1998 Annual Conference, American Solar Energy Society
June 14-17, 1998, Albuquerque, New Mexico

WILLINGNESS TO PAY (WTP) FOR SOLAR PHOTOVOLTAIC (PV) ENERGY LIGHTING SYSTEMS: THE CASE OF RURAL CHIHUAHUA

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ABSTRACT

This paper presents an analysis of a market survey conducted in rural Chihuahua, Mexico, which looks at consumer views on PV product features and preferences, energy consumption patterns and expenses, and the ability and willingness to pay for energy services in rural areas of Chihuahua not serviced by the electric grid. Results are presented in two forms, a descriptive summary of key variables; and estimated range of willingness to pay for PV systems based on a regression analysis. By including factors such as socioeconomic, demographic, and environmental conditions in the regression models, the underlying behavioral and causal relationship between consumers' willingness to pay (WTP) for PV systems is further explained.

1. INTRODUCTION

The use of photovoltaic (PV) systems in rural regions of developing countries has increased dramatically over the past decade due to the cost and difficulty of obtaining service from traditional grid electrification systems. Traditional large-scale rural grid systems, whether run by the public sector, private sector, or parastatals are economically inefficient. With the advent of a dependable modern technology alternative and more private participation and choices made available to the general public, PV systems have become attractive all over the world with nearly 500,000 rural households electrified via solar energy. Over 2 billion people in the world still have no access to electricity and this number is anticipated to grow in the future. It is also certain that these people will continue to remain without electricity unless decentralized renewable energy sources are promoted. Rural undeveloped areas worldwide represent the "natural" market for current PV technologies. The challenge is to develop credit and financing strategies that are affordable to rural people and are similar to their current energy expenditures; thus, it is important to understand what rural people in a region are willing to pay for PV technologies. This paper summarizes a study conducted by New Mexico State University in rural Chihuahua, Mexico for SunWize Technologies, Inc. in cooperation with New York State Energy Research and Development Authority and Sandia National Laboratories.

Mexico, which is one of the most electrified Latin American countries, still has more than 5 million people without electricity in over 87,000 communities (i.e. more than 2 million Mexican households without electricity). About 39,000 residential PV systems have been installed in Mexico through public programs since 1991. However, Comisión Federal de Electricidad (CFE) budgets for rural electrification have fallen to only 30% of pre-1996 levels due to political restructuring where a large part of government infrastructure funds are now distributed directly to the 2,418 counties in Mexico. Thus, in 1997 only a few hundred PV systems were installed through public programs, as compared to as many as 7,500 systems installed in as recently as 1995. In 1998, as was the case in 1997, the government budget for rural electrification probably will not exceed P$500 million for the entire country, which are the lowest electrification budgets in decades (Gonzalez, 1998). Thus, large public electrification programs are greatly hampered and an alternative to public programs incorporating financed or leased PV systems is rural people's best hope for obtaining electrical service in Mexico today.

Several issues are important for energy sector development in Mexico particularly within the context of NAFTA and its environmental side agreement. Sustainability is one such issue, which cuts across a number of areas, including ecological, economic, political, and cultural concerns for all societies. However, it is all the more important to note that solar photovoltaics are a relatively new technology and the success of its spread particularly in the unelectrified rural areas depends crucially on consumers' attitudes and their willingness to pay for PV lighting systems. It also depends on installing quality systems by qualified technicians and maintaining a support structure to meet the future operation and maintenance needs of rural consumers.

2. ARE CONSUMERS WILLING TO PAY FOR PV SYSTEMS IN MEXICO?

In an effort to better understand the prospect for solar PV systems in Chihuahua. a willingness to pay survey questionnaire was developed in the spring of 1997. The survey was developed to identify consumer views on PV product features and preferences, energy consumption patterns and expenses, and the ability and willingness to pay for energy services in rural areas of Chihuahua not serviced by the electric grid. Two pilot surveys were conducted in March 1997 to assist with the development of the final survey administered in April. One hundred and four surveys were conducted of randomly selected houses in 45 villages widely dispersed throughout the State of Chihuahua representing the wide range of rural populations living in Chihuahua, including indigenous ones. All interviews were conducted in homes that did not have electrical service, although a few homes (e.g., in Ciudad Juárez or Creel) were in communities that had electrical service, just not in that particular part of town (barrio).

2.1 Results

Results are presented in two forms: a descriptive summary of key variables; and estimated range of willingness to pay for PV systems based on a regression analysis. The summary statistics for all the variables in the questionnaire are not presented here, only some of those that have direct impact on the willingness to pay (WTP) for PV systems. The WTP for a product like a PV system basically can be viewed as a consumer's demand for a durable good; hence, the prices that they are willing to pay reveal the underlying demand for the PV system given several attributes of the PV system itself, consumer's income and household budget situation, their perception about the PV system, whether they own their house(s), and how they can finance the system. By including such factors in the regression model one can explain the underlying behavioral and causal relationship between consumers' WTP and several socioeconomic, demographic, and environmental conditions.

2.2 The Regression Models for Estimating the Maximum WTP and the Probability of WTP any Down-Payment

In one survey question, the respondents were asked how much does s/he think is the cost of a PV lighting system. Such a perception issue can depend on several socio-economic, demographic, and institutional variables. For example, if the person responding to this question had seen a PV system s/he may have a different view compared to one who has never seen or heard of a PV system. Second, when answering this question, the respondent may be silently debating whether s/he can afford such a system. In a follow up question they were further asked how much they would be willing to pay if a credit line was to be offered toward purchasing such a system. Thus, these two WTP questions—what is the cost, and how much they will pay if a credit line is offered—address the same purported issue: the price perception and the amount they are willing to pay. These WTP and the price perception are viewed as a host of socio-economic, demographic, and institutional variables as listed in the table below. The following regression equations were estimated:

(1) $PpPrice = a_0 + bX + e$; where PpPrice is the perceived price of the PV system, and X is a vector of the explanatory variables as described in Table 1 is the corresponding parameter set, and e is an error term distributed i.i.d. normal.

(2) $WTP|credit = g_0 + GX + e$; where WTP|credit is the monthly willingness-to pay amount given the availability of a credit line, and G is the vector of parameters, and e is i.i.d. normal.

(3) $Prob(Bid_j) = f_0 + hX + e$; where Bid is the bid variable. The bid variable is described below, and e is distributed as a logistic function.

First the vector of variables that were used in all of these regression models are reported with summary statistics below.

Table 1
Willingness-to-Pay and Price Perception

Variable Name (X)	*Description*
Gender of HH	Male = 1(97.2%) and Female = 0(2.9%)
Age of HH	Ranged from 24 to 74
Children under 15	Ranged from 0 to 12
How long have you lived here	Ranged from 0 to 65
Plan to Move	Yes (6.9%) No (93.1%)
Own home business	Yes (13.6%) No (86.4%)
Own your house?	Yes (90.3%) No (9.7%)
Have another house	Yes (25.0%) No (75.0)
Income	There were 10 income categories; however, all were in categories 2-7 (or N$401-N$4000 pesos per month)
Have any debt	Yes (21.6%) No (78.4%)
Heard of PV system	Yes (69.2%) No (30.8%)
Usage	1=Ranked light and radio (38.5%) 2=Ranked light and TV(33.7%), 3=Ranked light and some other (18.3%) 4=Ranked any other two except light (9.6%)
Radio & Boom Box	Sum the number of radio and boom boxes (range from 0 to 8). However, the majority was one (82.7%)
No of batteries	Sum of the number of batteries used for radios, boom boxes, and TVs (range from 0 to 8). However, the most common were 4 (35.65%) and 6 (32.7%)
Use of TV	Number of hours used the TV set (range from 0 to 5). The most common was none (73.1%) and 3 to 4 hours (22.1%)

The estimated coefficients of these two models can be used for several purposes. The variables that merit attention are gender of the head of household (HH), age of the head of household, how long the family has lived there, income, whether they have heard of the PV system before, number of radios and boom boxes. In the first model, all the variables combined explain only 22% of the variation in the dependent variable, perceived price of the system. The monthly WTP was calculated based on the estimated coefficients. The average predicted monthly WTP amounts to be in the range of P$143 - 150 based on the mean values of the independent variables as presented in Table 1. This implies that households are willing to pay either monthly, weekly (converted from monthly figure), or a one-time basis (converted from a monthly basis by multiplying the monthly figure by 12) if credit is made available. This correlates well with their actual energy expenditures shown in Table 2.

This type of analysis allows a substantive quantification and characterization of the potential PV market in Chihuahua. This is useful for determining what type of credit or leasing payments are possible for the rural PV market. Figure 1 shows the income ranges of rural households in Chihuahua. While incomes are very modest, the desire and the current expense for energy clearly show that these consumers do have a capacity to pay for modest PV lighting systems.

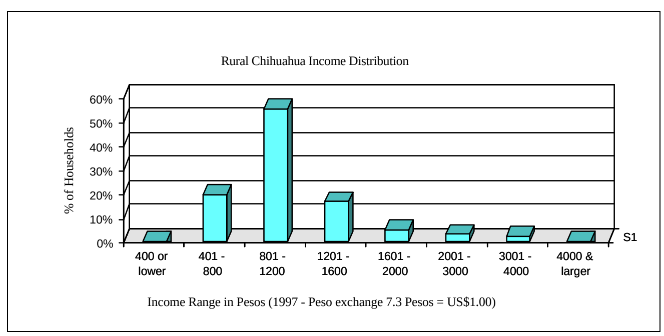

Figure 1: Rural Chihuahua income distributions.

As shown in Table 2, a rural household in Chihuahua on average spends P$180 per month on lighting, radio, and a boom box. It is worth noting that about 75% of the households are good candidates to purchase either 100 Wp

PV lighting systems or larger if proper credit or leasing arrangements are made. If PV systems are financed at P$180 per month, this would be equal to current household expenditures for electricity, plus allowing the users much more efficient and extended electrical usage (e.g., for a television). It is interesting to note from Table 3 that 69.2% of respondents had heard of PV systems, and that electric lights were the main driving force for wanting a PV system. Over half of respondents had seen a PV system already.

Table 2
Monthly Cost of Energy Use by Appliance in Rural Chihuahua

Item	Energy Source (batteries purchased)	Cost (peso)
Radio (Average)	Dry Cell Batteries (27.5)	68.75
Boom Box (Average)	Dry Cell Batteries (32.59)	81.48
Lighting (Average)	Kerosene (11.89 liters)	29.73
Propane Stove	Propane	105.30
Or Wood Stove	Wood	89.82

Table 3
Rural Chihuahuans PV Lighting System Knowledge

Issue	*Yes*	*No*	*Observations*
Have you heard of PV?	69.2	30.8	104
Have you seen one work?	55.6	44.4	72

Two most important items you would like to use with the PV system

	Percent	
Item	*Ranked 1st*	*Ranked 2nd*
Light Bulbs	90.4	0.0
Radio	5.8	38.5
TV	3.8	37.5
Tape Recorder	0.0	7.7
Ventilator	0.0	0.0
Refrigerator	0.0	3.8
Other	0.0	1.0

In the next set of regressions conducted, the dependent variable is the bid variable. This variable was constructed as the difference between the initial value consumers were willing to pay if financed and the value they gave after the interviewer attempted to get them to raise their payments. The bid variable took on three values. If the difference was zero (i.e. they did not increase their payments) the Bid variable took the value of 0. If the difference was greater than zero but not double the Bid variable took the value of 1. That is, the respondent was willing to pay more but not double their initial bid. In the last case, the difference was at least double their initial payment and the bid variable was assigned the value of 2.

The estimated parameters or their marginal effects show the relative strength of the variable concerned. For example, consider the effect of households owning a home business, the variable is significant in two of the three categories. The effect is negative in the first category implying that as the number of households owning home business increases, the probability of obtaining bids that are equal diminishes. This is further reinforced by the fact that in the next category the effect is positive and significant (i.e., the probability of obtaining different bids is likely to increase). Another variable that has significant effect is income. With increasing income, the probability of higher bids increases. Notice, however, none of these aforementioned variables have significant marginal effects on the third bid variable. The marginal effect of radio and boom box variables is positive and significant everywhere. This implies that as households possess more radios and boom boxes, they are willing to bid higher as a portion of their down payment toward the cost of the PV system. The marginal effect of the use of the TV variable is significant for only those households who are willing to bid two more times than their original bid. The variable is positive and statistically significant implying that with more use of TV, these households are willing to bid two or more times.

These probabilities are used to calculate the expected down-payment amount as follows. First, we look at the average initial bid and the average final bid under all the three categories mentioned above. The expected down-payment is then obtained as: $\hat{A}_i P_i B_i$; where P is the estimated probability of the particular bid directly obtained from the estimated multinomial Logit model (see Greene, 1993). The Probabilities calculated are 0.26, 0.22, and 0.52 respectively. The maximum expected bid that we calculated using the formula just mentioned above turns out to be in the range of P$340 – 360. The multinomial logit model's overall hit rate (percent correctly predicted) was estimated to be 69%. In other words, the maximum average down-payment amount that we predict with about 70% accuracy rate from this model is P$340 - 360.

3. WHAT DO RURAL CONSUMERS WANT IN A HOME PV SYSTEM?

SunWize Technologies, Inc. has funded the Chihuahua market survey to support its solar home systems (SHS) pilot project in the State of Chihuahua, Mexico. This pilot project will provide basic electricity to a minimum of two hundred (200) rural homes, and is the first application of a revolving loan program to be established in Chihuahua. The market study is being used to establish system price goals and develop the program financing structure.

In addition to its financial analysis benefits, the market survey analysis has proven useful in developing the size and type of the home power system. The price paid for a product or service is dependent upon product features and consumer expectations. In order to match customer willingness-to-pay with desirable product features, the initial market survey was developed to identify user preferences and energy consumption data which help define the product features and function.

One key to the success of a revolving fund program is the use of quality components and systems which provide safe, reliable, and maintenance-free service to the customers. International experience has shown that many systems used in rural electric applications in developing regions include substandard components in an effort to reduce the capital costs of solar electric systems, which results in poor performance, reduced service life, poor safety, and a subsequent lack of confidence in the technology. For example, field experience has shown that, often, independent solar home systems are installed without system charge controllers. Coupled with the inexpensive automobile batteries furnished with the majority of these systems, the typical result is reduced battery capacity, shortened battery life, and damage to the equipment load devices such as DC lighting ballasts. While first costs for these systems are generally lower, the shortened component lives result in higher life-cycle costs and decreased consumer confidence.

The intent of the pilot program in Chihuahua is to develop and demonstrate standard rural electric systems that utilize state-of-the-art technology at a low cost. The systems are designed to meet the specifications and needs of the Mexican rural electric market. They are also designed to provide a higher level of quality than “typical” solar home systems, with the belief that consumers will be willing to pay for advanced features and performance, and the overall program costs will be reduced.

The Chihuahua SunWize solar home system activities include specification and integration of system components, the development of improved processes for volume manufacture and factory test of the system, and product manufacture. Design work includes both electrical design and product packaging. The main innovation is the consumer-oriented packaging and integration of high-quality components for the target rural market.

A successful program for solar rural electrification is dependent upon a number of factors ranging from financing, to system reliability, to service. This project has demonstrated the value of an initial market survey, which jointly addresses customer preferences and willingness to pay, in order to best meet the needs of the growing rural market.

4. CONCLUSION

Several key implications follow from this study. The rural Chihuahuans are favorably disposed to the concept of solar photovoltaic systems as an alternative source of energy for their home lighting and entertainment needs. Currently, unelectrified households in Chihuahua spend P$180 a month for lights and entertainment, and they are willing to pay similar amounts of money to displace those services through PV. A PV system can compete with conventional energy sources and replace them for more efficient and broader usage. At present, kerosene is clearly the main energy source with which a PV lighting system is competing. The main reason for wanting a PV system is for electric light use, and the second reason is for entertainment with radio and TV sets being primarily the appliances of choice. Clearly, PV financing programs can be set up in rural Mexico to compete with conventional technologies in relatively poor rural areas so long as financing or leasing terms are compatible with current rural user expenses for similar services.

5. REFERENCES

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