The Feasibility of Domestic Solar Panel Use in the United States

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Joshua Merritt Belisle

Spring 2023

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Advisor

Kent A. Wayland, Department of Engineering and Society

What is the Feasibility of Domestic Solar Panel use in the United States?

Moving to clean energy is going to be a continued and necessary step in the United States. Solar energy is one of the many potential renewable energy sources being explored. Many believe that effectively harnessed solar power could be the future of sustainable energy. However, Americans have yet to fully adopt this new energy source. With rooftops and houses all across the country hosting nothing but HVAC systems or shingles, it would seem simple to add solar panels. The addition of photovoltaic (PV) systems to rooftops could prove enough energy for each building and the country. So why aren't there solar panels on every roof? This question seems simple, but is incredibly complex and ever changing.

Solar power could be the way of the future, with single home electricity production powering every home in America. The issue lies in the key difference between technology innovation and technology implementation. While solar panels have increased in energy production, the surrounding factors still pose challenges to the integrations of the technology with everyday life. Issues such as pricing, space, legislation, renting culture, and appearance all appear to stand in the way. This paper will expand upon these hinderances and attempt to explain the feasibility of domestic solar panel usage in the United States.

Context

The idea of harnessing the suns energy has been around for many years. In 1839, the first photovoltaic (PV) effect was discovered, leading to the first solar panel in 1883 by Charles Fritts (Chu & Tarazano, n.d.). A photovoltaic effect is a process that produces electricity when exposed to light (Chu & Tarazano, n.d.). At home solar was first tested in 1973 at the University of

Delaware with the creation of Solar One. Solar One was a house built for research and to demonstrate the practical potential of at home solar (Miller, n.d.). While the house didn't have true solar panels, they did design the roof with thin film solar and was the first to convert sunlight into electricity and heat for an entire building (Miller, n.d.). Shortly after Solar One, the energy crisis of the 1970s began along the United States government's involvement with solar. In 1974, congress passed two bills that specifically stated solar as a potential cure (Sabas, 2016). The "Solar Heating and Cooling Demonstration Act of 1974" stated that by 1977, solar heating and cooling methods needed to be installed in every federal building as a way to help the public become aware of the technology (Sabas, 2016). The Energy Tax Act of 1978 created Investment Tax Credits (ITCs) for commercial and residential solar installation in an attempt to incentivize the public to go solar (Sabas, 2016). However, the fight for solar slowed down as traditional energy prices fell. Solar once again became a hot topic at the turn of the century as gas prices rose. The ITC was temporarily raised and extended multiple times to incentivize interest again (Sabas, 2016).

In addition, in 2016 the National Renewable Energy Laboratory (NREL) released its finding in a research review of the potential for rooftop solar in the United States (Gagnon et al., 2016). This report details how light detection and ranging (Lidar) was used to calculate the feasibility of solar PV systems for rooftops in America. It uses the Lidar data to highlight areas, cities, states, and regions of potential implementation. The report describes the technical feasibility of PV adoption for rooftops in the United States. However, it fails to consider other aspects of adoption beyond if a rooftop has optimal sunlight and space.

Methods

My research consisted of an extensive literary review. Before starting, I identified some aspects within the socio-technical system of domestic solar panels. The initial factors I researched were pricing, government intervention, and aesthetics. In order to find literature on these topics, I used the universities databases. I filtered through sources based on the number of times it was cited in other works, relevance, and followed some works citations to find new sources. Through my research, I also realized that physical space, hope for improvements to the technology, and renters are key aspects of the system. I researched these additional aspects as well and added the findings to the growing network. To supplement the literature information, I also looked at surveys done by the Pew Research Center to gain an understanding for the general public's opinions. All of this information came together to highlight the socio-technical system and the struggle domestic solar is facing.

Results & Discussion

Pricing & Government Incentives

The first, and most important, aspect of the socio-technical system surrounding American solar panel adoption is pricing. The installation price of an at home solar system ranges from $16,870 to $23,170, as of 2022 (Leppert & Kennedy, 2022). These prices have decreased over time, but are still a hefty up-front cost to any potential new buyer. The gradual decrease in price has seen an increase in installations. In 2020, 2.9 gigawatts of production were installed. That number rose 34% to 3.9 gigawatts being installed in 2021 (Leppert & Kennedy, 2022). Despite this growth, many customers need loans and help from solar financiers. However, the typical

minimum credit score needed for a solar system purchase is 650, a score higher than 32% of Americans (Watkins, 2017). These initial factors of price and credit score immediately limit the potential market for domestic solar adoption. Unfortunately, there is no good way to limit these effects currently. Until the price point can be dropped in a way that solar is feasible for more Americans, it won't be accessible to all. With that being said, there is still a large percentage of Americans with a high enough credit score who could adopt solar.

For the possible adopter, the government has attempted to help by adding federal tax cuts for at home solar systems. The Investment Tax Credit (ITC) began in 1978 (Sabas, 2016). However, in 1985, the residential ITC expired and was only available for commercial solar developments (Sabas, 2016). Then in 2005, the residential ITC was reinstated, but was capped at $2000 (Sabas, 2016). The off and on status of the residential ITC can be identified as an issue for domestic solar panel adoption. The emphasis on commercial installation pushed solar panels away from rooftops and to the traditional solar farm. In an attempt to stabilize and refresh the residential ITC, congress passed an extension and raised the value to 30% as of August 2022. (*Homeowner's Guide to the Federal Tax Credit for Solar Photovoltaics*, n.d.). This will fall back to 26% in 2033, 22% in 2034, and will end in 2035, barring another congress renewal (*Homeowner's Guide to the Federal Tax Credit for Solar Photovoltaics*, n.d.).

The tax relief method is debated for overall effectiveness. For one, they have incentivized homeowners to install solar systems. This is an overall positive as the more solar adopters, the better. However, as described, the ITC applies to both homeowners and commercialized solar production, with an emphasis on solar reaching commercial viability (Perusse et al., 2009). Large scale solar energy production hasn't been perfected. However, when commercial solar is available to everyone and a company is able to utilize the ITC effectively, domestic solar could

no longer be needed. This would cause homeowners to not pursue the ITC themselves, rendering it useless. In addition, as anyone who has done their taxes can tell you, it is not a straight-forward process. The ITC has a long overall process, listing various criteria and special cases. The ITC is also applied to income taxes due, so there is no direct "payment" to the homeowner for installing solar (*Homeowner's Guide to the Federal Tax Credit for Solar Photovoltaics*, n.d.). It is instead argued that a more direct investment into solar would be a more effective approach (Perusse et al., 2009). This line of thinking believes funds should be used to make a more effective solar collection system for a lower price and sell that as opposed to incentivizing the current systems. While the ITC has helped gain some solar adoption, more could be done to simplify and effectively target domestic solar hopefuls.

Space & Renting Culture

All of the previously mentioned issues point to price being the main issue for domestic solar adoption. Going beyond the price tag, another main inhibitor can be identified: space. In the January 2016 National Renewable Energy Laboratory review, it is stated that only 22-26% of residential rooftops are suitable for PV systems (Gagnon et al., 2016). This initial percentage demonstrates how difficult it is to have an effective domestic solar system, especially with the current PV systems. The NREL review goes on to say this could be a faulty range because it "does not consider specific nuances in the buildings, such as heating, ventilating, and air conditioning systems on large commercial buildings or differences in the tree canopy in neighborhoods with newer housing versus neighborhoods with older housing" (Gagnon et al., 2016). Therefore, potentially even less houses could be viable for solar installations.

The review continues with its research using Lidar technology. Through the help of the Department of Homeland Security, the NREL was able to study actual rooftops all over America.

The NREL review's use of Lidar allows for a much more accurate percentage of viable space to be recognized. However, because of the large amounts of data and time it takes to conduct this type of research, no nationwide percentage can be produced. Instead, the review discusses findings for 128 cities, representing 122 million people (roughly 40% of the population) (Gagnon et al., 2016).

The findings for the study suggest that while space is limited, the percentage of total electric production that could meet estimated consumption ranges drastically from city to city; the largest being 88% in Mission Viejo, CA to 16% in Washington, D.C. (Gagnon et al., 2016). These specified results for cities with complete Lidar databases demonstrate the wide range of solar possibilities and criteria that should be considered. A city such as Mission Viejo, with low multi-residential buildings, high sunlight levels, and low energy consumption could greatly benefit from domestic rooftop solar. Other cities, such as New York City, contain many multi-residential buildings, low/inconsistent sunlight levels, and low roof area per capita and are poor options for implementing roof top solar. The breakdown by city highlights the differences in space and potential for different cities. This method does demonstrate promise as the city-by-city analysis could be expanded upon to maximize within cities, going neighborhood by neighborhood to find the optimal spaces for domestic solar installation. This would help cities and homeowners discover if their roof is not only a viable option, but a worthwhile investment.

One interesting aspect the review highlights is multi-residential buildings. These buildings, typically apartments, begin the conversation around renting culture in the United States when it comes to domestic solar installation. With more than a third of Americans renting their houses from landlords or living in apartments, incentivizing landlords to install solar panels, especially when residents pay the energy bill, can be very difficult (Pontecorvo, 2021). This

creates a unique challenge between landlords and renters. The owner of the home or apartment building ultimately gets the final say on whether to adopt solar systems. This creates an issue when the residents desire a solar system, but cannot themselves add on to the infrastructure. If they desire a lower energy cost and the adoption of solar, they have to somehow convince their landlord it is a good investment. While limiting climate change effects is a good point to bring up, eventually funding has to be discussed. Apartment buildings, as seen from the NREL study, contain too many residents for too little roof space to make solar viable. This is ultimately why those roofs are still empty.

Aesthetics & Hope for Better Technology

Another aspect of the socio-technical system for domestic solar panels is the visual appeal. Surveys have been conducted to understand the role visual appearance plays in customer preferences and overall adoption. One such study from 2017 studied both overall appearance and tradeoffs customers would make based on visual appeal (Bao et al., 2017). The study discovered color was the most important attribute related to visual appearance, followed by shape and surface pattern (Bao et al., 2017). These findings highlight how customers want the least visually intrusive option when choosing solar, often choosing a panel color that matched the roof color. The paper continues with findings on solar panels placed in context. For this, the researchers provided various information about the systems, such as price, reliability, efficiency, and grid type. The findings of this second survey concluded that systems with higher appearance ratings were preferred (Bao et al., 2017). This means that even if one system was better performing or cheaper, the customer would go against the rational choice and choose the more visually appealing design. The study summarizes itself nicely by saying:

> "the context in which the products are presented is linked to significant differences in user preferences. Simulating real use scenarios of renewable products will help capturing more realistic preferences from users…This can reduce the uncertainty of installing solar for customers, which could lead to more adoption." (Bao et al., 2017).

The tradeoffs customers make simply to have a better-looking solar system seems to contradict the idea of turning to solar in the first place. While it seems silly for appearance to be a large issue with Americans turning to solar, the idea of the classic rectangular solar panels sitting on a roof can deter buyers enough to not purchase. Homeowners want, on a basic level, a good-looking home. And if they believe the PV system they are choosing to install is ugly, they will not purchase it. While scientists are trying to improve the efficiency of solar cells, it also needs to be noted that the same improvements to visual appeal and ease of implementation needs to be taken.

Luckily, there are companies working on patent to improve both efficiency and aesthetics (Chu & Tarazano, n.d.). These systems are attempting to incorporate solar cells in a way that are discreet and can be easily adopted by homeowners. However, this brings us to the last issue of solar adoption in America. Some homeowners choose to hold out for the hope of better technology in the future (Sami, 2021). Just as all technology evolves, no homeowner wants to install solar panels that will need to be updated or redone when substantially better systems are created. One of the key evolutions of solar panel technology will be to building-applied photovoltaic (BAPV). BAPV is the incorporation of solar technology into the building materials themselves, as opposed to an additional PV system being added on (Staff, 2017). While some BAPV options are currently available, they are mainly used in new commercial buildings or added during renovations (Staff, 2017). BAPVs are viewed as the future of solar technologies,

improving efficiency and aesthetics (Chu & Tarazano, n.d.). Unfortunately, they are not yet common in residential projects. However, the display of them in commercial buildings could be causing homeowners to wait, wanting BAPVs in their own homes as opposed to the traditional rooftop solar collection system.

The Entire Socio-Technical System

BAPV's highlight the underlying issue to everything discussed: solar panels are not ready to be incorporated into every domestic American home… yet. While the pieces to the puzzle are beginning to come together, solar panels need more time. The current technology is not strong enough to overcome the surrounding factors of price, space, and looks. As much as the government has tried, homeowners do not have the economic and/or environmental incentive to purchase and install an at home solar system. While this realization is not ideal given the current energy situation and the desire for renewable energy, it is the status of the current socio-technical system.

Domestic PV systems need one of two things to occur: a transformative improvement to the point of necessity, or become cheaply viable for the current system. The first method will require the technology to improve. BAPVs demonstrate promise and could potentially be the replacement to the current rooftop solution. However, creating new technology takes time and is unpredictable. The second way requires changes to the socio-technical system to occur. More solar panels will be installed if current practices and factors continue such as decreasing prices, government incentives, and optimal spaces being identified. New technology such as augmented reality could be utilized to demonstrate aesthetics for new installations. This would allow customers to see which style they prefer and reduce anxiety for unknown aesthetics.

I suggest a more likely future, one where a combination of these two paths occurs. Based on the research and development being performed on solar power, new PV systems will be created for both increased efficiency and visuals. These improvements will help seamlessly integrate new home building with energy creation. This will also hopefully reduce prices for slightly less novel technology and increase demand for every residence. In addition, as solar collections systems become more popular, people will feel more accustomed to them. As with all technology, it takes time for adoption to occur, and continuously seeing PV systems will make them more normal and a part of everyday life. While this outlook is an optimistic one, the details highlighted in this report do show promise. The idea of every single house having its own PV system isn't possible for the current situation. However, the possibility for growth is there. It just needs time to improve and overcome the challenges currently being faced.

Conclusion

As can be seen, the adoption of solar in American households is a complicated issue. Solar systems currently require the correct house, with a true homeowner, hoping to better their energy source and have the means to purchase a solar system. Unfortunately, there aren't that many Americans that fit those criteria. To help incentivize solar, the government has implemented tax credits, which have worked to some extent. But some homeowners don't enjoy the look of solar panels.

The bottom line is domestic solar systems have not reached the point to where they can be implemented nationwide. The technology, while incredible, is not cheap, efficient, or aesthetically pleasing enough for the majority of Americans to adopt. Solar powered energy is

hopefully going to reach a point where the integration of energy production and home buildings will be normal, most likely coming from BAPVs. While that point has not yet fully come, the systems in place to incentivize the move to solar are there. The government support, public awareness, and initial adopters show promise for what will hopefully be an integral part of energy production in the future.

Bibliography

Bao, Q., Honda, T., El Ferik, S., Shaukat, M. M., & Yang, M. C. (2017). Understanding the role of visual appeal in consumer preference for residential solar panels. *Renewable Energy*, *113*, 1569–1579. https://doi.org/10.1016/j.renene.2017.07.021

Chu, E., & Tarazano, D. L. (n.d.). *A Brief History of Solar Panels*. Smithsonian Magazine. Retrieved April 16, 2023, from https://www.smithsonianmag.com/sponsored/brief-history-solar-panels-180972006/

Gagnon, P., Margolis, R., Melius, J., Phillips, C., & Elmore, R. (2016). *Rooftop Solar Photovoltaic Technical Potential in the United States. A Detailed Assessment* (NREL/TP--6A20-65298, 1236153; p. NREL/TP--6A20-65298, 1236153). https://doi.org/10.2172/1236153

Homeowner's Guide to the Federal Tax Credit for Solar Photovoltaics. (n.d.). Energy.Gov. Retrieved April 16, 2023, from https://www.energy.gov/eere/solar/homeowners-guide-federal-tax-credit-solar-photovoltaics

Leppert, R., & Kennedy, B. (2022, October 7). Home solar panel adoption continues to rise in the U.S. *Pew Research Center*. https://www.pewresearch.org/fact-tank/2022/10/14/home-solar-panel-adoption-continues-to-rise-in-the-u-s/

Miller, B. (n.d.). *Solar Strong | University of Delaware Research*. Retrieved May 8, 2023, from https://research.udel.edu/2015/10/12/solar-strong/

Perusse, B., Riggins, M., Rodgers, J., & Zimring, M. (2009). Melting down and scaling up: Stabilizing climate change by promoting private sector technology development. *The Review of Policy Research, 26*(4), 511-31

Pontecorvo, E. (2021, June 24). *Why doesn't every roof have solar panels?* Grist. https://grist.org/ask-umbra-series/why-doesnt-every-roof-have-solar-panels/

Sabas, M. (2016, February 18). History of Solar Power. *IER*. https://www.instituteforenergyresearch.org/renewable/solar/history-of-solar-power/

Sami. (2021, March 2). *Why Isn't Every Homeowner Using solar? Addressing the Misconceptions*. Dynamic SLR. https://www.dynamicslr.com/why-isnt-every-homeowner-using-solar-and-facts-to-counter-this/

Staff, G. I. (2017, February 10). *Discreet Solar Power For Your Roof*. Greener Ideal. https://greenerideal.com/guides/1017-discreet-solar-power-for-your-roof/

Watkins, F. (2017, August 8). A Shocking 80 Percent of Americans Can't Access Rooftop Solar. Here's Why. *Solstice Community Solar*. https://blog.solstice.us/solstice-blog/why-americans-cant-access-rooftop-solar/