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Literature Review: A Cost/Benefit Analysis of Installing Solar Panels in Albany, NY

According to Phillips (2019), in 1954, scientists from Bell Labs conducted the first public demonstration of silicon photovoltaic cells in Murray Hill, New Jersey. By attaching a small toy ferris wheel and radio transmitter to one of the first true solar "panels", the country was introduced to a new form of energy technology. This first panel yielded about 6% efficiency, very poor relative to today's standards, but its overall success fueled continued research and interest throughout the second half of the 20th century. Since then, the cost of manufacturing and installing these devices on residential rooftops and property has dropped dramatically and overall panel efficiency has increased close to fivefold over this same time period. By the early 2000s, photovoltaic technology had advanced enough to gain widespread interest among residential energy consumers. In 2006, the federal government further supported the growth of solar energy infrastructure in the United States when it enacted the solar Investment Tax Credit (ITC), incentivizing a large-scale transition from gas to solar energy generation across the country. Because of these developments, the United States has witnessed an exponential increase in solar power consumption over the past decade.

Although there's been a drastic uptick in consumption of solar energy domestically, there are still barriers to large-scale residential adoption. One of the main barriers is the up-front cost of installation. Phillips (2019) mentions that most estimates range from an initial cost around $15,000 to $20,000, which for many is still too steep of a financial investment. Additionally, Phillips (2019) noted that in the United States, "some states and locales have witnessed a recent resurgence in distrust in the scientific consensus around anthropogenic climate change, and that a largely politically motivated denial of a scientific consensus exists”. In an extensive review of the sustainability of solar power generation, Khan and Arsalan (2016) deem solar energy as the “clean” option relative to energy alternatives such as gas and coal that require the use of fossil fuels. Khan and Arsalan’s (2016) review is backed by countless literature to suggest that solar energy, and especially concentrated solar power (CSP) and solar photovoltaic (SP), are extremely “green” options. However, because of this scientific rhetoric and consensus, a political counterculture has developed in resistance to adopting these new technologies. As Phillip (2019) also mentions, this counterculture is supported by the fossil fuel industry -- which is in direct competition with solar energy providers for the domestic energy market.

The initial cost of solar panel installation and the energy consumer’s perception of the environment, are not just factors influencing residential solar power adoption in the United States, but are also leading questions posed to Swedish residents in a study conducted by Palm (2018). In this study, Palm (2018) interviewed 20 households in 2008-2009, and 43 households in 2014-2016 that were interested in purchasing solar panels for their household. Based on their responses, comparisons were drawn between the two time intervals to determine if there were any large-scale shifts in consumer motivations and barriers around household solar array adoption. Interestingly, households interviewed between 2008-2009, cited the most important driver for choosing to adopt solar panels for their household as growing concerns about the environment, and the environmental benefit of switching to a solar power energy solution. This contrasted slightly with the second wave of interviews conducted in this study between 2014 and 2016, where the leading driver for households was mainly financial. This shift, between the “early adopters”, described by Palm (2018), and the “second wave”, demonstrate that public perception of solar panels as a viable cost-saving mechanism became much more prevalent over time. Palm (2018) attributes this shift primarily to increases in solar array efficiency (leading to more cost savings), as well as government policies that were enacted to incentivize households to sell back extra electricity to the grid and obtain subsidies; these two factors seemed to have a large impact on the consumer perceptions. Additionally, in a study by Qiu et. al (2017) analyzing the impact of solar panel installation on home values in Arizona, the cost savings aren’t the only potential financial incentive for homeowners, but ultimately the shift could lead to a large premium (sometimes as high as 15% of the median home value).

When examining the broader trend of consumer adoption of residential solar panels, a study by Faiers, A., Neame, C., & Cook, M. (2007) connected a long-standing theory called the “Diffusion of Innovation”, referenced by Wikipedia as a way to explain the many components of how, why and the rate at which new ideas and technologies spread, to the public’s adoption of residential solar thermal panels. Since then, many others have used this theory to monitor the overall reception and adoption of this technology. Interestingly, in Palm (2018) the author referenced their interviewees that adopted solar panels during the first study interval between 2008-2009 as “early adopters”, however, these interviewees were most likely “innovators” (the first 2.5% of adopters) based on Diffusion of Innovation theory groupings. Since, according to Palm

(2018), roughly 0.08% of energy production was produced by solar energy in 2015 in Sweden, these interviewees characterize a small subset of the overall population that had adopted the newest technology at the time.

When comparing Palm (2018) to similar studies in the United States, Zhai and Williams (2012) conducted a study which surveyed more than 400 residents in the Phoenix, Arizona metropolitan area in 2010 to determine overall perceptions of photovoltaic panel adoption. Similar to Palm's (2018) "early adopters", this study found that respondents indicating that they had installed solar panels were motivated primarily by the benefits it would produce for the environment. However, in a related study by Bao et. al (2020), who surveyed solar panel adopters in Massachusetts and California, the largest motivation for installation by far was the cost savings. From the results of the surveys, Bao et. al (2020) mentions that the 25-year cost savings, frequency of array failures in a five-year period of time, and environmental benefits all exhibited the highest part-worth means based on their survey results. Therefore, we can conclude from a review of each of these studies that there seems to be a pretty apparent trend in consumer motivation for solar adoption, where those that adopted earlier in the decade were largely motivated by the benefits the transition had on the environment, whereas those that transitioned more recently are starting to take heed of the cost-saving (and potentially profit-making) potential of solar panel adoption.

Bauner and Crago (2015) conducted a study analyzing the impact of the uncertainty of the future value of solar panels on adoption practices in the residential sector of Massachusetts. They found that while financial incentives have certainly contributed to the adoption of solar panels in the residential sector, the uncertainty of just how much value the solar panel system will yield keeps many potential consumers from installing solar systems. Bauner and Crago (2015) concluded that assuming "households take into account the option value of their investment dollars, the present value of benefits from solar PV needs to be 60% greater than installation costs for investment to occur."

Kennedy & Thigpen (2019) claim that according to the Pew Research Center only approximately 6% of US households have installed solar panels on their homes as of 2019. According to the Diffusion of Innovation Theory this would place us firmly in the Early Adopters portion of the acceptance of solar panels. We know that this particular group tends to have a very strong position in terms of influencing future adoption, so clear and accurate information that reduces any uncertainty around the decision is a boon to the overall adoption timeline. As a response to this need, several solar calculators have appeared online to help a consumer weigh the benefits - Google's Project Sunroof and EnergySage being two examples. Project Sunroof calculates an estimated 20 year savings based off of a generalized monthly electric bill; EnergySage requires providing personal information and requesting quotes or viewing sample quotes from one's area. Our goal with this project is to provide a more detailed breakdown of the projected costs and benefits associated with installing solar panels on one's home in Albany, NY. Since literature, including Dhimish and Silvestre (2019), goes into much detail about how one's roof orientation, and its ensuing azimuth can play a large role in panel efficiency and performance, our calculator will seek to account for this on a household level. The calculator will also account for the actual solar irradiation information at the user's location, project the yield for various efficiency panels, confirm energy usage assumptions, and attempt to predict long-term financial outlooks including when exactly 60% of the investment cost would be recouped.

Sources

Bao, Q., Sinitskaya, E., Gomez, K. J., MacDonald, E. F., & Yang, M. C. (2020). A human-centered design approach to evaluating factors in residential solar PV adoption: A survey of homeowners in California and Massachusetts. *Renewable Energy, 151*, 503-513. doi:10.1016/j.renene.2019.11.047

Barbose, Galen L., Darghouth, Naim R., LaCommare, Kristina H., Millstein, Dev, & Rand, Joe. *Tracking the Sun: Installed Price Trends for Distributed Photovoltaic Systems in the United States - 2018 Edition*. United States. doi:https://doi.org/10.2172/1477384

Bauner, C., & Crago, C. L. (2015). Adoption of residential solar power under uncertainty: Implications for renewable energy incentives. Energy Policy, 86, 27–35. https://doi.org/10.1016/j.enpol.2015.06.009

Dhimish, M., & Silvestre, S. (2019). Estimating the impact of azimuth-angle variations on photovoltaic annual energy production. *Clean Energy, 3*(1), 47-58. doi:https://doi.org/10.1093/ce/zky022

Faiers, A., Neame, C., & Cook, M. (2007). The adoption of domestic solar-power systems: Do consumers assess product attributes in a stepwise process? Energy Policy, 35(6), 3418–3423. https://doi.org/10.1016/j.enpol.2006.10.029

Kennedy, B., & Thigpen, C. L. (2019, December 17). More U.S. homeowners say they are considering home solar panels. Pew Research Center. https://www.pewresearch.org/fact-tank/2019/12/17/more-u-s-homeowners-say-they-are-considering-home-solar-panels/#:%7E:text=The%20same%20Pew%20Research%20Center,installed%20solar%20panels%20at%20home.

Khan, J., & Arsalan, M. H. (2016). Solar power technologies for sustainable electricity generation – a review. *Renewable and Sustainable Energy Reviews, 55*, 414-425. doi:10.1016/j.rser.2015.10.135

O'Shaughnessy, E. (2018). Trends in the market structure of US residential solar PV installation, 2000 to 2016: An evolving industry. *Progress in Photovoltaics: Research and Applications, 26*(11), 901-910. doi:10.1002/pip.3030

Palm, J. (2018). Household installation of solar panels – Motives and barriers in a 10-year perspective. *Energy Policy, 113*, 1-8. doi:https://doi.org/10.1016/j.enpol.2017.10.047

Phillips, L. (2019). Solar energy. In *Managing Global Warming: An Interface of Technology and Human Issues* (pp. 317-332). Cambridge, MA: Elsevier. doi:https://doi.org/10.1016/B978-0-12-814104-5.09994-4

Qiu, Y., Wang, J., & Wang, Y. D. (2017). Soak up the sun: Impact of solar energy systems on residential home values in Arizona. *Energy Economics, 66*, 328-336. doi:https://doi.org/10.1016/j.eneco.2017.07.001

Zhai, P., & Williams, E. D. (2012). Analyzing consumer acceptance of photovoltaics (pv) using fuzzy logic model. *Renewable Energy, 41*, 350-357. doi:10.1016/j.renene.2011.11.041