Some Recent Research on the Markets for Residential Renewable Energy

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ABSTRACT

A considerable amount of research, consisting of both primary and secondary analysis, has recently been conducted at the National Renewable Energy Laboratory and the University of Colorado pertaining to residential markets for electricity from renewable sources. This research provides important new information concerning expansion of these markets. Selected findings drawn from five recent studies are assembled in this paper and used to critically analyze specific issues pertaining to market development. The analysis suggests that consumers may be somewhat more proactive, and their behavior somewhat more complex, than policy makers and utility companies have heretofore perceived; and that, contrary to opinions held within some segments of the utility industry, there may be few real consumer deterrents to expanded markets.

Introduction

In some parts of the utility industry, and within many energy policy-making organizations, there are a number of widely held beliefs about the markets for residential "green" power that suggest renewable energy is not an economically or socially viable enterprise. While these beliefs have not necessarily been expressed or publicized in any formal way, their existence seems to be common knowledge among those engaged in the ongoing debate about energy sustainability and environmental stewardship. Though perhaps anecdotal in nature, there is evidence to suggest that, in some areas of the country (California may be a notable exception), utilities seem to be reluctant to consider the development of residential markets for renewable energy on more than a small-scale basis (Buhrmann and Farhar 1998). On the other hand, the number "green-pricing" programs has doubled in the last two years, despite the fact that the sponsoring utilities may remain skeptical about the ultimate outcomes of such ventures (Swezey 2000).

Recently, considerable research, consisting of both primary and secondary analysis, has been conducted by the National Renewable Energy Laboratory (NREL), in collaboration with the University of Colorado and other partners, that specifically pertains to residential markets for electricity produced from renewable sources. The overall purpose of this research has been to obtain reliable empirical evidence concerning the public's interest in "green" power and to delineate the feasibility of various applications, such as alternative utility service options. While the various studies have addressed specific, individual objectives, there are themes that are common to all of them. The collective findings provide a combined body of knowledge that yields important new insights into the understanding of the marketplace for residential "green" power.

This paper presents and examines selected results gleaned from the research conducted by NREL that bear directly on the validity of some of the commonly held market assumptions. While most of the research is focused on a specific technology—residential grid-tied photovoltaics (GPV)—the findings serve to inform the broader debate about incorporating renewables into the residential energy mix.

Methodology and Data

Five studies have been completed at NREL over the past three years that address various social and economic issues pertaining to "green" power, renewable energy, and associated technology. As noted above, important new information is contained in these studies that impacts the development of residential renewable energy markets. Because utility industry assumptions about consumer attitudes and behavior control expansion of these markets, it is imperative that such assumptions be constantly re-evaluated. Consequently, the approach taken in this paper is to critically analyze the validity of some of these assumptions by juxtaposing them against recent key research findings from the NREL studies.

The five NREL studies are: (1) a qualitative market assessment of GPV systems and technology in Colorado (Farhar and Buhrmann 1998); (2) a qualitative follow-up investigation of the homeowners included in the first study to assess actions, outcomes, and long-term experiences associated with their participation in the Colorado Rooftop PV Program (Buhrmann and Farhar 1998); (3) a quantitative, statewide market assessment of residential GPV systems in Colorado (Farhar and Coburn 2000); (4) an assessment of Colorado homeowner preferences on energy and environmental policy (Farhar and Coburn 1999); and, (5) a secondary analysis of proprietary utility market research data concerning willingness to pay for electricity from renewable sources (Farhar 1999). The first four studies are thematically linked, while the fifth one stands completely independent, being itself somewhat of a meta-analysis of findings from a number of other investigations. For descriptive convenience, the five studies are henceforth referred to as Studies 1-5. The methodological aspects of each one are briefly described below.

The four studies pertaining to residential GPV systems and technology were initiated with a qualitative market assessment in 1997. The research was conducted using a convenience, or purposive, sample of Colorado homeowners thought to be interested in GPV technology. Individuals were recruited into this study through news releases, newspaper stories, and word-of-mouth contacts. A total of 550 people expressed interest in participating, and were mailed an informational flyer indicating that, in order to be interviewed, they must be willing to consider paying $8,000 for a 2kW system or $12,000 for a 3kW system. They were also informed that their names would be forwarded to their utility companies, which, in turn, would follow up to provide additional information and/or initiate the purchase process. Of these 550 individuals, 260 returned their registration forms and agreed to be interviewed under the stated conditions. In the interim, ten individuals moved away, and were dropped from the list, reducing the number of interested parties to 250. Ultimately, 120 people were interviewed, roughly representing the first 120 to return their information forms (although the actual list of interviewees was revised somewhat to ensure at least minimum statewide geographic coverage). Interviews were conducted around the state

using a focus group format and a focused interviewing approach similar to that of Merton (1990). The primary objective was to determine why people would be willing to pay more for their electricity than they had to. The operation was terminated after 120 interviews because of redundancy in the information being obtained. Farhar and Buhrmann (1998) provide additional details about the information gathering process, including a discussion of the kinds of questions included in the interview. Similar research has recently been conducted by EPRI (1999).

Study 2 was a follow-up to Study 1. As described above, the names of the 250 individuals who agreed to be interviewed were forwarded to their utility companies. The utilities were told that these individuals were interested in GPV systems and technology, and that they might be potential purchasers. Fifteen months after the interviewing process was terminated, individuals were contacted by telephone to determine what, if anything, had happened since the time their names had been given to their utilities. Of the 120 individuals interviewed as part of Study 1, it was possible to contact 107 people. Burhmann and Farhar (1998) summarize and analyze the information gathered from these conversations.

Following the completion of these two qualitative studies, a formal, statewide market research survey was conducted in 1998. The objective of the survey was to estimate the size of the residential GPV market, determine the potential market's characteristics, and ascertain preferred policies and marketing approaches, using the diffusion of innovations theory as an underlying model (Rogers 1995). The project was developed using the total survey design method of Dillman (1978). The survey involved administering a conventional mail survey to a randomly selected probability sample of 6,088 owners of single-family, freestanding homes in Colorado. The sampling frame excluded owners of townhomes, condominiums, and mobile homes, as well as residents of military housing. A pre-survey announcement postcard was mailed to all homeowners included in the sample, followed by a separate mailing that included a multi-page questionnaire and a monetary response incentive. A total of 3,001 responses were received, including responses to three follow-up mailings. Accounting for non-deliverable questionnaires and unqualified respondents, the response rate was approximately 60%. Questionnaire items were constructed from information obtained from the two previous qualitative studies, and from questionnaires constructed for earlier public opinion polls at both the national and local levels (e.g., Farhar-Pilgrim and Unseld 1982). The final questionnaire (the Study 3 questionnaire) was pre-tested and refined prior to mailing. Farhar and Coburn (2000) describe the survey design, survey operations, and data management in more detail, as well as the extensive statistical analysis of the data that was undertaken. The margin of error on the proportion of positive responses to questions representing the study's dependent variables is estimated to be 1.65%.

Study 4 was conducted in conjunction with Study 3. Of the 6,088 homeowners comprising the Study 3 sample, 556 also received an optional second questionnaire (the Study 4 questionnaire) consisting of broad questions about energy preferences, environmental concerns, and utility restructuring. This sample was selected using systematic sampling from a restricted sampling frame of married homeowners having a total annual household income of $50,000 or more. A total of 206 usable responses were received from the 556 households who were mailed the second questionnaire. Accounting for non-deliverable packets and unqualified respondents, the response rate was again approximately 60%. Because the specific questionnaire used for Study 4 was presented to respondents as an optional task,

there was the potential for the results to be biased. However, because of the care taken in sampling, the relatively high response rate, and post-survey statistical comparisons of response patterns to those observed in national surveys (Farhar 1993, 1996), the sampling bias is regarded to be negligible. The margin of error on the proportion of positive responses to specific items in the Study 4 questionnaire is estimated to be 6.7%.

Study 5 aggregates and analyzes data from recent proprietary market research conducted by utility companies on customer interest in, and willingness to pay for, electricity from renewable sources using a meta-analysis-like approach. The original data represents 14 different surveys conducted in 12 utility service territories in five western/southwestern states from 1995 through 1997. Other methodological aspects, along with discussion of the study's objectives and presentation of the analytical results, are contained in Farhar (1999).

Analysis and Discussion

As noted above, anecdotal evidence suggests there is continuing reticence on the part of utilities to become involved, and on the part of policy makers to encourage their involvement, in large-scale programs to promote the use of renewable energy at the residential level. Reasons for this reluctance might include concerns about specific geo-economic circumstances, continued adherence to market assumptions that may no longer be valid, or corporate or political inertia. Five specific issues or assumptions are critically analyzed here: willingness of residential consumers to pay for renewable forms of energy, the necessity of consumer predisposition towards environmentalism, price, consumer intentions versus consumer actions, and general market demographics. Rightly or wrongly, these particular issues are sometimes regarded as obstacles to the development of residential renewable energy markets, and so a critical examination of their validity in light of current data is appropriate to the evolution of the utility industry.

Willingness to Pay for Renewable Forms of Energy

The issue of whether or not consumers are really willing to pay for "green" power is at the center of many debates among the environmental, utility, and construction communities. Unfortunately, the data and the scientific analysis are sometimes lost or disregarded in the frenzy of argument, particularly when political agendas are involved.

The fact is that recent market research in local utility service territories has documented the same widespread preference for renewable energy that has been found in national polls for the past 20 years (Farhar, 1993, 1996; Farhar and Houston 1996). In various surveys, majorities of 52% to 95% of residential customers have said they are willing to pay at least a modest incremental amount per month on their electric bills to insure the use of renewable sources in their energy mix. The results of a number of deliberative polls have also shown that willingness to pay increases when customers are educated about utility energy options (Farhar 1999).

Study 4 provides some foundational evidence from the NREL research concerning the likelihood that residential energy consumers will pay more for "green" power. Using a one-to-ten scale, homeowners responding to the Study 4 survey were asked to indicate how likely they would be to voluntarily pay more money on a monthly basis to get some or all of their

electricity from renewable sources. Recall that these respondents were married homeowners, with total household incomes of at least $50,000. The mean rating of the responses to this question was 5.3. As Table 1 indicates, 38% of the respondents reported they were likely to participate in "green" pricing, but 37% also indicated they were not.

Table 1. Likelihood that Consumers will Voluntarily Pay More to Obtain Electricity from Renewable Sources

Response Category	Percent of Responses*
Likely (Ratings of 7 – 10)	38
Neutral or Mixed (Ratings of 5 – 6)	22
Unlikely (Ratings of 1 – 4)	37
Don't Know	4

*Percentages do not add to 100 due to rounding; n = 200

On the other hand, these same homeowners were asked in a second survey question how much they would be willing to voluntarily pay on their monthly electric bills to ensure that some or all of their electricity was produced from renewable sources. Table 2 shows that 76% indicated they would be willing to pay at least something more per month (though perhaps only a small amount) in a "green-pricing" program, while 24% indicated they would not be willing to pay anything more.

Table 2. Incremental Amounts Consumers are Willing to Pay on Monthly Electric Bills to Ensure Some or all Electricity Comes from Renewable Sources

Response Category*	Percent of Responses*
0 (not willing to pay more)	24
$1 more per month	14
$2 - $4 more per month	17
$5 - $7 more per month	22
$10 or more per month	23

*Some original response categories are combined here for presentation purposes; n = 200

In a third question, the Study 4 participants were asked how much they would be willing to pay for an electricity rate increase (rate-basing) to cover the cost of developing renewables (this assumes everyone would realize an increase in electricity rates). The results of this question are summarized in Table 3. Provided everyone pays, about 79% indicated they would be willing to accept at least some additional increase (though perhaps small) in monthly electricity rates. Nineteen percent indicated they would not be willing to pay any kind of increase.

Although the results of the first question are by no means decisive, when combined with those from the second and third questions, the evidence from Study 4 suggests that most consumers are indeed willing to engage themselves in at least a modest level of financial

small) in monthly electricity rates. Nineteen percent indicated they would not be willing to pay any kind of increase.

Table 3. Incremental Monthly Amounts in Electricity Rate Increases Consumers are Willing to Pay to Develop Renewable Sources of Energy

Response Category	Percent of Responses*
0 (not willing to pay more)	19
½% more (about 23¢ per month on a typical residential bill)	9
1% more (about 45¢ per month)	11
2% more (about 90¢ per month)	15
5% more (about $2.45 per month)	25
10% more (about $4.50 per month)	19
Other	2

*n = 202

Although the results of the first question are by no means decisive, when combined with those from the second and third questions, the evidence from Study 4 suggests that most consumers are indeed willing to engage themselves in at least a modest level of financial support to ensure that renewables are included among the sources used to produce electricity for their homes.

Study 5, which presents a combined assessment of survey results from 12 different utility service territories, contains even more extensive information about the amounts that residential customers are actually willing to pay. Figure 1, which is repeated from Study 5, shows the cumulative percentage of respondents in those surveys who indicate they are willing to pay specific incremental amounts on their monthly electricity bills for renewable energy. Although some respondents are willing to pay nothing or very little more, others are willing to pay moderate to substantial amounts. The figure includes an "average" curve depicting a nonlinear least squares exponential fit to the data ($R^2 = .76$) with the Y-intercept set at 100%. The scatter of response values around the curve probably represents variation in question wording, question placement, and the exact dollar amounts used in the response categories of the different survey questions.

Figure 1 suggests that willingness to pay follows a predictable pattern, with an average of about 70% of the survey respondents indicating they are willing to pay at least $5 more per month for electricity produced from renewable sources. About 38% of survey respondents say they are willing to pay at least $10 more per month, and about 21% say they are willing to pay at least $15 more per month. It is likely that the results of any utility market survey asking residential customers a general question about willingness to pay for electricity from renewable energy will exhibit a similar pattern (although, in any initial offering of a green pricing program, utilities should not expect participation rates at these levels).

Combining the evidence from both Studies 4 and 5, a case can be made that residential consumers are indeed willing to support the use of renewables for home energy production. The evidence suggests that utility companies and policy makers can faithfully move ahead with strategic plans to develop these resources fully anticipating financial support from the customer base, assuming the awareness level of customers is raised.

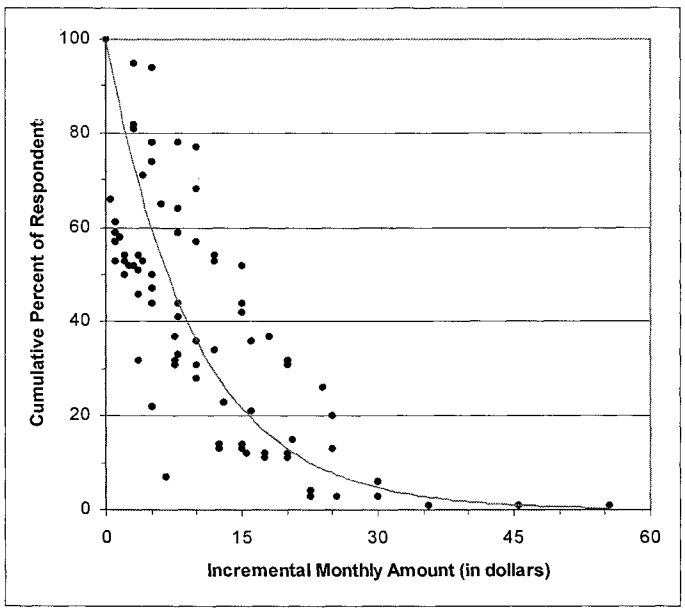

Figure 1. Aggregate Willingness-to-Pay Curve (Residential Customers)[1]

Consumer Predisposition towards Environmentalism

Some parts of the residential energy community believe the only people who will support the production of electricity from renewable resources are those with a "green" persuasion, or those who are predisposed towards environmentalism. While it may be true that more environmentally-conscious individuals tend to support such initiatives, to suggest that these are the only people who will avail themselves of alternative energy sources is to take a rather restrictive view of the marketplace (see the review article by Van der Pligt (1996) and the additional discussion below about the relationship between attitude and behavior). Evidence that a broader spectrum of consumers will embrace renewables and renewable technologies is provided in Study 3.

In Study 3, Colorado homeowners participated in a survey pertaining to the adoption of GPV as a residential energy source. While several nontraditional technologies could potentially be used to supply all or part of a household's energy needs, GPV is a specific example representing systems and equipment that can be currently manufactured and installed. Using a 1–10 scale, respondents were asked to rate the importance of 23 potential benefits of GPV, with a rating of one representing "not at all important" and a rating of 10 representing "very important."

Factor analysis was used to reduce data on these 23 items to a more easily interpretable set of three composite indicators: environmental advantages, financial advantages, and pacesetting. Such indicators are sometimes referred to as the major

[1]The equation for the curve is $Y = 100e^{-.104*M}$, where Y = cumulative percentage of respondents, and M = dollars more per month customers are willing to pay. $R^2 = .76$. The curve encompasses 95 data points from independent surveys of 12 service utility territories.

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Van der Pligt, J. 1996. Social Psychology and Environmental Issues. In Gun R. Semin and Claus Fiedler, eds. *Applied Social Psychology*. London: Sage Publications, pp. 173-197.

Van Liere, K. D. and R. E. Dunlap. 1980. The Social Bases of Environmental Concern: A Review of Hypotheses, Explanation and Empirical Evidence. *Public Opinion Quarterly*, vol. 44, pp. 43-59.

Wicker, Allan W. 1969. Attitudes versus Actions: The Relationship of Verbal and Overt Behavioral Responses to Attitude Objects. *Journal of Social Issues*, vol. 25, pp. 41-78.

dimensions, or themes, among all the responses. The three dimensions identified above collectively account for 66% of the variability in all the ratings assigned to all the items by all survey respondents. Farhar and Coburn (2000) provide more details about the use of the factor analysis approach, as well as interpretation of the subsequent results.

The first dimension primarily encompasses responses to statements that have to do with natural resource conservation, environmental protection, pollution reduction, enrichment of future generations, and reduction of global warming. The second dimension primarily has to do with items pertaining to immediate reduction of utility bills, selling excess electricity back to the utility company, increasing the resale value of the home, and self sufficiency. Such items reflect a desire, or even an expectation, that purchase of a GPV system would ultimately lead to positive financial rewards. The third dimension reflects the non-economic motivations of owning GPV systems largely associated with the notion of pacesetting, or "being on the cutting edge." The survey items incorporated in this dimension pertain to the personal satisfaction of being the first on one's block to own a GPV system, enjoyment of new technology, and the rewards of helping to create and expand a new market.

As described in Farhar and Coburn (2000), improvement of the environment, along with financial advantages, are assigned the highest importance, with the assigned importance of pacesetting being somewhat less. The significance of this finding, at least in the context of embracing this particular renewable technology, is that being of a "green persuasion" is apparently not the only reason consumers would be interested in residential "green" power generation. The results of Study 3 indicate that renewable energy can be effectively marketed to certain segments of the population that are broadly oriented towards any new technology. Perhaps even more importantly, they strongly suggest that individuals and homeowners who recognize the potential for ultimate financial rewards will be willing to participate whether the technology or the energy source is "green" or not.

The Price of Renewable Energy Technology

An argument that is sometimes advanced for not promoting renewable technology for residential use is that customers are only interested in the smallest, least expensive systems. The implication is that there is no sustainable residential market for renewable technology, ultimately making such a venture uneconomic. Some results from Study 3, however, provide direct evidence to the contrary.

In the Study 3 survey, Colorado homeowners were asked about the size of a GPV system they might like to own, while taking price into consideration. Small GPV systems can be designed to provide enough electricity to power a large appliance, while very large systems can be designed to supply the energy needs of an entire household and even to allow owners to essentially become net exporters of electricity. The survey question was phrased in such a way as to present various size and price trade-offs, with price representing the installed cost of a system. Respondents were told that estimates of installed system costs were centered around $45 for an average monthly home electricity consumption of 600 kWh, but that the costs were hypothetical since there is considerable variation in household electricity use. The results are summarized in Table 4.

Table 4. Consumer Preferences for GPV System Size/Price Trade-Offs

System Size/Price Option	Percent of Respondents
A very small system that powers one large appliance (such as a refrigerator) at a one-time cost of $2,500	1
A small system that provides 25% of your household electricity at a one-time cost of between $4,500 and $9,500, depending on your electricity usage	7
A medium-sized system that provides 50% of your household electricity at a one-time cost of between $8,500 and $16,500, depending on your electricity usage	18
A large system that provides 75% of your household electricity at a one-time cost of between $11,500 and $23,000, depending on your electricity usage	7
A very large system that provides 100% of your household electricity at a one-time cost of between $14,000 and $28,000, depending on your electricity usage	11
I would not purchase any of these systems	23
Other	11
Don't know	22

Of the 2,503 respondents to this question, 44% indicated a willingness to consider one of the systems described, while 23% of all respondents stated outright that they would not purchase any of them. Another 22% answered "don't know," and 11% responded "other" and/or placed some additional restrictions on the system/situation they would consider. Surprisingly, of those who indicated a willingness to consider one of the systems, the most frequent choice was neither of the smaller systems, but rather, the medium-sized system capable of providing half of a household's electricity at a one-time price between $8,500 and $16,500, depending on electricity usage. The second most frequent choice was the very large system capable of supplying a household's entire energy needs at a one-time cost of between $14,000 and $28,000, depending on electricity usage.

In the context of this particular renewable energy technology, price is apparently not the only consideration for those who could be motivated to purchase. As Farhar and Coburn (2000) describe in more detail, a more intricate market for such technology exists, with the size of the market likely being sufficiently large to sustain it as an economically viable venture. Complexity of consumer behavior and product demand in the context of utilities and environmental technologies is also the principal theme of recent work by Gellings (1996) and by Shove and Chappells (1999).

Consumer Intentions versus Consumer Actions

The point is sometimes made that a market for renewable energy and associated technology cannot be sustained, because no matter how much people say they are interested, their good intentions are not often played out in terms of an actual purchase or financial

support. Indeed, the relationship between attitudes and behavior is often difficult to dissect (Wicker 1969; Fishbein and Ajzen 1975). The effect of attitudes on behavior is a particularly important topic in social research that directly impacts the development of renewable energy markets. In the specific context of GPV adoption, the results of Studies 1 and 2 suggest that consumers *will* take action on the basis of their attitudes and stated intentions, but only when there is effective interaction and communication with suppliers (especially utilities and system manufacturers).

Recall that Study 1 involved face-to-face, focused interviews that yielded a rich body of information pertaining to the interest of participants in acquiring a GPV system. Participants provided important qualitative evidence concerning the motivation of consumers to embrace GPV technology, perceived barriers to adoption, preferred product attributes, information needs and information sources, and attitudes towards utility involvement. The names of these participants, along with those of others originally included in the interview pool, were provided, with their permission, to their utility service providers. By virtue of their participation, these individuals had expressed a willingness to purchase a GPV system that met their expectations, and were awaiting further contact. This aspect of providing names to the utilities was an effort to assist the utility companies in Colorado in identifying suitable sites for installing 50 federally subsidized GPV systems as part of a pilot program.

Study 2, then, involved a follow up investigation to determine what actually happened in the interim. About half of the 107 people who could be contacted reported that they did not initiate any contact with utilities or others regarding their involvement in a GPV program. There was a wide variation of reasons, but they tended to center around the understanding that it was the utility's responsibility to make the contact, confusion about whom to contact, and personal restrictions (such as lack of time or changes in housing situations). For those individuals who did initiate contacts with their utility companies, the results were mixed. A number of them reported that they were never able to reach someone who could give them information. Others said they were promised return phone calls that never materialized. A few were indeed given some information about GPV systems. No one, however, eventually obtained a system as the result of having initiated the contact with the utility company on his or her own. One large utility company reported having called only 30 of 141 names on its list, and in half these cases the utility reported communications and transactions that were different from those relayed by the homeowners during the follow-up interviews (Buhrmann and Farhar 1998). Despite these difficulties, nine homeowners (8%) did succeed in obtaining residential systems—five were grid-tied with net metering, and four were standalone equipment. Most of those originally interviewed for Study 1 reported being frustrated with the entire experience, and 20% reported they were less interested in purchasing GPV systems than they had been during the Study 1 interviews.

As is true in the case of other kinds of products, these largely qualitative findings suggest that marketing of renewables and renewable energy technology is a two-way street. It is true that not all consumers will do what they say they will. However, it is also incumbent on the organizations responsible for offering the products to make a reasonable effort to communicate their real costs, benefits, and availability, along with any true disadvantages. In the specific context involving the purchase of renewable energy

technology for home use, additional research into the relationship between consumer attitudes and actions would be beneficial, particularly as it is affected by actions and attitudes on the part of service and technology providers

Market Demographics

Knowledge of demographics can be an important contributor to the success of residential renewable energy programs and products. Without sufficient demographic data, as well as thorough analysis of that data, it is possible for generally unsubstantiated statements such as "only high-income consumers will be interested" or "only environmentalists will become involved" to effectively limit the scope of the market or to deter its development. Consequently, drawing on the specific context of residential GPV adoption, Study 3 provides extensive information about the demographics of consumers who would be likely to purchase GPV systems. Some of the findings are quite surprising.

Not unlike other investigations of this type, the initial hypotheses underpinning the research on demographic characteristics of the most likely purchasers of residential GPV systems were largely driven by conventional wisdom (Van Liere and Dunlap 1980; Heberlein 1981; Van der Pligt 1996) and diffusion of innovations theory (Rogers 1995). In general, homeowners with higher levels of education, employment, and income were hypothesized to be the most likely candidates for GPV purchase. To test these hypotheses, an extensive statistical analysis of the data was conducted, employing several different techniques. Ultimately, a cluster analysis approach was used to segment the respondents into categories reflecting their propensity to embrace GPV technology.

In the course of the data analysis, two different, but seemingly natural, ways to group the respondents were discovered—one addressing likelihood of purchase of a GPV system (a surrogate for action or behavior) and the other reflecting a range of attitudes or predispositions toward GPV. Farhar and Coburn (2000) address the technical aspects of this exercise and the statistical nature of the two grouping regimes in considerable detail.

Having assigned survey respondents to one action group and one attitudinal group, a crosstabulation of the two schemes to establish simultaneous group membership was performed, the objective being to statistically determine those homeowners who are both attitudinally inclined towards GPV and most likely to initiate a purchase. This is not to imply that there is necessarily a causal relationship between attitudes and behavior, but it does represent an attempt to establish consistency in a specific context (Fishbein and Ajzen 1975). It addition, it provides a convenient, statistically based mechanism for achieving a more refined respondent categorization based on the voluminous amount of data derived from the survey. The crosstabulation process consequently resulted in the identification of four specific "tiers" of consumers related to the different stages of market development (Lutzenhiser 1994; Rogers 1995). A demographic assessment of individuals comprising these tiers was then conducted for purposes of validating the original hypotheses about consumer characteristics.

The four market development tiers can be described as follows:

- Tier 1 (Early Adopters)—homeowners who indicated that their purchase of a GPV system was highly likely (assuming affordability), and whose overall

attitudes towards the technology suggested they might follow through with a purchase in the near future.

- Tier 2 (Mid-Term Adopters)—homeowners who said that their purchase of a GPV system was likely or highly likely (assuming affordability), but whose overall attitudes towards the technology suggested they would wait until the technology is more mature or until the experiences of others (presumably Early Adopters) are made known.

- Tier 3 (Late Adopters)—homeowners who said that they are likely or highly likely to purchase a GPV system (assuming affordability), but whose overall attitudes towards the technology suggested they may not be motivated enough to follow through with a purchase commitment in the foreseeable future.

- Tier 4 (Nonadopters)—homeowners who said they are unlikely or highly unlikely to purchase a GPV system, both now or in the future, and whose overall attitudes towards the technology are negative.

The rationale for extracting these particular categories of individuals for additional study is further described by Farhar and Coburn (2000). On a percentage basis, Tiers 1 and 2 constitute a large majority of all the respondents encompassed by the classification scheme, suggesting a widespread favorable predisposition toward the technology. However, as the descriptions of the tiers again suggest, behavior and attitude are not necessarily tightly linked.

Table 5 compares the percentages of each tier that are represented by selected additional demographic characteristics. The table also includes the statistical significance value (p) associated with a Chi-square test of the differences in percentages for each

Table 5. Demographic Representation Homeowners in Four Statistical Tiers Related to GPV Adoption

Characteristic	Tier 1	Tier 2	Tier 3	Tier 4	Total	p
% younger than 50 years	62	66	70	48	63	≤.0001
% with undergraduate degree or more education	47	69	58	55	59	≤.0001
% with $50,000 or more in annual household income	63	80	63	67	71	≤.002
% with professional or managerial jobs	51	67	51	43	58	≤.0001
% retired	14	5	5	28	10	≤.0001
% who are skilled workers	14	8	17	4	11	≤.0001

Note: Sample sizes vary for each characteristic and each tier.

characteristic. Note that, for every demographic characteristic, the Chi-square test indicates that at least one tier is significantly different from all the others. Other characteristics, such as gender, household composition, and type of locale in which the residence is located are not differentiating factors among the tiers and are not included in Table 5.

The results of the demographic analysis are striking. The single most remarkable finding is that the Early Adopters are not necessarily the individuals with the most education and the highest income. It is the Tier 2 individuals—the Mid-Term Adopters—who more closely fit the pattern originally hypothesized.

Consider, specifically, the issue of income. Figure 2 provides a graphical display of the distributions of annual household income for the four tiers, indicating that Tier 2 contains the largest percentage of individuals with the highest income. The respective mean values are approximately $67,456, $82,796, $73,175, and $72,704. Clearly, the Tier 1 consumers—the Early Adopters—are not necessarily individuals with the largest incomes, which is contrary to the usual assumption.

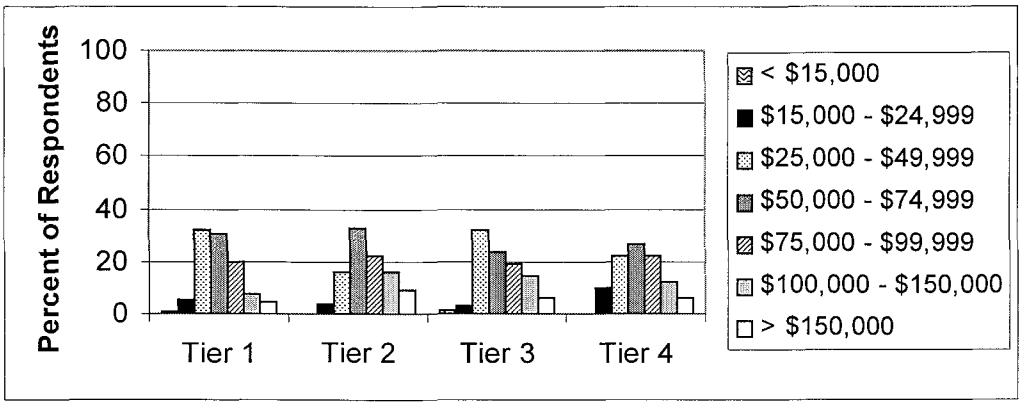

Figure 2. Composition of Four Tiers Pertaining to GPV Adoption on the Basis of Total Reported Household Income[2]

This evidence suggests that income is not the only factor governing whether or not a consumer will assume a positive stance toward renewables and renewable energy technology. In fact, many other demographic factors are conceivably confounded with income in such a way that identification of consumers who are most prone towards renewables is difficult on the basis of any one of them alone. In the context of GPV systems, this assertion is underscored by a visual comparison of Figure 2 with Figure 3, which graphically depicts the composition of the four tiers on the basis of educational attainment.

[2] n = 284, 363, 63, and 49, respectively, for the four tiers. Note that respondents predominantly fall in Tiers 1 and 2, indicating a greater overall predisposition of homeowners toward GPV technology than might have initially been expected.

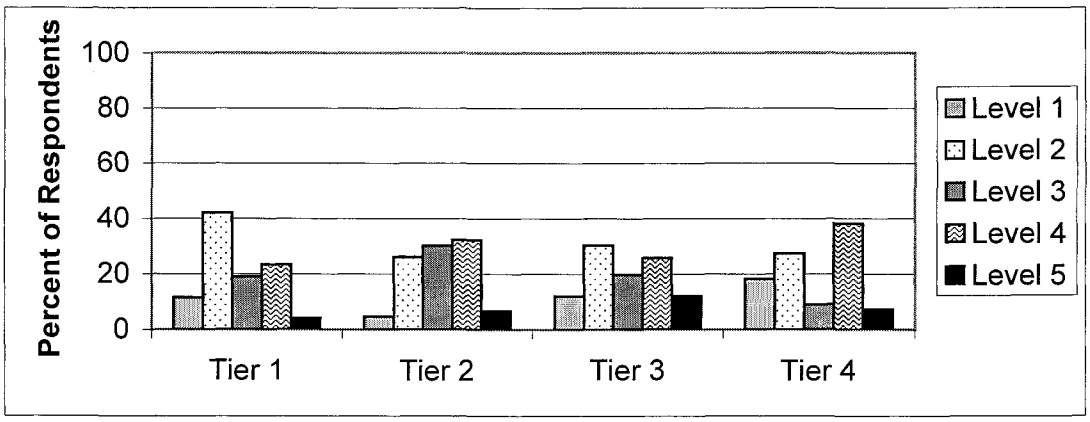

Figure 3. Composition of Four Tiers Pertaining to GPV Adoption on the Basis of Educational Attainment[3]

Conclusions

Collectively, information contained in the five recent NREL studies may be the strongest and most extensive evidence available to date about the residential markets for "green" power, renewable energy sources, and associated technologies. While much of this research is specifically focused on GPV, the findings should be applicable to other forms of residential renewable energy as well. Critical analysis of specific issues pertaining to the development of residential renewable energy markets suggests that (1) consumers are more proactive and their behavior is more complex than policy makers and utility companies have heretofore been willing to admit, and (2) there are relatively few real consumer deterrents to expanded markets for residential renewable energy and related technology. Strategies for developing markets for residential renewable energy will increasingly need to focus not solely on utility requirements, but also on technical options and capabilities, financing arrangements, investment incentives, and other contemporary customer needs. Additional research concerning institutional barriers also needs to be conducted in an effort to promote a more symbiotic, customer-driven approach to market expansion.

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[3]Level 1 = elementary through high school, or equivalent; Level 2 = some college, but no degree (or equivalent); Level 3 = Bachelor's degree; Level 4 = some graduate work, but less than a completed Doctoral degree; and Level 5 = Doctoral degree. n = 288, 371, 66, and 5, respectively.

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