INSTALLATION AND MANUFACTURING OF PHOTOVOLTAICS: AN ASSESSMENT USING CALIFORNIA AND NEW YORK

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Renewable energy studies are becoming increasingly important as world energy demand rises and current energy sources are increasingly questioned. Solar photovoltaics (PV) are the focus of this study as a renewable industry still in its infancy. This research examines the geography of solar panel installation and manufacturing from 2007 to 2010 in California and New York. California is the larger of the two markets and has implemented more policy support; programs that appear to have increased the pace of installations, reduce the size of the subsidy, and help lower total costs. Similar trends are observable in New York. US based companies are still making solar panels, but foreign competitors, most notably from China and Mexico, are capturing an increasing share of the market.

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INTRODUCTION

As our current carbon-based energy sources are linked to environmental problems, health, geopolitical tension, and price volatility issues, non-carbon based energy sources become increasingly necessary. Development of renewable energy technology is critical as fossil fuels are ever more difficult and expensive to procure. New energy sources will also be needed to keep pace with rising global energy demand, which is growing at an average of 1.7 percent per year (Solangi et al. 2011). Renewables generate energy in a manner that produces less harmful emissions, prfovide a path toward energy independence, lead to better environmental and health outcomes, and stimulate job creation. Furthermore, once the infrastructure has been constructed, the free fuel source (sunlight, wind, etc.) is unlimited and free.

Electricity makes up 39 percent of all energy consumed in the United States (Environmental Protection Agency, 2008), with 70 percent of that electricity being generated from fossil fuels (Energy Information Administration 2011). While there have been some investments in developing renewable sources of energy for our transportation sector, nearly all of our efforts to commercialize renewables has focused on the production of electricity. In 2009, 93 percent of renewable energy's generation produced electricity, with a small benefit in the transportation sector (Shrimali and Kniefel 2011).

Solar energy is one component in our efforts to diversify our electricity, and will play an important role in our future energy equation. By harnessing the sun's radiant energy and converting it into electricity, solar's potential is nearly unlimited; the sun radiates more energy upon the earth in one second than people have used since the beginning of time (Solangi et al.

2011). But making electricity from the sun is still in its infancy and there are still competing technologies vying to dominate this space.

Concentrated solar power and photovoltaics are two of the leading technologies. Concentrated solar power (CSP) uses mirrors to concentrate the solar power on a receiver that converts the sunlight to thermal power which is used by a steam turbine or heat engine to power a generator. Photovoltaics (PV), uses modules, also known as solar panels, to generate electricity directly, and are most commonly placed on roofs of buildings. CSP is akin to large power plants that require lots of land and capital, which is why this technology is sometimes referred to as utility scale solar. Although there are a few PV installations on the utility side, PV is generally viewed as a smaller-scale and a decentralized option (US Department of Energy 2011).

Adoption of solar energy systems is slowly spreading throughout the world, but trails wind, biomass, and geothermal in total global electricity production (Figure 1). Most of solar energy installations have taken place in the developed world, led by Germany, Spain, Japan, Italy and the US The US makes up approximately 6 percent of the world's installed solar capacity (Earth Policy Institute 2011). And while solar's share of electricity production continues to increase, the US mirrors the rest of the world in that it makes up less than 1 percent of total generation (EIA 2012).

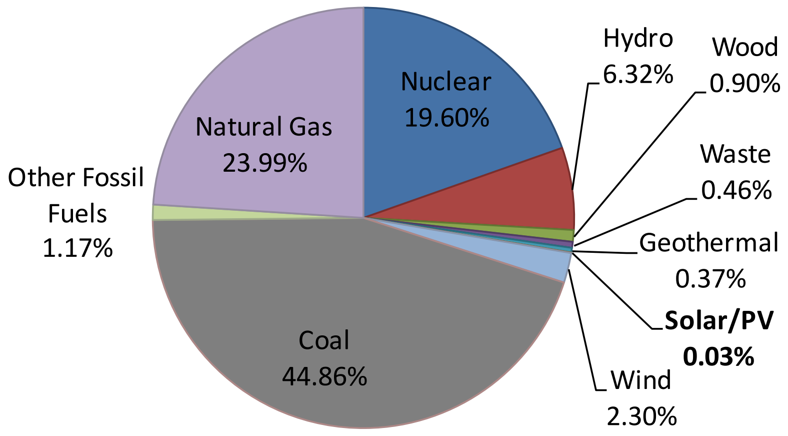


Figure 1 *US electricity sources as of 2010. (Source: EIA 2012)*

Nevertheless, the industry has strong tailwinds. Total PV production between 1995 and 2006 has grown from less than 200 megawatts (MW) to over 2,500 MW, establishing new highs every year (Figure 2). As production has increased, cost has correspondingly decreased from over $5.00 a watt to less than $4.00 a watt (Figure 2).

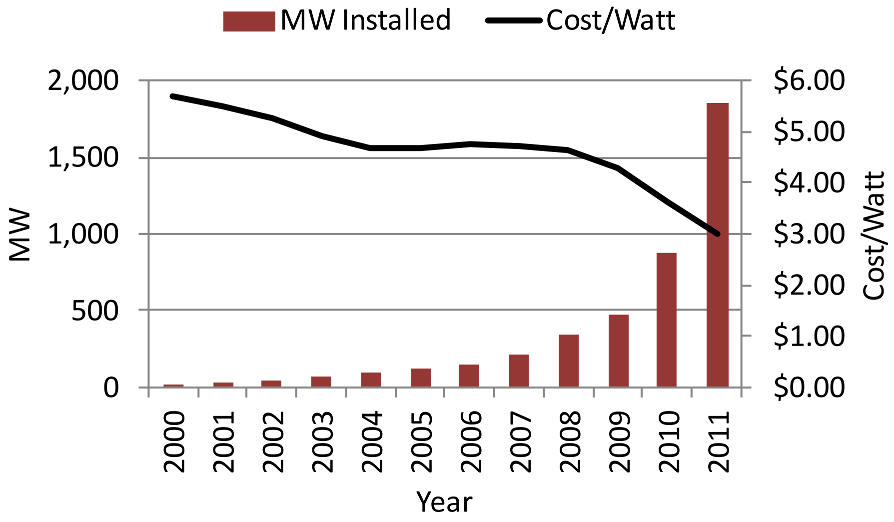


Figure 2 *PV production and cost. (Source: EIA 2011 and Solarbuzz 2012)*

Although solar technology has existed for decades, substantial levels of development have only materialized over the last few years. The market first showed signs of life in 1997 but it was not until 2003 that the technology began to make meaningful inroads in the market (Tour et al. 2011). Due to this relatively recent push, PV has become the subject of many studies including renewable technology and renewable policies. However, little has been done to look at the geographic and temporal nature of PV installations and manufacturers. Such studies can be pursued using US installation information which is most available from states including California and New York. California substantially leads the US in policies and installations while New York is still in the early stages of developing their solar market, however is among the top 10 states for installations. In addition to being at different stages in their installations and policies, California and New York are located at opposite ends of the country and house two varying demographics which make them suitable for comparison.

LITERATURE REVIEW

A growing body of research has studied energy, renewable energy, and specifically the various policies and technology contributing to the growth of the PV industry. Further studies of PV are extending into the more particular issue of where PV manufacturing is taking place and where that manufacturer's products are being installed.

Energy

Geography and energy have a connection that the mix "is so common it escapes casual notice" (Pasqualetti 2011). Politics and policies, resource production and consumption, and the arrangement of energy systems themselves are just some of the ways geography and energy are tied together (Zimmerer 2011). A large part of the interest geographers have taken in energy is captured by an attempt to understand and rectify the dilemmas and interaction which take place between humans and the environment. Politics is an important factor in this relationship as political will may be the largest influence in making energy related decisions. Such political intertwinement with energy has been especially prevalent regarding energy transition with much political resistance to renewable sources. Politics and policies are often the influencing factors for managing resource production/consumption and organization of the energy systems. But cost matters too. Growing energy demand has traditionally been satisfied with limited regard for anything except finding the least expensive option. So long as fossil fuels are available and their environmental costs are offloaded on to society, they will appear cheap and we will continue using fossil fuels, which in the case of electricity, means coal (Vanderheiden 2011).

There are multiple factors that can stimulate a transition from reliance on one energy source to another, which is especially important as society attempts to transition to an electricity system based on renewables (LePoire 2011). Although the future use of coal is controversial, phasing out this primary source of energy soon is both impractical and unreasonable (Solomon and Krishna 2011). As such, making this transition must be thoughtful which means balancing economic, social, and environmental interests.

Renewable Energy

Renewable energy cannot solve all the energy related problems, however it can contribute by resolving issues such as fossil fuel emissions and energy security (Laird 2009). Some believe renewable energy is not a short- or medium-term proposition, because they believe it will take decades to achieve parity with fossil fuels. Meanwhile, others believe a transition to renewable energy right now would provide an immediate boost to the economy as the investment creates economic growth (Solomon and Krishna 2011; Dewey 2011). Other than solar, the transition would include other energy sources including wind, bioenergy (biomass and biofuels), nuclear, hydropower, geothermal, and tidal, all which get various amounts of attention in the literature (Zimmerer 2011); and each will get a brief summary here.

Wind power is the most established renewable technology, able to produce electricity at a cost that is competitive with conventional sources of energy. As a result installed wind capacity is increasing faster than other renewable technologies, and makes up a large percentage of the electricity portfolios in many countries, most notably in Europe. The increased use of wind technology is spurring economic growth, creating more job opportunities, and protecting consumers from the price spikes and supply shortages which result from global fuel markets (Saidur et al. 2010). That is not to say that wind energy does still have some hurdles to overcome, including its intermittency, visual and noise disruptions, and its impact on wildlife, interference with Radar, and other NIMBY (Not in My Backyard) complaints (Pasqualetti 2011).

Bioenergy, energy derived from organic matter, accounts for approximately half of the United States renewable energy supply (within the transportation sector); and has been the subject of exhaustive academic inquiry (for summary, see Kedron and Bagchi-Sen 2011). Biofuels are the primary type of bioenergy, and in the US our biofuels (ethanol) is derived from corn. Despite biofuel's contribution to the US transportation energy mix, biofuel's governance is still in its infancy as regulations tend to be narrowly defined. Within biofuels there is much debating on topics such as land use change, use of marginal lands, and food security. These issues will have to be addressed in order to find biofuel's place in sustainable energy supplies (Bailis and Baka 2011).

Hydropower and nuclear are considered "non-fossil" energy sources yet as part of our legacy energy mix, they are generally not thought of as part of the future renewable landscape. Hydropower, although being aggressively expanded globally, is highly controversial. Because water resources are continuously replenished though the hydrological cycle, hydropower is considered renewable and it does contribute to our electricity portfolio. On the other hand, hydropower's adverse effects on the environment as well as socioeconomic conditions have earned it considerable scorn (Frey and Linke 2002). Regarding nuclear, it is an emissions free source; nevertheless the process requires finite elements such as uranium, which are currently showing no supply constraints (Solomon and Krishna 2011). As it was in 1979 with 3-Mile

Island, in 1986 with Chernobyl, and in 2011 with Fukashima, safety remains an important concern, although other concerns including disposal of radioactive waste, nuclear material losses, and weapons proliferation are equally worrisome (Solomon and Krishna 2011). More recently, the uneconomical aspect of nuclear has also been cited as an important drawback, as nuclear plants are extremely costly to build and over 100 percent dependent on subsidies (Lovins 2011).

The Electric Grid

One of the more vexing problems in the US is getting energy from where it is produced to where it is used. Since the end of WWII no "new movers" technology, a.k.a. transmission lines, have been introduced (Smil 2006). The current grid is divided into three zones; the Eastern interconnect, the Western interconnect, and ERCOT (which is made up almost exclusively of the state of Texas); and very little electricity is shared between the three. Within these large grids are many smaller power pools, which are largely independent. To make the entire country more electricity resilient, a holistic nationwide grid is needed. The grid is especially important as renewable sources grow as solar and wind are often generated in the isolated desert southwest or the rural great planes respectively, far from population centers; therefore creating importance for the improvement of the transportation of electricity (Smil 2011).

An important component of making a new national integrated grid function, deployment of something called a "smart grid" will be critical in sustaining the resilience of a grid that leans heavily on the intermittent supplies. The smart grid, which refers to a digitized and technologically advanced electric grid, is a concept which is broad and in the early stages of development. However, in general it provides an opportunity to improve efficiency, reliability, and reduce environmental impacts (Solomon and Krishna 2011). It shifts the historical one-way relationship of electricity delivered to your house or place of business without any knowledge of its costs, to a two way relationship where users have more information about costs and demand electricity more wisely. It requires installation of advanced meters (which can communicate with the utility) and eventually 'smart' devices that can take advantage of this additional information, or can be controlled by utility operators seeking to balance supply and demand.

This supply and demand balance is really at the heart of the smart grid. Rather than building additional generating stations, a smart grid would provide real time information to users so that consumers become more intelligent energy users and hopefully encouraging them to reduce or shift the time-of-day when they demand electricity. More intelligent energy uses, as well as investments in more efficient buildings and appliances are the necessary, easy, and most cost effective first steps in the energy transition. By one estimate, if a nationwide smart grid was rolled-out, emissions saved from increased efficiency would be equivalent to taking 53 million cars off the road (Solomon and Krishna 2011).

One central element of the smart grid is the vast deployment of renewables. The intermittent nature of renewables enables the smart grid to more effectively balance the electricity load. To date, the impact of renewables has only been modest, with wind accounting for the most installed renewable technology (Solomon and Heiman 2010). Meanwhile, PV is very young and immature and accounts for nearly imperceptible amounts of renewable generation. There are many reasons for this, including technology, costs, policies, and others, which explains why there remains an open “playing field” for manufacturing companies to enter and make an impact (Kramer, 2009; LePoire 2011).

Policy

A wide range of policies have been implemented around the world, though primarily in developed countries. Executed at different administrative levels including the federal, state, and local the primary intention of these policies is to promote renewable energy and close the cost gap between renewables and traditional energy sources. In general, some effective policy includes federal “stimulus” funds and federal renewable fuel standards. Federal stimulus funds are those allocated to one or more specific entity in order to encourage a response, such as increasing jobs or increasing consumer spending. Renewable fuel standards require a percentage of transportation fuel to draw from biomass (Outka 2011). Shimiali and Kneifel (2011) have found green power options and clean energy funds to effectively aid the penetration of renewable energy capacity. Net metering, voluntary green power markets, and public benefits funds are also seen as key drivers and are mostly found on a state or local level. Net metering encourages on-site energy generation, such as PV, by allowing electricity producers to receive financial payments for any surplus energy produced. Voluntary green power markets have customers pay higher electricity prices in exchange for green energy and public benefits funds provide incentives like production credits, which provide payback based on the amount of electricity produced, and rebates (Byrne et al. 2007).

Currently, feed-in tariffs (FITs) are the most commonly used policy by developed countries worldwide for promoting PV. FITs guarantees a fixed price to electricity suppliers (both small and large scale) for a fixed period of time (for instance, 20 years). FITs have been used in several countries; most notably Germany, Spain, and Japan, resulting in a rapid scaling-up of renewable capacity.

In addition to FITs found in individual European countries, the European Commission has formulated the goal of 20 percent renewables by 2020 for all countries in the EU. Goals for each individual state have been set based on their energy consumption in 2005, with each country contributing to the 20 percent total (Harmsen et al. 2011). Only a handful of countries are on target to meet their obligations.

Similar to the EU directive, the renewable portfolio standards (RPS) enacted by many states in the US mandates that utilities generate a minimum percentage of renewable electricity (Tour et al. 2011). RPSs are currently in place in 30 states and the District of Colombia (22 with mandates and 8 with goals), and the targets range from 10 percent to 33 percent (Database of State Incentives for Renewables and Efficiency 2012). Within RPS are set-asides or carve-outs which set targets for specific renewable technologies. The majority of states with an RPS have such targets with solar being the most common technology. New York, for example, has a distributed generation set-aside, meaning a set aside targeted towards on-site electricity generation, which therefore likely leads to support of solar development (Wiser, Barbose, and Holt 2010). Despite attempts made by congress in 2005, no RPS exists on the federal level (Byrne et al. 2007; Outka 2011).

The US is unique because, compared to European countries there is little support from the federal government; therefore the majority of the support from renewable energy is coming at the state level (Solomon and Heiman 2010). Federal energy funding is instead concentrated towards nuclear and “clean” coal (Byrne et al. 2007). Many attempts that have occurred by congress to promote renewable energy have failed to be carried out. Public pressure on the government is increasing, however, as their lack of certainty for the reliability of fossil fuel industries, among other things, have led people to seek renewable energy sources and energy independence (Shrimali and Kniefel 2011).

The most effective policy that has been implemented at the federal level is the production tax credit (PTC). PTC subsidizes new energy projects and encourages private investment; by allowing producers to obtain a tax deduction for the energy they produce (Dewey 2011). However, the PTC has been inconsistently reauthorized, and rarely for extended periods of time, preventing long term visibility for companies seeking to make sustained investments in the renewable space. Thus, allowing the PTC to expire makes renewable investments financially uncompetitive. This ultimately deters investments in the renewable energy space (Dewey 2011). Also a disadvantage is the financial burden of tax credits that is placed on tax payers (Tour et al. 2011). More involved directly with solar energy is the investment tax credit (ITC), which has been implemented in order to support the domestic solar industry by catalyzing investment in manufacturing and construction projects. The ITC reduces the overall taxes paid for individuals or businesses who invest in solar energy technology. The ITC provides a 30 percent uncapped tax credit for residential and commercial solar systems (Solar Energy Industries Association 2011a).

Although the solar ITC does not expire until 2016, capitalizing on the tax credit is not straight forward. Companies’ bottom lines have been battered by the recession and therefore do not have a large enough liability to take advantage of the tax credit. Consequently, Congress passed what is called the 1603 Treasury grant program as part of the 2009 stimulus. As a result, the tax credit has been into a flat grant so that anyone could qualify. This partially explains why the US solar installations have enjoyed some success over the past three years. However, the program has cost some $9.6 billion in three years, which is more than lawmakers expected. The 1603 grant program has expired as of the end of 2011, and if not renewed solar producers expect output to fall dramatically in the coming years, by as much as two gigawatts in 2013. Some renewable energy experts, however, think the industry might be better off without the grant (SEIA 2011a).

California, which has experimented with various policies since the 1970's, has been a driving force behind a variety of energy and environmental initiatives. California has been most aggressive with policies such as their RPS of 33 percent by year 2020 (DSIRE 2012). Since 2006, the California Air Resource Board (CARB) has been in charge of implementing more regulations such as formulating a cap on green house gas emissions, which limits the amount of green house gases the largest industrial companies can emit. Such standards require emissions to return to 1990 levels by 2020, an 11 percent decrease from current levels, and nearly 30 percent decrease from projected 2020 levels (California Energy Commission 2011). As part of the regulations, CARB has recently adopted the first US state administered cap-and-trade regulations. Beginning in 2013 the state's largest carbon emitters will be give a cap for emissions and if they are unable to meet the cap, these companies that are subjected to the cap in the early years will be required to purchase credits. (Cart 2011).

Implementing the cap will be made a bit easier since California has become substantially less dependent on coal. As a percentage of electricity, coal accounts for less than 8 percent, compared with about 50 percent nationally. California actually acquires less of its electricity from coal than it does renewables, where California gets 12 percent of its total electricity. The majority of California's coal use comes from out of state, and in 2007 the state banned utilities from signing new contracts with out of state coal plants (California Energy Commission 2011). The most recent of California's policies is the California Solar Initiative; initiated in 2006 it aims to make California a leader in solar technology. By using $2.6 billion for solar initiatives, the state aims to install 3,000 MW of solar by 2017 (Bryne et al. 2007).

Outside of California, each state has its own set of policies. New York has one of the most aggressive RPSs of 29 percent by 2015 (Database of State Incentives for Renewables and Efficiency 2012). In addition New York is pursuing a variety of policies to complement the RPS including large scale projects such as wind farms and hydroelectric as well as customer sited-generation. Customer cited-generation goals were established in 2010 creating source specific policies such as those geared towards PV (New York State Energy and Development Authority 2011). New Jersey, ranked second in US PV installations, has also had a variety of programs designed to stimulate solar demand while nine states and three cities have considered or proposed FITs (Hart 2010). Overall in the US funding from third party financial investors is on the rise. Previously funding was solely dependent on residents, however in order for capacity to continue to increase, financial investors must be involved (Szabo, Jager-Waldau, and Szabo 2010).

Although policy is a critical part of solar energy's success, the market is beginning to show signs of standing on its own. For example, Bank of America Merrill Lynch is lending $350 million for solar projects without backing from the federal government. The bank is lending to the company SolarCity who will then install systems for more than 100,000 military housing units. Originally SolarCity applied through the Obama administration's loan guarantee program to receive a larger loan from Bank of American Merrill Lynch, however following the fall of Solyndra and the loan guarantee program's expiration, they failed to receive approval. The bank however was attracted to SolarCity's financial profile and is providing the scaled-back loan despite the lack of guarantee from the government. Additional banks and companies such as Google are also investing in solar programs who make solar more affordable to homeowners (Cardwell 2011).

Technology

The irony of technology is that it has previously and currently been the driver for an increase in energy demand. This pattern however is in the process of reversing, as technology has to inspire new and better ways to make and use energy (Haas et al. 2008). Renewable energy is the fastest growing energy technology in the world with Europe, China, and the United States leading the way (Martinot 2006). In order for green energy to be successful, a substantial amount of funding will be required, in order to drive down the costs and stimulate demand (Lund 2011). Funding for renewable energy technology however is historically low relative to the size of the energy market, as the US's $1 trillion industry cannot be transformed with $1 billion (Laird 2009). As long as renewables remain more expensive than traditional sources, they will need strong and consistent public support (i.e. subsidies) (Lund, 2011).

Haas et al. (2008) believe that new clean energy technology development is on the wrong path as the development is too slow compared to the rise in energy demand. While some believe PV technology will never reach a successful level, others do consider it to be 'the' (Dincer 2010). Nonetheless, researchers are working to fill the gaps that exist in current technology (Rockett 2010). "Photovoltaic technology has grown considerably fast in the last thirty-plus years" and there are a lot of reasons for this growth (Liu et al. 2011). PV is appealing because of its noiselessness, lack of carbon emissions, flexibility of scale, simple operation, and low maintenance (Dincer 2010).

Primarily, there are two competing technologies within PV, crystalline and thin-film, thin-film being a newer form of solar technology. Although there is competition between the two technologies, 77 percent of the market in 2009 was crystalline (EIA 2011). Silicon (Si) is the primary ingredient in crystalline systems. Silicon is also the primary ingredient in amorphous thin-film systems; however other thin-film technology rely very little on silicon and instead have found a way to make solar cells using a wide variety of other materials (Fthenakis 2009). Crystalline systems lead the market due to the abundance of silicon compared to elements used in thin-film technologies (Rocket 2010). In addition, thin-film materials lack the efficiency of silicon (Brown 2008). Liu et al. (2011) used patents of PV technology to estimate the lifecycles of both silicon and thin-film technologies and came to the conclusion that thin film technologies have already surpassed their mature stage and will not bring any more growth in the industry while silicon and other emerging technologies will not mature until 2014 and later. Nonetheless, efforts continue for both crystalline and thin-film technologies.

PV will also need to match the direct cost of grid electricity in order to be successful. Achieving grid-parity with traditional generation will require economies of scale, improved production, and higher module efficiencies, all things that, in the near-term, requires financial incentives. In addition, materials, such as those used in thin-film systems, have limited supply.

As demand for these materials increase with the increased manufacturing of thin-film systems, availability of materials is examined on an annual basis.

There are also environmental impacts. While PV is a carbon free energy provider, there are emissions during its production and therefore there have been concerns regarding net-energy yield, meaning the total energy produced by a PV system minus the energy required to manufacture that system (Fthenakis 2009). PV technology however is net energy positive (Dincer 2010). Reliability of PV technology, in terms of electricity generation performance, is another obstacle, whereby the investment community remains skeptical about its dependability. Wind power has already overcome this challenge, and PV must do the same (Szabo 2010). In order to improve the technology the PV industry is constantly seeking new materials, improving cell design, and optimizing production technologies in order to produce modules with higher efficiency and lower costs (Bayod-Rujula, Lorente-Lafuente, and Cirez-Oto 2011).

Trade and Manufacturing

Logistics and supply chains have long had an important place in economic geography as understanding and explaining the flow of products across space is integral in our global economy (Cowen 2010). International trade is a function of many issues including factor endowments, labor, skills, technology, and capital (among others). The idea that trade is both necessary and beneficial was first set forth by Ricardo (1821). His ideas of comparative advantage explained why it is in the interests of all countries to exploit their inherent advantages and then trade with other countries that are better able to produce other goods or services. Over time however, it has turned out that with respect to some manufactured goods, the benefits of specialization and trade are not always available. Some goods require economies of scale which is limited to a handful of factories around the world (Krugman 2008). This is what has occurred in the wind industry and is expected to eventually occur in the PV industry. Because economies of scale accrue only the most efficient firms, manufacturing will occur at a limited number of sites for each good, these sites would preferably be located near the largest demand areas (Krugman 1991). This idea however was developed when the world was split between the global north and south. Since then, the rise of China has disrupted the traditional views on the location of manufacturing (Rodrigue 2012).

Today, countries are becoming more interconnected through trade flows as exports have grown considerably faster than outputs. Since 1960, world merchandise trade has increased nearly twenty times while world merchandise production has increased just over six times. This would not have been possible without the current world economic integration and trade agreements (Rodrigue 2012). There has been much done in the last several decades to create widespread global trade including the establishment of the General Agreement on Tariffs and Trade (GATT) in 1947. GATTs purpose was to promote free trade by reducing tariffs and other trade barriers between countries. Previously, developing countries had criticisms regarding their goods lack of penetration into developed country markets. GATT therefore gave manufactured and semi-manufactured goods from developing countries preferential access into developed country markets, thereby exploiting their comparative advantage (Dicken 2011). Now, many firms have relocated segments, if not entire processes, to other countries (Rodrigue 2012). In 1995 GATT was replaced by the World Trade Organization (WTO) which currently holds 153 member states and regulates approximately 97 percent of the world's trade.

Liberalization and globalization of international trade has enhanced the interdependence between producers and consumers in supply chains (Janvier-James 2012). Trade today between third world countries and developed countries is most often driven by price as the trade mostly concerns either standardized goods produced via mass production or low technology goods produced with cheap labor (Storper 1992). This outsourcing process among supply chains is well understood as firms aim to lower production cost on focus on its core competencies (Rodrigue 2012). On the other hand, trade among wealthy countries is not based on cost but rather various qualities of product differentiation (Storper 1992). As all PV is virtually the same quality, relying on mass production and low wages, the developing countries will dominate in the production.

The US has been one of the biggest advocates for free trade. Therefore the US has increased willingness to participate in bilateral trade, which has been seen best through the North American Free Trade Agreement (NAFTA) between Canada, Mexico, and the US (Harvey 2011). Naturally this regional agreement increases trade volume between member countries due to the elimination of tariffs (also known as trade creation) and a member country's likeliness to import from a less-efficient member country rather than a more efficient non-member country (also known as trade diversion). NAFTA has drastically changed the economic map of North America. NAFTA has also changed the geographic trade pattern between the US and the rest of the world because of changes in the spatial distribution of firms. Due to the agreement with Mexico firms which might have been located in the Northeast will be more likely to move south and west to be closer to their manufacturing facilities. In doing so they change their relative position with the rest of the world becoming a more convenient trader with China rather than Europe (Wall 2003).

While globalization has allowed international trade to thrive, an implicit and foundational component driving these stronger economic ties has been the vast reach of global supply chains. There are two primary ways to define a supply chain; producer-driven and buyer-driven commodity chains. Producer-driven commodity chains are those controlled by large, usually transnational, manufacturers which are usually capital and technology intensive. Examples of this would be the automobile industry. Buyer-driven commodity chains are controlled by large retailers, marketers, and branded manufacturers who create decentralized production networks in various exporting countries, particularly third world countries. Such industries are labor-intensive and result in common goods such as footwear and toys (Gereffi 2001). PV would be an example of a producer-driven commodity. As a result of this trade-based globalization the center of gravity of manufacturing shifted from the core to the periphery of the world economy (i.e. developed to developing nations) (Gereffi 2001).

Because of this evolution in international trade, global manufacturing has also shifted. Despite that globalization has internationalized supply chains, 71 percent of the world's manufacturing remains concentrated in only four countries; US, Japan, China, and Germany. With one-fifth of the world's manufacturing though, the dominant position long enjoyed by the US is eroding (Dicken 2011). Because of their advocacy for bilateral trade, Americans, who used to be a dominant manufacturing country, are beginning to look at what has turned into a dependence on goods made overseas. As the second largest producer of manufactured goods (behind the US), China has exploded onto the world stage as a formidable manufacturing powerhouse, as it has rapidly transformed from a poor closed country to a rapidly developing country manufacturing many of world's products. In 2000, 90 percent of China's total exports were manufactured products (Zhang and Li 2006). China has replaced Japan, who had explosive growth after World War II, as America's most feared manufacturing competitor (Dicken 2011).

Like many other manufactured goods, the focus has been on China for the production of PV products as they have become the leader in manufacturing PV and renewables in general. The US was previously the leader, then taken over by Germany and Spain, who was then more recently surpassed by China. In 2007, PV produced in China made up 35 percent of the world's share, making them the world leader in production (Liu et al. 2010). This was achieved without domestic demand, which did not begin in earnest until 2009 (Tour et al. 2011). China's green-tech firms, particularly PV and wind turbine manufacturing, have become global leader due to strong state support (low interest loans, subsidies, etc) and cheap labor (Ross 2010).

In 2009 however, federal stimulus money from the American Recovery and Reinvestment Act (ARRA), which provided funding for tax credits, research, and so forth, were designated to fund clean energy. Several American PV companies used ARRA to ramp-up solar production. However, companies eventually began to transfer operations overseas, primarily to China and Germany, where more favorable policy environments are found (Ross 2010). For example, in 2010, Evergreen Solar shut down its Massachusetts manufacturing facility and moved it to China. This process has caused ARRA to come under intense scrutiny as American shunned the idea that stimulus money was supporting Chinese jobs (Ross 2010) Further scrutiny arrived in 2011 when Solyndra, an ARRA backed solar company declared bankruptcy.

It is debated, however, what portion of the manufacturing process actually occurs in China. Tour et al. (2011) claims that China's strength is in assembling cells and modules, with technology and expertise originating in the developed countries. China is therefore the middleman; importing technology, information, and supplies from developed nations, assembling the product, and exporting it right back to those same nations. Others believe that final assembly is more likely to occur domestically, claiming that it is more beneficial for panels to be assembled and distributed with the "Made in USA" stamp as well as transportation costs being highest for assembled modules (Ross 2010).

More recently issues have arisen of solar panels being manufactured in China due to Chinese government support which allows the panels to be sold at prices lower than the cost of production. Subsidies have been a large part of the "Renewable Energy Law" including a program which started in 2009 for the government to subsidize up to 70 percent of PV related costs (Zhao et al. 2010). As a result, China now produces three-fifths of the world's PV and wholesale module prices have fallen from $3.30 per watt in 2008 to $1.00-$1.20 per watt in 2011. As China exports 95 percent of their PV products, further price drops are expected, which will have important, yet unknown impact on foreign producers (Bradsher 2011c).

Due to the recentness of this activity it is not published in literature but rather in the news media. China's aggressive campaign to establish a strong PV manufacturing sector has brought accusations that they are violating international trade rules. American manufacturers (and other foreign firms) are seeking legal action, encouraging the government to place tariffs on panels imported from China. Several major American manufacturers have either filed for bankruptcy or laid off workers (Bradsher 2011c).

In addition to the potential Chinese subsidies driving down the costs of solar PV, the collapse in silicon prices is another important factor. The silicon supply glut of the post dot-com bubble made PV expensive. As a result, the market sought out alternative solar design options, leading to the development of both concentrating solar thermal and thin-film designs. However, as silicon supplies have recovered, the price of PV has come down, thus curtailing demand for non-PV solar options. Several smaller companies have suffered or gone bankrupt due to the rapid drop in silicon prices, and thus module prices (Bradsher 2011a).

US manufacturers account for approximately 10 percent of the global PV production. These manufacturers typically locate in states where incentive packages are the greatest. For example, New Mexico has invested over $500 million supporting Schott Solar, funding jobs, infrastructure, training, tax credits, etc. In addition to New Mexico such incentive packages have been allocated in Ohio, Oregon, and Michigan, who each house at least one manufacturer. Overall there are at least 51 active facilities in the US, located in 21 different states. PV manufacturers have favored western and eastern states where the most installations are taking place. Yet, a geographic shift is taking place as states in the Midwest (Wisconsin, Illinois, etc) become favorable manufacturing sites at the expense of the northeast (New Jersey, Massachusetts, etc) where multiple plant closures have recently taken place. California remains the leading state in production due to its leadership in the end-market (SEIA 2011b).

These geographic trends of the PV manufacturing industry have been compared to that of the automobile industry (Dicken 2011). In the 1960’s the automobile industry was dominated by a multitude of small companies who manufactured vehicles for the consumers in the market which they were located. Today a handful of large, transnational companies dominate the world market. The PV industry is made up of a large number of manufacturing companies however is beginning to dwindle down as the large transnational companies expand the capacities and business. As Japanese companies have come to reign in the auto industry, Chinese companies are doing the same in PV (Dicken 2011).

The debate continues between domestic and foreign manufacturing facilities. However, even with support, domestic production would have a difficult time increasing capacity to actually be able to fulfill the demand laid out by the US Department of Energy (Kramer 2009). Nonetheless, the US Department of Commerce is investigating and will make a decision on claims of dumping and illegal subsidization which will most likely lead to the implementation of tariffs against Chinese products (Bradsher 2011c). A provision in the military authorization law signed by President Obama in January 2011 has already stated the US Department of Defense must “Buy American” in its purchase of solar panels (Bradsher 2011b). Although American, Japanese, and European companies hold the advantage of technology, Chinese companies still hold the lower costs advantage (Bradsher 2011a).

RESEARCH QUESTIONS

While the solar industry is still in its infancy, it is important to begin understanding the geography of solar panel manufacturing and solar system installations. This study seeks to quantify the evolution of solar PV in two different markets, California and New York, in order to differentiate and explain the geographic relationship between installers and manufacturers from 2007-2010. This research is important because the solar industry specifically, and the renewable energy industry more broadly, is considered a possible catalyst for future economic growth (Ross 2010). But if an increasing number of the PV systems are foreign made, then some of the economic arguments encouraging robust policy support are deflated. California has been the most aggressive state in promoting PV, so this research is important because it will shed some light on whether they are successfully nurturing a PV ecosystem, where local (in-state) manufacturers are preferred for local projects/systems. By comparing the relationship between manufacturers and installations in California and New York, this empirically driven research will provide a clearer picture of just what future policy should expect to accomplish. Therefore, the main contribution of this research is to illustrate how the linkages within the PV supply chain change over time. Additionally, the time period of this study (2007-2010) provides a unique opportunity to examine these changes as the economy entered, and then exited from, the recession. To accomplish this, three specific questions will be addressed.

My first research question is what is the geographic and temporal nature of PV installations in California and New York? Having identified these two major markets in the US, little is known of what is happening at a finer scale and if there has been variance over time. Knowing from the literature that policy is a driving factor of PV installations, are there other factors playing a role in where PV is installed, such as the size, urban/rural, and so forth? And how do these qualities of PV systems relate to one another? This question is answered using cost, size, county, and zip code information from each individual installed PV system in California and New York.

My second question is to examine the geographic and temporal nature of PV manufacturing. Who are the major manufacturers contributing to the US market, and how have they varied over time? China has received much recent attention in the literature and media; therefore are they the only major player or are other manufacturing countries involved in US installations? Also, as installations increase domestically is there a correlating upwards trend with domestic manufacturing? Thus are domestic installations benefiting domestic or foreign manufacturers? This is addressed using various data from California and New York as well as other sources.

My third question is how does the solar market behave in response to the overall US economy? Is there an increase in application withdrawals in correlation with the recession and the changes in GDP (reported quarterly)? Do withdrawals of applications lead or lag GDP indicators? How did the solar market react in 2010 as the economy began to recover? California is used exclusively for this question as it accounts for half of the US PV industry and has a unique data set unlike what is provided for New York. This is answered using the number of applications withdrawn from California's program on a quarterly basis.

DATA AND METHODS

Various data were used to look at these manufacturing trends. Preliminary data from the US International Trade Commission (ITC) as well as the US Energy Information Administration (EIA), Solar Energy Industries Association (SEIA), and Interstate Renewable Energy Council (IREC) will be used to examine general production patterns, with a specific emphasis on the geography of domestic and foreign sources of PV. Further data is collected from the states of California and New York for detailed information on individual installations.

Data from the ITC was acquired from the ITC website where a query can be run for desired information, in this case, imports of assembled PV modules. The resulting query provides detailed information on the quantity of PV which has been imported from each country (in dollars). EIA, SEIA, and IREC data are all available online. EIA data is maintained by the US Department of Energy. SEIA and IREC are both non-profit organizations.   Data from these sources also provided a general view of import data from individual countries as well as domestic information in terms of state of origination, a comparison of imports versus domestic, installations, etc.

The largest of the installation datasets is from California. In 2007, California launched the Go Solar California campaign. Go Solar California has become the umbrella over all solar initiatives throughout the state, serving as a clearing house for state incentive information. Go Solar California's ultimate goal of 3,000 MW by 2016, is made up of three monitoring entities: the California Public Utilities Commission; California Energy Commission; and Publicly Owned Utilities (Figure 4).

Table 1 *Components of the Go Solar California Campaign (Source: State of California, 2011)*

Program Administrator	**California Public Utilities Commission**	**California Energy Commission**	**Publicly Owned Utilities**	**Total**
Program Name	California Solar Iniative (CSI)	New Solar Homes Partnership	Various Program Names	Go Solar California
Budget	$2,167 million	$400 million	$784 million	$3,351 million
Solar Goals	1,940 MW	360 MW	700 MW	3,000 MW
Scope	Large IOUs	Large IOUs New Homes	POU's	All of CA

A majority of the campaign is comprised of two programs, the California Solar Initiative (CSI) and the New Solar Homes Partnership (NSHP), making up over two-thirds of the campaign's goals. CSI applies to solar systems for customers of the large investor owned utilities, excluding new homes. New homes in the investor owned utilities (IOU) service territories are covered by the NSHP which provides financial and other incentives to home builders to encourage energy efficient home construction. The remaining MW in the campaign is accounted for by various programs provided by public owned utilities (POU's), which includes both municipal utilities and electric cooperatives (KEMA Inc 2005). California's data is available through the campaigns website and includes each project that has been installed through the CSI and NHSP components, starting in 2007.

California's dataset has approximately 50,000 installed projects (2007-2010) with more than 100 different variables available for each project including: solar technology, various dates (i.e. application, completion, etc), location, costs, manufacturer, and inverters, among others. The data is managed by the state, unfortunately the POU's are not included and since California exercises limited control over these entities, it is likely POU projects may not be reported.

New York served as a comparable state. The total amount of solar PV installed in New York is only a fraction of what has occurred in California, yet NY is the state with the 7th most installed PV capacity as of the end of 2010, behind New Jersey, Colorado, Arizona, Nevada and Florida (Sherwood 2011). In 2009, 6 percent of US installed modules went to New York. The primary purpose of data from this state was to provide a comparison against the data from California.

NY data came from the state's various PV incentives run by the New York State Energy Research and Development Authority (NYSERDA). New York's database contains nearly 4,000 installed projects with 20 variables including program, cost, location, and manufacturing information. The data includes three different Program Opportunity Notices (PONs) which generally have economic, technical, environmental and other goals attached to the program for encouragement purposes (New York State Energy Research and Development Authority 2011).

Each dataset contains records with missing components, such as costs, manufacturers, or dates and therefore were unusable and disposed of for analysis purposes. For much of the analysis the data is divided into small and large sized systems. Small systems include all systems (residential and non-residential) less than or equal to 10 KW. Large systems include all systems (residential and non-residential) larger than 10 KW. This is done in order to eliminate skewing of certain analysis due to extremely large projects with outlying variables. The 10 KW divide is what is used by the state of California. 10 KW systems are typically used for small commercial projects as residential systems are usually around 4 or 5 KW. Data will also be further filtered to include only the 2007-2010 time period.

Some variables had to be added to the dataset such as cost/watt, which could be easily calculated using total cost and size of each system. Location of the manufacturing facility for each module was another variable that had to be manually added. Exact production location of any individual module is impossible to track and therefore an assumption was made to assign the module's production to the country of origin. Various sources were used to determine where the most appropriate manufacturing facility for each manufacturer was located. Some companies listed their locations on their websites. Press releases were the most common source used. These releases occurred whenever a new manufacturing plant was opened or shut down for a specific country. The releases often specified as well when a plant was opened to specifically serve the North American market. An example is Sanyo Electric, a Japanese company, who opened their first manufacturing facility outside of Japan in November 2009. The plant is located in Mexico and was built in order to better serve the North American market. Based on this information, all Sanyo Electric PV products installed following this opening were considered to have been produced in Mexico.

Analysis took place through a mixed methods approach, focusing on three different methods. The first method to be used was descriptive statistics to paint the picture of existing trends. The second is chi squared. Chi squared is a non-parametric test which has an advantage for this study, because no normal distribution is required. The dataset from California is significantly larger than the dataset for New York. Chi squared was used to measure the significance in size of a system and whether it is located in an urban or rural environment. Finally, geographic information systems (GIS) was used to visually represent the data which provides clearer representation of certain trends geographically. Chi squared and descriptive statistics was performed using Microsoft Excel and Microsoft Access. GIS used the ArcGIS software.

RESULTS

Installations

Approximately 90 percent of the world's installed PV capacity is located in eight countries (Figure 3). Each of these leading markets have progressed differently over the past few years, but the general trend is higher, culminating in 2010 with the highest levels of installations. But within those figure lie some important geographic variations.

Roughly 80 percent of global installations in 2010 occurred in countries of the European Union. Germany is and has been the world leader for PV installations due to their renewable energy policies, most notably their feed-in tariff (FIT) which has led to their escalating renewable sector (Laird 2009). Spain, which was ranked second worldwide in 2010, experienced a spike in solar installations in 2008, but the following year, as a direct consequence of poorly designed policy, demand cratered. Their policy error was to provide an overly generous FIT which caused a solar boom, as producers rushed in to take advantage of payment rates. The drain on the governments resources forced a restructuring of the FIT, and dramatic cuts to the payments, making new projects uncompetitive. Due to FITs and other support measures, France, Italy, and the Czech Republic saw significant increases in installations in 2010 as well. Future increase in these countries is unsure however due to instability in future policy measures (European Photovoltaic Industry Association 2010).

The only countries outside of the EU to reach one gigawatt of installed PV are Japan and the US. Japan was an early leader in renewable energy policies and newly implemented net-metering. Japan's market is expected to continue to grow due to a variety of incentives. The only developing country on the list of top capacity countries is China. As of 2009 China's primary PV installations were marginal and off grid and their share of world PV generation was 0 percent (Liu et al. 2009). However a series of policies under the “Renewable Energy Law” have been formulated to establish a more sustainable energy system including a domestic PV market (Zhao et al. 2010). At the end of 2010 China accounted for approximately 2 percent of the world’s installations.

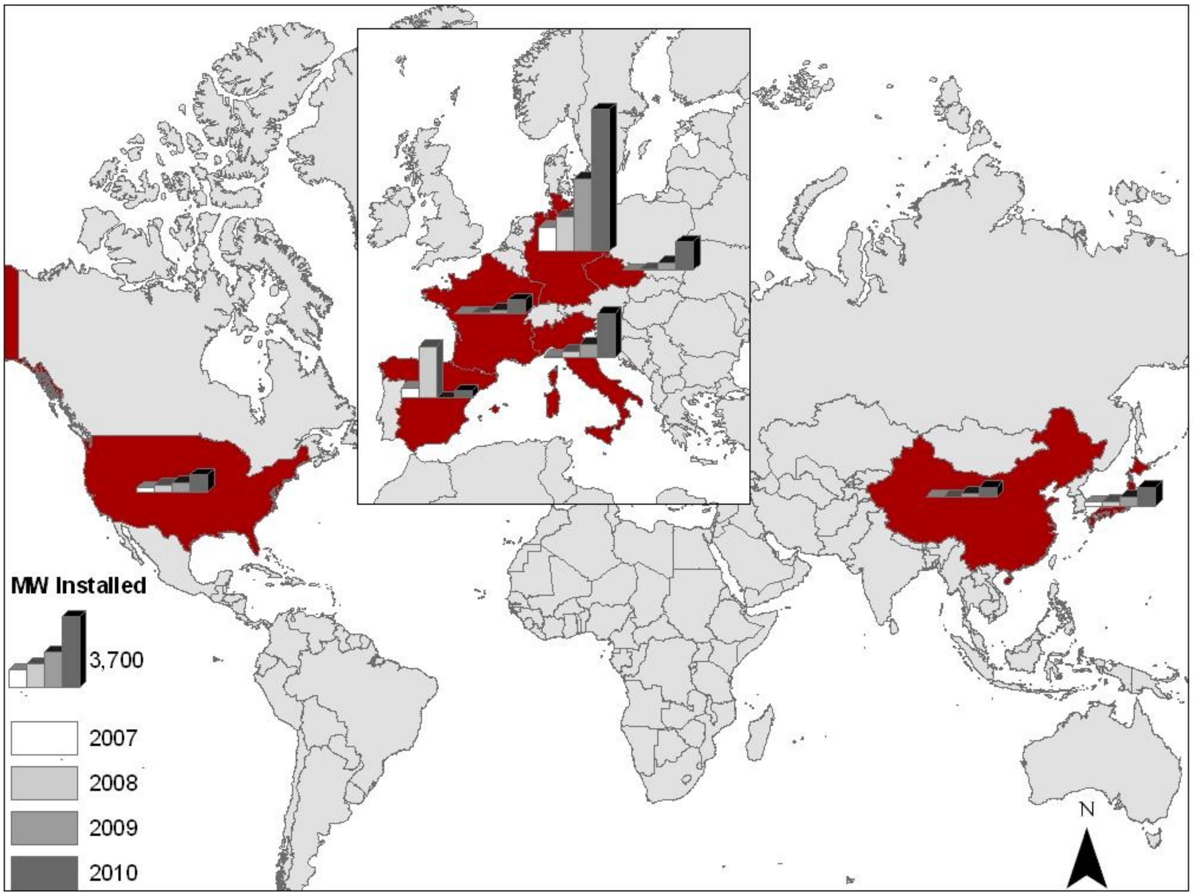


Figure 3 *Installed PV capacity for the world’s top PV countries (MW), per year 2008-2010. (Source: Earth Policy Institute, 2011; map drawn by the author.)*

As of 2010 the US accounts for approximately 6 percent of the world’s cumulative installed PV infrastructure (EPIA 2011). 88 percent of the US installations are in 10 of the 50 states, with California alone accounting for nearly half of all US installations (Figure 4 and Table 2). There is a large gap in total installations from California to second ranked New Jersey and again to third ranked Colorado. The percentages then level off. A majority of US installations are occurring in two regions of the country, the west/southwest and the northeast. With exception of Florida and Hawaii the top 10 states fall in these regions.

While California has the most total MW installed, Nevada actually leads with respect to the percentage of the state's electricity generated by PV (Table 2), with California coming on at number two. The remaining states register even smaller percentages while New York, when the figured is rounded registers at virtually 0 percent.

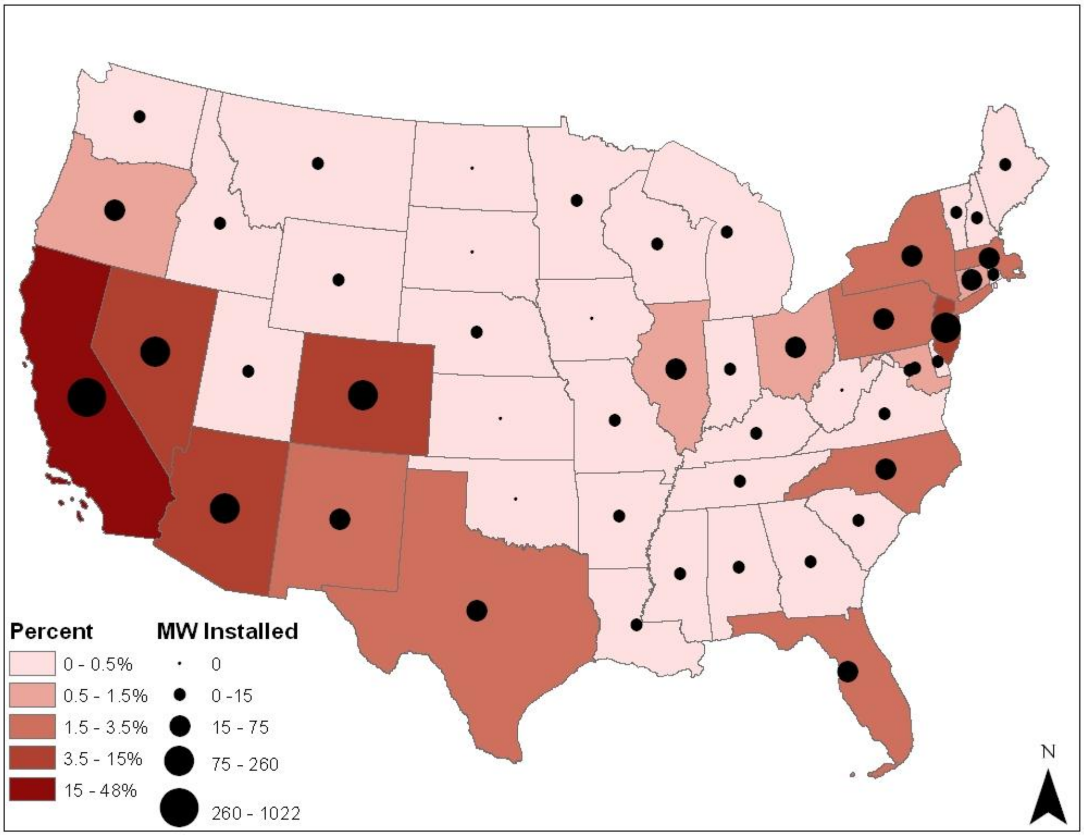


Figure 4 *Cumulative US Installations 2010. (Source: Sherwood, 2011; map drawn by author)*

Table 2 *Cumulative US Installations 2010 (Source: Sherwood, 2011 and EIA, 2011)*

State	**MW**	**Market Share**	**% State's Electricity**
California	1,022	48%	0.19%
New Jersey	260	12%	0.02%
Colorado	121	6%	0.04%
Arizona	110	5%	0.01%
Nevada	105	5%	0.31%
Florida	73	3%	0.02%
New York	56	3%	0.00%
Pennsylvania	55	2%	0.00%
Hawaii	45	2%	0.01%
New Mexico	43	2%	0.01%
Other States	264	12%	-
Total	2,153	100%	-

California (#1) and New York (#7) are the two states chosen to examine more closely in this study. Using these states, more detailed geographic information about installation patterns is observed (Figure 5). A majority of the installations in California are located in counties with larger sized cities. Given the population distribution in the state, this is logical. Counties void of larger cities, and therefore PV installations, correspond with the rural areas of the state. Counties which stand out with the largest numbers of installed KW are San Diego, Los Angeles, and Santa Clara.

Installations in New York (Figure 6) are concentrated in the southeast region of the state, also known as the Hudson Valley region. This region is just to the north of the highest concentrations of population which are found in and around New York City. Other notable counties can be associated with larger populations such as that in Buffalo and Syracuse.

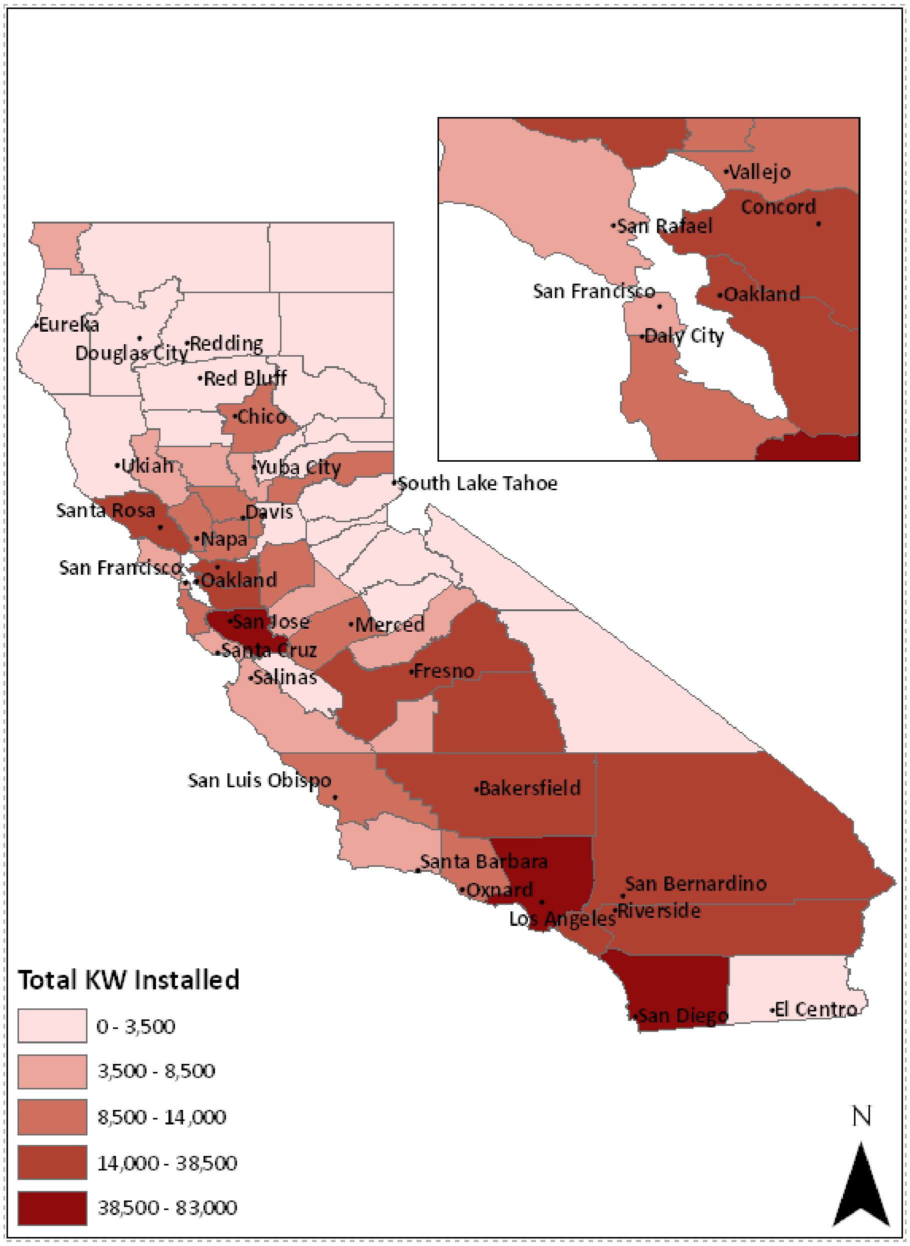


Figure 5 *California total PV capacity (KW) by county. (Source: State of California 2011; map drawn by author)*

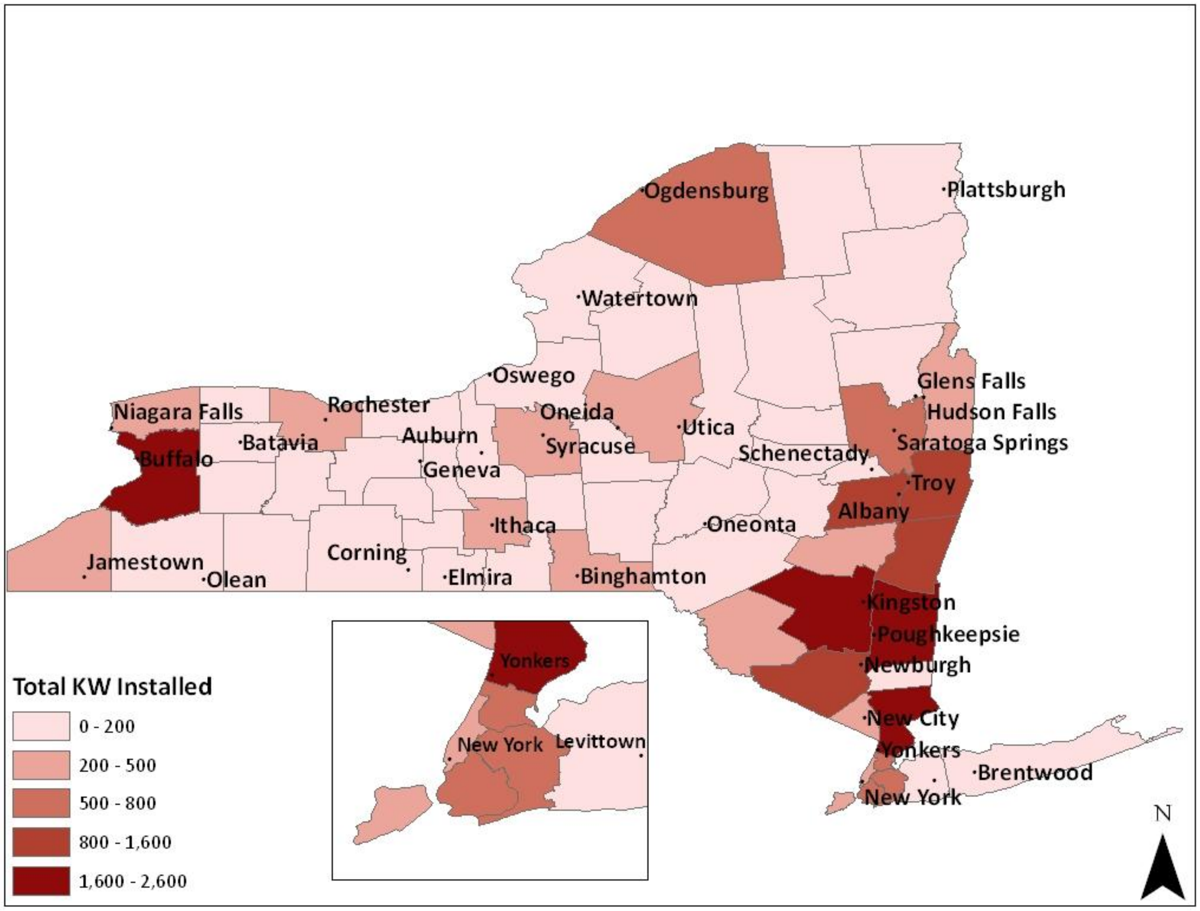


Figure 6 *California and New York total PV capacity (KW) by county. (Source: NYSERDA 2011; map drawn by author)*

By further breaking down of installations into KW per year, a consistent growth trend is observed in California (Figure 7). Far southern counties stand out most for the steady growth and high 2010 installations. Markets in other counties have been less progressive such as San Francisco, Marin, and San Mateo where total KW installed year to year have been flat.

Total system costs are closely tied with installations as historically, early PV adoption was something that was not affordable to people of limited economic means (Bolinger, 2009). Consequently, income is a potentially influencing factor in PV adoption. Overlaying median income and installed KW, confirms that the wealthier area are where PV systems are found (Figure 6). But wealth is not a requirement, which is confirmed by the correlation between median income and installed KW which indicated as income increases KW installed increases. However the relationship is very weak with $R^2 = 0.13$. Fresno County and Kern County (Bakersfield) represent the exceptions which have less than $50,000 median income yet make up approximately 4 percent of California's total installed KW each.

Few New York counties have experienced sustained installation growth; rather most have varying amounts from year to year (Figure 8). However the southeast region remains a stand out in the state. Overlaying income with installed KW indicates installations are more prevalent amount the middle income group ($50,000 – $70,000). The resulting $R^2 = 0.08$ indicates a positive correlation between increasing median income and increasing KW installed, however a very weak relationship. Buffalo, Tompkins (Ithaca), and Broome (Binghamton) counties represent the counties with low incomes yet higher rates of installations.

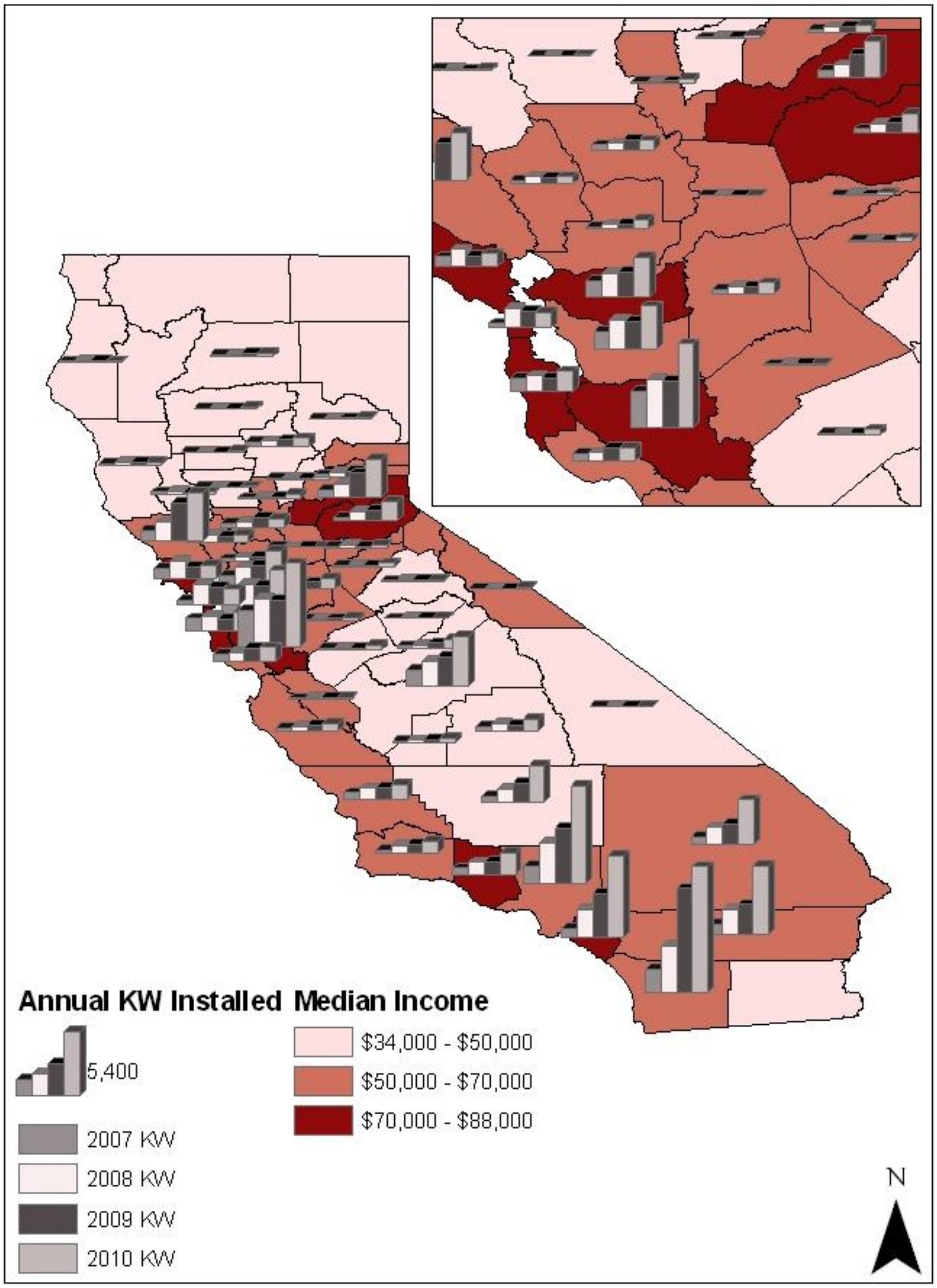


Figure 7 *Total KW per year of small projects and median income per county in California. (Source: State of California 2011; map drawn by author)*

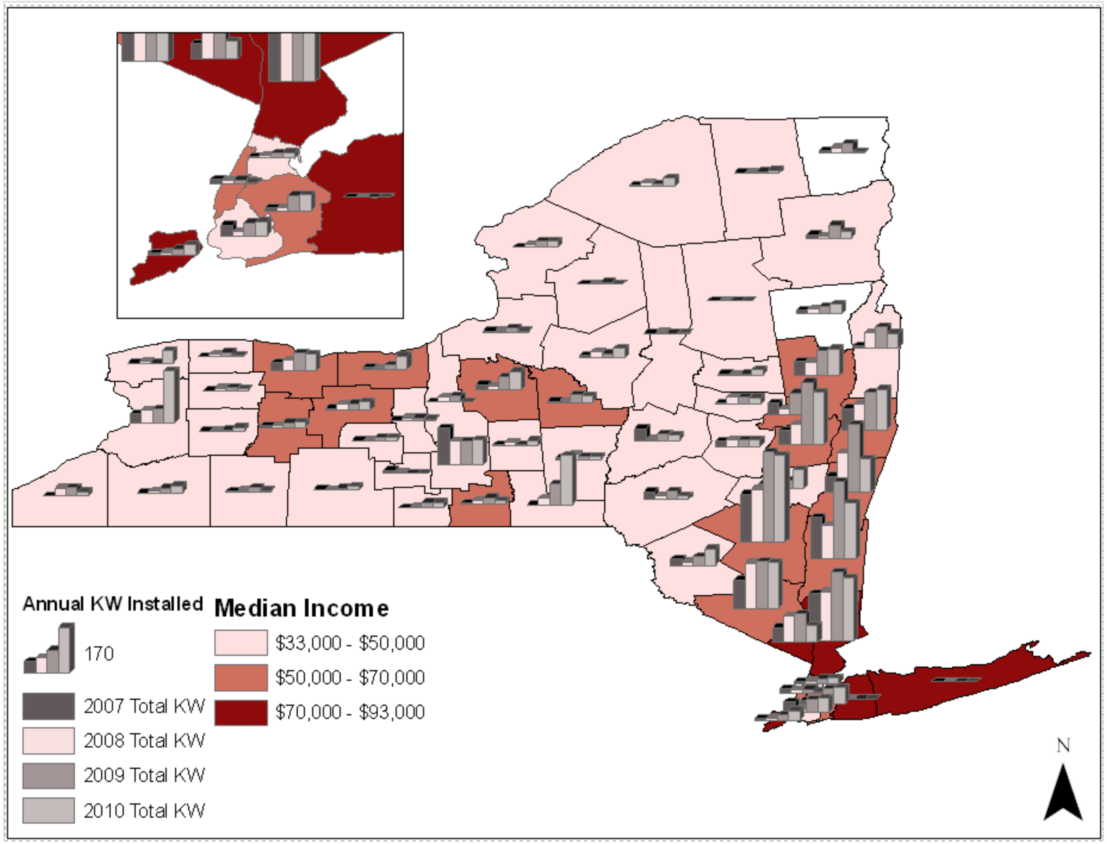
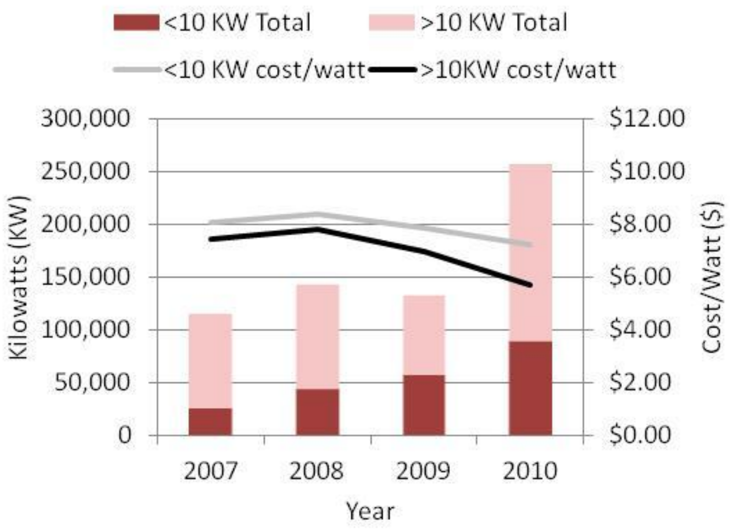


Figure 8 *Total KW per year of small projects and median income per county in New York. (Source: NYSERDA 2011; map drawn by author)*

California and New York's total installations are progressing as expected with increasing installations and decreasing costs over time (Figure 9). In California, installations of smaller sized systems (<10KW) have steadily increased while larger systems (>10KW) experienced a hiccup in 2009. This interruption could have been caused by the 2008 financial crisis which left industries unable to meet the large cost demands of PV systems. Nevertheless, installations of large systems soared in 2010. Cost ($/watt) includes all components of an installed PV system including the modules, inverter, mounting equipment, labor, etc. While costs of small and large systems have decreased overtime, economies of scale are clearly prevalent as larger systems have visibly lower costs.

New York's small systems (<10K KW) experienced a steady increase from 2007-2009, but leveled off in 2010. On the other hand larger sized systems (>10 KW) have expanded in total numbers every year. While New York's cost is also on the decline, the cost difference between small and large projects is smaller. This dissimilarity between California and New York can be attributed to their contrasting volumes noting California's total installed KW in 2010 reached 259,000 KW compared to New York's remaining less than 15,000 KW.



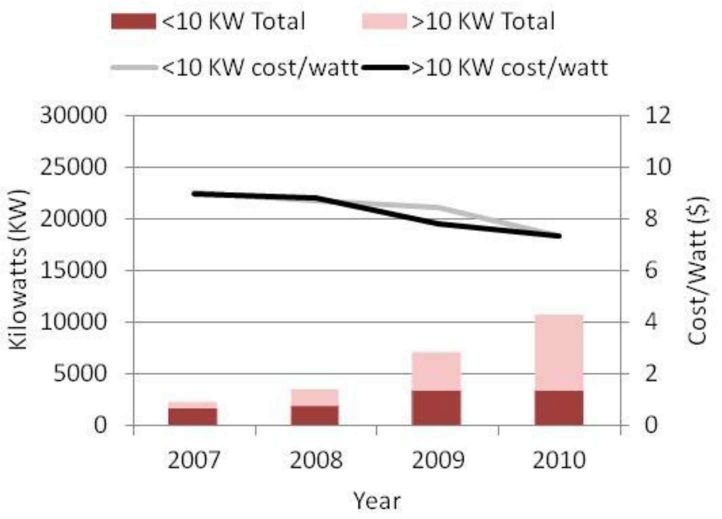


Figure 9 *Total KW and total installation costs per year. (California on top, New York on bottom) (Source: State of California 2011 and NYSERDA 2011)*

The geography of cost presented regional patterns within the states. In southern California as well as around San Francisco, prices are higher, correlating with the largest cities. Larger sized systems traditionally have lower costs due to economies of scale and with the removal of these projects from the equation a counties average costs increases. A large number of counties' cost remains unchanged after removal of larger systems. Five unusual counties actually experience increase in price after the removal of large systems including Los Angeles and Madera.

New York experiences similar trends, as the counties surrounding New York City experience the highest prices. Also, when focusing on small systems only, county average costs tend to increase or remain about the same from when large sized systems are factored. No counties in New York experience an unusual decrease in costs with the removal of large systems costs.

Cost and the size of PV systems are related factors, as generally the larger the system the more it cost, therefore it is important to note systems in these datasets are overwhelmingly part of the residential sector, therefore causing the majority to be classified as "small" sized (<10KW) systems. Consequently, focus is often generated towards small sized systems only. Non-residential systems have the tendency to be larger than residential systems due to more availability of money and space. In California more than 98 percent of small systems are residential compared to nearly 94 percent in New York (Tables 3 and 4). Though making up a small minority of the total systems, the influence of these non-residential systems is important to keep in mind with the results.

Table 3 *Number of small systems and average size by sector in California (Source: State of California 2011)*

Sector	# of Small Systems	Percent	Average KW
Commercial	94	4.65%	5.71
Government	19	0.94%	5.14
Industrial	2	0.10%	7.09
Non-Profit	15	0.74%	5.22
Residential	1,891	93.57%	5.11
Total	2,021	100.00%	5.14

Table 4 *Number of small systems and average size by sector in New York (Source: NYSERDA 2011)*

Sector	# of Small Systems	Percent	Average KW
Commercial	1,261	22.71%	222.12
Government	454	8.18%	279.25
Non-Profit	211	3.80%	107.16
Residential	3,626	65.31%	14.87
Total	5,552	100.00%	87.07

California and New York's sectors differ more in among the large size systems (Tables 5 and 6). California's prevalence of residential systems and New York's relative prevalence of commercial systems is clear as those sectors make up 60 percent of large systems in their relative states.

Table 5 *Number of large systems and average size by sector in California (Source: State of California 2011)*

Sector	# of Large Systems	Percent	Average KW
Commercial	277	58.32%	32.8422852
Government	10	2.11%	24.162
Industrial	8	1.68%	26.1125
Non-Profit	101	21.26%	24.61225743
Residential	79	16.63%	12.14241772
Total	475	100.00%	27.35352

Table 6 *Number of large systems and average size by sector in New York (Source: NYSERDA 2011)*

Sector	# of Large Systems	Percent	Average KW
Commercial	433	0.99%	5.44
Government	146	0.33%	3.65
Non-Profit	135	0.31%	4.79
Residential	43,151	98.37%	4.82
Total	43,865	100.00%	4.82

The average size of a residential system in California is a 4 KW system (State of California 2011). Distribution of size of small systems (Figure 10) is slightly skewed to the left most likely due to limited space on residential roofs and expenses. The larger the system size the larger a roof must be. Even among larger systems, they are usually less than 25KW, suggesting that there is substantial physical barriers to systems that are too large.

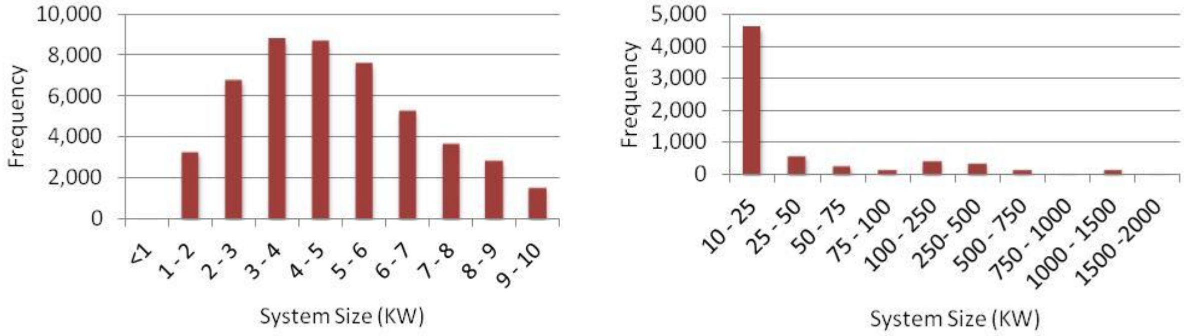


Figure 10 *Frequency of size among systems in California. (small on left, large on right) (Source: State of California 2011)*

The average size of a small system in New York is 5.14 KW. The distribution of small systems is skewed with a more extreme drop off of systems over 6KW (Figure 11). The trend toward smaller systems in California (>25KW) is less prevalent in New York, where the total systems larger than 25KW is equal to the number of systems in the 10-25 KW range as the non-residential sector installations escalate in the state as a percentage of total installs. New York's frequency of large systems seems to vary from California's.

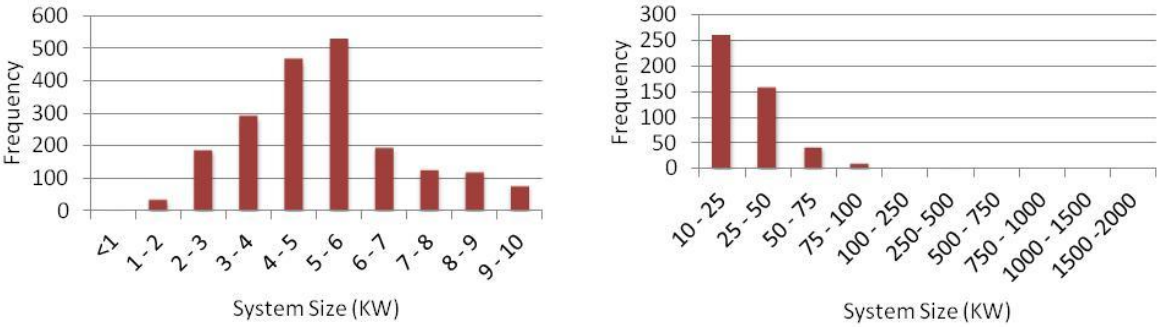


Figure 11 *Frequency of size among systems in New York (Small on left, large on right). (Source: NYSERDA 2011)*

Isolating the ten largest projects in each state there are stark differences between the two markets (Tables 7 and 8). First is the difference in sizes, as California's largest project is nearly 2,000 KW, New York's is only approximately 250 KW. New York's recent growth in the non-residential sector is also visible as all ten systems were installed in 2009 and 2010, which California's were spread throughout all four years. Also, New York's systems were only spread among four counties, which each of California's were located in a different county. Together however, US manufacturers played a small role, as only three out of 20 were manufactured domestically.

Table 7 *10 largest PV systems in California (Source: State of California 2011)*

Rank	Size (KW)	County	Year	Manf Location
1	1795.5	Kern	2010	Europe
2	1308.32	Butte	2008	Japan
3	1249.36	San Luis Obispo	2009	China
4	1239.7	Santa Clara	2010	China
5	1205.624	Fresno	2007	U.S.
6	1201	Alameda	2010	China
7	1199.88	San Bernardino	2010	China
8	1198.74	Los Angeles	2009	China
9	1197	Tulare	2008	China
10	1193.92	Santa Clara	2007	U.S.

Table 8 *10 largest PV systems in New York (Source: NYSERDA 2011)*

Rank	Size	County	Year	Manf Location
1	253.92	Erie	2010	U.S.
2	81.7	Orange	2009	Mexico
3	81	Westchester	2009	China
4	80.64	Orange	2010	China
5	80.64	Saratoga	2010	Mexico
6	80.52	Westchester	2009	Mexico
7	80.5	Kings	2010	Mexico
8	80.19	Westchester	2009	China
9	80.19	Kings	2010	China
10	80.08	Westchester	2009	China

Comparing the average incentive (per watt) in California and New York there does not seem to be any encouragement for larger systems in the small (<10KW) category (Figure 12). In California incentives increase as system size increases in the larger (>10KW) category. This cannot be interpreted in New York however as there are no systems larger than 100 KW and on the contrary systems larger than 50 KW receive less incentives.

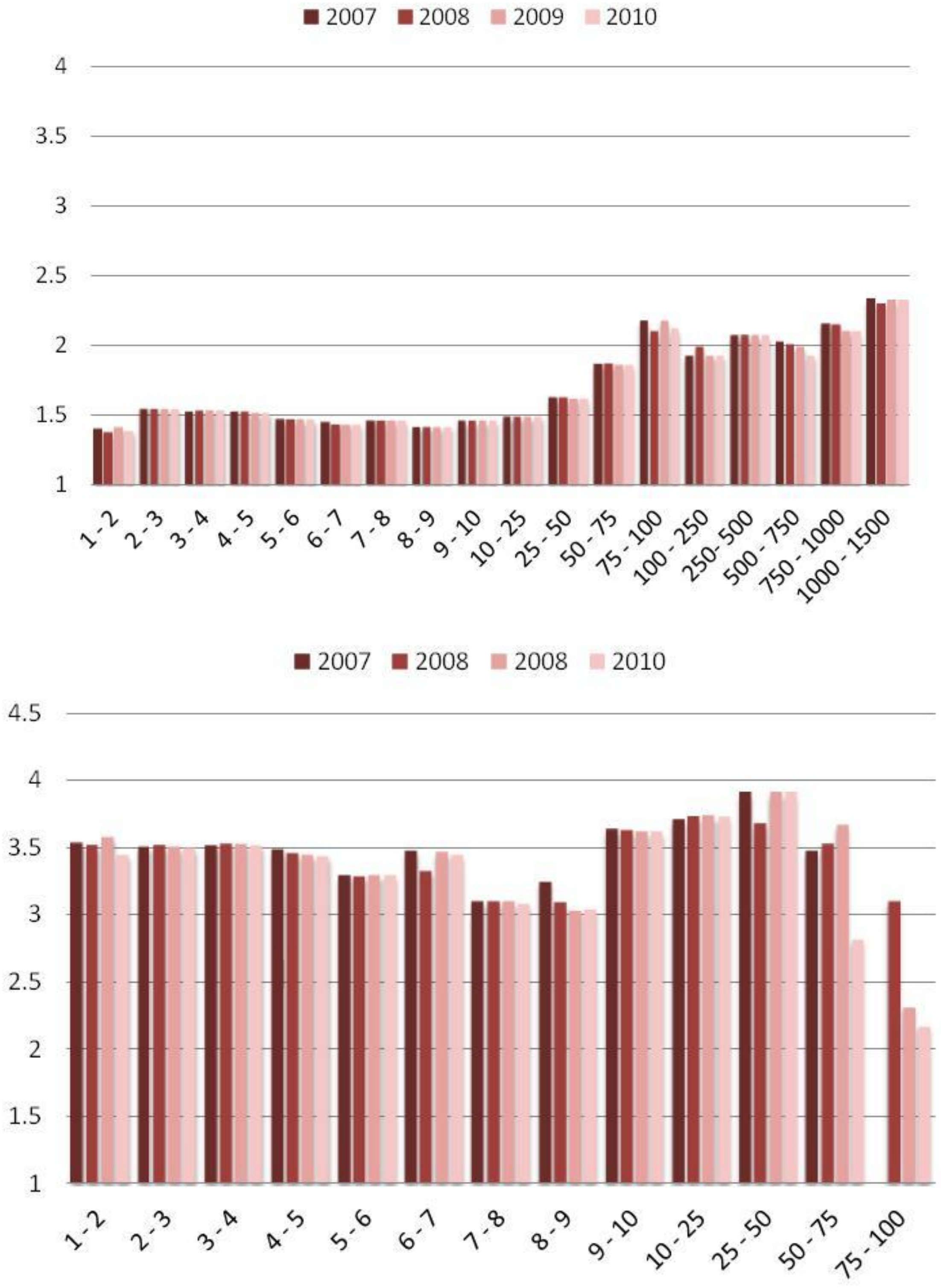


Figure 12 *Average incentive/watt per system size (KW) per year (California on top, New York on bottom). (Source: State of California 2011 and NYSERDA 2011)*

The geography of the size of PV systems can be considered as well. Some counties in California do seem to exceed the 4 KW average (Figure 13) though that could be due to smaller commercial systems which are included in the small sized category while the average considers only residential systems. The largest average sizes are seen in the center region of the state which correlates with the region's lower population density and therefore more available space. However in several of these counties there are a small number of systems, with the exception of Fresno and Kern. Contrarily, the smallest average size is seen in the northwest, though again the number of systems is low. It is assumed that as the number of systems in a county increases the average size decreases as a majority of systems are installed in cities where there is less available space.

The geography of system average size in New York takes on a scattered distribution (Figure 14). Focusing on the southeast region where the majority of installed systems are located, there is some pattern that would suggest that the further removed from NYC, the average size increase. Space is extremely limited in New York County and would explain the small average size. The relationship of increasing system size with increasing number of systems in a county could be considered as a large portion of New York's installed KW being located in the Hudson Valley rather that in the city, where the environment is most likely rural to suburban.

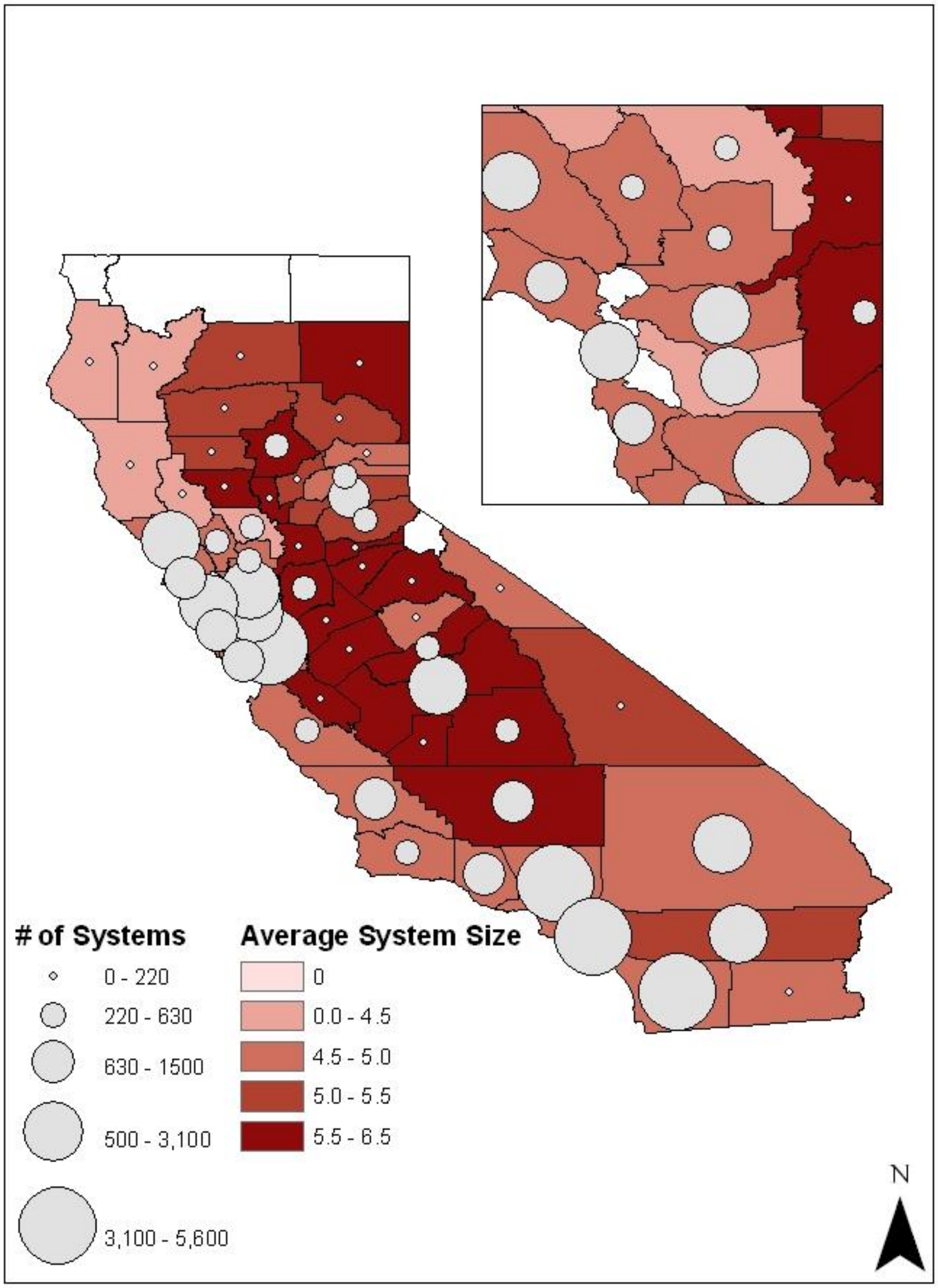


Figure 13 *Average system size and # of small systems in California. (Source: State of California 2011; map drawn by author)*

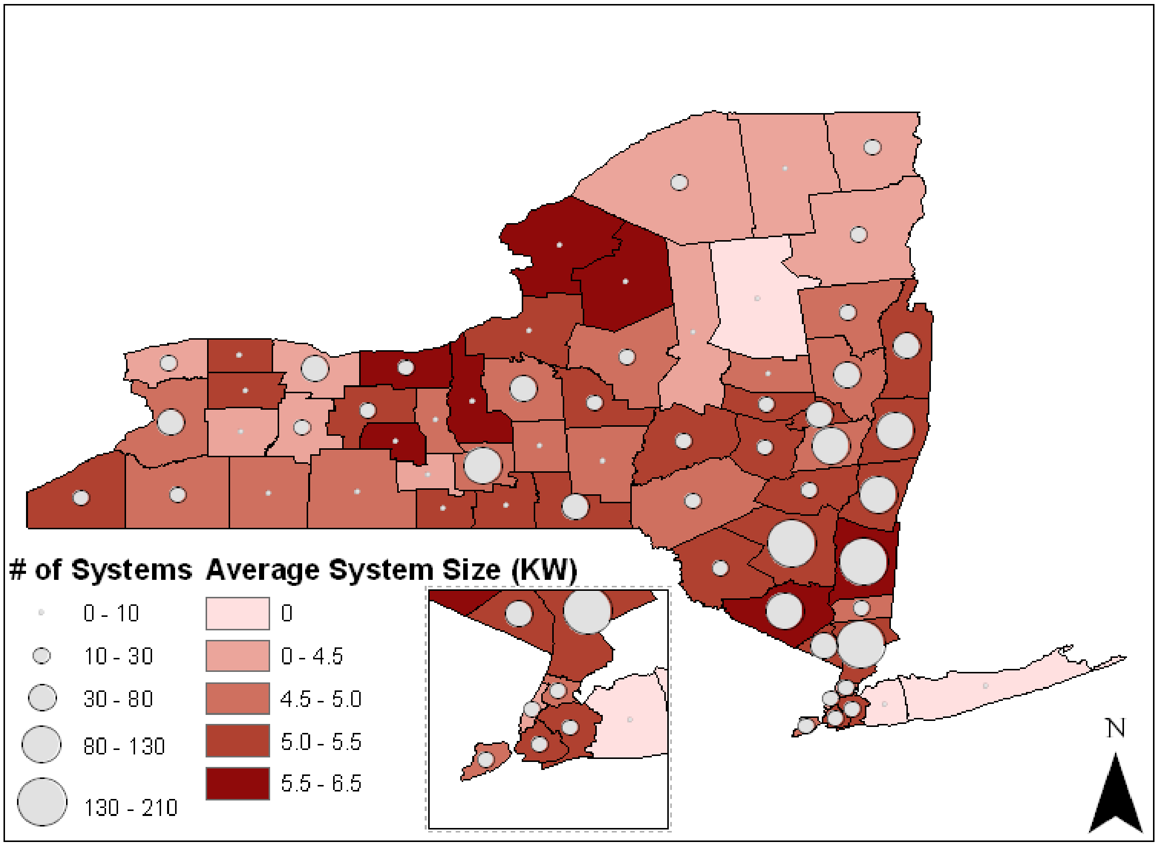


Figure 14 *Average system size and # of small systems in New York. (Source: NYSERDA 2011; map drawn by author)*

Because of the trends seen between average system size and number of systems, whether a system is installed within an urban or rural classified zip code is investigated. Urban or rural classification is assigned by the census, based on the population density of census blocks or block groups. A population density of at least 1,000 people per square mile is considered urban. Bocks with 500 or more people per square mile which surround those highest density blocks/block groups are also classified as urban. For the purposes of this study, a PV system's urban/rural classification was determined by its zip code. The zip code was classified by whether the majority of households in that zip code are urban or rural.

California has more installations in urban zip codes than does New York. The total number of urban systems in California is 51,747 accounting for 760,249 KW, and 3,321 systems are rural or 55,586 KW, making over 90 percent of installations urban. Some rural projects are most likely left out of the equation due to the fact that California's dataset does not include projects installed through miscellaneous program run by POU's such as municipal utilities, which could therefore exclude some if not the majority of the rural based PV systems. However, IOU's serve approximately 90 percent of all households in California and therefore the majority of the market is captured (Division of Ratepayer Advocates 2011). The total number of urban systems in New York is 1,495 systems accounting for 16,184 KW and 1,001 systems are rural with 7,192 KW, making only 60 and 70 percent urban respectively.

Systems in rural environments are on average larger than those in the urban environment (Table 9). A chi squared test was performed to test to examine the relationship between size and the urban/rural classification (Tables 10 and 11). The relation between these variables was significant, *p* <.001, in both California and New York. The majority of systems fall into the small and urban categories.

Table 9 *Average size of small systems in California and New York for urban and rural (Source: State of California, 2011 and NYSERDA, 2011)*

	Avg Size (KW)	
	CA	**NY**
Urban	4.79	5.11
Rural	5.29	5.17

Table 10 *California crosstabs for small/large versus urban/rural (Source: State of California 2011)*

Size	Urban	Rural	Total
Small	45,672	8,756	48,428
Large	6,071	565	6,636
Total	51,743	3,321	55,064

Table 11 *New York crosstabs for small/large versus urban/rural (Source: NYSERDA 2011)*

Size	Urban	Rural	Total
Small	1,165	856	2,021
Large	330	145	475
Total	1,495	1,001	2,496

Manufacturing

Like installations, the cost of PV is expected to impact where a PV module is manufactured. PV modules are manufactured worldwide with a variety of countries exporting their products to the US market (Table 12). Influence of modules manufactured outside of the US is on the rise as imports increase as in 2010 nearly 60 percent of US installations used imported modules. In 2010, 99 percent of the US imported PV modules came from ten countries. China accounted for approximately half of these imports (EIA 2011).

Table 12 *US imported assembled modules (in thousands of dollars) (Source: ITC, 2011)*

Country	2007	2008	2009	2010	2007-2010 % Change
China	$183,177	$227,249	$407,724	$1,150,964	528%
Mexico	$54,310	$213,172	$349,261	$480,097	784%
Japan	$195,303	$241,889	$151,799	$238,493	22%
Taiwan	$1,315	$7,176	$51,030	$167,801	12661%
Malaysia	$0	$2	$54,854	$139,004	
Germany	$60,144	$140,109	$28,413	$38,093	-37%
India	$11,664	$4,127	$3,914	$29,965	157%
Philippines	$15,325	$136,051	$168,339	$27,664	81%
Sweden	$28	$16,727	$14,578	$15,276	54457%
Korea	$39	$133	$1,243	$13,970	35721%
Other	$23,636	$28,416	$10,646	$13,502	-43%
Total	$544,941	$1,015,051	$1,241,801	$2,314,829	325%

Domestically, US power production has increased, growing from 170 MW in 2007 to 1,115 MW in 2010 (Earth Policy Institute 2011). US manufactured PV modules are being utilized both domestically as well as outside the US. However, the country is running a solar module trade deficit. In 2009 the US imported $1,242 million and exported $1,010 million, leaving a net of $232 million in imports. In 2010 imports grew to $2,398 million and exports only grew to $1,201 million, leaving a much larger net of $1,197 million in imports (SEIA 2011b).

Of the two technologies, the majority being imported is crystalline. In 2010 only 31 percent of crystalline installed modules were domestically manufactured, altough an increase from 24 percent in 2009. Contrarily 94 percent of installed thin-film was domestically manufactured, which was up from 77 percent in 2009. 87 percent of that thin-film production is estimated to be by the company First Solar, located in Ohio (SEIA 2011b).

Locations of domestic module manufacturing facilities (Figure 15) are scattered among two regions, the west/southwest and east of the Mississippi River. California houses the largest percentage of domestic production. Some states can attribute their high percentages of production to a single company/facility such as Tennessee, the home of Sharp. Other states however have multiple facilities, California again leading the way with 10 facilities. Other than California, no state houses more than 3 facilities.

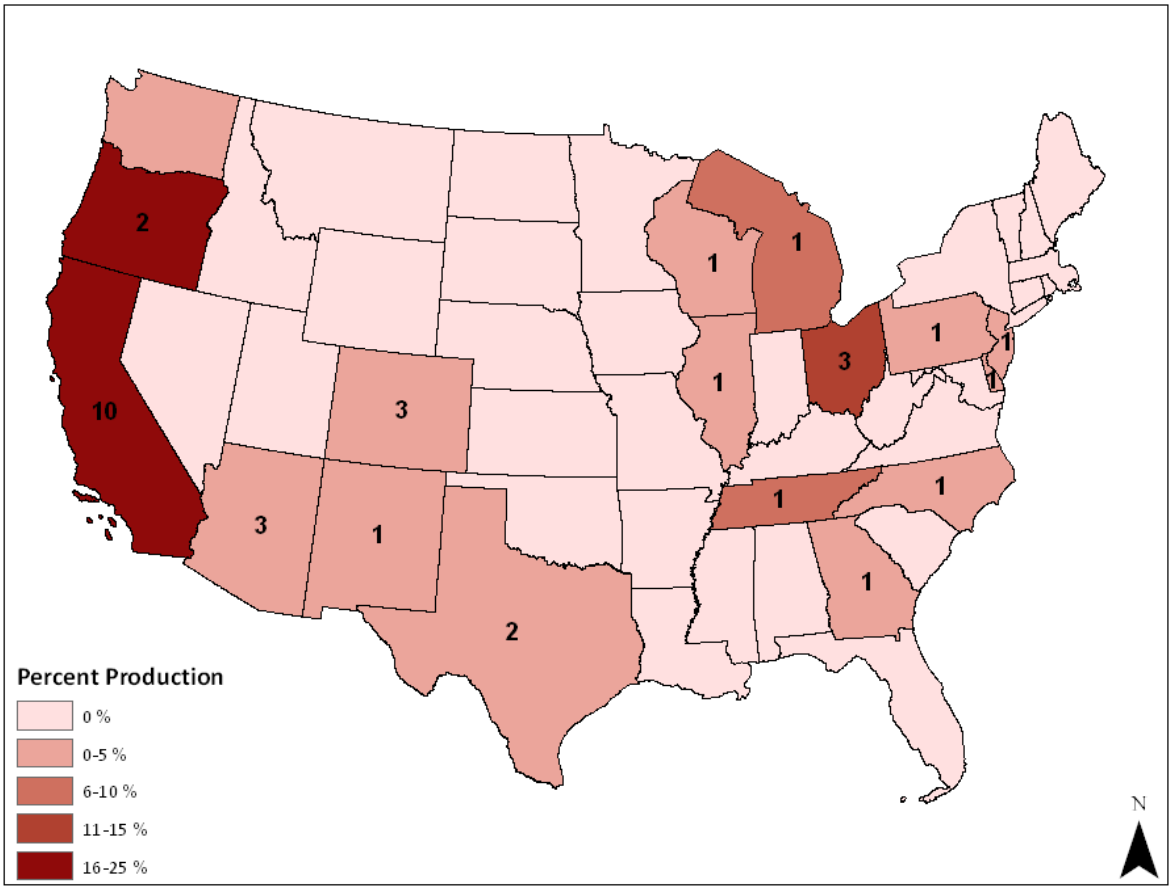


Figure 15 *US domestic module manufacturing in percentages and number of facilities. (Source: SEIA 2011c; map drawn by author)*

There has been a notable shift in the location of the manufacturing location of the solar panels that are installed in California and New York (Tables 13 and 14). In California, China has been the largest player in the market. While total US modules have increased, domestically manufactured products are losing ground to imports. Europe and Japan are also losing market share. The story for the Philippines is due completely to the one major manufacturer (SunPower) moving their US targeted production to Mexico.

Table 13 *California installations manufacturing location (KW) 2007 vs. 2010 (Source: State of California 2011)*

		2007			**2010**			**Change**	
Manf Locat	**Small**	**Large**	**Total**	**Small**	**Large**	**Total**	**Small**	**Large**	**Total**
Japan	1,490	7,299	8,789	441	3,956	4,397	-70%	-46%	-50%
Europe	3,282	8,408	11,690	4,110	5,821	9,931	25%	-31%	-15%
Philippines	5,598	20,281	25,878	0	0	0	-100%	-100%	-100%
China	209	3,541	3,750	20,521	57,775	78,296	9735%	1532%	1988%
Mexico	2,179	9,897	12,076	29,226	15,713	44,939	1241%	59%	272%
Total Impor	12,758	49,426	62,183	54,299	83,265	137,564	326%	68%	121%
U.S.	10,989	30,672	41,661	23,816	26,577	50,393	117%	-13%	21%

New York experiences similar trends, although Mexico has secured a more dominant market position, even surpassing Chinese manufacturers. Europe has lost what limited share of the New York market it had, while SunPower no longer manufacturers in the Philippines, which accounts for its loss. US made solar panels are enjoying more success in New York than California, where growth is up 269 percent in the three years (albeit off a modest base), compared with a much smlaler 21 percent rise in California. Nevertheless, imports continue to claim additional market share.

Table 14 *New York installations manufacturing location (KW) 2007 vs. 2010 (Source: NYSERDA 2011)*

		2007			**2010**			**Change**	
Manf Location	**Small**	**Large**	**Total**	**Small**	**Large**	**Total**	**Small**	**Large**	**Total**
Japan	13	0	13	30	85	116	126%		759%
Europe	185	40	225	0	0	0	-100%	-100%	-100%
Philippines	569	337	906	0	0	0	-100%	-100%	-100%
China	9	0	9	598	1,818	2,416	6773%		27669%
Mexico	119	23	142	1,911	2,279	4,190	1500%	9984%	2850%
Total Imports	896	400	1,296	2,540	4,182	6,722	183%	947%	419%
U.S.	678	314	992	663	2,998	3,661	-2%	854%	269%

Although California and New York share gerneral trends in where their installed products originate, there are a few more detailed differences. For example, US domestic manufacturers are prefered in California for small sized systems, while in New York they make up a majority of large sized. Also, although China and Mexico are the largest players, Mexico is more prevelent in New York and China in California. While it is beyond the capacity of this study, we can speculate that there are higher transportation costs to the east cost from China than from Mexico. Chinese products often enter the US through west coast ports. Transporting within California would be minimal addition to the transportation costs versus transporting across the entire country to New York. However, Europe has to be noted in the case of transportation costs as it would be expected that New York would still be importing from European manufacturers.

Focusing on China, Mexico, and the US; there is a decrease in price over time for all three countries (Figures 16 and 17). While the price from each country decreases, China remains the lowest price just as the literature suggest. Once again in terms of installations, China and Mexico's presence in 2010 stands out as the two markets soar among their lower prices. Mexico especially dominates smaller sized projects in both the California and New York markets, despite Chinese prices being lower. Europe, Japan, and the Philippines are ignored here due to their small volume of projects.

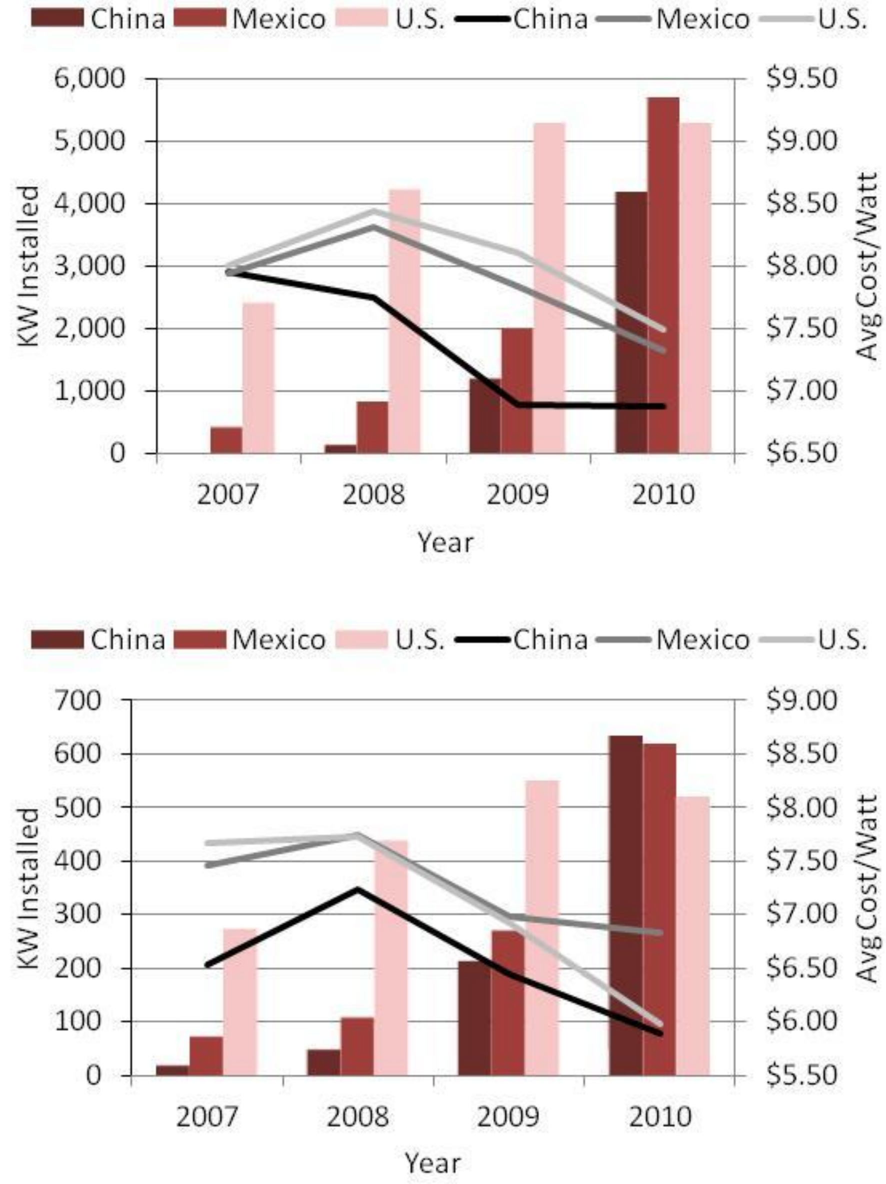
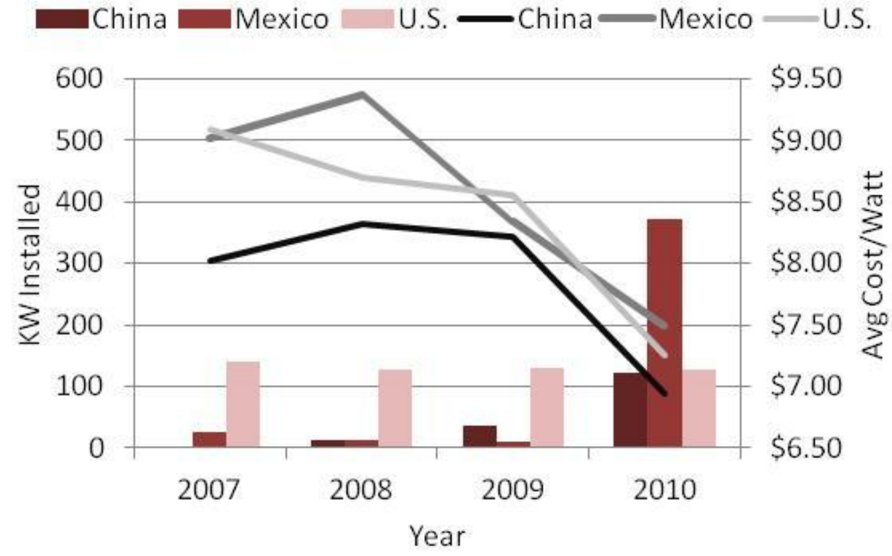


Figure 16 *Number of small systems and cost per manufacturing location (California on top, New York on bottom) (Source: State of California 2011 and NYSERDA 2011)*



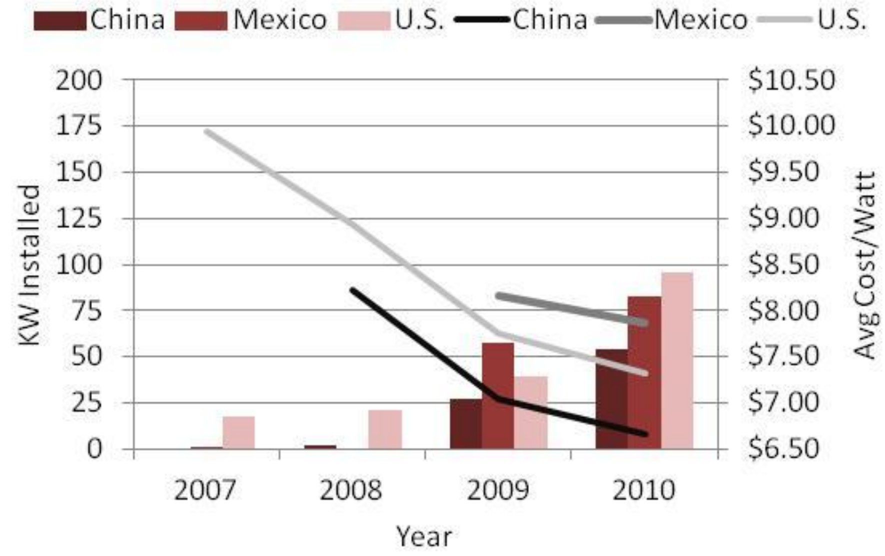


Figure 17 *Number of large systems and cost per manufacturing location (California on top, New York on bottom). (Source: State of California 2011 and NYSERDA 2011)*

No striking trend is present among counties in terms of percent of domestically made KW (Figures 18 and 19). Very few counties hold over the 2/3 majority for domestic KW. While some of the biggest cities such as San Francisco use very few domescally produced PV modules, Buffalo uses a majority US made modules. Others such as San Diego and Manhattan fall right into the middle using approximately half of each. Overall, in California 37 percent of systems and 27 percent of KW are domestically made products. In New York 28 percent systems and 32 percent KW are of dometic origin. Although the maps hint at New York having more domestically made products California actually has the slight edge, because although having a fewer number of domestic systems, has a larger number of domestic KW.

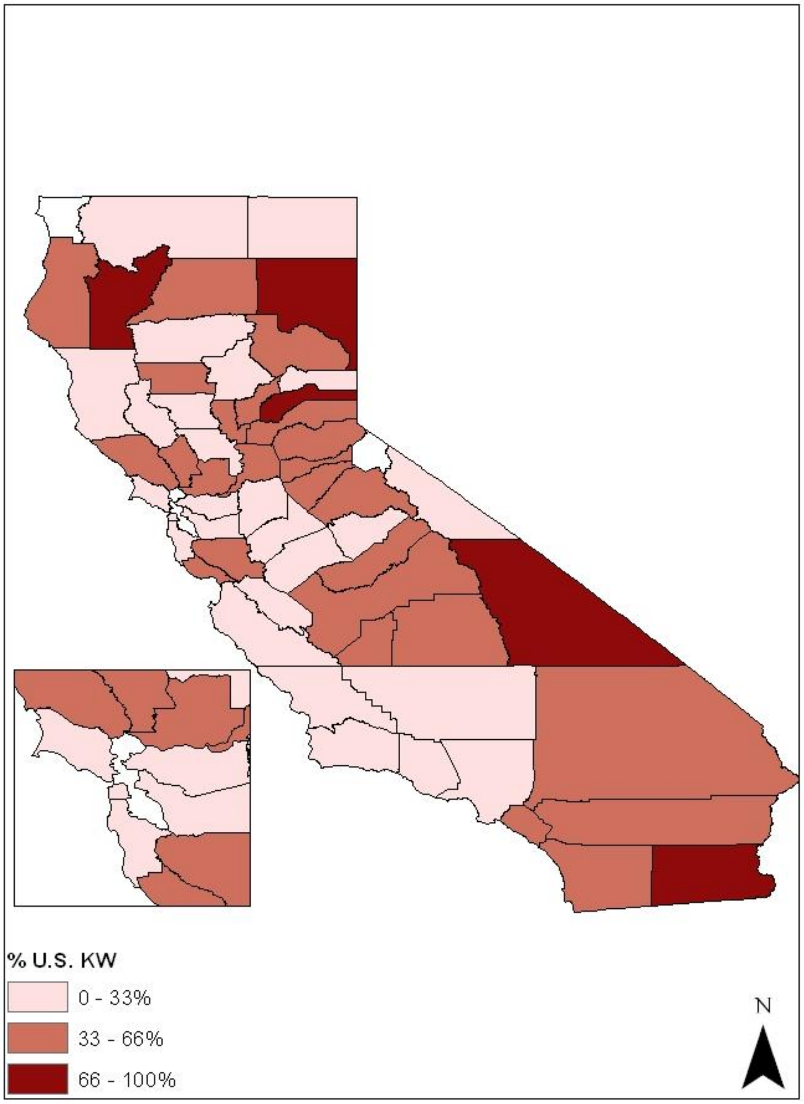


Figure 18 *California % KW from domestically made PV modules. (Source: State of Claifornia 2011; map drawn by author)*

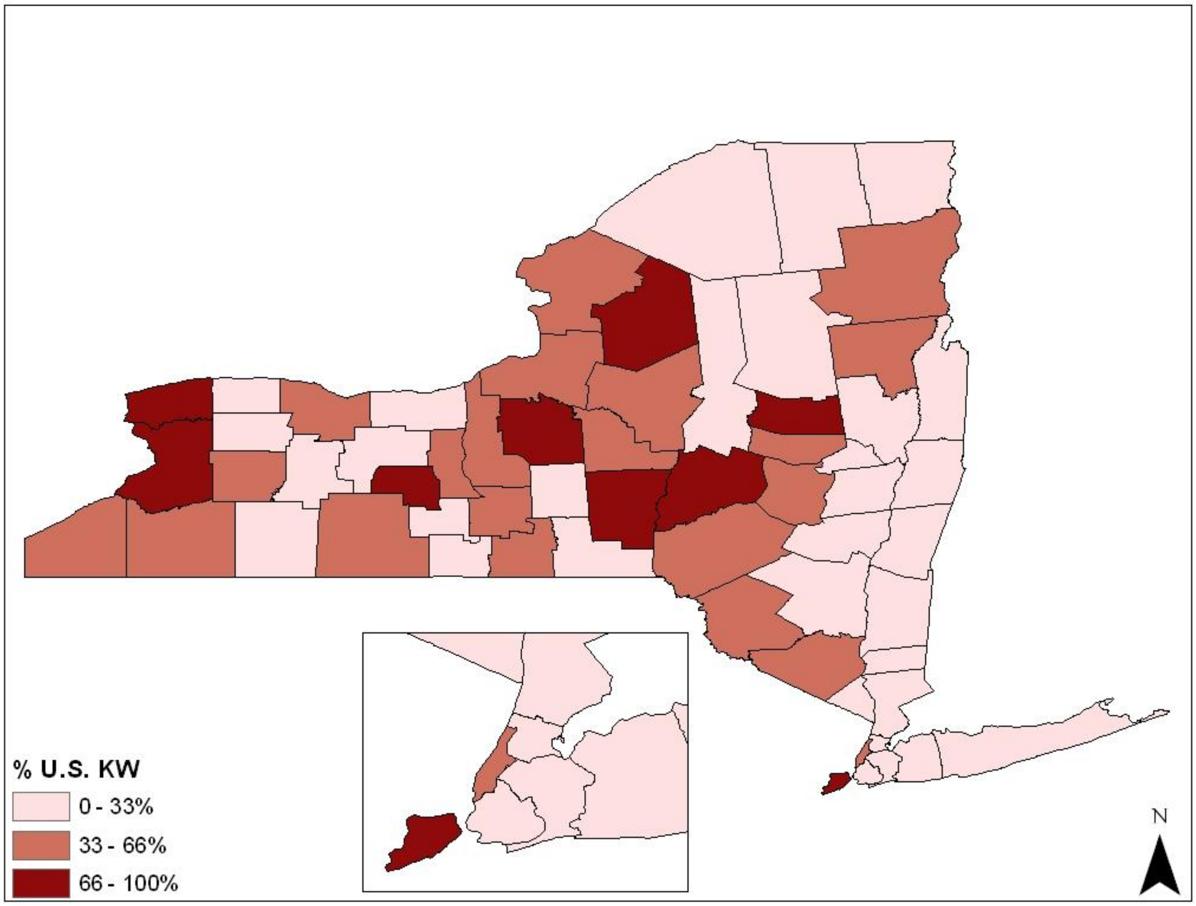


Figure 19 *New York % KW from domestically made PV modules. (Source: NYSERDA 2011; map drawn by author)*

The Economy

As the PV industry is very young it is dependent on policy mandate and available subsidies. Consequently, the solar industry and the economy are indirectly connected. Not all applications for a PV system through programs such as the California Solar Initiative and NYSERDA result in a new system installation. Withdrawals from the California Solar Initiative were recorded when the applicant withdrew their application in the program. Comparing the time of withdrawals with the US GDP shows that withdrawals spiked following the onset of the recession (Figure 20). As GDP as gradually recovered, withdrawals have also decreased. Therefore, we can say that, at least with respect to these two states, solar PV installations (as measured by the number of applications that are withdrawn) is a lagging economic indicator. That is, as the economy is doing well, people (or businesses) are more inclined to install a solar system. While this is intuitive, it is reassuring that the data supports this idea.

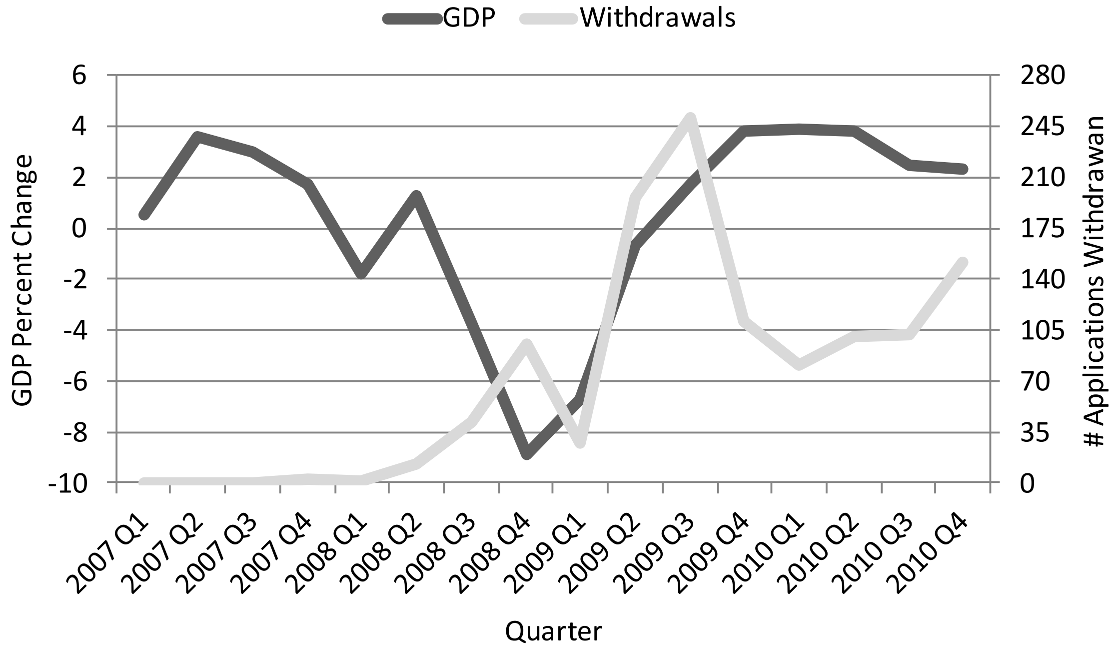


Figure 20 *GDP v. application withdrawals. (Source: Bureau of Economic Analysis, 2011 and State of California, 2011)*

The most withdrawals between 2007 and 2010 occured in southern California (Figure 17). In a couple counties withdrawals have increased every year, however a majority of counties experienced a spike in 2009 and subsequently decreased in 2010 as the economy recovered. This trend correlates with the total withdrawals as seen in Figure 21. In regards to the percent of applications withdrawn in each county there is some overlap with the number of withdrawals, particularly in southern California (Figure 22). However, in central/northern California the counties with high percentages of withdrawals do not stand out as much relative to the number of withdrawals.

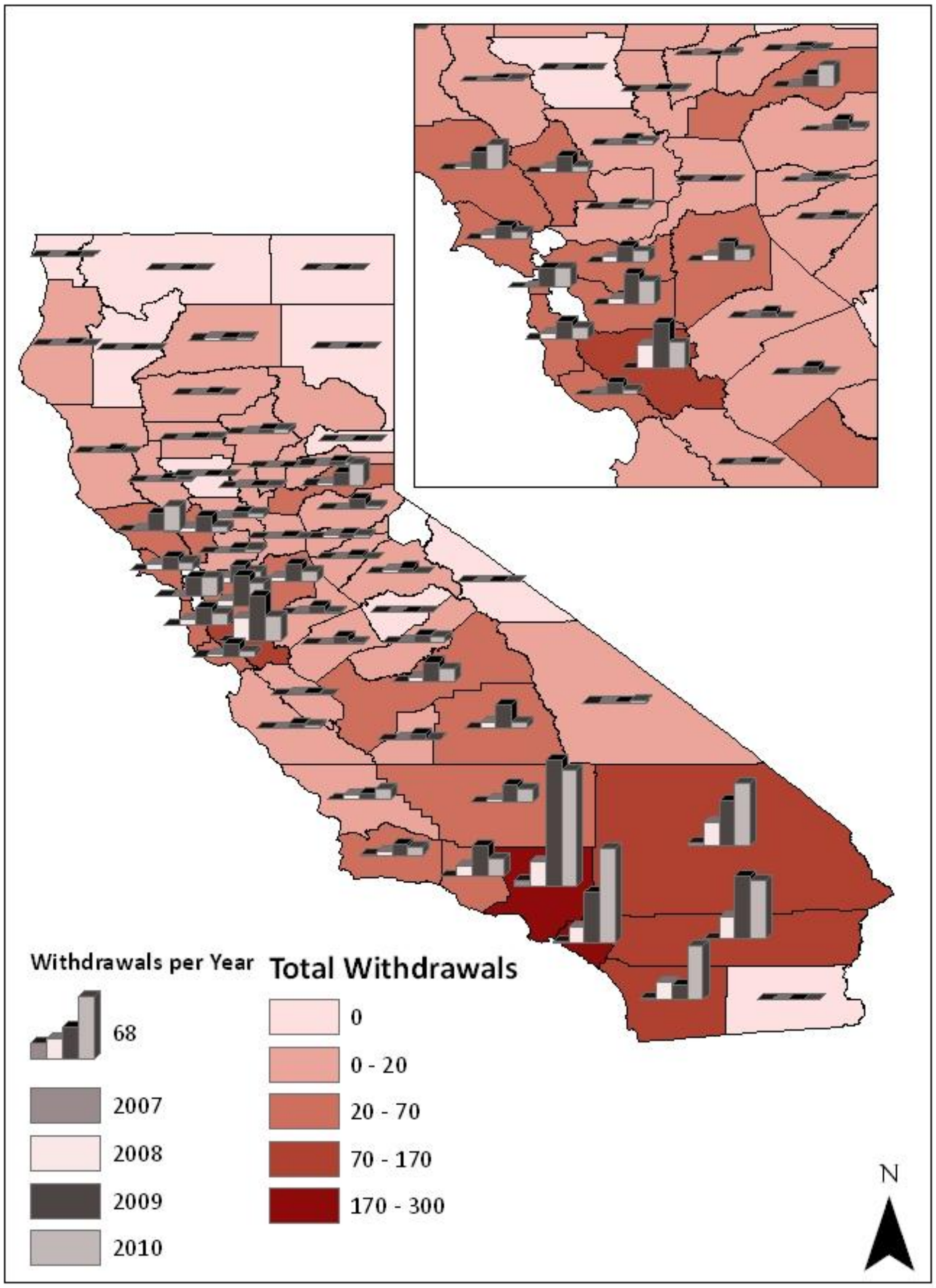


Figure 21 *Withdrawals per county. (Source: state of California 2011; map drawn by author)*

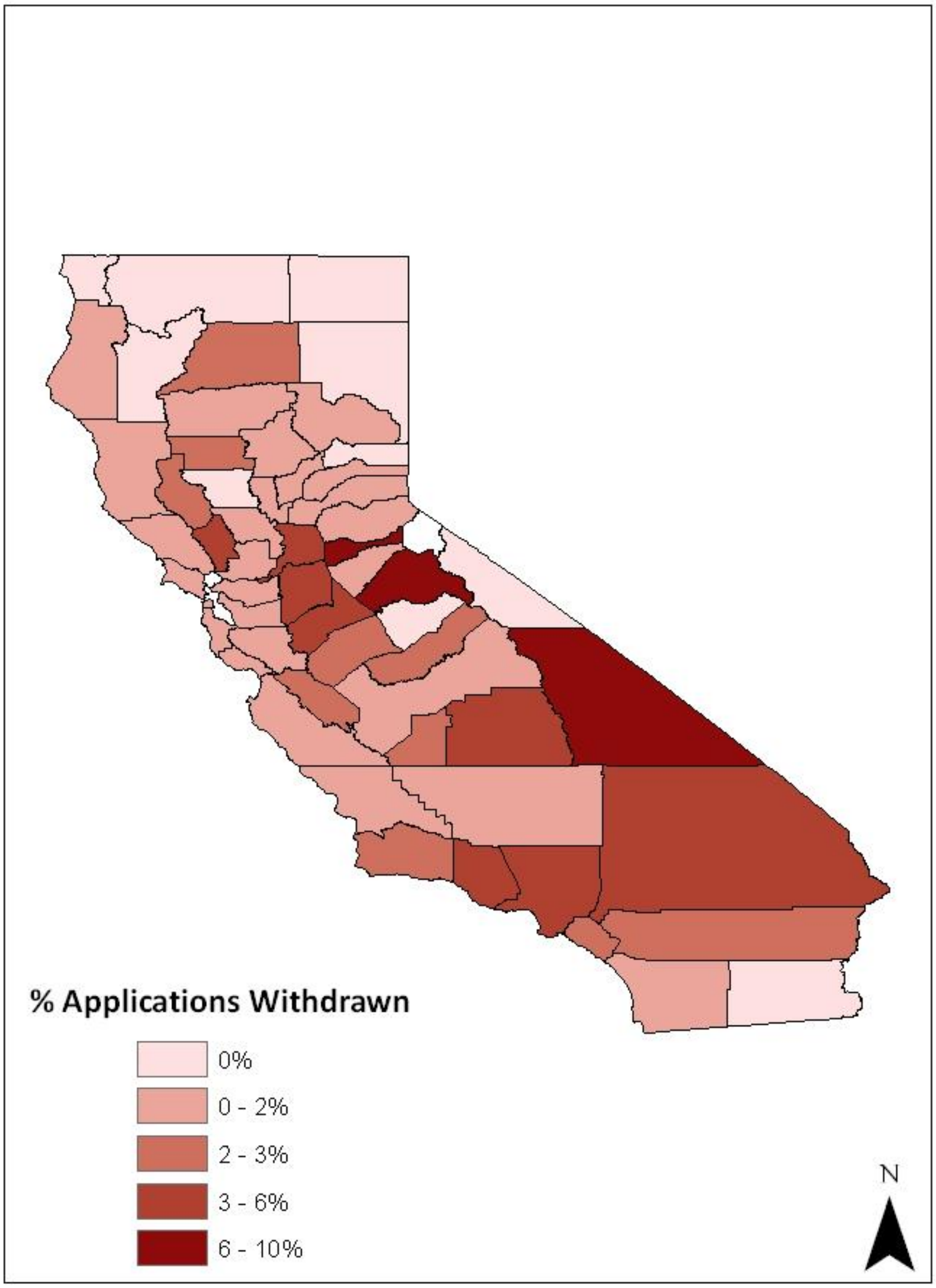


Figure 22 *% applications withdrawn per county. (Source: state of California 2011; map drawn by author)*

This trend is also visible when referring back to past figures. Figures 7 and 8, which showed the annual KW installed per county, shows a dip in installations in 2009 that is prevalent in the central/northern California counties, which correlates with the withdrawals seen in Figure 21. Also in the number of imported assembled modules (Table 12) there is an overall lag in 2009. Although the number of imports increased in 2009 it was significantly less than the increases between 2007-2008 and 2009-2010.

The financial incentive level has not been as drastically affected by the changes in the economy (Tables 15 and 16). In general, the states have given out more overall incentive money each year. However, and very importantly, the average size of the incentive received by each applicant has been declining each year. There are several explanations for this drop. First, each year more poeople are applying to install solar panels as part of the CSI; as a result, the available pool of money is spread more thinly. But more encouragingly, despite this reduction in overall subsidy size, the ecnomics of the solar system are improving so that the PV market is moving clost to standing on its own. Overall New York's incentives are making up a larger percent of the overall cost. However, California has a more stable PV market and a larger volume of PV installations.

Table 15 *California average incentive, average cost, and incentive as % of total cost*

	Average Incentive ($ per watt)		**Average Cost ($ per watt)**		**Incentive % of Total Cost**	
Year	**Small**	**Large**	**Small**	**Large**	**Small**	**Large**
2007	$2.30	$2.51	$8.08	$7.64	24.69%	36.35%
2008	$1.94	$2.07	$8.37	$7.82	20.20%	28.10%
2009	$1.52	$1.57	$7.85	$6.97	17.23%	25.54%
2010	$1.00	$1.13	$7.22	$6.18	12.47%	24.19%

Table 16 *New York average incentive, average cost, and icentive as % of total cost*

	Average Incentive ($) ($ per watt)		**Average Cost ($ per watt)**		**Incentive % of Total Cost**	
Year	**Small**	**Large**	**Small**	**Large**	**Small**	**Large**
2007	$4.00	$4.00	$9.03	$9.17	45.39%	44.54%
2008	$3.92	$4.09	$8.73	$8.83	45.31%	45.69%
2009	$3.55	$3.86	$8.47	$7.80	41.80%	49.76%
2010	$2.58	$3.42	$7.36	$7.36	35.48%	44.78%

DISCUSSION

These results show that the PV market is growing worldwide as installations and manufacturing increase exponentially. In addition, as the market grows and costs decline, solar PV is showing signs that it can stand on its own. The more the costs decline, the less subsidies are needed to foster demand. Geographically and temporally, patterns in PV installations have begun to form.

The European Union is leading the world in installations as its governments progress with policies in support of solar. Policies and popularity in the United States is lagging compared to the EU, however it is not nonexistent. With California leading the way states have begun to take the reins in designing and implementing policies which support their residents to install PV. However, many states still lack the necessary policies to support solar, especially those in the plains states and the Deep South.

California and New York serve as two good examples of states implementing PV. While California is further along than New York, both states are experiencing an upward trend in their installations. However, due to its advancements, California has a more defined area of where installations are occurring within the state. Also a key quality of California's market is the substantial volume of installations, with more installed systems and KW than any other state. Correspondingly, California has more jobs related to the industry than any other state including trained installers, repair workers, and so forth. New York is still early in their ramp up, but their volume levels are beginning to increase and with it, the expertise should develop. The relationship between any two factors mentioned demonstrates how a variety of components, including income, size, etc, are involved with where a PV system may be installed. By and large, policies such as those seen in California and New York, are necessary to provide the support required for PV installation. Because cost is a driving factor in adoption of PV and the wealthy are more likely to install a PV system. However with help of incentives, adoption is occurring in areas that are not seen as traditionally wealthy markets.

Size of a PV system does not seem to be determined by cost, but instead, it is the physical space for the solar system to reside (size of the roof). Without incentives encouraging people to purchase larger systems and a weak correlation between the counties with the largest sizes and the highest incomes larger systems are simply being installed where there is more space. To illustrate, in California 17 percent of rural systems are large compared to 12 percent of urban systems being large as rural areas have more space and ability to accommodate larger systems.

California's installations are more geographically diffuse, while installations in New York are largely concentrated in the southeastern region. Other markets, such as Buffalo and Syracuse are observable, but they are still lagging in total installs. California sees a predominately urban and residential market, while New York has experienced a recent growth in their non-residential sectors and has more presence in the rural areas although there are issues with reporting of projects in rural areas of California's. The California Solar Initiative appears to have more financial resources combined with industry willingness to have the ability to support systems much larger than 100 and even 1,000 KW as New York has only installed a single system over 100 KW.

As PV is a future catalyst for economic growth, where PV modules are manufactured is an important consideration. Over half of PV products installed in the US are being imported

(EIA 2011). Installations in California and New York have further verified this trend. Although installation of domestically made products is on the rise, installation of modules manufactured in China and Mexico are increasing even further. Other countries such as Japan and various countries in Europe have also played a role in the market, particularly prior to 2008 or 2009; however have not had roles as significant as Mexico and China. This has been heavily influenced by the development of international trade and therefore globalization. However, although manufacturing has been influenced by globalization, only a handful of countries dominate the world's PV manufacturing. Furthermore, those dominant countries are being accused of manipulating prices in order to gain a cost advantage (Greider, 2010). Such cost advantage is clearly visible in the price differences among Chinese products installed in California and New York.

This is not to overshadow the fact that US domestic production is indeed expanding marginally as is the installations of domestically made products. However, a large portion of products are being exported rather than being utilized domestically. This is due to the fact that companies rather than countries exchange products and therefore installation companies will buy and sell for the best monetary benefit regardless of country of origin. Nonetheless, domestic PV installations are benefiting foreign manufacturer's more than domestic manufacturers. If this trend persists, policies supporting those installations will also be attributed to supporting foreign made products, and therefore contradicting the purpose (let alone the actual potential) to stimulate the domestic economy.

The result of the unique opportunity to examine the relationship between the US PV market and the changing economy was a clearly visible correlation. The PV market is a lagging factor in the economy as installations and imports took a dip in 2009 and withdrawals of applications in California spiked to their highest levels. However despite the economic downturn, California and New York's budgets for PV incentives have regularly increased. Amount given per project is on the decline due to increase in volume as well as the ability for the PV market to begin to stand on its own.

CONCLUSION

The PV market is in its infancy and influenced by a variety of factors, however we are beginning to understand the PV supply chain and what and how policies can be most utilized to encourage the installation market as well as the usage of domestically made products. Cost is a major factor in PV adoption however the price for solar PV is becoming less significant as policies and incentives are implemented that helping bring the technology down the cost curve. Other factors contributing to PV adoption will have to then be addressed such as consumer perception, intermittency and storage of solar energy, and so forth. California has demonstrated that implementing aggressive policies to force the acceptance of a particular technology can generate important results. Other states are following and gradually closing the large gap that exists between California and the rest.

China and Mexico have surged over the past couple of years to take a hold of the US installation market. This trend is expected to continue as China offers cheaper product prices and Mexico is susceptible to lower transportation costs due to geographic location and trade agreements. US domestic production is ever increasing and the location of these domestic facilities is forming a clear geographic pattern by following the location of installations in California, the west/southwest, and east of the Mississippi River. However, there are no manufacturing facilities in New York. Nonetheless, domestic installations remain in benefit of the foreign manufacturers as US products are exported and the US is a net importer. It is unclear if US policies designed to stimulate the solar industry is helping US PV manufacturers, and those green jobs have been touted as an important component of the budding solar industry. It is likely that the PV industry will someday stand on its own in the competitive energy market place, but for now, the continuation of policies designed to support the industry are important to improving installation rates in the US. And while green jobs are important, getting off fossil fuels is more important, and it is clear that these policies are playing an important role transforming our energy systems.

Recommendations for Future Research

The major contribution of this research was to begin to illustrate the linkages in the PV supply chain over time by looking at installations and manufacturing. As more data becomes available (i.e. the Go Solar California Campaign is a 10-year program that will last through 2016), this study can be extended to examine longer-term trends. For example, over time, total imports from China may be affected by the US investigation into China's allegedly illegal trade practices (subsidies) for PV manufacturing, as future tariffs could be placed on those items if US allegations are upheld. Another suggestion for future research would be to complete the analysis can also be done at a finer geographic scale, as far down as the zip code level, in order to even further analyze the specific installations and manufacturing geographic patterns. Also analysis of domestic manufacturing in terms of region, east or west of the Mississippi River can be considered as well. Are products being installed in California coming from California manufacturers, or do states east of the Mississippi River procure their PV from manufacturers in the eastern half of the country.

As cost is a major factor influencing PV, a further cost analysis can be carried out, investigating prices for different components, as opposed to the total system cost. Also, while this study focused on the module assembly step of the supply chain, the geographic and temporal nature of manufacturing the many other components (silicon, cell, wafer, etc) can be investigated. As more focus narrows in on domestic manufacturing and the possibility of energy independence, domestic production can be investigated further to explore whether it could actually support the domestic installation market on its own. This would require observing domestic manufacturing of all components of a PV system and if production is ramping up at the same speed as installations.

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