USPTO Project

Solar Technology Patents since 1973

Team #1: R. Jentoft-Valenzuela, D. Nordstrom & T. Shirk

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Introduction

Although Arizona might not be known as the sunshine state, (that distinction is held by Florida) there are more sunny/clear days in Arizona in an average year than any other state in the United States, according to the National Weather Service. In fact, Arizona’s city of Yuma sees the sun 90% of the year (USA Today, 2004). Arizona’s weather conditions, along with much of the western United States, make it an optimal place for solar energy to be harnessed through the use of solar energy systems. Solar technology has a long history in the United States with the first solar hot water heater having been patented in 1891, the first photovoltaic (PV) solar cells capable of running everyday electrical equipment having been created in the 1950’s and NASA having used PV solar technology as an energy source for its space applications as early as the late 1950’s (U.S. DOE, 2009). After the 1973 Arab Oil Embargo, working to free the United States from dependency on fossil fuels from the evil oil cartel became an act of patriotism. By 1975, over five thousand had made grant inquiries regarding solar technology and a year later over three thousand new solar firms had been incorporated from an eclectic group of engineers, anti-nuclear organizers and energy techies. In 1978, 94 percent of Americans favored the rapid deployment of solar technology (Berman, 1996). This was the same year that President Carter held the infamous press conference atop the White House roof (see Figure 1) symbolically unveiling the recently installed solar panels and his ambitious new energy policies, where he declared a goal of 20 percent solar energy production by the year 2000 (Laird, 2007).

The United States is still far from Carter’s 1978 goal. According to the Energy Information Administration (EIA), solar energy makes up less than one percent of the total energy powering the United States (EIA, 2009). This project seeks to map out the solar industry trends from the 1973 Arab Oil Embargo to present day based on solar technology patents filed with the United States Patent and Trade Office (USPTO) during this time frame. Of particular interest to us, is the influence of the executive branch of government on the U.S. solar industry throughout this era. Has there been a strong correlation between the political party (Democrat or Republican) serving in the executive branch of government and the solar industry represented by patent growth?
Literature Review

Two different types of literature were reviewed. Literature on the technical aspects of solar technology was necessary in order to gain a better understanding of the types of solar technology that would be considered to be within the scope of our project. O’Connor’s “101 Patented Solar Energy Uses” depicts the enormous range of solar technology. A liberal view of solar technology can range from architectural designs in solar space heating and cooling to using solar energy in the process of the desalination of sea water (O’Connor, 1981). However, for the scope of this project, the focus is on the three core solar technology categories most conducive to power production: solar heaters, photovoltaics and solar concentrators. Solar heaters are the oldest of the three technology types. A central piece of a solar heater is a solar collector, which gathers solar energy from the sun, transforms the radiation into heat and then transfers the heat into fluid or air (U.S. DOE, 2009). Solar water heating is the main type of solar heating and has been used in the United States as early as the 1920’s, especially in California and Florida (Berman, 1996). Photovoltaics convert sunlight directly into electricity using semiconductor materials like crystalline silicon. They are also commonly referred to as solar cells. The electricity generated from PV system can be used for a diversity of functionality including pumping water, charging batteries or supplying power into the energy grid. Concentrating Solar Power (CSP) technologies use mirrors to concentrate sunlight on a fluid. This fluid reaches a high-temperature and is used to power an engine or turbine that produces electricity. CSP technologies are a utility-scale option for producing electricity via CSP plants or solar farms. (U.S. DOE, 2009).

Secondly, literature on energy policy from 1973 to the present was necessary in order to determine which energy policy various U.S. administrations and foreign countries had over this time period. It wasn’t until the early 1970s that a centralized energy agency was created within the executive branch of government. Before this, small energy agencies were never able to achieve a mandate and therefore had no real power to promote change in U.S. energy policy. The only solar energy technology being promoted at that time was merely for niche markets, such as for space exploration under NASA (Laird, 2007). Under the Carter Administration, the Department of Energy was created in 1977 and the Solar Energy Domestic Policy Review (DPR) was initiated in 1978. The DPR was a comprehensive review of policies for renewable energy conducted by multiple agencies including the DOE and led to new policy initiatives that included solar energy subsidies and residential and business tax credits. However, Carter was not able to change the official framing of the energy problem. Carter’s administration cited national security, economic growth and a market-based democratic society as primary reasons for their shift in
energy policy. Environmental concerns were secondary in their framing. The environmentalist movement at this time also failed to frame the problem correctly by combing their visions of social transformation (universal healthcare, racial and social equality, comprehensive sex education, etc.), with their environmentalist motivations. Figure 2 is a poster that demonstrates this desire for social transformation. This miscellaneous political problem framing alienated them and their cause from most mainstream Americans and infuriated the conservatives (Laird, 2007). This failure to reframe the energy problem provided Reagan with much more political leverage to roll back Carter’s initiatives. Much of Carter’s energy policy was dismantled during Reagan’s eight years in office. Reagan didn’t see a need for energy policy beyond oil reserves and militarily controlling the Middle East. Federal funding for renewable energy fell from $124 million in 1980 to $59 million in 1982. Reagan allowed the solar energy tax incentives to expire in 1985. He even attempted, but failed, to eliminate the DOE (Miller, 1995). As a result of Reagan’s policies and lack of financial support, many renewable energy firms that started out in the 1970s went out of business in the 1980s. These companies and their technologies were purchased by Japanese companies (Hegedus, 2003). Bush Sr. carried on Reagan’s energy policy, but unlike Reagan he was affected by the Gulf War in the Middle East in 1991, which caused oil prices to rise. After the Gulf War, Bush Sr. increased funding for renewable research and development. Under the Clinton administration, a scientific consensus on climate change placed more pressure on policy makers to create energy policies involving renewable energy (Laird, 2007). In the early 1990s both Japanese and German governments invested heavily to develop and deploy solar technology in their countries. The German PV industry began in 1991 with the government’s “1000 roofs program”. German is now the world leader in PV manufacturing and installation. In 1993, the public concern for global warming and high energy prices led Japan to start the “New Sunshine Project”. PV systems have been installed on 500,000 Japanese homes and PV solar electricity is now competitive with Japanese domestic electricity rates (Soaking Up the Sun, 2009). A consensus on global warming has helped lead to a reframing of the energy problem within the United States as well. Even the environmentally unfriendly Bush administration found it necessary to include environmental discourse in their framing of energy policies. This shift led Bush Jr.’s very conservative administration to propose modest funding increases to renewable energy research and development as well (Laird, 2007).
From our Literature Review, we hypothesize that the centralization of energy agencies with the executive branch in the 1970s coupled by the energy crisis will lead to a steady increase in solar technology patents being filed. Under the Carter Administration, solar technology patent filing will increase dramatically. However, the Reagan era energy policy will have a negative effect on the solar patent industry and a dramatic decrease in patent filing will occur up until the first Gulf War. During this time period, however, foreign patents from Germany and Japan will continue to steadily increase as German and Japanese institutions will take advantage of their country’s different energy policies. Both Japan and Germany’s patent filing will increase during the 1990s when their countries begin their national programs in support of PV development and deployment. An increase in U.S. patents filed will also take place under the Democratic Clinton administration, which will be sparked in part by policy and in part by the environmentalist movement and reframing of the energy problem. A predicted decrease or stagnation of solar technology patents being filed under Bush Jr., however it will not compare to previous Republican administrations (Reagan and Bush Sr.) because of the energy problem having been reframed and the extra environmental pressure applied to policy makers.

**Methodology**

Our research methodology consisted of six parts. First, we needed to gather our solar technology keywords, which we would use to spider the USPTO database and extract relevant solar technology patents. The process of gathering our keywords was partially covered in the Literature Review. We referenced literature on solar technology in order gain an overview of the applicable industry technologies. Three solar technology categories were selected for the scope of our project. The technologies within these categories were repeatedly cited in the literature (Anderson, 1982; McVeigh, 1983; U.S. DOE, 2009) as solar technologies having the most impact on providing viable energy alternatives to fossil fuels. Using glossaries and controlled vocabularies from our resources, we developed a set of keywords we felt would provide us with a relevant collection of solar technology patents. Engineering librarian, Maliaca Oxnam, helped to confirm the selection of our keywords by offering her expert knowledge of engineering, technology and patents. Our initial set of keywords consisted of both broad terms (i.e. photovoltaic, solar thermal) and narrow terms (i.e. homojunction, heliostat, flat-plate). Since this initial extraction would spider the full content of the patent, we decided that the term “solar” would be too broad and would result in excessive noise. We therefore included a variety of keywords that included the term solar, but would further narrow the results from the
extraction (i.e. solar power, solar energy, solar cell). The more technical terms were included in the extraction based on advice from Maliaca Oxnam. She warned us of the extreme technical language used in many of the patents. Had we not included these technical terms, we risked missing many of the relevant patents. See Figure 4 for an example of the keywords used during this part of the process.

Secondly, we performed the data extraction by utilizing the tools provided to us by our Teacher Assistant, Mandy Dang. We ran a Perl script that included our keywords to retrieve the relevant patent numbers. These patent numbers were then filtered using Excel to eliminate any duplicates. Another Perl script was used to retrieve the patent content in the form of an HTML file for each of the unique patent numbers. A Java program parsed the data within the HTML files and provided us with an output of tab delimited TXT files, which we could enter into our database.

Thirdly, we created our database. A MySQL database management system was used to house the extracted patent data. We used an open source web platform called MAMP (acronym standing for Mac OS X, Apache, MySQL & PHP) to interface with our database. We created the necessary tables and fields in the database, then proceeded to import the tab delimited TXT files into the appropriate tables. Below is a screenshot of our database as depicted using MAMP.

Fourthly, we filtered out irrelevant patents by running a SQL query in the patent abstract field using our keywords. Since we were limiting our search to only the patent abstract, we used the broadest term “solar” as a key word instead of the keywords meant to limit the return of noise from the patent extraction. This was the only difference in our keyword list used for this data cleaning and the list used
for the data extraction. The table below provides an example of the difference between the two lists with keywords used in our project. Initially we extracted 46,000 patents. However, after we purged the data of irrelevant patents using the SQL query, we were left with close to 8,000.

<table>
<thead>
<tr>
<th>Keyword Examples for Data Extraction (All Fields in Patent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• solar power</td>
</tr>
<tr>
<td>• solar energy</td>
</tr>
<tr>
<td>• solar cell</td>
</tr>
<tr>
<td>• solar collector</td>
</tr>
<tr>
<td>• %photovoltaic%</td>
</tr>
<tr>
<td>• hetero-junction</td>
</tr>
<tr>
<td>• homo-junction</td>
</tr>
<tr>
<td>• multi-junction</td>
</tr>
<tr>
<td>• flat-plate</td>
</tr>
<tr>
<td>• heliostat</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Keyword Examples for Data Cleaning (Abstract Only)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• %solar%</td>
</tr>
<tr>
<td>• %photovoltaic%</td>
</tr>
<tr>
<td>• hetero-junction</td>
</tr>
<tr>
<td>• homo-junction</td>
</tr>
<tr>
<td>• multi-junction</td>
</tr>
<tr>
<td>• flat-plate</td>
</tr>
<tr>
<td>• heliostat</td>
</tr>
</tbody>
</table>

Fifthly, we analyzed the data using the relevant 8,000 patents. We created a new table with only the relevant 8,000 patents and used this table as the basis of our analysis. We used the resulting data from our queries to create visual representations of the information in Excel. Our analysis can be broken into three parts. First, we wanted to determine the general trends of solar technology patents being filed from 1973 to present day. Secondly, we wanted to breakdown this general trend by country and by state. Thirdly, we wanted to establish the largest companies involved in filing solar technology patents during this time period. An important aspect of our analysis is the fact that we used the patent filed date and not the patent issued date. Since our project is seeking a potential correlation between energy policy and solar technology trends, we felt that the patent filed date would provide us with more applicable data to perform our comparative analysis. While we don’t capture all of the patents being filed each year of our time period because only patents that are issued make it into the USPTO database, we capture the highest quality patents having been filed during this time period. We argue that this makes our data more relevant, because it excludes the patents of less quality that were filed but were not issued.

Lastly, our analysis was completed by gathering supplemental resources to add to our body of literature from our initial Literature Review to help explain the visualized results obtained from our three categories of analysis.
Results

The general trends of solar technology patents from 1973 to the present day were similar to our hypothesis. From the below graph, we can see that there is a steady increase in solar patents filed after the Oil Embargo of 1973. A steep increase in solar technology patent filing occurs under the Carter Administration (1976 – 1980). A decrease of patent filing occurs starting in 1980 with the beginning of the Reagan Administration and a general stagnation of solar technology patents being filed occurs up until the Gulf War. Thereafter, solar technology patents begin to increase throughout the Clinton Administration. After 2002, we see an initial decrease in the number of patents being filed, followed by a dramatic decrease around 2005. This is to be expected based on our analysis having used the filing date of patents and not the issued date. The USPTO database only contains patents that have been actually issued by the USPTO and not just filed. Therefore, many patents having been filed after 2005 have not been issued yet and would explain their absence in our data.

![Patent Quantity by Year](image)

Figure 5

By breaking down the patent trends over this time period by country, we can again see that many of our hypotheses were correct. As expected, the top three patent filing countries were United States, Japan and Germany. However, the low number of German patents filed (they only accounted for only 6% of total patents) was much less than anticipated. We were correct in predicting a steady increase of United States solar technology patents being filed during the 1970’s, reaching its peak under the Carter Administration and subsequently declining.

![Figure 6](image)
under the Regan years. Japanese patents also continued a steady increase throughout the Reagan years and began a dramatic increase during the beginning of the 1990s. Germany however, did not increase as steadily as predicted during the 1980s. Their patent increase did not begin until the late 1990s. This increase was later and less substantial than expected.

![Patents by Country](image1)

**Figure 7**

Analyzing the patents by U.S. state, we see that the overwhelming majority of U.S. solar technology patents were filed by institutions from the state of California (a total of 803). The second most patents were filed by institutions from the state of New York (a total of 322). It is also interesting to note, that the five of the top six solar technology filing states are blue states (excluding Washington D.C.). This is consistent with the trend of an increasing number of solar technology patents being filed under Democratic serving administrations (Carter, Clinton) and a stagnant or decreasing number of patents being filed during Republican administrations (Reagan, Bush Sr., Bush Jr.). Following the patent trends from 1973 to the present of the top two patent producing states also gives us an insight into the successes of California, especially during the decades of the 80s and 90s, compared against New York. Whereas New York was
producing solar technology patents at a rate comparable with California in the late 70s, their rates dramatically dropped off in the 80s and the industry seemed to never recover.

An analysis of the patent assignees shows that Japanese institutions maintain a strong grip on the U.S. solar industry in terms of solar technology patents filed. The top four institutions having filed the most patents were all Japanese, with Canon having filed the most. Five of the top 10 ten patent filing institutions were Japanese. United States institutions accounted for four of the top ten with the German institution Siemens rounding out the top ten.
Implications

The results of our data analysis show a correlation between energy policy and solar technology patent filing. Below is a graph that shows academic literature on solar technology that was published between 1973 and present. It is interesting to note this graph’s similarity with the trends from the USPTO patent data. Jimmy Carter’s creation of the DOE and his energy policy that funded renewable energy research and development, solar energy subsidies and tax incentives had a dramatic impact on the solar industry.

![Documents Published By Year](image)

Figure 11 – EI Compendex

Reagan’s removal of much of Carter’s polices led to a decline and stagnation of solar technology patents being filed. There are two steep declines in solar technology patents filed during the Reagan administration. One occurs in between 1980 and 1982, when federal funding for renewable energy fell from $124 million to $59 million. The second decline occurs after 1985, the year Reagan allowed the solar tax credits to expire. A spike in solar technology patents filed occurs during the Gulf War in 1991, which holds the pattern of solar technology patents being increasingly filed during times of energy crisis, as occurred after 1973. One also notices that the consensus of climate change and global warming in the 1990s also had an effect on solar patents being filed. This could be attributed to the added pressure on policy makers to make relevant polices. We can also see the impact Japanese and German solar initiatives had, as Japanese and German patent filings increased during the 1990s after Germany’s “1000 Roofs Program” and Japan’s “New Sunshine Project” had been adopted. If we look at the leading solar technology patent filer Canon and its evolution in the solar industry, we can see that it might have benefited from U.S. companies that failed during the 1980s and Japan’s energy policy during the early
1990s. The company had little to show until 1986 and then starting in 1992 it blossomed into an industry leader in solar photovoltaic technology. According to a 70 page report by Semiconductor Insights, Canon is among the largest patent holders in solar photovoltaic panels (Merritt, 2008).

Figure 12

Effective energy policy translating to increased solar technology patents being filed was also consistent with the finding that California was the leading solar technology patent filing state. California has been a leader in solar technology policy since the late 1970s. California has invested in renewable energy research and development, supported mandates and subsidies that have been used to create solar energy customers and used its monopoly-regulating power to force utilities to invest in research and development and either become or create solar customers (Taylor, 2008). A website called SolarPowerRocks.com rated all fifty states on their individual solar power rebates, incentives and tax credits. California, New York, Massachusetts and New Jersey all received a five of five rating and Washington D.C. and Michigan each received a four of five rating, providing further support of a correlation between energy policy and solar technology patent filing.
**Limitations & Future Directions**

One of the main limitations of this project is we see a globalized solar industry only through the lense of the USPTO. It is therefore difficult to capture a true global perspective of the solar industry. For example, Germany is solar leader in photovoltaics, however this wasn’t accurately depicted from the USPTO patent data. Therefore, a future direction would be to replicate this project using the EPO and JPO databases. The findings from such future projects would help to provide a true global perspective on the solar industry trends since the 1973 Arab Oil Embargo.

Another limitation of this project was the use of the patent filing date not enabling an analysis of solar patent trends past 2005. A future replication of this study that would capture this time period and future time periods under an Obama administration would be extremely valuable. Obama has pledged to create energy policy that would benefit the solar industry. It would be interesting to see the effects, if any, from his policy decisions. Such a replication could also show if the Republican dominated states of Florida and Texas will become key solar industry states, as certain literature has suggested (Galbraith, 2009 & Loder, 2009). Florida and Texas, like Arizona, have an abundance of sun. However, their state energy policies have never enabled them to take advantage of this natural asset. Evidence of solar growth in these conservative states would further support the impact of the reframed energy problem.
References


