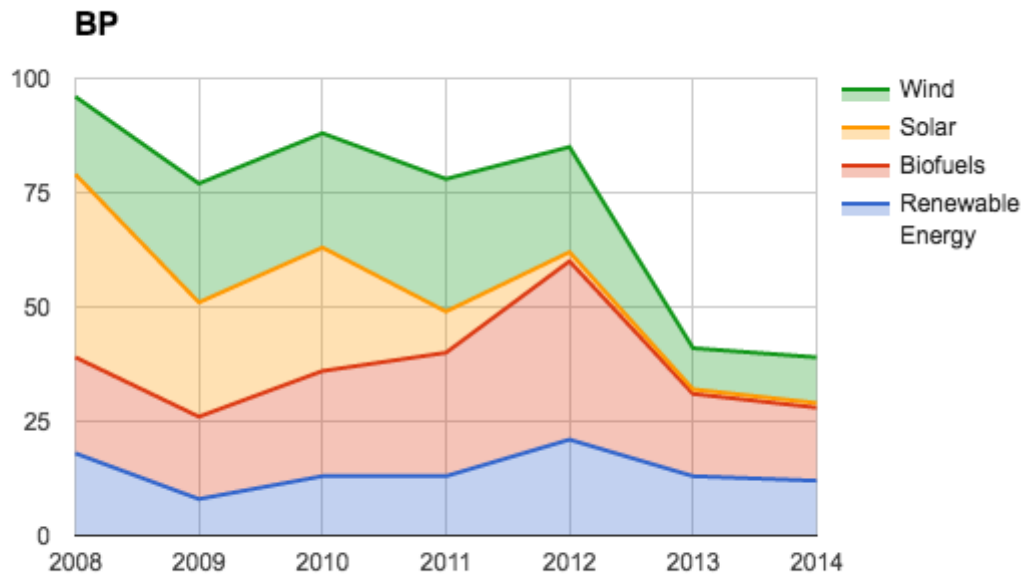


Figure 6: Annual report mentions of renewable energy keywords for BP

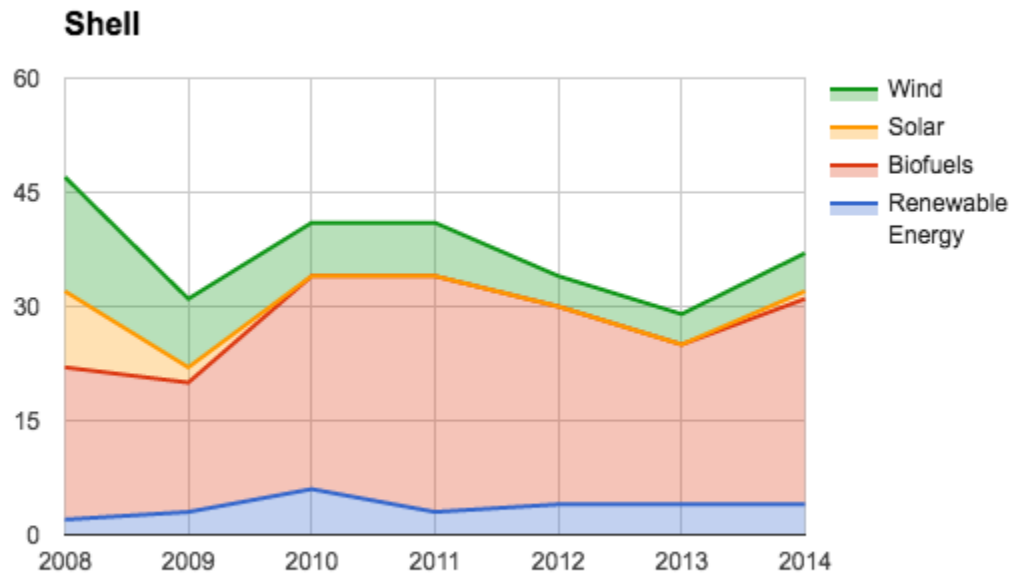


Figure 7: Annual report mentions of renewable energy keywords for Shell

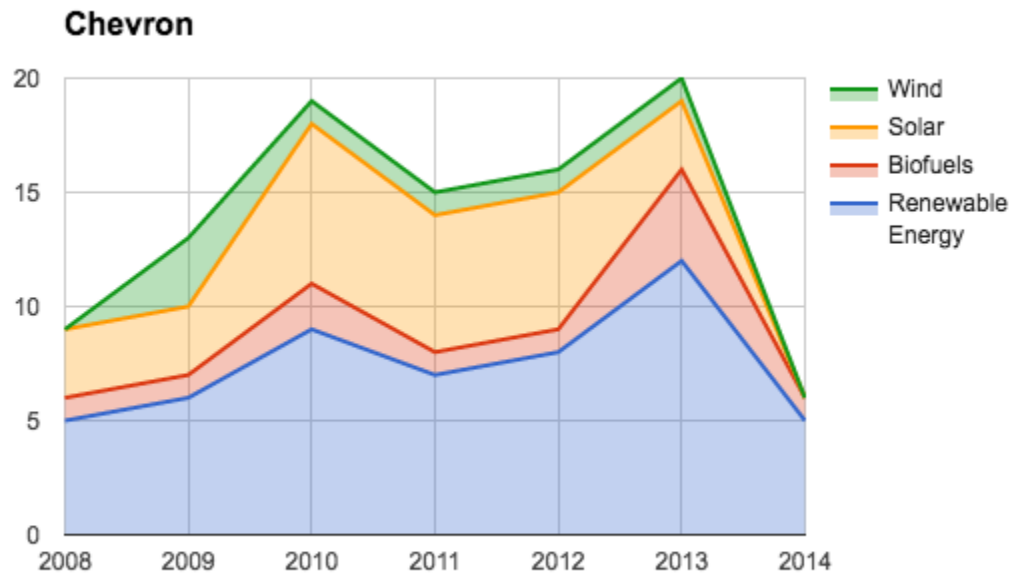


Figure 8: Annual report mentions of renewable energy keywords for Chevron

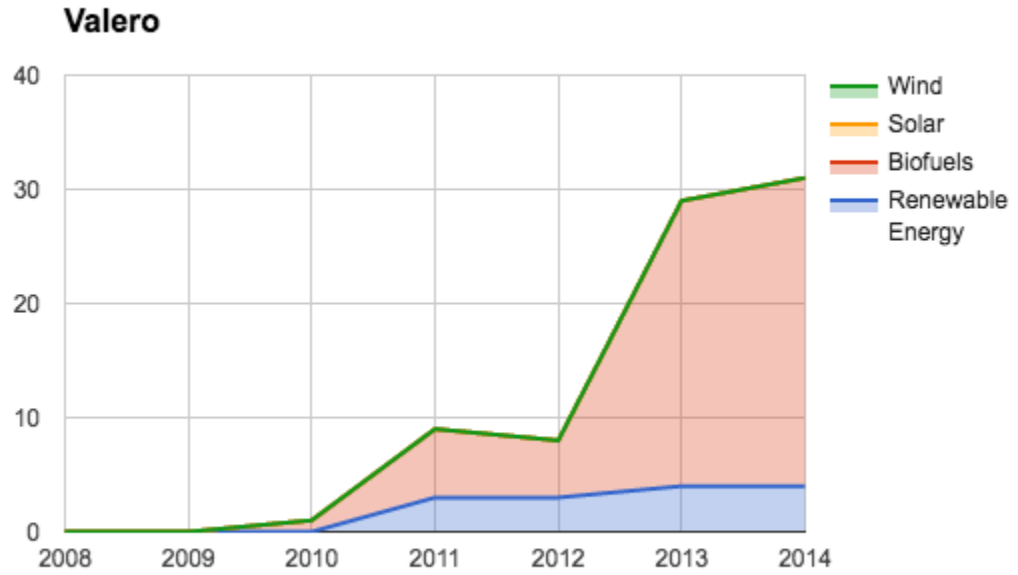


Figure 9: Annual report mentions of renewable energy keywords for Valero

Alternative Energy Sources	USPC Mainclass	USPC Subclass
Agricultural Waste	44	589
Biofuel	44	605, 589
Chemical waste	110	All
For domestic hot water systems	126	All
For passive space heating	52	All
For swimming pools	126	All
Fuel cell	429	All
Fuel from animal waste and crop residues	44	All
Gasification	48	All
Genetically engineered organisms	435	All
Geothermal	60	641.2-641.5
Geothermal	436	25-33
Energy from man-made waste	75	958
Energy from man-made waste	431	5
Hospital Waste	110	All
Hydroelectric	405	All
Industrial waste	110	All
Anaerobic digestion of industrial waste	210	All

Alternative Energy Sources	USPC Mainclass	USPC Subclass
Industrial wood waste	44	All
Inertial (ex. turbine)	290	51,54
Inertial (ex. turbine)	60	495-507
Landfill gas	431	5
Municipal waste	44	552
Nuclear power (induced nuclear reactions)	376	All
Nuclear power (reaction motor)	60	203.1
Nuclear power (heating motive fluid)	60	644.1
Photovoltaic	136	243-265
Refuse-derived fuel	44	552
Solar cells	438	57, 82, 84, 85, 86, 90, 93, 94, 96, 97
Solar energy	126	561-714
Solar energy	320	101
Solar thermal energy	126	561-713
Solar thermal energy	60	641.08-641.15
Water level	405	76-78
Water level	60	495-507
Wind	290	44, 55
Wind	307	64-66, 82-87
Wind	415	2.1

Figure 10: Selected US Patent Classification (USPC) classes for renewable energy-related patents (USPTO 2009)

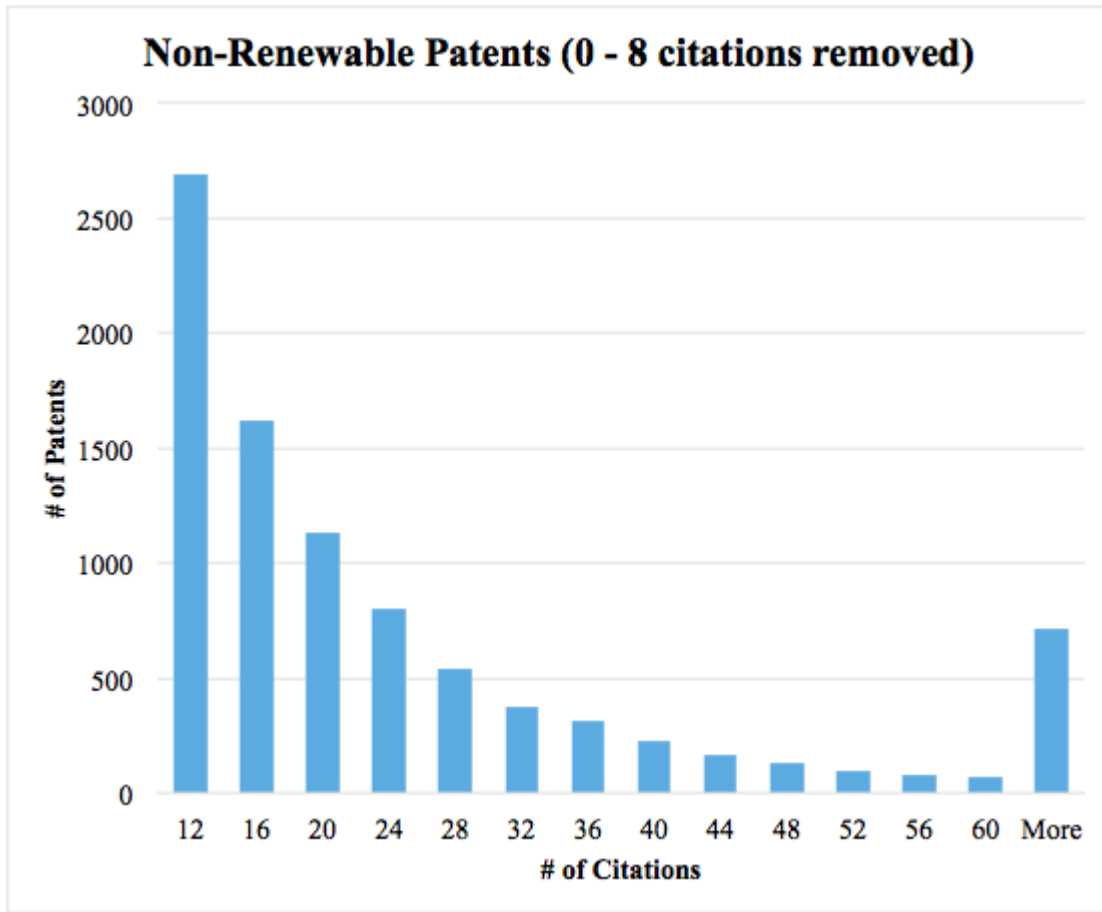


Figure 11: Histogram of number of patent citations for patents not related to renewable energy sources

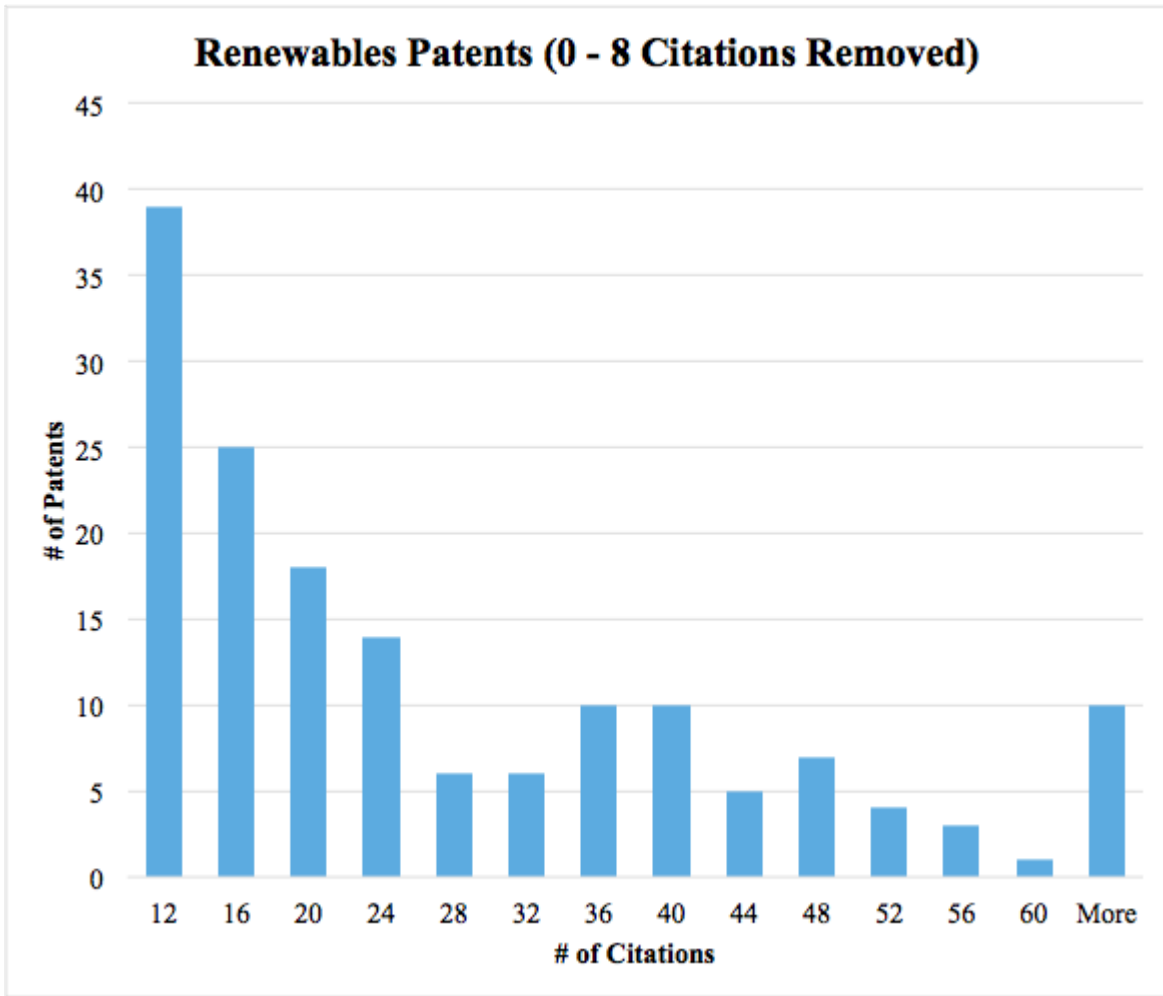


Figure 12: Histogram of number of patent citations for patents related to renewable energy sources

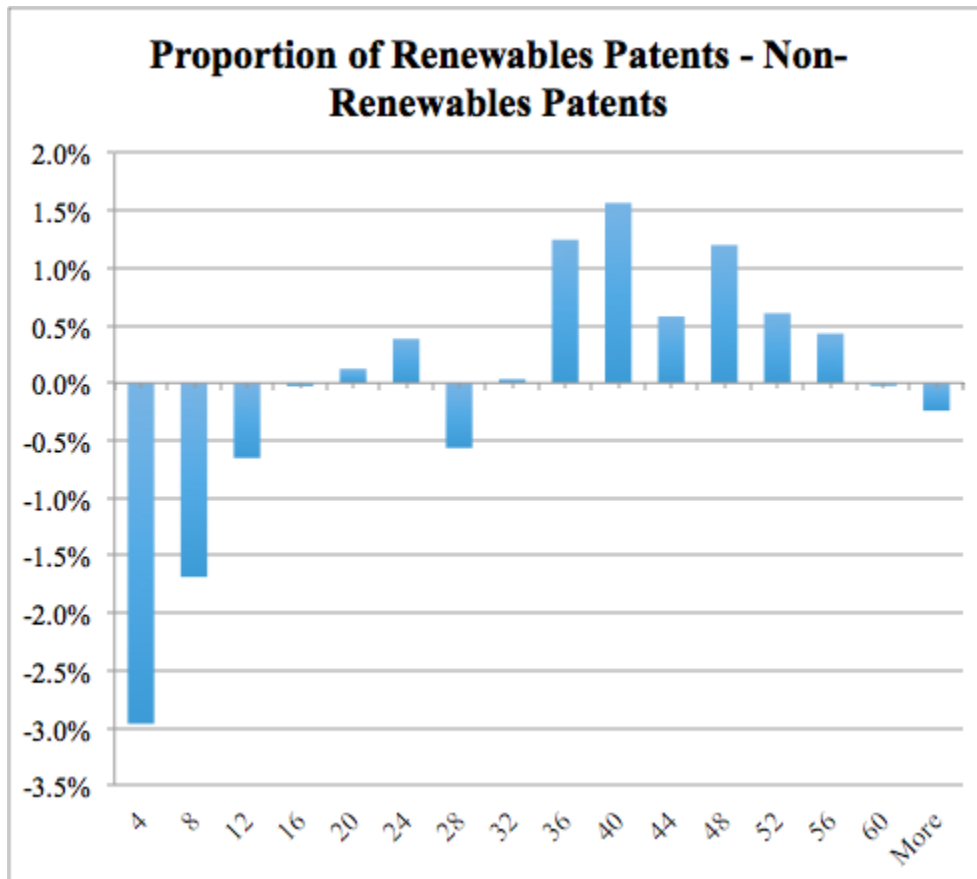


Figure 13: Histogram of differences between proportion of renewables patents in each histogram range and proportion of non-renewables patents in each histogram range

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