Feasibility of Solar Panels Satisfying Most of Power Needs of a Home Bucks County, PA.

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This report addresses the feasibility of using rooftop solar panels to satisfy most of the electrical needs of a home in Bucks County, PA according to the criteria of cost, longevity, and performance.

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Executive Summary

Solar panels are an excellent investment for any homeowner who can afford it. Installing a roof-mounted solar panel system to a home in Bucks County would yield a return-of-investment within the life of the solar panel system. On top of financial aspects, they also greatly reduce the carbon emissions of a household and help work toward a more sustainable planet.

The purpose of this report is to determine the feasibility of using rooftop solar panels to greatly satisfy most of the electrical needs of a home in Bucks County, PA. This will be evaluated based on cost, longevity, performance, and environmental impact. The homeowner needs to be able to afford the system with little-to-no savings or loans. The system must last long enough to return the initial investment and make a profit. Enough electricity must be generated to satisfy at least 75% of the consumption of a household. Carbon emissions of the system must be less than that of the electric power plant.

This report will not be considering several factors, such as the possibility of the system not being installed correctly or optimally. It also will not be closely examining areas outside of Bucks County. Other areas that are mentioned are for a brief comparison. Additionally, a house not having a compatible roof is a possibility, but will not be considered in this report. Oil is being used as the primary heating method of the house, and the kitchen appliances are assumed to be electric. Finally, this report uses historical averages for weather data and does not account of anomalies.

Solar panels are a smart investment for a homeowner in Bucks County. Using average electric bills and consumption, a homeowner could afford to have a 7-kWh system professionally installed with minimal budgeting or saving. Within 9 years it would return the investment and start making a profit. This system would last at least 25 years. It could generate approximately 85% of the home’s electric needs. Finally, it would massively reduce the carbon footprint of the home by generating clean energy and reducing the reliance on fossil fuels.

To begin implementing this system into one’s home, the best place to start is using online resources to get quotes from multiple companies. Using those numbers, compare with the current electric bill to make sure it is a smart financial decision. Next, pick the company that best suits the home’s needs. Having a professional from the company come out and install the panels will help ensure that they operate properly and deliver the optimal amount of power. Simple maintenance such as cleaning the panels after heavy snowfall and clearing away stray branches will help keep the system in proper working order. Finally, minimizing electricity usage will help maximize the investment and work toward being a more sustainable home.

Introduction

Sustainability has become a pressing issue as scientists continue to discover the devastating effects that humans are having on the environment. The overuse of nonrenewable resources such as fossil fuels is impacting the planet in potentially irreversible ways. Researchers are constantly looking for ways to lower humanities consumption of oil, natural gas, and coal. Sustainable and renewable resources such as solar, wind, and hydro are often considered to be the most viable solutions. While all three of these can be used as a source for a power plant, wind and hydro are typically difficult to implement on a consumer level. Roof-mounted solar panels, however, are easier and more effective for the average home.

There are several factors that cause consumers to be wary of integrating solar panels to their homes. Cost, for example, is one of the leading concerns that drives people away. This could be due to lacking the upfront capital or being unsure if the investment is worthwhile in the long term. Another potential problem is the longevity of the panels. The potential frustration and hassle of regularly maintaining and replacing the panels can drive people away. The actual performance of the panels varies in different areas. An area with high cloud content such as Seattle or Buffalo will have less sunlight on average. This means that the panels are not generating as much electricity as they would in areas with a lot of sun like Phoenix or Albuquerque. Finally, the environmental benefits of solar power are often overlooked. While these concerns are valid, they do stem from a general lack of knowledge. Roof-mounted solar panels are a good idea for almost any homeowner.

Purpose, Scope, and Methodology

The purpose of this report is to determine the feasibility of using rooftop solar panels to greatly satisfy most of the electrical needs of a home in Bucks County, PA according to the criteria of cost, longevity, and performance. If all the criteria are satisfied, then it would be a good idea for a homeowner to make the switch to roof-mounted solar panels.

There are many factors that cannot be accounted for in this report. This report will assume that the solar panels are not defective and that they are installed properly by a professional. Other geographical regions will be mentioned only for the sake of comparison, and will not be as closely examined. Different houses will have different roof materials, orientations, and slopes. For simplicity, this report will assume that the house is large enough and fully compatible with the system. This report assumes that the house is heated by oil and that the major kitchen appliances are powered by electricity. Finally, the evaluations in this report assume that the weather will operate based on previous averages and that there will not be any extreme changes in climate.

To fully explore the criteria mentioned above, many scientific records will be looked at, typically involving historical averages. These averages will be used to mathematically evaluate the performance of solar panels in the specific conditions. The National Renewable Energy Laboratory (NREL) has a wealth of information about insolation based on geographical location. This will be used along with information from solar panel manufacturers to assess the average power output of a solar panel. The U.S. Department of Energy (DOE) will be referenced for

average electricity costs. EnergySage, a U.S. DOE-endorsed website, also has a great deal of information about solar panel efficiency, cost, and performance.

Organization of the Report

The five sections in this report are as follows: *Solution Overview*, *Solution Criteria*, *Evaluation of Criteria*, *Conclusions*, and *Recommendations*. The *Solution Overview* discusses how most people view solar panels in the current market. *Solution Criteria* details the criteria used in evaluation. *Evaluation of Criteria* assess the feasibility of the solar panel system providing most of a house's electrical needs. *Conclusions* summarizes the feasibility of the system. *Recommendations* discusses how to proceed based on the information learned in the report.

Solution Overview

Solar panels are often seen as a consumer-friendly way of integrating sustainability into a home. They have zero emissions, can lead to getting paid from the electric company, and help lead to a greener planet. However, consumers are often worried about many aspects of implementing such a system into their own home.

If deemed feasible, a solar panel system could be installed at an affordable price and last long enough to make a net profit. It will also be able to provide a majority of a house's power while having less of an environmental impact than fossil fuels.

Solution Criteria

Determining the feasibility of implanting a roof-mounted solar panel system was evaluated based on the criteria detailed below.

Cost

Cost is often the most important factor when one is looking to make home improvements. As such, the cost of implementing a solar panel system will be carefully evaluated. The median income and cost of living in Bucks County will be recorded based off US Census data. These numbers will be used to evaluate if an average household in Bucks County can afford the hardware and installation. If the upfront cash price is too high or the loans are not reasonable, then the system is not feasible.

Longevity

Loosely associated with cost, the longevity of solar panels is important. Most solar panel systems come with a warranty that guarantees many years of use. To be feasible, the system must last long enough to recoup the initial investment and make a net profit.

Performance

Ideally, this system will cover 100% of the household's needs. This might not be possible, however, due to the insolation of Bucks County. The solar panel system must be able to cover at least 75% of electrical needs of a house to be feasible.

Environmental Impact

The environmental cost of creating solar panels is significant. They use many caustic materials and recycling old panels will eventually become a problem. To be feasible, the solar panels must have a lower environmental impact than nonrenewable sources in less than 5 years.

Evaluation of Criteria

Cost

There are many factors that need to be closely examined when evaluating the cost of a solar system. First, the average electric bill of a household will provide many important numbers. For this report, the average electric use of a home in Newtown, a borough in Bucks County, will be used for reference. This average home will be referred to as "this home" or "the home". At a rate of 12.9 cents per kilowatt hour (kWh) and using 900 kWh per month, the average electric bill comes out to approximately $120 (Newtown).

The maximum generation of the solar panel system selected will vary depending on the electrical needs of a household. According to NREL's calculator, a 7-kWh photovoltaic (PV) system would be needed for this home (PVWatts). This calculation is based off the energy consumed as well as the insolation. Next, an electrical inverter needs to be selected. The optimal PV-to-Inverter ratio is between 1.1 and 1.3 (Gregg, Alan, et al.). For this home, a ratio of 1.2 was selected. Thus, an 8.4-kWh inverter is needed.

"As of January 2017 the average cost of solar in the U.S. is $3.26 per watt" (How Much). With a 7-kWh system, this comes out to $22,820. There is also a 30% federal investment tax credit, bringing this down to $15,974. In addition to that, there is the PA Sunshine Program which would take off $5,590 for a total of $10,383. This number is only an approximation, and will change based on factors such as a different PV-to-Inverter ratio as discussed above.

The median household income in Bucks County is $77,568 (Data Access). The MIT living wage calculator estimates that the average living expenses of a household with 2 adults and 2 children is $58,441 (Living Wage). This gives a difference of $19,127.

The following are the most common methods of financing a solar panel system: cash, solar loan, lease, and power purchase agreements (PPA). Cash is the ideal method if one can afford it, as it is the cheapest in the long term. It also means that the homeowner gets to sell electricity back to the power company if that is part of their contract. A solar loan is the same as any other home improvement loan, and still allows the homeowner to own the solar panels. A quote from SolarCity comes out to approximately $93 per month. Leasing and PPA are acceptable options, but they need to be more scrutinized as they could end up costing slightly more if the panels do not generate enough electricity.

Overall, this household could afford to buy the panels with cash. There are likely other costs that that the family is incurring that are not factored into the calculation, but there is still a $8,743 difference. Saving for a year or two before purchasing is an option if the unaccounted costs are too great. A solar loan could still make this an affordable option depending on how much power the panels generate. There is a $27 difference between the monthly electric bill and the solar loan cost. If the panels generate enough electricity to bring down the electric bill, this is a viable option.

Longevity

The output capacity of a solar panel will naturally decrease as time goes on. The amount by which it does this is known and tested. This rate of degradation is most prominent in the first year. Most manufacturers will have a warranty on the solar panel systems guaranteeing that they will maintain at least 80% capacity for typically up to 25 years. A 7-kWh system with a degradation rate of 0.5 and derate factor (imperfections in the system) of 0.77 would still maintain roughly 88% of its original capacity after 25 years. These numbers can greatly vary between manufacturers (See Figure 2 in the Appendix). Additionally, they usually guarantee that the physical structure of the panel will hold up for at least 10 years.

Despite the degradation, solar panels still hold up very well. There is not a definitive answer as to how long consumer-grade solar panels can last. The first modern solar panel has been around for approximately 60 years and is still functional. Several manufactures report that their panels from over 30 years ago are still functional as well (Maehlum).

Overall, solar panels are robust and will last a long time. If the homeowner takes care of their panels with maintenance as-needed, the panels will almost certainly last long enough to recoup the investment and make a net profit. Based on energy generated as discussed in *Performance*, and the cost of the system as discussed in *Cost,* it will take approximately 8.75 years for the system to start making a profit. This is well within the lifespan of the solar panels.

Performance

Solar panels will be more effective depending on the insolation of the area they are being used in. The insolation is measured based on the kilojoules of solar radiation per square meter. Generally, the Southwest tends to get most sun in the United States while the Northeast gets the least (See Figure 2 in the Appendix). Figure 3 in the Appendix shows the numerical representation of Bucks County. In addition to insolation, solar panel performance is evaluated using the peak sun-hours. This is calculated based on the average daily insolation. A greater number of peak sun-hours means that the solar panels will work more efficiently. Bucks County has approximately 4.4 peak sun-hours (See Figure 4 in the Appendix).

The average consumer-grade solar panel currently on the market is just over 20% efficient (Solar Panels). However, solar panel efficiency continues to climb and can only be expected to get better as time goes on. “The size, shape, and slope of your roof are also important factors to consider. Typically, solar panels perform best on south-facing roofs with a slope between 15 and 40 degrees” (Homeowner’s Guide).

At 900 kWh per month, this home uses 10,800 kWh per year. A 7-kWh solar system can generate an annual average of approximately 9,200 kWh (How Much). This means that the system can generate about 85% of the home's electrical needs in each year. A larger solar system could be used to cover 100% of the electric consumption, at the expense of a higher investment. The selected system performs to a feasible level.

Environmental Impact

The goal of sustainable energy is to reduce humanities carbon footprint and try to reduce reliance on fossil fuels. However, solar panels are built using a large amount of energy and caustic materials. It turns out that most of this is upfront and they quickly payback that energy.

The initial energy used to produce a solar panel is so high because of all the raw material processing. Quartz crystals must go through an extensive manufacturing process involving various metals and components to make one single cell. These cells also must go through an extensive heating process that uses a lot of energy. By comparison, coal has very few steps: mine, clean, then burn.

Batteries in solar panel systems are made up of rare-earth metals and caustic chemicals such as lithium ion and lead acid. These materials have many negative impacts on the environment during both harvesting and processing. This also contributes to the steep upfront cost of solar panels.

Finally, there are currently not many options for recycling dead panels. This will likely prove to be a problem in the future as more people install solar panel systems. While this does not have an immediate environmental impact, it is important to consider (The Positive and Negative).

As previously mentioned, these upfront costs are steep, but they quickly become worth it. Once created, solar panels do not generate any emissions. The use of the sun for energy also means that less fossil fuels are being burned, which also helps. Solar panel systems can be anywhere from 3 to 10 times more environmentally friendly than coal (See Figure 5).

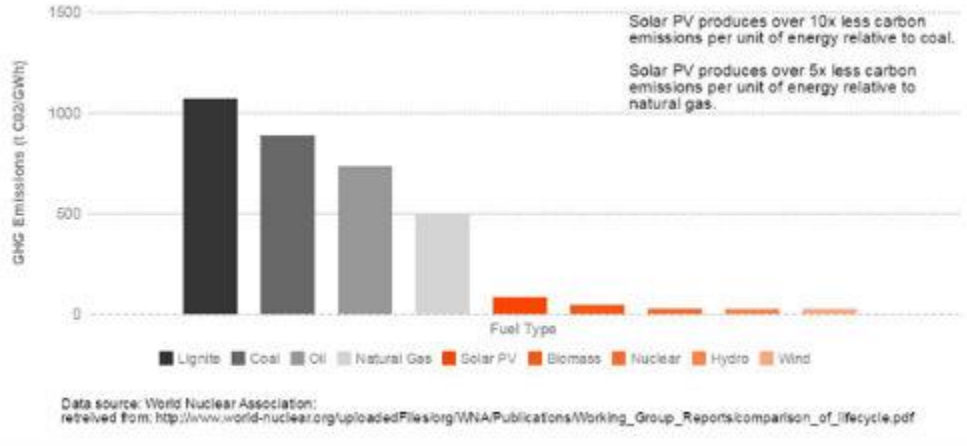

Figure 5: Comparison of Carbon Emission Intensity of Various Energy Sources

Conclusion

After examining the criteria of cost, longevity, performance, and environmental impact, it is feasible to satisfy most of the electrical needs of a home in Bucks County using a solar panel system. A household making the median income could afford to buy the solar panels without a loan and little-to-no savings. This system will last long enough to make a net profit due to the reduced electric bill, as well as potential money from the electric company buying generated electricity. The system can generate approximately 85% of the average home's electric needs in each year using a 7-kWh array. Lastly, the environmental impact of creating a solar panel system is significantly less than that of using fossil fuels.

Recommendations

1. Get quotes from various solar panel companies to get the best price
2. Compare the monthly price of electricity generated by solar panels to the monthly electric bill
3. Pick the company that has the best price and long-term efficiency
4. Have a professional install the panels to ensure they are installed properly
5. Clean panels as needed (e.g. after heavy snowfall) and clear stray branches away
6. Try to minimize electricity usage to be as environmentally friendly as possible

Appendix

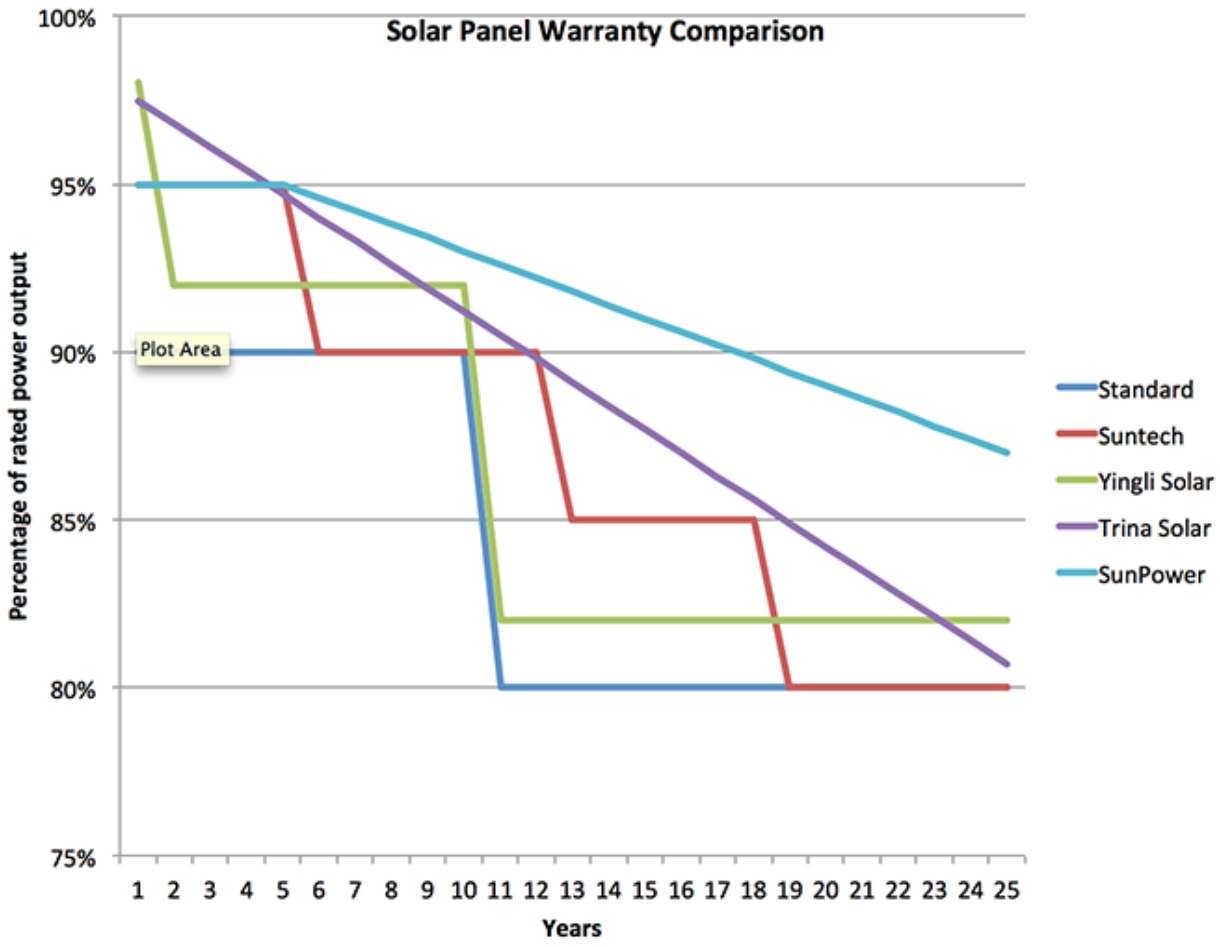

Figure 1: Comparison of Solar Panel Manufacturer Warranties

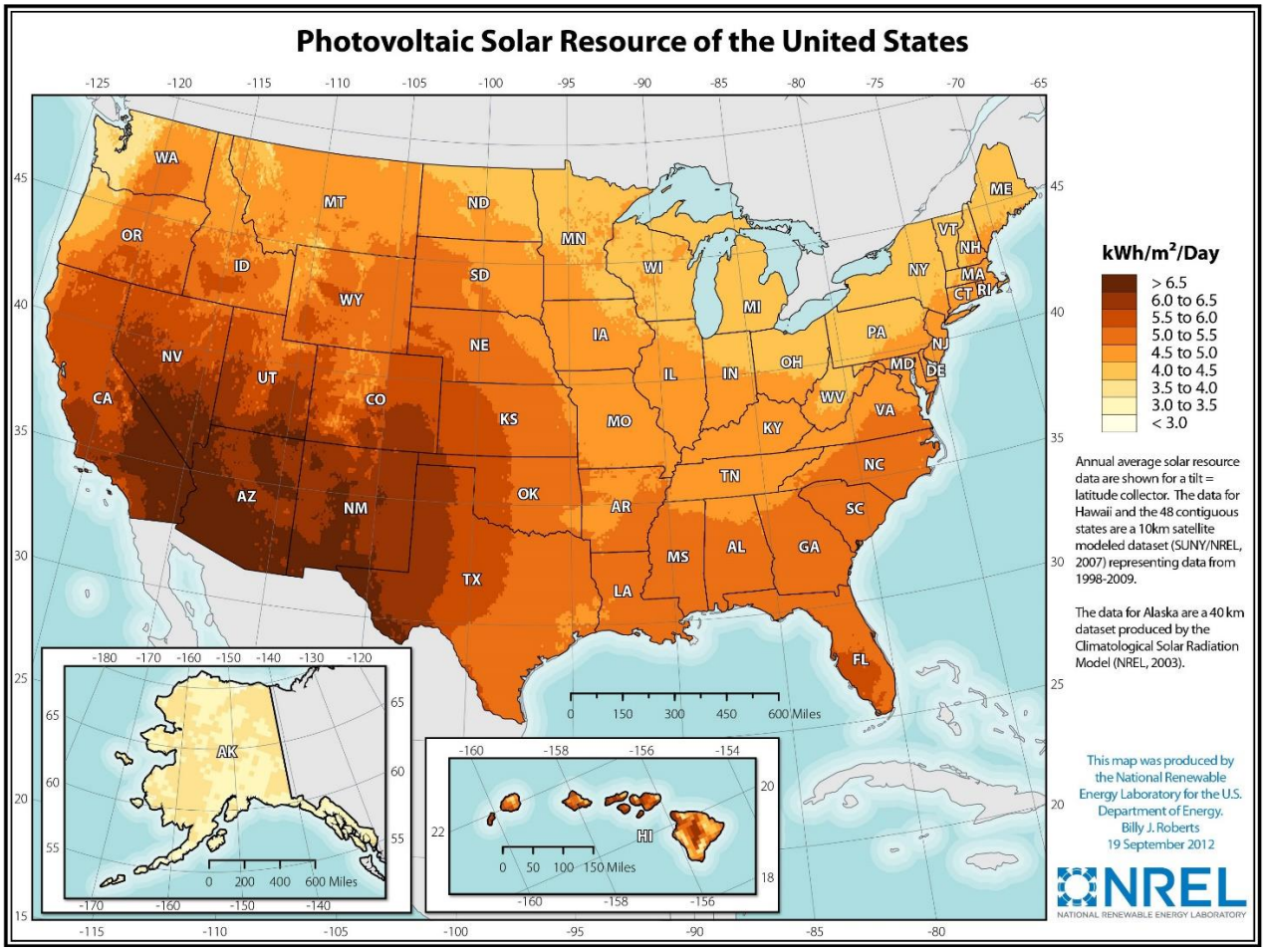

Figure 2: Insolation Map of the United States

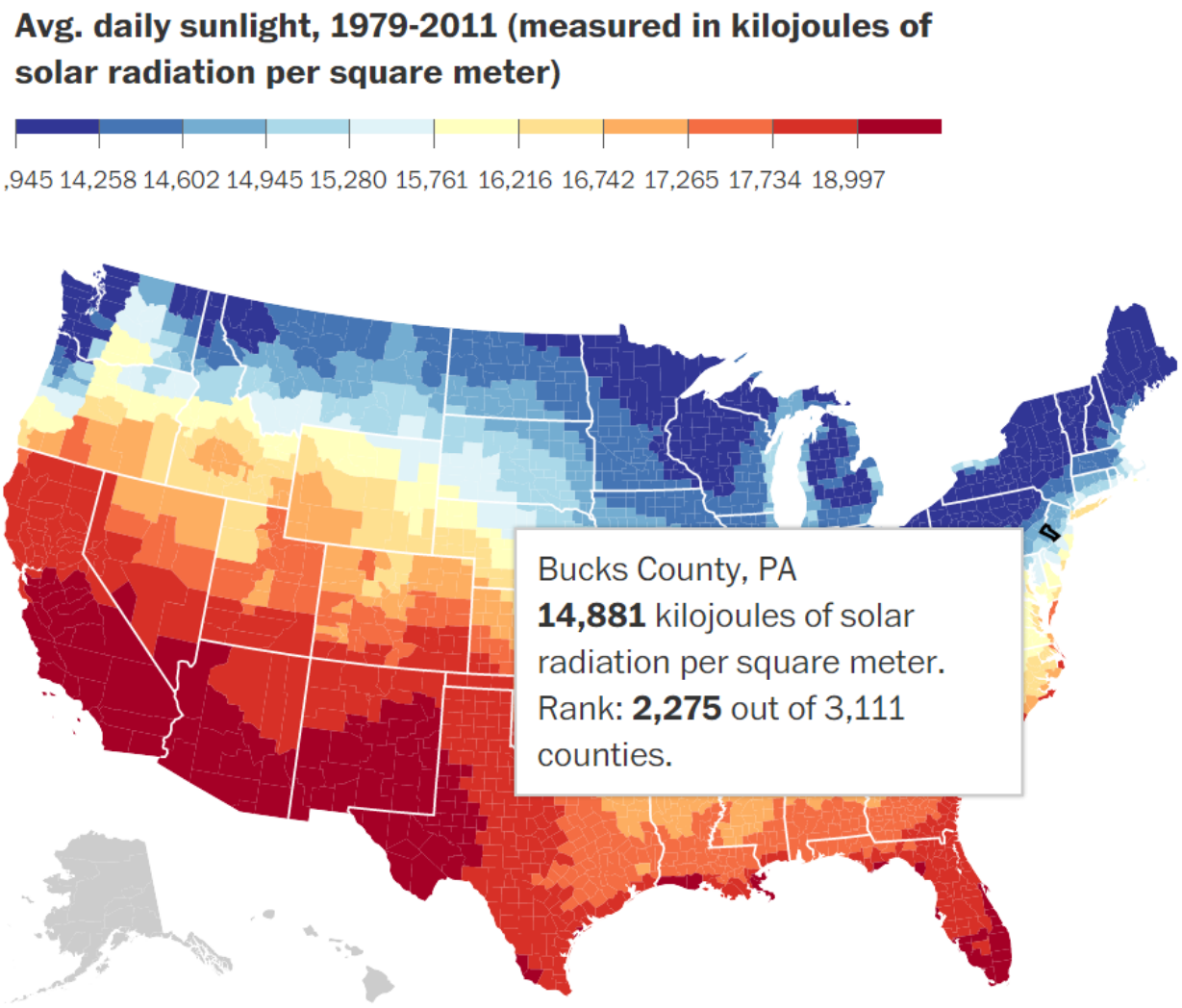

Figure 3: Insolation Map with Bucks County's Data

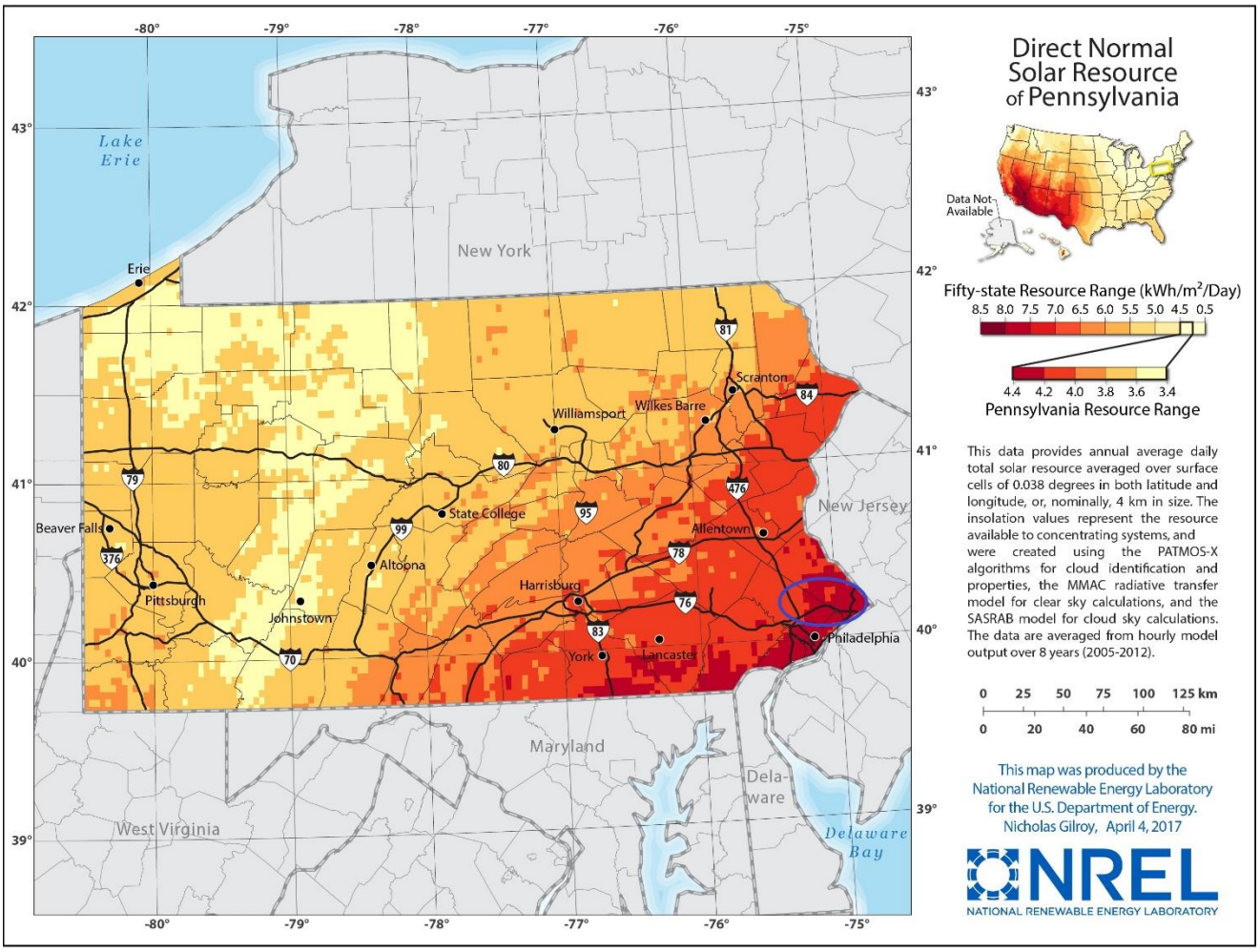

Figure 4 – Peak Sun-Hours of Pennsylvania

References

Data Access and Dissemination Systems (DADS). “Selected Economic Characteristics. 2011-2015 American Community Survey 5-Year Estimates.” *American FactFinder*, United States Census Bureau.

“Direct Normal Solar Resource of Pennsylvania.” *Geospatial Data Science*, National Renewable Energy Laboratory.

Gregg, Alan, et al. “Optimal PV-to-Inverter Sizing Ratio.” *SolarPro*, vol. 3, no. 3, 2010.

“Homeowner's Guide to Going Solar.” *Office of Energy Efficiency & Renewable Energy*, U.S. Department of Energy.

“How Much Does a 7kW Solar System Cost in 2017? | *EnergySage*, 27 July 2017.

“Living Wage Calculation for Bucks County, Pennsylvania.” *Living Wage Calculator*, Massachusetts Institute of Technology.

Maehlum, Matthias Aarre. “The Real Lifespan of Solar Panels.” *Energy Informative*.

“Newtown, PA Electricity Rates.” *Electricity Local*, 2017.

“PV System Estimated Value.” *PV Value*.

“PVWatts.” *PVWatts Calculator*, National Renewable Energy Laboratory.

“Solar Panels: How to Evaluate Quality & Efficiency.” *EnergySage*.

“The Positive and Negative Environmental Impacts of Solar Panels.” *Kuby Energy Edmonton*.