Determining Typical Buyer Sensitivity for Solar Installation Cost—Energy Savings Benefit

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ABSTRACT

A survey was conducted at the U.S. Department of Energy Solar Decathlon 2011 in Washington, DC to determine why American consumers have not yet adopted solar electric technology in their homes. With over 700 respondents, the data showed the three most prevalent concerns include: cost of installation and maintenance, geography, and knowledge about the technology. The survey also sought to find what customers accepted as a payback period if a solar electric home would cost them 20 percent extra.

Purdue University's entry in the 2011 competition, the INhome, promoted the practicality of solar living by presenting an efficient, affordable, and conventional home. With a second place finish in the decathlon, Team Purdue's design showed consumers the reality that solar living is achievable today.

The following analysis of the survey data obtained at the decathlon compares American residential consumer concerns and desires regarding solar electric power with Team Purdue's INhome.

1. INTRODUCTION

The technology that enables the harnessing of the sun's energy into useable electrical current has existed for decades. The first tangible device using this technology was created over 50 years ago with the discovery of the silicon p-n junction photocell. (Chapin, Fuller, & Pearson, 1956). As the worldwide goal to reduce carbon emissions becomes an increasing priority, many nations are looking to solar energy as a viable solution. However, amidst the many benefits of solar energy, a lack of adoption in the residential sector is taking place. Many hypothesize why the mainstream adoption of solar electric technology has yet to be seen. What is lacking in the relevant literature is empirical evidence of the public's current perceptions of solar energy devices on the market for residential applications. Thus, a survey was conducted at the U.S. Department of Energy Solar Decathlon 2011 which sampled over 700 attendees of the decathlon regarding their perceptions.

1.1 Solar Decathlon Competition

The U.S. Department of Energy Solar Decathlon competition is an intercollegiate, international competition held biannually, which hosts twenty universities from across the world. The purpose of the competition is to design, build, and operate net-zero solar powered homes. The 2011 competition required homes to be no greater than 1,000 square-feet, and for the first time in the competition's history, introduced an affordability contest which encouraged teams to stay under a construction cost of $250,000. The purpose of the affordability contest was to illustrate affordable methods of implementing solar power.

The decathlon consisted of 10 competitions including subjective and objective contests of 100 points each; creating a total of 1000 points. Juried competitions included architecture, engineering, communications and market appeal. Also, throughout the duration of the 10 days of competition, teams simulated a lived-in environment by conducting tasks similar to those a homeowner would perform, i.e.: cooking meals, washing and drying towels, and boiling water. The purpose of these tasks was to prove that the homes could perform at net-zero energy not only when the homes were unoccupied, but also when the homes were in use.

Fig. 1: Aerial View of the INhome located on the National Mall in Washington, D.C. during the U.S. Department of Energy Solar Decathlon 2011.

Team Purdue was one of only seven teams out of 20 to achieve net-zero energy over the course of the 10 day competition. Team Purdue's INhome, shortened from Indiana home, challenged the competition in 2011. The INhome was perceived as different from the other competition homes, because of its normalcy. The goal of the INhome team was to present a conventional, practical, and affordable home that would appeal to the broad market of American residential consumers. It was Team Purdue's philosophy that in order to see an increase in the use of solar electric technology across the nation, consumers must be exposed to the reality that solar powered homes can be comfortable and efficient.

A common view towards residential solar applications is that they are only incorporated into modern architectural styles, and only welcome in isolated locations. Team Purdue sought to change that view, by showcasing the "all-american" home, with an architectural style similar to those currently found in neighborhoods across the United States. Team Purdue received second place overall in the competition. During its 10 days on exhibit to the public on the National Mall in Washington, D.C., the INhome was toured by over 18,000 people. Of these attendees, over 700 took a voluntary survey addressing their perceptions of solar electric technology and its residential application.

2. SURVEY DEVELOPMENT AND METHODOLOGY

The following research question originated during the development of this survey to clarify which specific information was sought: What are the current perceptions of American residential consumers regarding the implementation of solar electric power in residential applications? In order to gain information pertaining to perceptions from the specific audience, the authors define "American residential consumers" as persons above the age of 18. To clarify the term "solar electric power" a note was included at the top of the survey stating that "solar electric power refers to electricity generated from solar panels". This clarification was intended to limit the scope of the survey to only solar panel electricity production, rather than including solar thermal and passive solar technologies.

2.1 Pilot Survey

Before conducting the survey in Washington, D.C., a pilot survey was conducted in West Lafayette, IN on the Purdue University campus at the construction site of Team Purdue's INhome. During an open house hosted by the INhome team to educate the local Indiana community, this pilot survey was administered to over 50 visitors. The pilot survey was conducted to test the effects of question phrasing on responses. Included in the original survey were questions regarding governmental influence on the implementation of solar electric power. It was noticed that visitors who took the survey began arguing amongst each other about their views. The pilot survey data from these questions showed very strong conservative and liberal polarization in responses. The potential for conflict could affect the ability for participants to respond independently of each other due to the introduction of this topic. Thus, these questions were removed from the final survey.

Fig. 2: Public tours given on Purdue University Campus in the Fall of 2011.

2.2 Final Survey Conduction and Analysis

The data was collected in person at the U.S. Department of Energy Solar Decathlon. Visitors of the decathlon were approached while waiting in tour lines with the option of participating in an anonymous voluntary survey for educational purposes. Those who agreed were given an 11 question survey consisting of likert items, dichotomous questions, multiple choice questions, and ratio scale questions. The surveys were completed by hand on paper and placed into a box to maintain anonymity of volunteers.

After all surveys were completed, the entries were input and analyzed using the Qualtrics software. The data was analyzed in two ways. The data was first analyzed on an independent question-by-question basis looking at the entire sample set of responses for each question. Secondly correlations and relationships were found linking information together which enabled data to be filtered showing varying responses from different groups to particular questions. For instance, the authors analyzed differences between homeowner's vs. non-homeowner's responses.

2.3 Hypotheses

The purpose of conducting the survey was to gain insight into current public perceptions of solar photovoltaic technology pertaining to residential applications. Thirty-three of the United States have either set renewable portfolio standards or goals for adoption of renewable energy by 2030, but adoption in the residential sector has been slow to take place. (U.S. DOE, 2009) Hypotheses predicting why the mainstream implementation of solar energy in the residential sector has been slow included an insufficient cost benefit, unpleasing aesthetics, and a lack of encouragement from political and public influence. A total of 725 attendees of the decathlon were surveyed providing information on these theories.

3. FACTORS PREVENTING IMPLEMENTATION

As stated previously, the survey consisted of 11 questions pertaining to current perceptions of solar electric power, however, for the purpose of this paper, an in depth analysis of the final two questions is included in this section. Survey questions 10 and 11 asked respondents which factors are currently preventing the implementation of solar electric power in their residences, and what payback timeline would justify the expense of implementing a solar electric system. The combination of the two questions seeks to form a relationship between the factors of cost and time.

3.1 Data

Question 10 included in the survey asked: "What factors would prevent you from installing a solar electric system in your future home?" Respondents were asked to circle all that applied of the following options: cost, aesthetics, knowledge, geography, and inconvenience, with the option of writing a comment in the provided blank. Refer to Figure 3 for the response data.

Seventy-nine percent of those surveyed identified cost as a factor preventing consumers from implementing the use of solar electric technology. Following cost, geography was the second most prevalent factor identified by 21 percent of respondents. Knowledge at 12 percent, Inconvenience at 11 percent, and Aesthetics at 10 percent, were also factors that were found to be important in the minds of consumers. Finally, 6 percent of respondents attributed the lack of adoption to other factors.

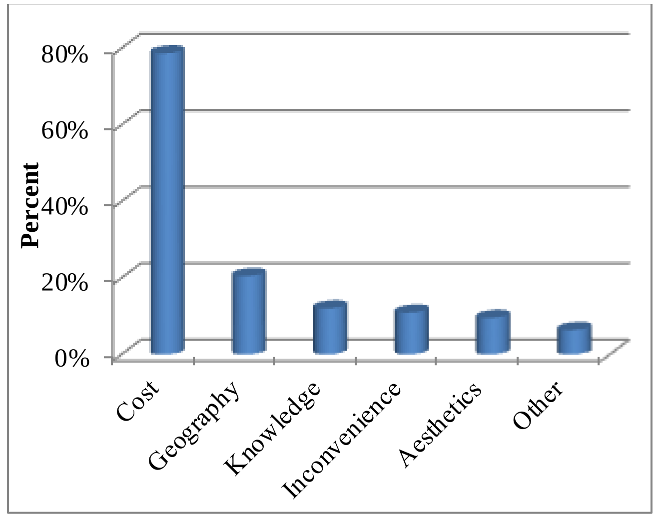

Fig. 3: Major Factors Preventing Adoption (Total).

3.2 Cost Factor

As previously mentioned, respondents were asked to select any and all preventative factors. Seventy-nine percent of people who completed the survey claimed cost was a preventing factor. This predictable factor has an overwhelming lead as most prevalent concern. Not only did 79 percent of respondents claim cost as a factor, but 46 percent claimed cost as the only factor preventing their adoption of solar electric technology. Cost is determined by a multitude of elements including but not limited to, utility price of electricity, manufacturing costs, installation and maintenance costs, net-metering policies, panel efficiency and inflation over time. With all of these elements at play, it is difficult to determine which specific factors are more influential in the prevention, but it is believed that a combination of changes resulting in reduction of costs to homeowners will affect this percentage in the future.

3.3 Geography Factor

Twenty-one percent of surveyed people claimed geographical factors are preventing the implementation, with 6 percent claiming it as the only factor. It is observed that this response could have various interpretations to respondents. Geographical factors may include orientation of the home, location in the United States (latitude), exposure to sunlight, shading from trees, etc. Further research through a more specific survey may lead to more concise conclusions addressing this concern.

3.4 Knowledge Factor

At 12 percent, knowledge of the technology or the lack thereof, is an important factor preventing consumers from adoption. Without understanding of how solar electric technology works, consumers feel hesitant to invest. Increased public education through projects like the U.S. Department of Energy Solar Decathlon may reduce this percentage.

3.5 Inconvenience Factor

Inconvenience was reported as a factor by 11 percent of the respondents. As this survey pertains to new home construction, inconvenience refers to installation and maintenance concerns. It is difficult to counteract these concerns because many inconvenient factors that come with a solar electric system are out of the manufacturer or distributor's control. Necessity for maintenance may stem from natural occurrences such as heavy winds, rain, and snow. Guaranteed warranties of replacement may contribute to the reduction in this percentage.

3.6 Aesthetics Factor

With 10 percent of respondents stating aesthetics as a factor preventing the implementation of solar electric systems on their homes, the concept of Team Purdue's INhome seems essential. Homes like the INhome illustrate that solar powered homes can fit into residential neighborhoods across the country without being an eye sore. Also, as solar photovoltaic panels become more efficient over time, a lesser amount of surface area will be required for panel arrays.

Fig. 4: Purdue INhome.

3.7 Other Factors

In addition to the five provided factors, six percent of respondents chose to fill in the blank with other factors preventing their adoption of solar electric power. Twelve respondents stated that their homeowner's association would not allow the installation of solar panels. Some stated they intended to move before payback was achieved and resale value would be affected by the system. Other respondents stated old age and health concerns prevented the adoption. All of these factors are valid reasons that show different demographics and lifestyles among consumers create differing perceptions of the advantages and disadvantages of adopting solar electric power in the residential sector.

3.8 Conclusions from Findings

The data obtained from this question show which major factors are currently preventing the implementation of solar electric power in residential applications. Among homeowners and non-homeowners alike, cost is the most prevalent factor, followed by geography, and knowledge. This information is relevant to manufacturers and distributors in the solar photovoltaic industry because it defines current problems creating the gap between supply and demand of solar electric technology in the United States. Improved marketing strategies, increased education and further development of more efficient panels can contribute to the reduction of this gap, and the increase of adoption in the residential sector.

4. JUSTIFIABLE PAYBACK TIMELINE

The final question on the survey asked: "If the installation of a solar electric system costs an additional 20 percent of your home's value, in order to pay the system off, what length of time would justify your investment?" With cost as the most prevalent factor found in the pilot study, the purpose of this question was to determine at what point cost would no longer prevent adoption.

During the development of this survey question, the authors chose to use 20 percent as a base cost of system installation. This value was drawn from the associated costs of installation for the 8.64 kilowatt solar photovoltaic array designed for Team Purdue's INhome.

The question was presented in ranges from 1-5 years, 5-10 years, 10-15 years, 15-20 years and 20-25 years. Also, the response "Not sure" was included for those who were uncomfortable answering the question. Figure 5 is a graphical display of the number of responses in each category, while Figure 6 shows the percentage break down for each range.

4.1 Analysis of Responses

Three-hundred and twenty-eight of the responses, or 42 percent, claimed they would justify an upfront investment

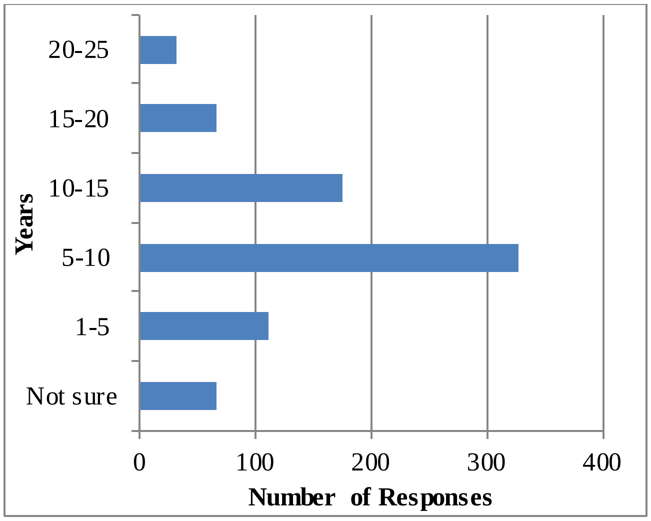

Fig. 5: Number of Years to Justify Investment

over a timeline of 5-10 years. At 22 percent, 175 of the responses claimed 10-15 years. Also at 14 percent, 112 responses stated they would justify the investment at 1-5 years. When we combine these three ranges it is concluded that if the payback timeline of a solar photovoltaic system was 15 years or less, 79 percent of respondents would justify the investment.

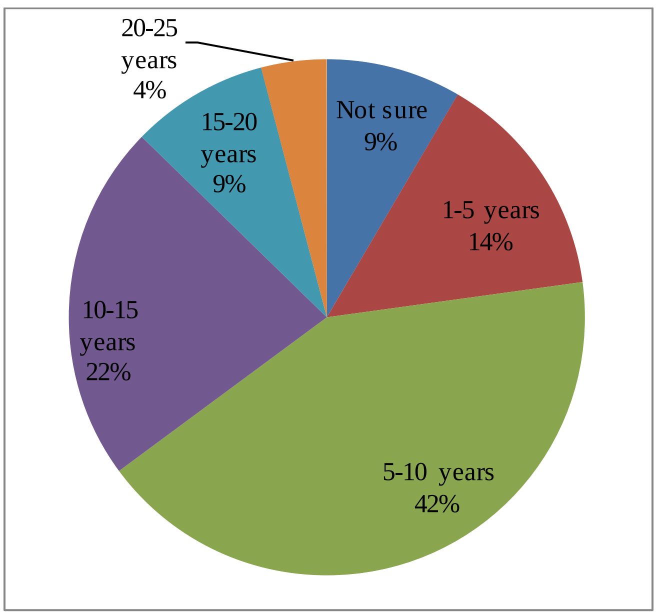

Fig. 6: Percentage of Responses in Each Range of Time

4.2 <u>Purdue INhome Payback Calculations</u>

The Purdue INhome, was designed to be net-zero in West Lafayette, IN. Net-zero is a term used to describe buildings that produce as much energy as they consume over the course of a year. Team Purdue developed an energy model to estimate annual consumption and production of the home. Based on an occupancy of 3 residents, and performance assumptions given by current ASHRAE standards, information given from the model showed energy consumption to be approximately 7,000 kilowatt-hours (kWh) per year. In order to achieve net-zero with Indiana's average daily sun exposure, approximately four sunshine hours per day, the INhome team sized the photovoltaic array at 8.64 kilowatts. Simplified, on a daily basis the INhome would produce on average 20 kWh per day.

The INhome's construction cost was estimated at approximately $250,000. The cost of the system's 36 panels at 240 volts each totaled approximately $50,000. Installation costs added an additional $10,000 due to the fact that a specialized professional solar installer was required for installation. A professional installer was necessary because the INhome's system was centrally inverted, as opposed to micro-inverted.

Combined, panel purchase and installation costs totaled approximately $60,000. Federal rebates were factored into the payback calculations as well. Using a current 30 percent federal rebate a total of $15,000 was credited back to the sum of expenses. Combined, the upfront cost of the INhome's solar photovoltaic system totaled $45,000.

Item	Cost
36, 240VDC Modules	50,000
Installation	10,000
30% Federal Tax Rebate	(15,000)
Total	45,000

The U.S. Energy Information Administration (EIA) releases an electricity report on an annual basis titled "Electric Sales, Revenue, and Average Price" which quantifies electricity rates in each of the 50 United States by publically and privately owned utilities. In 2001, the average nationwide electricity cost per kilowatt hour was $0.086. In 2010, the average cost per kilowatt hour increased to $0.114, an increase of 32.56 percent over the nine years. This equates to an annual compounded rate of 3.18 percent. (U.S. EIA, 2011)

Using the national average from 2010 of $0.114 per kWh, and the estimated daily production by the INhome's solar array stated above of 20 kWh, average savings of the net-zero system equates to $2.28 per day over the course of a year. This is a total savings of $832.20 per year.

*Cost/kWh * kWh Produced = Savings*

*$0.114 * 20kWh = $2.28 daily*

*$2.28 daily savings * 365 days/year = $832.20 annually*

The annual compounded utility rate increase calculated from 2001-2010 from the U.S. EIA of 3.18 percent can be applied to the INhome calculations to estimate the payback period. The payback calculation assumes a scenario where inflation maintains a constant rate, no improvements are made in panel efficiency, and no mandates are set on the use of renewables. Table 1 shows the payback period of the INhome's solar array purchased in 2010 at an efficiency of 19 percent.

TABLE 1: PURDUE INHOME PAYBACK TIMELINE

Year	Savings	Remaining Deficit
0	*$0*	($45,000)
10	*$1,103*	*($35,380)*
20	*$1,508*	*($22,225)*
30	*$2,063*	*($4,233)*
31	*$2,129*	*($2,104)*
32	*$2,196*	*$92*

Payback occurs between Years 31 and 32.

The initial investment would be paid off between the 31st and 32nd year of ownership. This timeline is more than twice as long as the majority of surveyed consumers desire currently to justify the expense. As stated previously this payback calculation does not take into account many variables affecting cost and payback. Also, the numbers used to formulate the calculation are based on averages from 2010. Each year utility costs and inflation rates change. Also, due to the global competitive market, reductions in solar photovoltaic costs have transpired benefiting both commercial and residential buyers. While a 30 year payback is accurate using numbers from 2010, this may not be the case in 2012 or following years.

Using the Purdue INhome as a model for solar powered housing in the United States, it can be concluded that the technology and associated costs of solar electric systems in residential applications do not currently meet consumer desires. If the industry targets a 15 year or less payback timeline and can continue research and development towards this target, the mainstream adoption of solar electric systems may improve in the future.

5. POPULATION ASSUMPTIONS

Although this survey gives insight into the current perceptions of residential consumers, the sample does not represent the entire population of American residential consumers. This sample was drawn from an audience of visitors at the U.S. Department of Energy Solar Decathlon 2011. The Department of Energy did not allow the compiling of demographics within this survey due to the fact that the decathlon took place on the National Mall. However, a few assumptions can be made about the sample. Those attending the competition took time from their schedules to visit and tour the homes showing there was some level of shared interest in the topics being presented. The authors assume respondents had pre-conceived opinions either for or against solar electric technology. It is also assumed that those attending the decathlon were interested in learning about which solar electric technologies were currently offered on the market. With these assumptions in mind, it is believed by the authors that the audience surveyed was somewhat biased.

6. CONCLUSIONS

The survey conducted in Washington, D.C. at the U.S. Department of Energy Solar Decathlon 2011 sought to investigate some of the current perceptions of American residential consumers regarding the implementation of solar electric systems in residential applications. The survey specifically inquires about solar photovoltaic installations in new construction in the United States. Data obtained from respondents conclude that the three main factors preventing consumers from adopting the technology on a mainstream scale are cost, geography, and knowledge. In addition, the majority of respondents claimed that they would justify the initial expense of a solar photovoltaic system if the payback occurred in 15 years or less.

Due to the fact that this survey of 725 consumers was conducted at the decathlon in Washington, D.C. it is determined that the sample is biased. A replication of this survey with a simple random sample of the general population of American residential consumers would result in more accurate data for the nation as a whole. However, the data that was collected is valuable information for solar panel manufacturers, distributors and consumers alike. In order to gain customer support, the industry as a whole should focus on current consumer desires as a target for research, design and marketing goals. Although the mainstream adoption of solar electric technology is not currently taking place due to a number of factors, with developments in efficiency, education, and cost competitiveness, the United States may see a change in recent years to come.

7. NOMENCLATURE

Qualrics- a research software tool used to create, conduct, and analyze surveys.

Likert item- Likert items are image based responses to survey questions designed on a Likert scale. The Likert scale is the summation of the Likert items. In example, a horizontal line can contain Likert items including strongly agree, agree, neutral, disagree, and strongly disagree.

8. ACKNOWLEDGEMENTS

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9. REFERENCES

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