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Implications for Solar Energy Expansion

Introduction

The expansion of solar energy production has huge consequences for consumers, policymakers, and utility companies. Solar energy has seen dramatic growth in recent years, particularly in California. Dropping solar costs, changing regulations, more efficient technology, and new financing models have all contributed to this growth and are expected to continue facilitating the rapid adoption of solar technologies in coming years. The strategies of solar companies up until now have been to target regions where government subsidies are available for consumers and regions with maximum and consistent sun exposure. With the impending exponential growth of the solar industry forecasted for the next decade, will these strategies continue to be effective models for expansion and implementation and are they targeting the best potential customers?

As technologies become cheaper and more efficient, traditional energy costs continue to rise, and government policies adapt to changing utilities, solar companies have the opportunity to expand into new customer bases, markets, and geographies. In particular, how can the existing reach of the solar industry, geographic conditions, and data about energy consumers be used to inform this expansion? This project seeks to use geographic information systems to analyze and compare data on existing solar strategies and energy consumption patterns to posit potential opportunities for solar companies in the coming years.

Background and Context

Solar energy production in the United States has seen a rapid increase in the past four years (see Figure 1 on page 2 for California solar generation compared to the US and western states). In 2014, the solar industry installed 32% of all new electricity generating capacity, second only to natural gas. California has led the country in solar implementation with a 37% growth in residential solar photovoltaic (PV) capacity in 2014 (SEIA). Several factors have contributed to this rapid growth of solar power.

Firstly, decreasing costs of systems and equipment, as well as increasing efficiency of these systems, have made solar prices more attractive to consumers and opened up the market to new customers. The cost of installing solar PV modules has dropped by 73% since 2006 and they will continue to fall (SEIA).

Secondly, new financial solutions such as power-purchase agreements, leases, and increasingly solar-optimized loans have further increased demand among new customers in residential, commercial, and utility. These leasing options have become very popular and have made solar energy a feasible option for many by alleviating the burden of upfront costs. Customers no longer have to buy solar equipment upfront and wait for long-term energy savings to cover costs; energy savings frequently exceed monthly payments to the solar installers.

Finally, the regulatory and policy environment have made conditions favorable by providing subsidies and tax credits to solar customers. In California, energy standards requires that all utilities in the state to source 33% of electricity generation from renewable resources by 2020 (Clean Energy Authority). This has driven incentives throughout the state, particularly in the populous counties like San Francisco, Los Angeles, and San Diego.

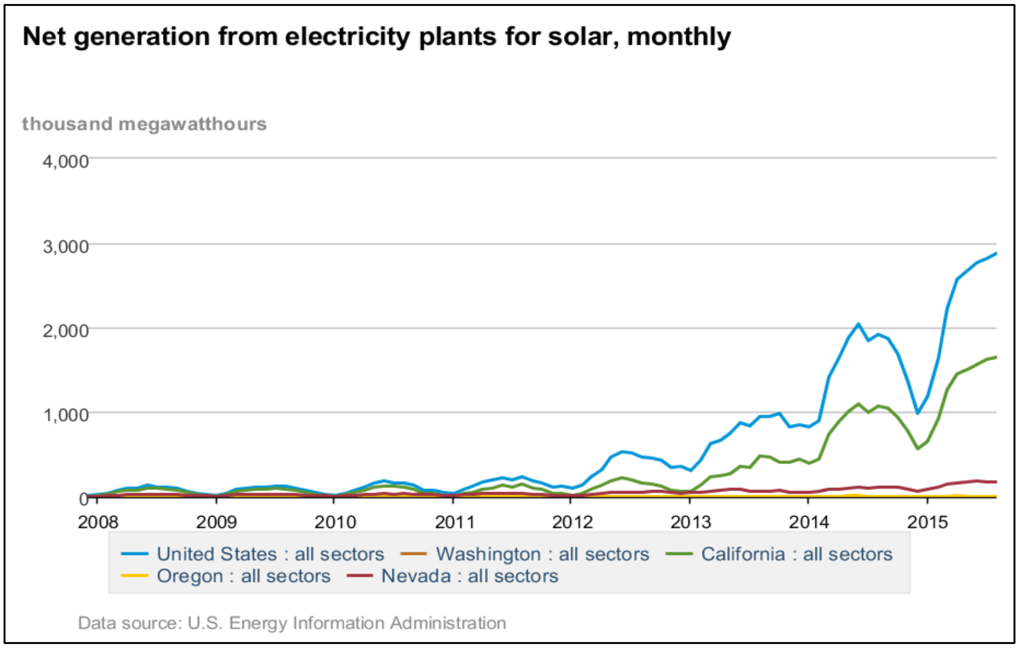


Figure 1. Retrieved from the US Energy Information Administration (EIA)

Growth is expected to continue. In fact, SEIA predicts that between 2014 and 2016, the country's existing solar capacity will double. Solar companies had primarily been pursuing two primary strategies for expansion: following government subsidies and tax credits and focusing on where solar radiation is the most consistent.

The continually falling price of installation will potentially open up new markets without incentives. Furthermore, federal tax credits are expected to expire in 2017 and many other local subsidies are gradually declining (SEIA). About 3,000 residential systems were installed in areas in California without any state incentives in 2013 (Lacey, 2013). Installers are also seeking to expand to target two potentially lucrative and previously untapped customer bases who have not benefited from tax incentives: renters and small businesses. Targeting businesses will not only allow companies to scale their operations by number of installations but also by size. In fact, small and medium business have around five to 80 times the average capacity of its residential systems (Motley Fool).

The pursuit of sunshine has also made California a prime target for solar companies. California's energy consumption, however, is 31% less than the US average due to more mild climate and lower reliance on air conditioning and heating. In fact, average residential electricity consumption in California is among the lowest in the nation. Spending on electricity, however, is closer to the national average due to high prices in the state (EIA Factsheet).

As the industry grows, solar companies will face some challenges. The industry as a whole, while booming, is still in its nascent stages. While growth seem promising and inevitable by almost all predictions, some experts are cautioning about whether today's business models and technologies are going to be successful in the future (Lacey, 2013).

Data Collection and Methodology

Five sets of data were utilized in this report to create Figures 2, 3, and 4 on pages 6 to 8:

1. **Solar radiation shapefiles** were retrieved from Mapcruzin.com. These geospatial data detail the average daily solar energy resource available to surface grid cells about 10 kilometers across in size for the entire continental United States, expressed in kWh/m2/day. According to MapCruzin, "this model uses hourly radiance images from geostationary weather satellites…and monthly averages of atmospheric water vapor, trace gases, and the amount of aerosols in the atmosphere to calculate the hourly total insolation (sun and sky) falling on a horizontal surface." While California has higher than average values compared to the US, this data shows some regional variation.
2. **California county shapefiles** were included in ArcMap's database of sample maps. These shapefiles were utilized as clip features for the solar radiation map; all solar radiation grids outside of California were removed using Editor and grids that protruded beyond California state lines were clipped using the county shapefiles as clip features.
3. **Population by county** information was retrieved from California Demographics website as an Excel spreadsheet. This table was imported into ArcMap and joined to the county attribute table using the similar Name fields. This data was used to calculate per capita values for subsequent data.
4. **Energy consumption** data was retrieved from OpenEI as an Excel spreadsheet. This data includes total residential and commercial energy consumption in 2014 expressed in millions of kWh by county. This table was added to ArcMap and joined to county attribute table using the similar Name fields.
5. **Solar energy capacity** ("PV Modules") data was retrieved from California Solar Statistics as an Excel spreadsheet. It details every documented solar installation in the state, including the cost, address, and number of photovoltaic (PV) modules installed in each array. Only PV module quantity and county name was used. Quantities were subtotaled by county name. This table was added to ArcMap and joined to county attribute table using the similar Name fields.

Figure 2 (page 6) was created by displaying the solar radiation layer with graduated colors to show the variation in sun exposure. A new county layer was created to display PV module installations by county using graduated symbols, with hollow fill over the solar radiation map. Graduated symbol classes were adjusted and resized in order to maximize visual disparity between low and high values.

Figure 3 (page 7) was created with a similar solar radiation map as above. A new county layer was created to display energy consumption. A new field was added to the county attribute table for "per capita consumption" and Field Calculator was used to divide total consumption in each county by population. Per capita calculation is used to mitigate the vast differences in population size across California's counties. Consumption per capita is shown using graduated symbols, with hollow fill over the solar radiation map. Graduated symbols were adjusted similarly as above.

Figure 4 (page 8) was created by calculating module installations per capita with Field Calculator (similarly to Figure 3) in order to compare with energy consumption per capita across California's counties. Per capita module quantities and per capita consumption from Figure 3 are displayed without solar radiation for the purposes of this map. This side-by-side comparison highlights discrepancies between where solar companies have been focusing and where people use the most energy per capita, and, presumably, would be ideal candidates to adopt solar.

Conclusions

The map in **Figure 2**, which displays total number of PV modules installed over solar radiation exposure, demonstrates the solar industry's existing strategy. Counties in the southern portions of the state contain the highest number of PV modules, namely San Diego, Orange, Riverside, and Los Angeles counties. These are also the counties with some of the highest solar potential, as shown by the deeper colors. When solar energy was first catching on a few years ago, it makes sense that solar companies would market to and target sunny regions and that people living in these regions would be more likely to adapt to solar. The rationale and the sales pitch are wholly sensible for the people who can make the most of their solar panels. Other notable areas with high PV module quantities are the populous Bay Area counties, including San Francisco, San Mateo, Marin, Napa, Alameda, Contra Costa, and Santa Clara counties. According to the California Solar Rebates and Incentives website, there are a multitude of incentive programs offered by utility companies and local municipalities in these counties. This reinforces the power of these tax incentives and rebates to lower the barrier to solar adoption and to be a driver in solar industry expansion.

The map in **Figure 3**, which displays energy consumption per capita in 2014 by county over solar radiation exposure, highlights high-energy consuming regions and shows little correlation with solar radiation exposure. If anything, the southernmost counties with the highest solar potential have the lowest per capita energy consumption, curiously. Coastal regions show very little energy consumption, likely due to mild climates that reduce reliance on air conditioning and heating. Conversely, counties in the central valley, Sierra Nevada mountains, and northernmost regions have the highest energy consumption per capita, likely due to more extreme temperatures.

Finally, **Figure 4** highlights the geographic discrepancies between where PV modules are installed and where the highest energy consumption rates are (both adjusted to per capita figures for better comparison). In other words, there is a great discrepancy between where solar companies have been focusing their efforts and where potential customers are consuming energy at above-average rates and may have much to gain by switching to renewable solar energy. These discrepancies can inform solar company strategies three ways:

- **Decreased Reliance on High Solar Radiation**: Only focusing on higher solar radiation areas may not be the best strategy moving forward. With the increasing efficiency of solar panels, the highest level of solar radiation is no longer required to achieve desirable results and energy production. As PV modules become more efficient and energy storage capacities improve, solar companies can expand into areas with less extreme and less consistent radiation. Without needing constant direct sunlight, northernmost consumers can still achieve cost savings by utilizing solar panels. All regions of California will have, on average, more solar radiation than the rest of the country, so continued expansion within California and southwestern states is reasonable.
- **Target Higher Energy Consumers**: Coastal and southern counties, while tempting customer bases, are not necessarily those where customers will benefit most from solar. That is, those regions do not have the highest per capita energy consumption. If the solar industry wants to continue growing, not only by scaling up but by depth of market penetration and sustaining long-term customers, it should move away from the impression that only those who live in geographically ideal regions can benefit from solar and focus on the energy savings potential. Those who live in the central valley, mountains, and northernmost counties have seen very little solar industry penetration, partially due to inconsistent solar radiation. These counties, however, have a high reliance on heating and cooling and represent major untapped customer bases.
- **Decreased Reliance on Incentives, and Tax Rebates**: In addition to inconsistent radiation, counties with highest energy consumption also tend to be more sparsely populated. While incentives have been critical in driving the growth of solar, it has also created disproportionately high installations in counties where consumption is not high (most notably the “wine country” counties of Napa and Sonoma and “gold country” counties just north of the central valley). By targeting less populated regions without generous incentives, solar companies may have less potential for economies of scale, but targeting high per capita energy consumers may open up long-term and reliable customers.

Figure 2

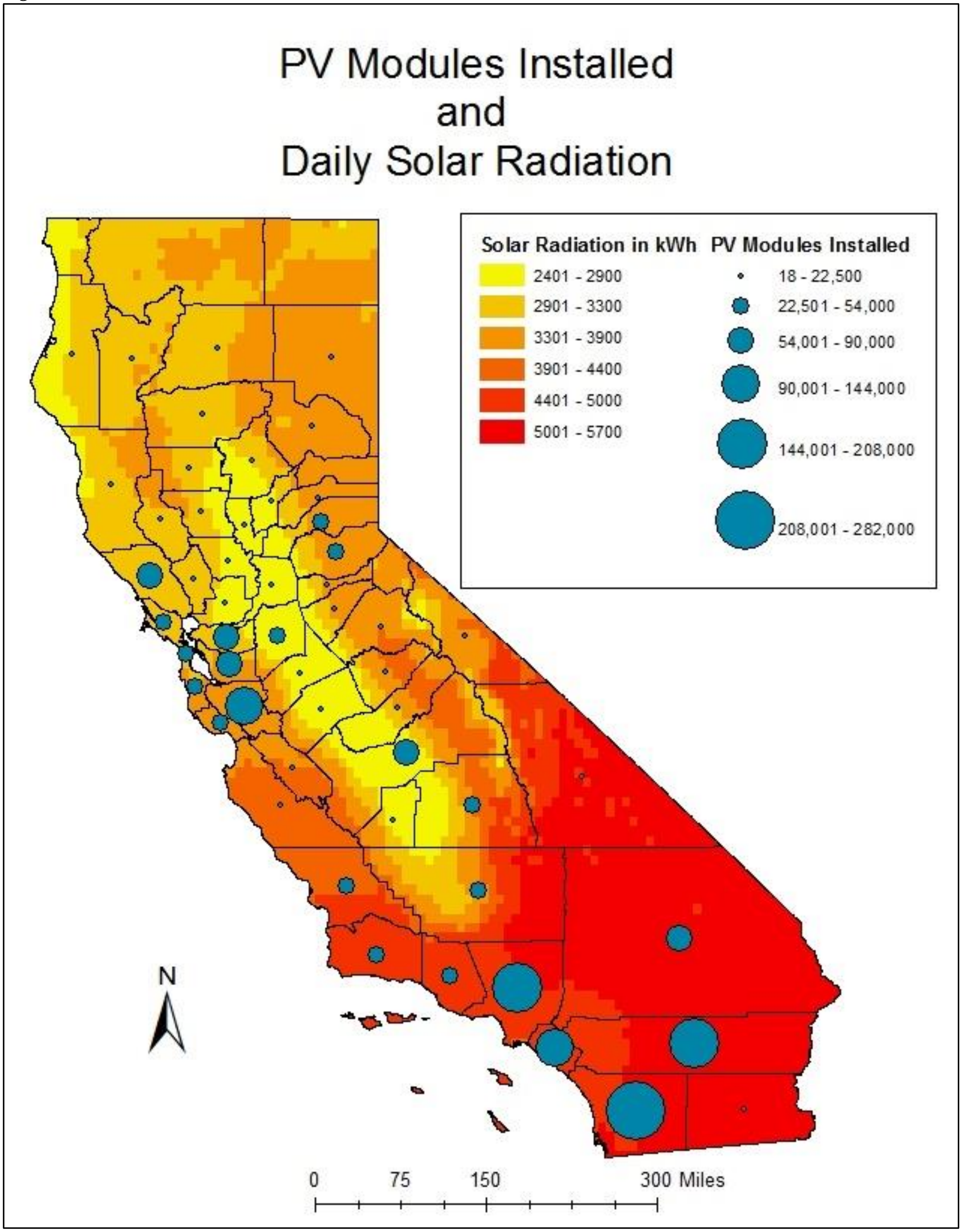

PV Modules Installed
and
Daily Solar Radiation
Solar Radiation in kWh
2401 - 2900
2901 - 3300
3301 - 3900
3901 - 4400
4401 - 5000
5001 - 5700
PV Modules Installed
18 - 22,500
22,501 - 54,000
54,001 - 90,000
90,001 - 144,000
144,001 - 208,000
208,001 - 282,000
N
0
75
150
300 Miles

Figure 3

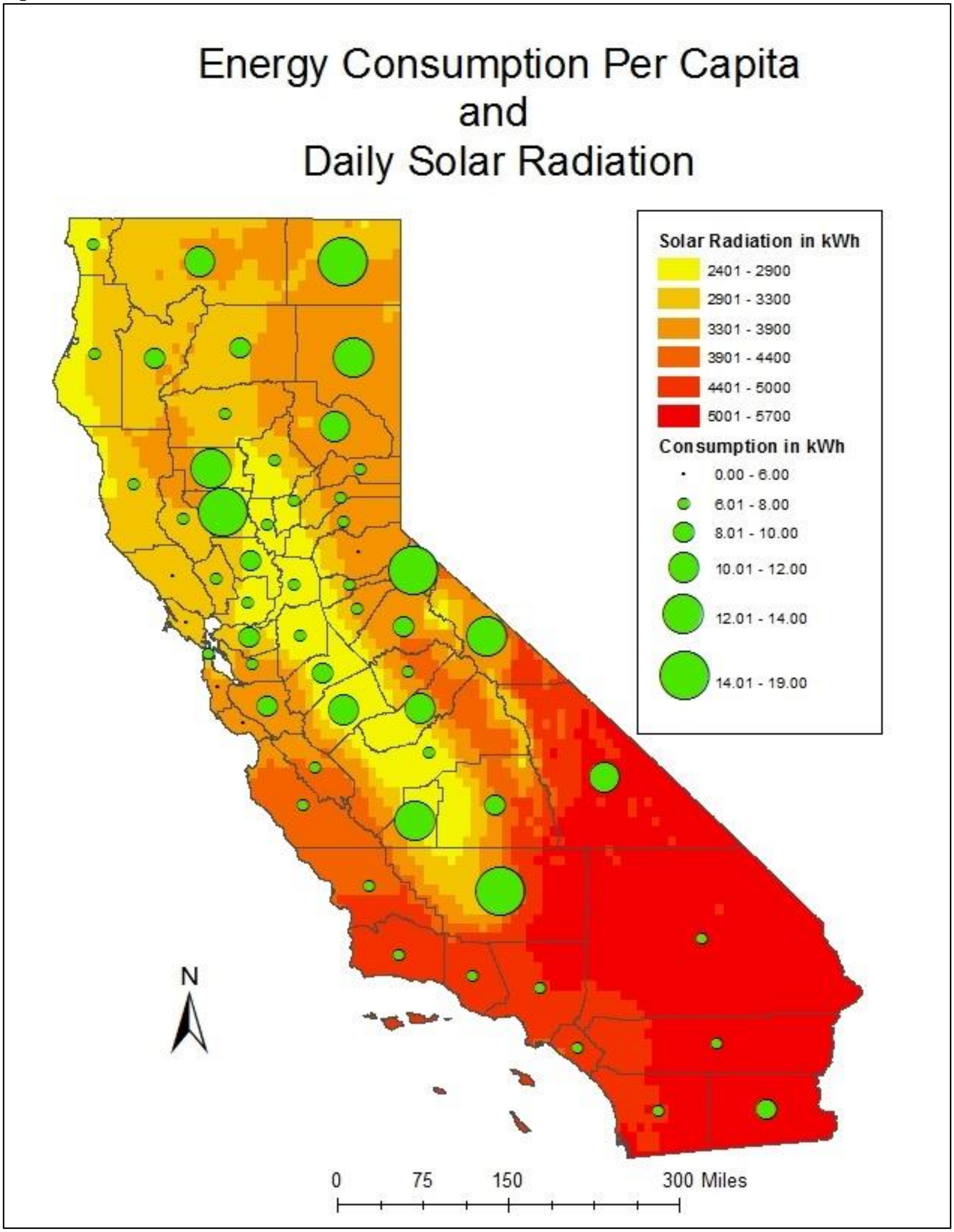
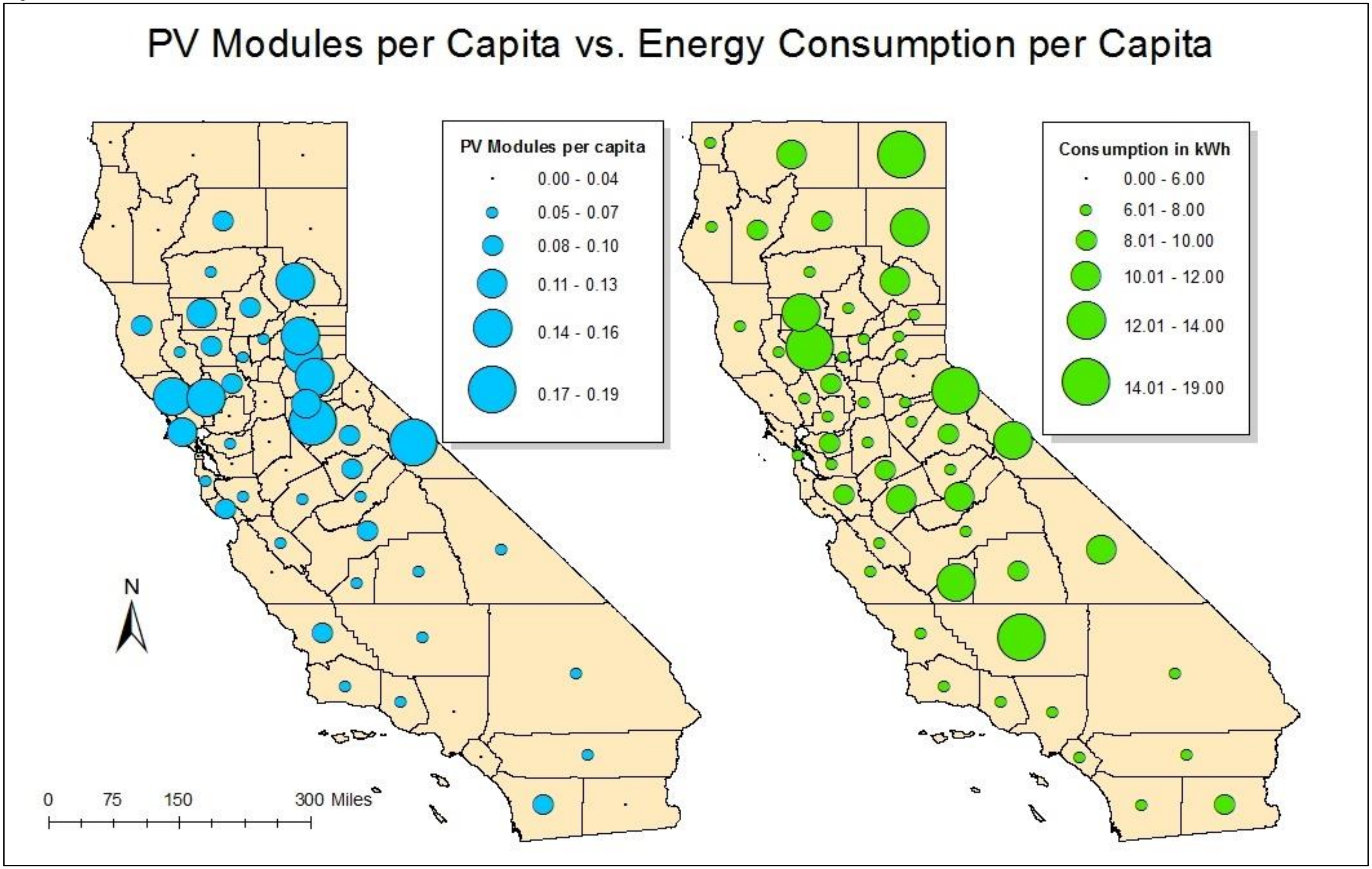

Energy Consumption Per Capita
and
Daily Solar Radiation
Solar Radiation in kWh
2401 - 2900
2901 - 3300
3301 - 3900
3901 - 4400
4401 - 5000
5001 - 5700
Consumption in kWh
0.00 - 6.00
6.01 - 8.00
8.01 - 10.00
10.01 - 12.00
12.01 - 14.00
14.01 - 19.00
N
0
75
150
300 Miles

Figure 4


PV Modules per Capita vs. Energy Consumption per Capita
PV Modules per capita
0.00 - 0.04
0.05 - 0.07
0.08 - 0.10
0.11 - 0.13
0.14 - 0.16
0.17 - 0.19
Consumption in kWh
0.00 - 6.00
6.01 - 8.00
8.01 - 10.00
10.01 - 12.00
12.01 - 14.00
14.01 - 19.00
N
0
75
150
300 Miles

Data Limitations

While solar PV module installation was available at the ZIP code level, energy consumption data was not. Energy information at the county level is abundant, broken down by sector and even by household appliance. County level analysis, however, is not ideal due to the vast size of some counties. Such large-scale information overlooks critical local level discrepancies in income level, geographic features, and government policies. This prevented lower level focus within LA County that would have offered interesting insight into energy consumption patterns. Furthermore, ZIP code and county lines do not line up, frustratingly, so these comparisons would have been imperfect.

Solar radiation information was also too large scale for more meaningful analysis. The 10km squares were useful for comparing average radiation values between counties and large portions of land, but information that is more detailed would have been useful for looking at radiation variation within cities. Some online map interfaces allowed for street level optimization of solar panel placement, taking into account trees and surrounding tall buildings. This data was not publicly available for download.

Without data limitations, this study could go further in depth by mapping a variety of characteristics to analyze solar adoption and solar potential, including how solar capacity relates to income, zoning regulations, ownership status, and available tax rebates.

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