A REPORT ON A SURVEY OF RESIDENTIAL PHOTOVOLTAIC SYSTEMS IN HAWAII COUNTY

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Abstract

This report presents the findings of a survey of 79 users of residential solar photovoltaic (PV) systems in Hawaii County (also referred to as the 'Big Island' of Hawaii). The survey was carried out in the summer of 1994 and was designed to illuminate specific attributes of the usage of solar PV systems by people in Hawaii County, as well as typical characteristics of the solar PV systems in service there. As such, it was an attempt to provide an indication of what the answers could be to some basic questions regarding the use of solar energy technology in Hawaii. These questions include:

- "What does a typical PV system look like?",
- "What kind of homes have PV systems?",
- "How are these systems installed and maintained?",
- "Where do people get information about PV components?",
- "How are the typical residential PV systems financed?", and
- "How have the batteries in these systems performed?".

This survey was also an experiment to determine if pertinent information could be extracted from the users of these solar energy systems.

This report organizes the survey data provided by the surveyor in a form that concisely addresses the issues for which this survey was commissioned. It concludes that the users of PV systems in Hawaii County will discuss their experiences with adept and knowledgeable surveyors, and recommends areas of future research and inquiry. The final version of the surveyor's report, complete with a copy of the survey instrument and a tabulated summary of the survey data is included in this report as an attachment.

Introduction

The State of Hawaii has a stated goal of reducing its dependence on imported petroleum as an energy source. It also recognizes that the development of any indigenous source of electrical power has the potential to mitigate Hawaii's reliance on imported fossil fuels. Hence, any efforts that promote the use of indigenous renewable power sources are considered to be in the interest of the State.

This survey of the residential users of photovoltaics (PV) has as its ultimate goal the promotion of renewable energy in general, and the use of solar energy (photovoltaics, or PV) in specific. Something that is considered to be of assistance in achieving these goals is current knowledge of the residential PV systems already installed in Hawaii County (also known as the Big Island). Information that is

particularly sought include data associated with the selection, financing, installation, and maintenance of residential PV systems.

One reason such knowledge is desired is to possibly identify any constraints of the PV technology in residential applications in Hawaii which might have been heretofore un-articulated. Another point is to seek out areas where value can be added to the systems and services currently available from local PV distributors. A further benefit of gathering such data from end users is that it can provide a general indication of the breadth of the range of different types of systems in use, as well as what could be the condition of these residential units. A survey has a potential for unearthing such new information, as end users who have not been serviced in any way by local PV dealers may be respondents.

A draft report by the Asia Alternative Energy Unit of the World Bank provides an indication of the significance of the PV use in Hawaii. (This report was the Solar Photovoltaics: Best Practices for Household Electrification, presented for comment at the December 6, 1994 Roundtable: Photovoltaics and Rural Electrification at the Hilton Waikoloa on the Big Island the day before the opening of the First World Conference on Photovoltaic Energy Conversion at the same venue.) According to statistics in this report, current estimates of the number of homes using PV in Hawaii County (ranging from 2,000 to over 5,000) imply that the state of Hawaii could be ranked as high as the 5th largest user of PV's in the world. This means that Hawaii's experience is significant and warrants the efforts taken to commence the recording of the substantial volume of local knowledge on the application of residential PV systems.

It is hoped that this data collection effort will be part of an initiation of the documentation of the considerable amount of experience and local knowledge of residential PV systems within Hawaii County. The initiation of this documentation effort is considered particularly timely as the results of this survey, including the characterization of Hawaii's residential PV systems, were presented to the representatives of the U.S. national laboratories and the solar industry at the recent Workshop on Pacific Island Photovoltaic Applications (December 3-4, 1994 at the Hilton Waikoloa on the Big Island. This workshop was held the weekend immediately prior to the opening of the First World Conference on Photovoltaic Energy Conversion at the same venue). It is hoped that such exposure could attract the resources of the national PV community for assistance in addressing local PV issues.

In addition to the above, this survey is hoped to provide practical insight into a larger issue of information collection in this part of the state. The need for a comprehensive count of all the off-grid PV users in Hawaii County has generally been recognized by Hawaii's renewable energy community. However, the feasibility of such an effort is a subject of debate. The perceived character of the residents that will be the target of such a survey, especially their reported aversion to outsiders, strongly suggests that surveys in this area will be difficult to conduct. This eight week survey by an experienced surveyor who is a resident of the region has provided an indication of the practicalities involved in a future larger effort. Such insight may become valuable soon, as researchers from at least one national lab have expressed an interest to PICHTR about participating in later survey work on this island.

Background

Members of Hawaii's Photovoltaics for Utilities (PV4U) working group recognized that there was a great deal of local knowledge about photovoltaics that has not been catalogued or documented due to the remote nature of the residential applications in this state. (Note: the PV4U national working group consist of thirteen states (including Hawaii) which have each established broad based working groups consisting of regulators, state energy officials, utilities, and others interested in identifying opportunities

as well as constraints to the increased use of photovoltaics.) This was especially true in Hawaii County, where a large number of residents are living in areas not served by the utility grid. On this island there are also thousands of yet to be developed residential lots without access to the power distribution lines, as well as over 1,000 customers who have actually applied for (but not yet received) line extensions with the local utility company, with some of these applications dating back a number of years.

Although there has been no quantitative assessment on how prolific the use of remote, residential PV systems is, it has been conservatively estimated that there may be as many as a few thousand residential PV applications on the island. The independent development of residential PV systems has been supported over the last ten to fifteen years by a number of local PV system hardware vendors, several qualified PV systems designers and installers, and the active interests and experimentation by resident do-it-yourselfers.

Given that the cost of installing one utility pole can reach $3,000, the provision of electrical power with photovoltaic systems can be cost effective on the island of Hawaii. (As utility poles can be spaced as close as 200 feet apart, a one mile (or 5,280 foot) extension of the grid can cost up to $78,000.) This situation has helped create a substantial base of experience with the use of PV systems for remote residences in Hawaii County. In fact, parts of the Hawaii County may be considered to be in effect a large spontaneous PV experiment in progress, but without any existent data collection procedures.

Origin of the Survey

In spring of 1994, Eileen O'Hora-Weir, a graduate student from the University of Hawaii, approached the Hawaii Energy Extension Office in Hilo and inquired about performing a survey of the PV systems in Hawaii County during the summer of 1994. Ms. O'Hora-Weir was a Ph.D. student at the University of Hawaii at Manoa in field of Resource Economics with a specialty in Energy Economics, and had an interest in PV utilization. She also had previously developed and conducted a survey for the island of Hawaii's floriculture industry and was a resident of this island's Puna district. Further, she lived in a home that was off of the island's electric utility grid and had practical experience with photovoltaic equipment. The availability of such a qualified surveyor for an initial attempt to collect data from Hawaii County residences was an opportunity that was recognized by both the state Energy Office and the PV4U working group. In July of 1994, this surveyor was commissioned by PICHTR (with funding from the State Energy Office) to complete a survey (75 to 100 response) of residential PV users on the Island of Hawaii.

Methodology

The Survey Instrument

The survey instrument was a six page questionnaire designed to be administered in person, over the phone, or by mail in a questionnaire/interview strategy. Only 5 percent of these surveys were completed by mail. The survey questions were developed with input from selected Hawaii PV4U members, including representatives of the largest PV equipment supplier in the state (Will Hartzell, Vice President of Inter Island Solar Supply of Honolulu, Hawaii), and the electric utility (Steve Burns, Integrated Resource Planning Specialist) on the Island of Hawaii, the Hawaii Electric Light Company (HELCO).

The survey had 41 questions which preserved the anonymity of the respondent. It was designed to collect data on the following points:

- PV system configuration and components,
- User satisfaction,
- Financing of the systems,
- Installation and Maintenance of the PV systems,
- County permits,
- State tax credits,
- Attitudes toward the local utility company.

The sampling plan involved targeting that segment of Hawaii County's population already using PV, which in this case was, and still is, an unknown. The sample was a non probability sample of the mode often referred to as a `convenience' sample. This simply means that the individuals surveyed were the easiest population members to survey in terms of accessibility and the extraction of desired information. Attempts were made to diminish the `self-selection' aspect of this type of sampling by `networking' to reach respondents with whom the surveyor was personally unacquainted.

This `networking' was achieved by making contacts in most areas of the island where PV users were known to reside due to lack of infrastructure. Those contacts were made through the surveyor's previous knowledge of individual households, referrals from Real Goods´ of Ukiah, California (who identified some of the participants in the Real Goods 1993 Tour of Independent Homes), and referrals from local alternative energy `specialists' and retailers of PV components. Since the scope of this survey was not limited to only PV users who had acquired and installed their systems with the help of professionals, survey respondents were asked if they could recommend other households who might be willing to be interviewed. This approach allowed for contacting users in most of the developing off-grid regions of the island, with emphasis on the Puna and Ka'u districts of Hawaii County (which together accounted for 83 percent of the respondents).

A total of 79 surveys were completed between July and October, 1994. Statistics are included that indicate the populations of the various districts on Hawaii County and (where possible) the change in the population during the interval between the last two census counts.

Survey Limitations

This survey was a very small sample of the households in the region of interest. Tabulated below are statistics on the population in the various regions of Hawaii County, together with an estimate of the households in each region. As only 79 households were surveyed, the sample size of this survey was only 0.2 percent of total number of households on the island. Furthermore, as the population of residential PV systems on the island was unknown, it was impossible to express the survey sample as a percentage of the targeted households (i.e., those residences with a residential PV system).

As mentioned earlier, there is no comprehensive list of all of the residential PV systems users available for Hawaii County. This prevented a random sample from being selected for this survey. Instead, a networking approach was used to locate potential respondents. The response rate of the survey effort was very high, with 79 out of the 80 people approached by the surveyor agreeing to participate in this survey.

Given these limitations, the survey was therefore designed to provide a indication of the residential PV systems in use in Hawaii County. The hope was that this survey could corroborate existing notions about Hawaii County residential PV systems, and to indicate areas where further study may be warranted. This survey also sought to gauge user satisfaction and to indicate if there were issues that needed to be

addressed if the promotion of PV systems for residential use was to continue by either the state or the local PV suppliers.

Findings

The information collected by this survey was designed to illuminate specific attributes of the usage of PV systems by people in Hawaii County, as well as typical characteristics of the PV systems in service. The survey was an attempt to provide a crude indication of what the answers could be to some basic questions regarding the use of PV technology. Presented below are the broad questions answered by the data collected with this survey.

What Does a Typical Residential PV System in Hawaii County Probably Look Like?

The average number of panels on a residential PV system is 6.7 panels, with 79 percent of the systems having roof mounted panels.

The average peak power of a residential system is 355 Watts, which indicates an average of 53 Watts/panel.

The average number of batteries on a residential system is 7.1, with an average total storage of 985 Amp Hours (AH) or 139 AH/battery.

Seventy-five percent of the Hawaii County PV systems use a charge controller, with the Trace C30A being the most common.

Seventy-six percent of these systems have inverters to convert direct current (DC) to 120 volt alternating current (VAC).

Thirty-eight percent have an auxiliary battery charger.

Eighty-five percent have another source of power. (Ninety percent of these alternate power sources are engine generators. These generators are run an average of 4 hours per week for additional power and battery charging.

Sixty-two percent of the systems are less than 6 years old.

The average time respondents have used their current residential PV system was 5.6 years.

What Kind of Homes Have a Typical Residential PV System in Hawaii County?

The average distance of a PV powered home from the island's electric utility grid was reported to be 1.6 miles. (Note that estimates obtained from HELCO on the cost of a one mile line extension range from $66,000 to $78,000. These estimates were obtained by specifying a simple one mile straight flat terrain extension to an average residential customer (a load representing 1.5 to 3 KW). Estimated line cost for a grid extension involves the actual design of the extension, and depends on many factors, including the terrain, the number of poles required, the route of the extension considering property easements, the number of turns in the line, etc. Only the actual survey of the site can render enough information for a design that can be used to establish true line extension cost.)

The average size of these homes is 1,315 square feet.

The average family size of these homes is 2.49 people which is the same as the county average.

Ninety percent of the surveyed group owned their own homes, while 96 percent of the surveyed group owns their own PV system. This means that some of the renters own at least part of their PV system.

Forty-nine percent of the respondents use PV for only lighting or small household appliances, with 15 percent using PV for refrigeration. Other residential uses of PV include powering washing machines, computers, sewing machines, and central vacuums.

Households that used residential PV systems employed various household circuit wiring voltages:

- 25 percent use all 12 volt direct current (VDC) wiring,
- 22 percent used all 120 volt alternating current (VAC) wiring,
- 47 percent used both 12 VDC and 120 VAC wiring, and
- 6 percent used both 24 VDC and 120 VAC wiring in their homes.

Do the PV Systems have County Permits?

Only 17 percent of the residential PV systems surveyed have a County Permit. Roughly half of these were identified as conventional electrical county permits, and the other half identified as "Alternate Energy" permits.

Note: The Hawaii County Code, Chapter 11, is the housing code. It applies to all structures in Hawaii County intended for human habitation and says that the electrical equipment needs to be in accordance with applicable laws. One of these applicable laws is the Hawaii County Code, Chapter 9, the electrical code. It applies to all residential electrical work in the county. It cites the National Electrical Code (NEC) as the standard for the county. The NEC has a chapter covering solar electric power system equipment. Hence, the NEC is applicable to all residential PV systems in Hawaii County. Additionally, the Hawaii County Code, Chapter 11 also has a provision that if a home owner wants power from a source other than the utility, he or she can install an alternate energy system if it is designed by a Hawaii licensed electrical engineer or architect. The permit issued under this chapter is frequently referred to by the home owner as an "alternate energy permit" (Note that the County of Hawaii "Application for Electrical Work" is the same for all electrical work, whether the power source is from HELCO, alternate energy, etc. Hence, there is no official "Alternate Energy Permit").

Two thirds of those respondents without permits indicated a reason why they did not have a permit. The distributions of these reasons are tabulated below.

About a third of those without permits did not know that their PV system required a permit. These people either expressed complete ignorance of the permitting system, or felt that their system didn't require a permit for some reason, including the fact that their system or house pre-dated the applicable building codes.

Fourteen percent of those without permits expressed reasons that indicated that they did not wish to abide by the permitting system.

How Is A Typical Residential Photovoltaic System Installed and Maintained?

Thirty-one percent of the residential PV system owners purchased their system as a complete package. The rest bought components for their system over time.

Sixty-seven percent installed the systems themselves or with the assistance of friends. (The rest hired the services of others for installation.)

Forty-seven percent received help in designing their system and most of these (92 percent) were satisfied with the help received.

Ninety-three percent of the users of residential PV systems do their own maintenance. This maintenance takes about 2.2 hours per month if the time for maintenance of the backup generator is included. (Without generator maintenance, the average time for system maintenance is about 25 minutes per month.)

Ninety-nine percent of the residential PV users monitor the state of charge of their batteries.

Ninety-nine percent say they can access all of their system components. However, 10 percent of the PV system users reported that they are unable to move their own batteries.

Thirty-seven percent of the PV system users reported having difficulty understanding the available instruction manuals.

Twenty-two percent of the residential system users admitted to having called someone in the past for technical advice, repair or other assistance. This implies that 78 percent of these users never called (or do not admit to calling) anyone for help with their residential PV system.

Sixteen-percent of respondents claim to never to have read any instructional manuals, implying that 84 percent have looked at their instructions.

Where do People Get Information About PV Components?

The survey results indicate residential PV users get their information from the following sources:

71% Trade Magazines and Catalogs (e.g. Home Power magazine and Real Goods Source Book catalog)

68% Friends

66% Retail Dealers

14% Other sources (local alternate energy specialists and contractors)

13% PV workshops (held by manufacturers or State Energy Extension Office)

10% State Energy Office

How Satisfied are the Users of Typical Residential PV Systems in Hawaii County?

Seventy-seven percent of respondents claim their system is adequate for their needs.

Sixty-four percent of the residential PV users said that they would like to expand their system. However, the high costs of components was cited most frequently as a barrier to further expansion.

Thirty-seven percent of the Hawaii County residential PV users said that there was something they didn't like about their PV system; these negatives included:

- the high initial cost,
- the lack of sufficient power,
- expensive and low quality 12 VDC appliances,
- a lack of troubleshooting information, and
- the lack of a realistic utility intertie program.

Fifty-four percent of the respondents have had component failures; the most common failures involved charge controllers. There were also two inverter problems, three premature battery failures and one fire due to a dead short in the main line to the breaker box.

Fourteen respondents (or 18 percent) would prefer conventional electrical service if the cost of the service was "reasonable" (The average "reasonable" cost of conventional electrical service suggested by the respondents was about $70 per month. HELCO's 1992 Average Monthly Residential Bill was approximately $77 per The State of Hawaii Data Book 1993-1994, Table 17.10.). Of these 14 respondents, 3 respondents wanted the service only for a commercial application.

How are the Typical Residential PV Systems in Hawaii County Financed?

Nine percent of the residential PV users financed the purchase of their PV system, with roughly half of these systems being financed via a loan from a family member. Most people did not seek financing since the systems were purchased piecemeal as funds were available.

Thirty-six percent said they would replace or upgrade their system if loan financing for PV systems were available.

Seventy-six percent knew about the State tax credit for solar equipment, but only 46 percent made use of this tax credit. These credits are the lesser of 35 percent of the actual system cost or $1,750 for single family residential buildings. Taxpayers can exhaust the credit by employing it against income in subsequent years, if necessary. (Reasons cited for not using the credit included an incorrect belief that the credit was of no use unless a taxpayer had at least a $2,000 tax liability each year.)

Residential PV System users were asked to report the replacement cost of their systems. The average replacement cost was $5,683, with the maximum being $50,000, and the minimum being $500. The distribution of the reported replacement costs are graphically represented below.

How Have the Batteries of these Residential PV Systems Performed?

Thirty-eight respondents had replaced some of their batteries. The average lifetime of the batteries replaced was 4.7 years.

Ten percent of the respondents reported major battery problems. These reports included one case of an explosion, one case of excessive fumes, with the rest being cases of excessive corrosion.

Eighty-five percent of the respondents reported that they thought they knew how to maintain and monitor their batteries. This information is related to the respondents' perception of their own knowledge, and is not a true test of their real knowledge of battery operation and maintenance.

Forty-six percent reported using distilled water for their batteries. The rest use filtered rain catchment water.

Ninety-seven percent have their batteries protected from the elements in some manner, with many of them being kept under the house.

Fifty-five percent have a main battery fuse installed in their system.

Seventy-nine percent of those who have replaced batteries have recycled their old batteries, generally when they purchase new batteries. Ten percent admitted to dumping old batteries, and 5 percent have stored the dead batteries at their residences.

What Does the Typical Residential PV System Owner in Hawaii County Think About the Local Electric Utility Company?

Over 80 percent of the users of residential PV systems reported that they prefer being independent from Hawaii Electric Light Company (HELCO), the local utility company, and liked the notion of not having to pay monthly utility bills.

Despite this affirmation of the desire to be independent of the electric company, the following statistics indicate that residential PV users in Hawaii County will entertain the idea of dealing with HELCO under certain conditions.

Eighty-nine percent of the users of residential PV systems thought that the local utility company should offer PV service to people in its Hawaii County service area rather than line extensions.

Those people who said that they thought that the utility should get into the PV business were also asked a follow-up question:
"Would you consider obtaining your system from HELCO?"

Eighty-two percent said "Yes, but....", with most qualifying their answers with comments about price competitiveness and system quality, as well as questions about ownership issues and tax credits.

Conclusions

One of the primary conclusions that can be drawn from this survey effort is that there is a great deal of information available which can be gathered from the experiences of residential PV users in Hawaii County. This effort proved that the users of PV systems in Hawaii County will discuss their experiences with adept and knowledgeable data collectors.

This survey found that in general, the residential PV systems in Hawaii County are fairly small (averaging 355 watts (peak) of generating power) and new (with over two-thirds of the systems less than six years old). Three quarters of the systems use an inverter to convert the DC power to AC power, and 85 percent use some sort of back up power source (typically engine generators). These systems have on

average 7 batteries with a total storage capacity of 985 AH. Seventy four percent of the PV systems would cost less than $6,000 to replace, but there was a wide range in the costs of these systems (from $500 to $50,000). An important point to be made is that most of these PV systems cost between a third to a quarter of what a typical "utility grade" PV system costs. (Per John Prescott's presentation at the April 1994 Hawaii PV4U working group meeting, the typical residential PV system offered by Idaho Power Company to its off-grid customers costs between $20,000 to $25,000.) Thus, cost will be a major issue for HELCO entrance into the residential PV market.

People who use residential PV systems usually own their own homes, live less than two miles from the HELCO electric grid, and have the same family size as the county average. Most people do their own maintenance on their systems, and 69 percent of the residential PV systems were purchased piecemeal over time as funds were available. The average life of the batteries for these systems is 4 years and 8 months, and 79 percent of the respondents try to recycle their used batteries.

It was also learned that even though residential PV users in Hawaii County are generally independent of the electric utility in terms of their supply of electrical power, these same people cannot be considered true isolationist. Twenty-two percent of the surveyed PV users have called for help on their systems. Friends and neighbors play an important part in the installation, component selection, and even system design. These people also appear to be interested in listening to any message the utility company has to deliver regarding the supply of PV services.

This research also uncovered some important knowledge gaps among the users of residential PV systems in Hawaii County. Fifteen percent of the surveyed PV users admitted to not knowing how to take care of their batteries, and 37 percent said that their component instruction manuals made no sense to them. At least 20 percent did not know that their systems required permits. Additionally 24 percent of those surveyed didn't know of the tax credits available for their equipment, and some of those who knew of these credits displayed a lack of knowledge on how to apply these credits. This is important when one considers that over a third of the users say that the lack of financing is a barrier to the expansions of their systems.

The survey also provided data that corroborates a common sense notion that people who have enough panels with their systems tend to be more satisfied with their systems. Those residential PV users who had something they disliked about their system had, on average, 200 watt peak array output systems (or about 4 panels). The systems of those with no complaints averaged 400 watts peak array output systems (or about 8 panels). Furthermore, even though 54 percent of the surveyed systems had major component problems, 63 percent of those surveyed had no complaints what-so-ever about their systems.

Recommendations

An important area for further study is the costs, availability, and utilization of energy efficient appliances in homes with residential PV systems. This represents a huge "hidden cost" that is often not appreciated until after the commitment to PV is made. Another area where further study is needed is related to where the users of PV systems purchase their equipment, and why they selected that source for equipment supply. A correlation of this information with data on the use of Hawaii solar equipment income tax credits would also provide an indication if the state tax credit is benefiting out of state equipment suppliers.

It was observed during the performance of this survey that there is an eager and interested audience for any message that HELCO has regarding PV services on the island of Hawaii. However, this group is a fairly well informed audience which will want to immediately read and scrutinize the fine print of any conditions regarding these services. HELCO would be well advised to consult with the users or potential users of PV services in any of its future efforts with remote photovoltaic applications.

Finally, even though word of mouth and the local PV industry has done a good job of disseminating information about the technology to the people using PV systems, there are still important messages about system maintenance, design standards, and tax credits that have not yet reached everybody. Efforts to saturate the island with critical information regarding the use and financing of PV systems may be beneficial.

SURVEYOR'S REPORT

Prepared by Eileen O'Hora-Weir for PICHTR

FINAL REPORT ON SURVEY OF PHOTOVOLTAIC POWERED RESIDENCES ON THE ISLAND OF HAWAII CONDUCTED JULY - OCTOBER 1994

Background

According to 1990 census data, the Big Island of Hawaii supports a population of 120,317 consisting of 48,253 households. Some of these households are in areas and "subdivisions" not supported by the electrical power grid operated by the local utility, HELCO. Instead, many of these households depend on solar energy to produce electricity and, due to the average lot size and configuration of land holdings, may represent the most concentrated use of residential photovoltaic systems in the United States. The exact number of residences powered by alternative forms of energy is unknown and hard to estimate using conventional methods. Estimation of this number is further complicated by a 5 year boom in rural home construction starting in 1987, coupled with a rapid expansion of HELCO's grid as a result of the Special Subdivision Program Provision (SSPP).

This development of residential alternative energy systems resulted from land use decisions made in the past combined with an unanticipated population growth, mostly from in-migration. During the decade from 1980 to 1990, in-migration accounted for 48% of the state's population growth. The creation of approximately 80,000 residential lots in the Puna and Ka'u districts is recounted in the thorough, although somewhat outdated, Chapter 8 of Land and Power in Hawaii by Cooper and Daws. According to their account, only 5% of these 80,000 lots had been developed by 1983. In 1994 the estimate on build-out in these subdivisions rose to nearly 20%, representing a sharp increase in population growth in an area largely unsupported by the grid. Due to the distances separating subdivisions, as well as a lack in the planning of infrastructure for the potential development of these areas, HELCO has been unable to deliver power to all these areas at a pace equal to the population growth.

A recent switch in policy has increased HELCO's ability to provide service to more residents in these subdivisions.

Previously, HELCO's policy required that persons requesting a line connection pay the full cost of the line extension less a liberal estimate of their utility bills for the first three years. They would then be required to pay the amount of the estimate for the first three years even if their actual usage was less than the estimate. This provided a disincentive for the use of energy efficient appliances, solar water heating and solar photovoltaic panels. Before 1987, County ordinance stipulated that anyone living within 300 feet of a

utility power source had to purchase power from that source without provision for independent power producers.

The SSPP program provides a more equitable method for connecting off grid subdivisions. All land owners along the proposed path of expansion are contacted and given the option to hook up to the grid. HELCO makes an estimate of the costs of extension based on an average price per pole of $3000-$4000 depending on the location and distance from Hilo. Distances between poles vary depending on lot dimensions but must be less than 300 feet and usually more than 200 feet. HELCO then subsidizes a third of the total extension cost and the land owners who choose to participate share the remaining costs. Extension costs may be paid in full or by monthly installments. In order to keep monthly payments between $30 and $45, the repayment period may be anywhere from 5 to 30 years depending on initial cost. If additional persons hook up to the extended line at future dates, HELCO recovers its subsidy before giving rebates to customers in the form of reduced repayment periods.

Although some of the larger subdivisions such as Hawaiian Paradise Park (HPP), Hawaiian Acres, Fern Acres and Hawaiian Ocean View Estates (HOVE) now have power extended to approximately ª or more of the subdivision, there are still many subdivisions and remote areas with no utility power. In particular the following subdivisions in Puna still have no utility power:

Wa'a Wa'a Subdivision Puna Beach Palisades (PBP)

Papaya Farms Kalapana Seaview Estates

Eden Rock Richard K. Lovell

Kehena Beach

Throughout the 1980's the incoming residents of these areas utilized alternative means of generating electricity because of the unavailability of conventional land line power. Due to Hawaii's wealth of sun, photovoltaic became a primary source of residential electricity for this alternative energy culture. Another reason that photovoltaics flourished is that the initial investment, both in terms of cash and knowledge needed, is relatively small when compared with other available forms of alternative power. Even 12 years ago, a simple 12 volt DC system could be purchased for under $1,000, less than the average cost of a small generator which requires more maintenance and higher operating costs.

Methodology

Since users of residential photovoltaic systems can not be easily identified except by geographical location, a networking approach was used. This approach allowed for contact with users in most of the developing off-grid areas of the island with greatest emphasis on the subdivisions of Puna and Ka'u. Due to recent line extensions as a result of the SSPP program, some of the respondents now have grid power available to them but

haven't connected. Others expect grid expansion in their area in the near future. Some help in locating respondents was received from Real Goods of Ukiah, California and their annual Tour of Independent Homes. Two of the three participants in the 1993 Big Island Tour are respondents to this survey.

The instrument used in this survey was written with assistance from Leonard Greer of PICHTR and Will Hartzell of Inter-Island Solar, Oahu. It was designed to:

1. provide information on individual system specifications and uses;
2. gain insight into users' perceived satisfaction; and
3. illuminate procurement, operational and regulatory problems associated with residential photovoltaic development in Hawaii.

A draft of the instrument was reviewed by both Steve Burns at HELCO and Andrea Beck of DBEDT's Energy Extension, Hilo and their suggestions were incorporated in the final version.

The survey was administered by personal interview, telephone interview and by mail. A total of 79 surveys were completed between mid July and mid October 1994. Of that total, 34 surveys were conducted as on-site personal interviews, 41 were conducted as telephone interviews and 4 were completed through the mail. The majority of the respondents, 83.5%, live in the Puna and Ka'u districts with the remaining 16.5% from the districts of South Hilo, Hamakua, North Kohala and South Kona.
A combination of questionnaire/interview strategy was used to gather input. All input was recorded, reviewed and considered. Analysis was done on completed questions only. The data was analyzed using a computer spreadsheet in order to compute mean averages and percentages.

Due to difficulties in determining the extent of residential photovoltaic systems on the Big Island, the total population is unknown. Therefore, it may not be assumed that the analysis presented here is statistically significant. It is this researcher's opinion that the sample size collected for this study represents no more than one or two percent of the total number of systems on the Big Island. As such, this report may be used as a guide to further research efforts.

Questions & Answers

House size: The average size is 1,315 square feet and the range extends from 200 square feet to 5,300 square feet.

Family Size: The average household size is 2.49 persons which is exactly the same as the average for the Big Island, but less than the State's average of 3.01 persons per household.

Ownership of Home: 90% of the people surveyed own their home while the rest are renters

Ownership of System: 96% of the people surveyed own their photovoltaic (PV) systems. This means that of the 8 individuals surveyed who rent, 5 of them own at least part of the PV system.

Length of time on this PV system?

Average length of time respondents have lived on their current system is 5.6 years. This number reflects the fact that some people had moved the system from previous residences while others had bought new systems while remaining in the same home. The length of time of home ownership is critical in determining the possibility of cash bonuses in terms of a pay back period. The national average is 5 years but a cursory investigation of data supplied in the Hawaii Data Book indicates the State's average may be closer to 10 years.

Distance from the grid? The average distance is 1.6 miles.

SYSTEM:

1) Why are you using a PV system? Check all that apply

a. No utility power available: 70% responded yes to this question. It should be noted that the availability of power in many areas is a function of price. Although power poles might be within a mile of a residence, some considered it unavailable due to the cost while others considered the same situation as "available".

b. Prefer to be independent of utility company: 84% responded yes to this question.

c. Prefer to generate electricity from renewable resource: 84% responded yes to this question.

d. Prefer PV because it is environmentally benign: 67% responded yes while the rest were either not concerned or felt that the production of PV modules was not environmentally benign.

e. Don't want to pay monthly utility bills: 80% responded yes to this question. Many people indicated this as their primary reason.

f. It is quieter and requires less maintenance than other forms of alternative power: 82% agreed with this statement and only one individual strongly disagreed in favor of wind power.

2) Average number of panels connected to a house system? 6.7 PV panels.

3) Average Peak Power per system? 355.4 watt/hours.

Additionally it was noted that 21% of the PV panels were bought used. The most common brands were Arco (Siemmens), Photovolt and Solarex. The average

watt/hour per panel is 53 which points to the Siemmens M-55, (which is well suited to the tropics), as being the most commonly used panel.

79% have the panels mounted on the roof, many have mounts with racks that can be manually adjusted for the seasons. Only 16 of the 79 surveyed have trackers. Of those, 8 have had problems with the trackers.

4) Charge Controller?

75% use charge controllers with the Trace C30A being the most common. SCI, Heliotrope, Ananda, Bobier and Sun Selector are a few of the other brands mentioned.

5) Inverter?

76% have inverters to convert the DC power into AC 120 volts. Again the most common brand is Trace. Most larger Trace models (models 1512 and up), as well as some other brands, have a built in battery charger option so that the inverter switches to a high amperage battery charger when a generator back-up is used. This switch over causes a momentary power interruption which some people find inconvenient. These people prefer to use auxiliary battery chargers.

6) Auxiliary battery charger?

These are used by 38% of the respondents, primarily those without the built-in inverter option.

7) Batteries?

The average number of batteries per system is 7.1 with an average total storage of 984.8 amp/hours.

b) 92% or 65 respondents use deep cycle, lead acid, 6 volt batteries for storage. One uses nicad batteries and 6 use RV/marine 12 volt batteries and 7 use deep cycle, lead acid 2 volt fork lift batteries.

8) Wiring?

20 respondents have their homes wired strictly 12 volt DC, 17 are wired strictly 120 AC. 37 have a mix of 12 volt DC and 120 AC while 5 have a mix of 24 volt DC and 120 AC. The reason for having a mix of AC/DC is due to the fact that the one of the primary uses of power is to pump water. The extent of County water lines is even less than the power grid. Most of the subdivisions and remote areas are reliant on catchment water. 12 volt DC water pumps are a common feature in most of these homes as they are far more energy efficient than an AC pump. DC refrigerators are more energy efficient and require a direct line as well.

9) Other sources of power besides PV?

85% have other sources of power.

10) Information on other power sources:
90% of those with other sources listed a generator. The most common brand is Honda. The average number of hours the generator is run for additional power and to charge batteries is 4.16 hours a week.

b) Of the 7 households who have power sources other than a generator, 4 use windmills and 3 get back-up power from their vehicles equipped with an RV/marine battery.

11) Uses for PV:
51% reported employing PV for uses other than illumination and powering small household appliances. Most alternative energy homes on the Big Island depend on propane refrigerators since DC refrigerators, although energy efficient, draw considerable power and cost 5 or 6 times the price of AC refrigerators. Of the 12 respondents who run DC refrigerators from their PV systems, the brand most commonly used was Sunfrost.

Other residential uses for PV included running power tools, washing machines, central vacuums, sewing machines, musical instruments, computers and fax machines.

Commercial uses for PV where residences also support a business included running irrigation systems, electric fences, fruit drying equipment, packaging equipment, post-production video equipment and light tables. The biggest need not met by PV in commercial application is refrigeration.

12) Replacement cost:
Excluding the cost of back-up power, installation and design costs, and energy efficient appliances, the average cost of a system is estimated as $5,683.60 with considerable variation. The range for this system cost is from $500 to $50,000. It would appear that systems installed in the last 3-4 years are more elaborate and thus more expensive, but further study would need to be done to support that claim.

13) Only 31% purchased their PV system as a complete system while the rest purchased components separately over time.

14) How did you get information on PV components?

Retail distributors: 66% get information from this source.

Trade magazines: 71% get information from this source with Home Power Magazine and the Real Goods Source Book cited most often.

Friends: 68% get information from neighbors and friends.

State Energy Office: Only 8 respondents (10%) have made use of the Energy Extension Office.

Workshops: 13% have attended a workshop on photovoltaics. Two persons attended workshops on the mainland; one given by Real Goods and the other by a photovoltaic manufacturer. Some attended workshops sponsored by the Energy Extension Office.

Other: 14% get information from other source such as Alternative Energy Specialists.

SATISFACTION:

15) Is there anything you dislike about your PV system?
In response to this question, 37% answered yes. Most of those who responded positively mentioned issues such as the initial cost of a system, the lack of sufficient power, the expense and low quality of 12 volt appliances, the lack of trouble-shooting information and the lack of a realistic utility intertie program.

16) Have any components of your system failed?
54% have experienced some component failure. As noted before, trackers gave problems 50% of the time. 3 of the 16 systems with trackers were over 10 years old and only 1 was still working. The other 13 trackers in use were installed in the last 5 years and 6 have had problems.

Charge controllers were frequently mentioned as a component that has failed perhaps due to a mismatch of the model's specifications with the system's capacity. Two respondents mentioned problems with inverters, three had batteries quit before the rated life expectancy and one had a defective panel.

The most serious problem reported was a fire in an inverter as a result of a dead short in the main line to the breaker box.

17) Is your system adequate for your needs?
77% responded yes. Some qualified their answer by adding "currently".

18) Would you like to expand your system?
64% responded yes and money was most commonly cited as the main barrier to expansion.

19) Would you prefer conventional electrical service if the cost for a line extension was reasonable?
Only 14 (18%) answered yes to this question and 3 of them qualified their answer to apply to commercial applications only. Of the 11 who indicated their `willingness to pay' for such service, the average monthly amount was $69.95.

20 a) Do you think HELCO should offer PV systems to customers rather than line extension?
89% responded positively to this question. Some were enthusiastically in favor of this while others were undecided.

20 b) Would you have considered obtaining your system from HELCO?

82% of those who responded positively to the previous question answered yes to this question although most gave a conditional positive response. The conditions most commonly cited were price competitiveness and systems quality. Also of concern was the ownership issue and use of tax credits.

FINANCING & INSURANCE:

21) Is your system covered under your homeowner's insurance?

Only 19% have their systems covered under their home owner's insurance. This low percentage may be more indicative of the state wide residential insurance crisis than a problem directly attributable to PV systems. Two respondents did discuss having problems getting insurance as result of being off power. The only option available to these people was Hawaii Property Insurance Association (HPIA) the state's `fair' plan, which was mandated to provide insurance to all home owners.

22 a) Did you seek financing for your system?

Only 7 (9%) financed the purchase of their PV systems and of those 3 received family loans. Others received unspecified short term loans and one person reported great difficulty getting a mortgage on the purchase of an off power home, but was finally accommodated by American Savings Bank. Some of the banks and credit unions on the Big Island do not make either mortgage loans or building loans to off power areas. Others will loan but reduce the amount they will lend by a fixed number of percentage points.

Most people did not seek financing because they purchased their systems piecemeal as funds were available. Others did not seek financing because they didn't think it was available.

22 b) If financing were readily available would you replace or upgrade your current PV system?

36% responded yes to this question and some who responded negatively felt it was a nice option to have available.

23) Are you aware of the state tax credits for solar?

76% knew about the state tax credits, but many expressed frustration with trying to apply for the credit. The amount that can be applied is the lesser of 35% of the cost of the system or $1,750. Also, a family of two must have an income in excess of $25,000 to generate a tax liability of $1,750 or greater. Hence, low income households or households claiming several dependents, who have spent more than $5,000 on a system, may receive very little benefit from the credit.

24) Did you take tax credits for your system?

Of the 76 who responded to this question, only 35 (46%) had made use of the state tax credits for solar.

INSTALLATION & MAINTENANCE:

25a) Who installed the system?

67% installed the system themselves or assisted friends with the installation. Others had alternative energy specialists install the systems and a few were installed by licensed electricians.

25 & 26) Did you receive help in designing your system?

Half of those surveyed (47%) received help in designing their PV systems and of those 92% were satisfied with the help they received.

27) Who does the maintenance? 93% do their own maintenance.

28) How much time is spent maintaining the system monthly?

When a generator is calculated into the monthly maintenance time the average is 2.2 hours per month.

Without generator maintenance, the average time spent maintaining the system is 0.4 hours per month.

29) Called on a technician?

22% had called on either a friend, electrician, dealer or alternative energy specialist to do a repair to give technical advice.

30) Can you easily access all components of your system?

99% responded yes to this question.

31 a) Monitoring the charge state of your batteries?

99% monitor the charge state and most people use amp meters, amp hour displays and volt meters. Hydrometers were mentioned the least often.

31 b) On the average, how long have your batteries lasted?

Only 38 of the respondents had replaced batteries and the average length of time reported for the longevity of batteries was 4.7 years. Since the most commonly used batteries are 6 volt, 220 amp hour with a 3-5 year life expectancy, this figure is in line with expectations.

32 a) Have you had any serious problems with the batteries?

Only 10% reported problems with batteries, one explosion, one fumes and the other reported excessive corrosion.

32 b) Do you have a main battery fuse installed?

Slightly more than half (55%) claim to have a main battery fuse installed.

33) Moving the batteries?

10% reported being unable to move the batteries.

34 & 35) Are the batteries protected?

97% have the batteries protected from the elements. Many have them under the house since pier construction is very common on the Big Island. Some have separate sheds for the batteries.

36) Distilled water?

46% use distilled water when topping off the batteries. The rest use filtered catchment water.

37) Would you be willing to pay twice as much for sealed (gel) batteries, if they last twice as long as regular lead-acid batteries?

Only 62 of the 79 people surveyed answered this question. The other people felt they needed more information in order to make a choice. Of those who answered, 63% responded positively.

38) How do you dispose of dead batteries?

Most people returned the batteries when purchasing replacements. This is currently mandated by state law. Surplus batteries, beyond the amount being replaced, have posed a problem for recycling in the past. Currently, for a charge of $1 or $2 per battery, there are places in both East and West Hawaii that will recycle the batteries.

39) Do you feel that you understand how to maintain & monitor the batteries?

85% responded yes to this question although it is more a matter of their perception rather than a test of their knowledge about battery functions.

40) Do you find it hard to understand the owners manuals and instruction books available from the manufacturers?

37% claimed to have difficulty in understanding the instruction manuals available while 11 respondents said they have never read any literature.

41) Do you have a permit for the system?

Only 13 of the 77 who responded to this question have permits. Of those 7 are conventional electrical permits with a generator source and 6 are alternative energy permits. The 1993 NEC clarifies the conditions for alternative energy permit in Article 690. The County of Hawaii amended the NEC as shown in Ordinance #8746. The County requires that the electrical plans must be stamped by an electrical engineer or architect for an alternative energy permit. This represents an additional expense. Since HELCO uses generators to provide electricity, the County will give a conventional electrical permit to a system powered by a generator. This method is less costly and less of a hassle.

Conclusion

The responses to the survey as reported above indicate that there is great deal of information that is available and can be gathered from the experiences of residential

photovoltaic users on the Big Island. More in depth questions concerning types of appliances used and load demand could help in designing more satisfactory systems. Further investigations into component failure would help design efforts as well.

In general, people surveyed are hoping to see reductions in the cost of PV components, pure sine wave inverters (now available), smaller panels and lighter batteries. In particular, the most needed technological advance involves the storage mechanism. Deep cycle, lead acid batteries are best suited to Hawaii's photovoltaic systems, but a cost effective and more environmentally benign alternative would be well received by most PV users.

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