

Strategic Planning for an
Information Services Market:

Photovoltaics for Utility Scale Applications
[PVUSA]



Final Project Report

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EXECUTIVE SUMMARY

Photovoltaics for Utility Scale Applications [PVUSA] is a collaborative research and development project between the electric utility industry and the government. PVUSA's mission is to "narrow the gap between a large utility industry that is unfamiliar with photovoltaics and a small photovoltaics industry that is aware of a large potential utility market but unfamiliar with how to meet its requirements.

PVUSA is currently at a crossroads. The electric utility industry is moving toward greater competition. Photovoltaics costs have not decreased as rapidly as expected and fuel costs have not increased as much as had been projected. Photovoltaics is prohibitively expensive to be considered as a bulk power generating option for U.S. electric utilities. There are many applications in which PV is cost-effective or nearly cost-effective, though. These applications offer the opportunity for electric utilities in two ways: as a potential customer and as a business opportunity. PVUSA can provide a competitive advantage to electric utilities by providing the technical knowledge needed to capitalize on these opportunities.

The thrust of our project was to characterize the PVUSA program with a customer-focused perspective. In this case, the customers are electric utilities. The product is technical knowledge about photovoltaics. Conjoint Analysis was employed to estimate the electric utilities' demand for the PVUSA program as a function of a number of important program features. The sensitivities derived from this market evaluation can be used as a product design tool to optimize the design of the program. We evaluated the demand sensitivity to price for today's base case program design and evaluated optimal pricing strategies based on the objective of maximizing expected revenue. The Conjoint Analysis model was compared with directly assessed estimates by knowledgeable experts, resulting in different optimal prices depending on which model of customer preferences was used.

The uncertainty in the two customer preference models was then incorporated using a simple decision analysis framework as an example of the basic strategy for addressing uncertainty in the optimal product design decision.

Several important observations and recommendations are presented in the report. No change from the present price level is recommended at this time, but we do recommend instituting price incentives for longer-term memberships. We recommend that PVUSA next undertake a focus-group approach to improving the customer demand estimate before making any significant program design changes. Implementing an engineering services feature in the program is anticipated to increase the expected number of member utilities. PVUSA should also clarify their stance on protection of intellectual property in order to improve participation rates. Finally, more emphasis should be added in PVUSA's marketing literature on the benefits of understanding PV. The current information tends to set a frame of reference of, "if you are interested in PV, you should talk to us". A more appropriate frame would be something more like, "you *should* be interested in PV, here's *why*, and you should talk to *us*."

We found the project to be very stimulating and filled with complex a far-reaching issues. We believe that PVUSA can provide competitive advantage to U.S. electric utilities and thus can survive, even thrive, in a competitive electric utility environment. The key to success will be maintaining a competitive attitude -- internalizing the idea that the value of the program will depend on the value perceived by the customer. This customer-focused strategic planning perspective can keep PVUSA progressing well beyond the status quo.

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I. BACKGROUND

RENEWABLE ENERGY INDUSTRY

Renewable energy technologies include biomass, geothermal, photovoltaics [PV], high-temperature solar thermal, wind and non-utility hydropower. The early growth of renewables in the 1980s was stimulated by a political environment that encouraged reduced oil dependence and experienced environmental pressure to reduce pollution. The slow penetration of renewables in the 1990's is mainly attributed to technical, economic and government regulation factors. [Ref. 1]

With renewables' costs still higher than projected and fuel price lower than expected, renewables simply are too expensive for the belt-tightening utility industry, which is awash in surplus capacity and increasingly facing the demand for lower rates, to afford. Especially at a time when the natural gas is plentiful and gas-fired generating plants so inexpensive to operate. Plants fired by natural gas can produce electricity for 3 cents per kWh or less while the wind turbines produce power at about 5 cents per kWh. Geothermal plants cost from 5.5 cents and solar power is 14 cents and higher.[Ref. 2]

Apart from economic and technical factors, State and Federal programs that fostered the growth of renewables by guaranteeing them a market despite high start-up costs have been effectively gutted by a recent decision of the Federal Energy Regulation Commission. In its ruling, the commission greatly weakened a provision of 1978 Federal law [the Public Utility Regulatory Policies Act, or PURPA] that enabled states to force utilities to use renewables for some of their electricity through long-term contracts. Because of the Federal ruling, producers of alternative power have to be able to compete in the market. [Ref. 2] It is clear that the market for renewables could only reemerge if the cost continues to fall. Therefore the most important issue facing renewable industry now is the willingness to pay for the research and development in order to reduce the cost, and consequently, who will pay for it. State regulators and legislators who support renewables are also want to bring more low-cost power into their states to prepare their utilities for more competition. Coupled with the regulatory disallowance of cost recovery by utilities conducting PV research and demonstration projects, the utility deregulation further reduces the incentives of private investment in renewables.

The boom and bust cycles of renewables markets in the past have caused industry to be reticent about committing any major investments without stronger signals from the marketplace that there will be a stable increase of the demand for such technologies. Private investment has languished due to early project failures, overoptimistic cost estimates and diminished government support. The lack of capital for renewables has severely hampered technological R&D, industry technology transfer for commercial project testing and market development activities. Obviously, the future of renewables is not nearly as bright as it was in the 80's. [Ref. 1]

PHOTOVOLTAICS INDUSTRY

General Market Dynamics

PV technology, which uses semiconductor material (solar cells) to convert light directly to electricity, is modular, allowing incremental additions that can meet load growth needs on a fine-tuned basis. It is virtually emission free, silent, and requires no fuel or cooling water, it involves negligible environmental impacts and regulatory risks. Other benefits of PV include: reduced dependence on imported fossil fuels, short construction times, unattended operation,

and the ability to site plants in areas where conventional power generation is unacceptable. [Ref. 3]

Currently, PVs are a \$500 million global industry which is dominated by U.S., Japan and a few European countries. Although the output has doubled since 1985, and the annual growth rate is ~20 %, all but a few firms are sustaining substantial losses. The reason for these losses is the enormous R&D cost coupled with the increasing of price competition. The challenge facing by PV industry now is how to finance both the expensive R&D and the capital-intensive plant and equipment needed to stay competitive. [Ref. 1]

The vision of utility scale application of photovoltaics has not been fulfilled thus far. The main cause lies in its initial capital costs (five or more times that of gas-fired plants), coupled with the continuing stable price and good availability of fossil fuel. Due to high start-up cost, PV is one of the most expensive renewable sources and has the least installed capacity in comparison to others. [Ref. 1] Recently, the cost-effective applications of PV are limited to small-scale. For example, using the PV in rural areas is relatively common in developing countries. Rural area PV applications of developing countries are characterized by relatively small loads from 0.1 to 100 kW in a widely scattered areas which make the grid extension costly and decentralized systems attractive.

Utility Perspective

Photovoltaic has long being considered as a utility generating source. PV power plants are different compared to the central generating stations traditionally employed by utilities. The advantages of photovoltaics over grid-connected electricity include: [Ref. 24]

- PV is modular which enables the systems can be modified to match local demand.
- PV systems require relatively little maintenance and do not require costly transmission and distribution systems.
- Electricity theft can be avoided if individual household systems are used.
- PV systems require no fuel and have low environmental impact.
- PV is cheaper than diesel engines for small systems, and cheaper than grid extension for areas far from the existing grid or in harsh terrain.

Continuing PV cost reduction due to the technology advancements and increased production volume has initiated a number of government/industry programs aimed at accelerating the market (i.e. Climate Change Action Plan, UPVG-a group of 86 electric utilities that is initiating a \$500 million program, PVMaT, STEP etc.). With the prospect of lower cost for PV, utilities are also being prompted to reevaluate PV technology by industry forces which include: incremental growth in power demand; high capital costs for large conventional plant construction and transmission upgrades; tighter emissions controls; regulatory requirements for cleaner fuels; regulations requiring integrated resource planning (IRP); increased permitting and decreased land availability. [Ref. 5] There are many advantages for utilities to run the PV program which include: capable of large-scale planning; have the technical expertise and financial assets; have the access to the suppliers; have the resources needed to do R&D and have the existing infrastructure for selling electricity to customers.

However, there are also barriers to PV acceptance by utilities. PV is not yet well-known and understood to large utilities. Utilities everywhere tend to be risk-averse and biased towards large, centralized generating facilities which makes PV difficult to gain acceptance by utilities. At the same time, the small PV industry is aware of a potential large utility market, but is

unfamiliar with how to meet its requirements. Other barriers include direct or indirect fossil fuel subsidies.

PV Diffusion Model

One model that has been proposed for the future evolution of the PV industry is PG&E's diffusion model. The diffusion model characterizes current and future markets as shown in Figure 1. Many domestic utilities are presently involved with Type I. Type III and IV are the ultimate goal of utilities. The Type II applications are considering as a bridge between the gap of today and tomorrow. In order for PV to diffuse into Type IV applications, the cost must be reduced to a level comparable to conventional power generation. Evidently, the relationship between cost and benefit is the ultimate driver of market development. Any successful future utility market development strategy must capitalize on photovoltaics' unique characteristics and the value these characteristics produced for utility and its customers. To implement such a strategy, alternatives such as the Distributed Utility concept to the traditional central station planning paradigm must be developed. Without these alternatives, utility market entry will be sorely dependent upon cost based competition; and this is a competition PV could not possibly win over the next one to two decades.

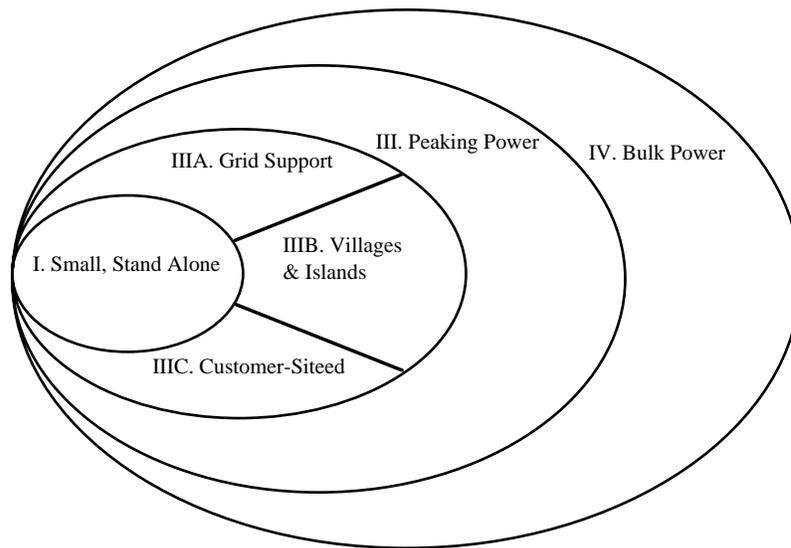


Figure 1 PG&E Diffusion Model:

- I. Encourage and install early utility uses of photovoltaics in currently cost-effective "remote" applications (10W to 10 kW per site).*
- IIA. Install photovoltaics (as one of several technology options) to provide local utility grid support (100 kW to 3 MW per site).*
- IIIB. Install photovoltaics (as part of hybrid systems containing fossil backup and / or batteries) at remote villages, islands, etc., for stand-alone power (10 kW to 1 MW per site).*
- IIIC. Install rooftop photovoltaics in grid-connected systems for residential and commercial applications (1 kW to 100 kW per site).*
- III Begin and continue scaleable photovoltaic central power peaking plant design and test activities, such as PVUSA (leading to 10- to 100-MW systems.) [Ref. 4]*

Many analysts feel that the primary role the government should play in the PV industry is to stimulate its markets. The federal government has been supportive on the technology side such as basic R&D. It has also recognized the importance of funding programs to improve manufacturing process efficiency. The major logjam for the industry has been on the market development side. There are an enormous number of cost effective PV applications about which buyers are not fully aware and are reluctant to adopt. However, in order for photovoltaics to reach the point where they can play a significant role in the bulk power market in a reasonable amount of time, increased government funding is essential. To institute the successful PV diffusion, government should: [Ref. 4]

- Institute reforms in the electricity sector.
- Integrate energy conservation and environmental measures into utility planning.
- Provide a "level playing field" for all technologies.
- Use appropriate technologies.
- Target the appropriate sector.
- Institute energy planning for sustainable development.
- Provide more information about PV and other forms of renewable energy.
- Provide institutional support.

PVUSA

Utility Interest

PVUSA is a collaborative PV project jointly sponsored by the U.S. DOE and several utilities and state governments. The main objectives of PVUSA are to maintain and to monitor several grid-connected "utility-scale" PV power plants for evaluation and testing purposes. Currently PVUSA has more than half a dozen field sites at eight locations in the United States and planned at three others. The project allows emerging module technology and innovative system-balancing approaches to be tested in "utility-scaleable" systems ranging from 200 to 400 kW. The project offers participants the hands-on experience required to evaluate and utilize PV technology and provides manufactures with a test bed for their products. The data provided by PVUSA which are useful in reports and technical guidelines of field applications of PV systems will give utilities and other potential users the detailed technical information on system performance and cost that will be needed for implementation decisions, and case study experience for evaluating a PV grid-support application. [Ref. 5, Ref. 6, Ref. 7]

With numerous systems now in place or nearing completion, the PVUSA project is increasing its focus as a national clearinghouse of results of the various demonstrations. Work will proceed in a number of key areas. [Ref. 8, Ref. 9]

- To directly compare and evaluate the electrical performance, reliability and value of promising current and emerging photovoltaic modules and balance-of-plant components side by side at a single location.
- To conduct assessments of the operation and maintenance costs of photovoltaic systems within an electric utility setting.
- To test and compare promising PV technologies in differing geographic areas.
- To provide U.S. electric utilities with hands-on experience in the installation and operation of utility scale PV Power generation systems.

- To document and disseminate the knowledge gained from this project.
- Special studies (i.e. development of a performance index appropriate for PV, update of PVUSA specifications for system procurement;
- Topical reports (i.e. BOS Design, Cost and Lessons Learned, Data Acquisition Systems etc.)
- Workshops
- New installations
- Routine reporting

The project will continue to have a real impact on the development of cost-effective photovoltaics for utility applications. The mission for PVUSA is to narrow the gap between a large utility industry that is unfamiliar with PV and a small PV industry that is aware of a potential large utility market but unfamiliar with how to meet its requirements.

II. PROBLEM DEFINITION

The situation facing PVUSA is that the historical prime mover champions for the project [PG&E] want to exit their role as manager. The current plan is that the California Energy Commission [CEC] will assume ownership of the project assets, and management responsibilities will be transferred to Sacramento Municipal Utility District [SMUD]. The basic question is, “How to proceed?” As a collaborative research and development effort, PVUSA’s product is *information* about utility-scale photovoltaics. This product provides the opportunity to more rapidly ascend the learning curve for businesses interested in knowing more about what photovoltaics have to offer.

We felt that by bringing some of the available strategic planning tools to bear on this issue, we could help PVUSA do much more than simply maintain the status quo. We set out with the following main objectives for the project:

- Bring structure to the complex issues facing PVUSA.
- Improve the understanding of PVUSA’s customers’ perspective.
- Use simple models and assumptions to complete a *pilot cycle* through the analysis process in order to capture and represent the conventional wisdom and validate the basic approach.
- Provide specific marketing strategy recommendations to PVUSA management.

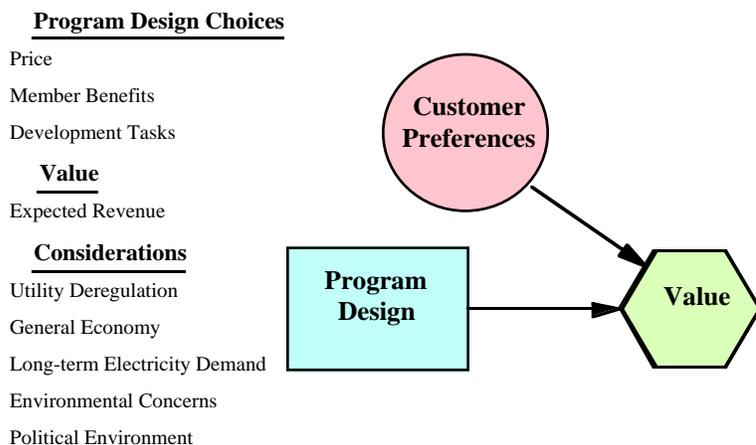


Figure 2: Decision Diagram

The decision situation facing PVUSA, though, can be fairly represented in the very simple decision diagram of Figure 2. There are a set of *program design* choices to be made, namely price, member benefits, and specific development tasks upon which to focus. The *value* being considered in this analysis is the expected revenue, which is the price per member times the expected number of participating utilities. There are numerous categories of uncertainty that may influence the possible response of PVUSA’s potential customers to a program design offered to them. All of the uncertainties facing PVUSA management are embodied in the notion of uncertain *customer preferences*. These preferences are influenced by considerations including utility deregulation, the general state of the economy, long-term electricity demand, environmental concerns, and the political environment, to name a few. However, the basic question that, if answered, would enable PVUSA management to select the best program design is, “What is the demand curve for any particular PVUSA program design?” We set out to improve the understanding of these customer preferences and to illustrate techniques for incorporating the uncertainty about these preferences into program design decisions.

III. ANALYTICAL APPROACH

We chose Conjoint Analysis [CA] as the method to estimate PVUSA customer preferences. CA is a technique that utilizes paired trade-offs of multi-attribute products in an ordinal fashion to estimate scaled part-worth representation of the value to a customer of particular levels of different product features. CA can also be used to estimate customers' probability of purchase, among other marketing-related measures such as market share for existing markets. For an excellent discussion of using conjoint analysis as a services-oriented product design tool, please refer to Zinkhan [Ref. 10]. A recent article in *The Electricity Journal* [Ref. 11] also illustrates the use of conjoint analysis as a tool for determining customer's willingness to pay for difficult-to-assess product features (used in this case to estimate willingness to pay for environmental amenities).

Figure 3 illustrates a block diagram representation of our approach to this particular strategic planning problem. With a set of product attributes defined, several electric utility experts familiar with photovoltaics and PVUSA in particular were interviewed. The CA software package [Sawtooth] was employed to produce estimates of the relative utility values (part-worths for each attribute) and probability of purchase for any given set of program design choices. From this preference model, a sensitivity analysis of the projections yields a number of program design insights with respect to most and least sensitive product features and the relative magnitude and direction of change in value and purchase probability with changes to the program. For the purpose of the pilot cycle, potential revenue from membership beyond electric utilities were excluded.

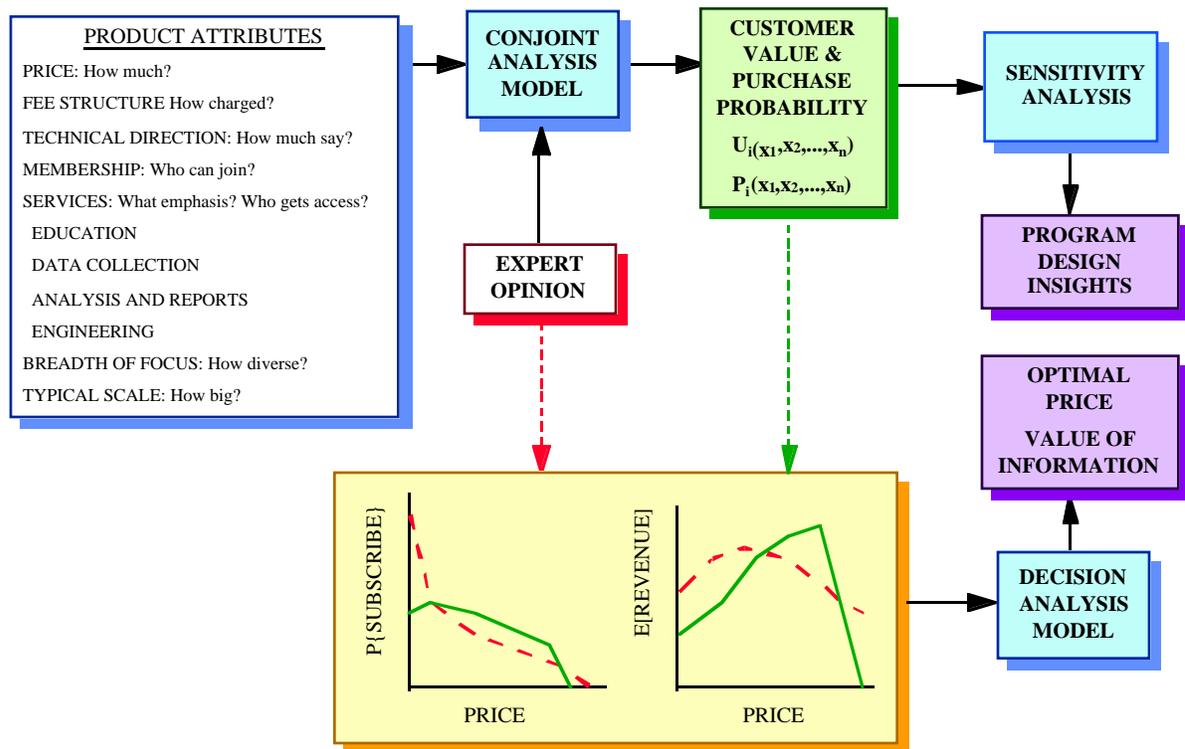


Figure 3: Project Approach

We were also interested in comparing the CA model predictions with expert probability assessments obtained from the same experts, but as directly assessed questions rather than indirectly inferred from CA survey techniques. These two representations of probable customer response to changes in price for today's status quo program design were compared to determine if the optimal price decision depended on which preference model method was used, and if so, how to incorporate such uncertainty into the optimal pricing decision using a simple decision analysis approach. This basic technique could actually be applied to all variables, not just price, but price was the most immediate interest to PVUSA, and was used to illustrate the techniques that could be employed on a second round with refined information modeling techniques if needed. This comparison is represented in the bottom half of Figure 3. There were no constraints included in the optimization of expected revenue.

IV. ANALYTICAL RESULTS

PVUSA's PRODUCT

With the specific approach and problem formulation clarified, the bulk of the initial effort was focused on defining exactly what are the attributes of a PVUSA program that impact the value to an electric utility. PVUSA has been working on answering this question, and was able to make available recent survey data and reports completed by PVUSA and by UNISUN of Camarillo, California, as well as market development work undertaken by the Utility Photovoltaic Group [UPVG, a market and policy research group investigating photovoltaics from an electric utility perspective]. This information provided much of the fundamental characterization of the program upon which to build [Refs. 6, 9, 12-14]. Also very helpful in guiding our thoughts in the early stages were interviews with Chris Eberspacher of UNISUN, Brian Farmer of PVUSA, and Frank Goodman of EPRI.

Finding the appropriate choices for product attributes started with evaluating the decision hierarchy, shown in Figure 4. Many features of the program are essentially inflexible, which we considered as fixed or *policy* level issues. Others were more specific or *tactical* -level issues, such as which specific research tasks to study once a program design foundation is set. We wanted to consider only feasible choices for various levels of each attribute, even if such a choice may represent fiscal or political difficulties. The basic categories under consideration are represented in the *strategy* level of the diagram.

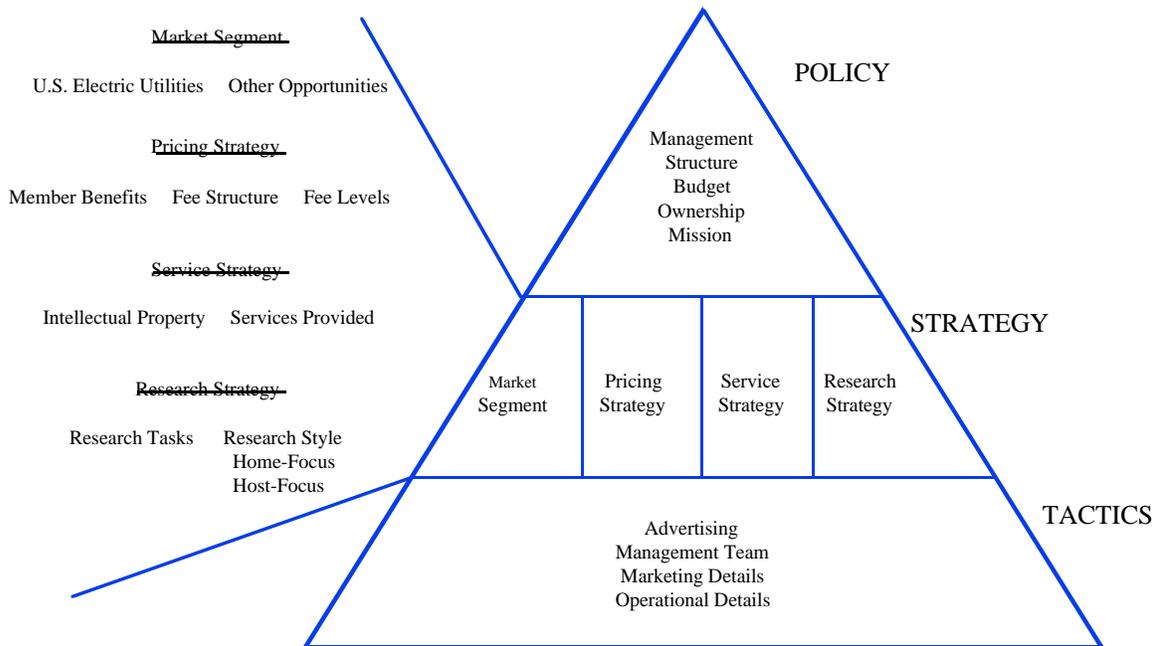


Figure 4: Decision Hierarchy

Our initial list of the important attributes numbered over twenty, each with many levels. Selecting numerous attributes in order to achieve complete characterization of the problem can easily overwhelm the practical application of the survey approach, however, and it is therefore critical to distill down only the key features of a program. Software capabilities limited us to ten attributes, as well. Each member of the project team experienced the questionnaire first-

hand to incorporate our immediate feedback into reducing the total number of levels and improving the definitions for the first field tests. The final attributes used in the conjoint analysis survey are summarized in Table 1. There are a total of ten attributes, with 40 total attribute levels. They are defined so as to be mutually exclusive. A unique program design consists of one selection from each column. This characterization is very similar to the Competitive Decision Matrix [Ref. 23] or the strategy table formulation used in decision analysis [Ref. 20], each unique combination determining a particular strategy. In this case, there are 699,840 possible strategies.

Table 1: PVUSA Product Attributes And Levels

ATTRIBUTES										
	1	2	3	4	5	6	7	8	9	10
Level		Price Level		Membership Composition	Education & Workshops	Data Collection		Engineering Services	Breadth of Focus	Applications Typical Scale
1		2		Utilities Only	Members Only	Members Only	Members Only	Members Only		>100 kW
2		5		Generators & T&D	Non-Members for a Fee	Non-Members for a Fee	Non-Members after 2 years for a Fee	Non-Members for a Fee	Several key tasks	30 -100 kW
3		10		Generators + Contractors	None	General Public		None		10-30 kW
4					-	None		-	-	<10 kW
5								-	-	-
6										
40	3	6	3	5	3	4	6	3	3	4
Permutations=										699,840

SURVEY DESCRIPTION

The instructions provided to each survey participant are included in the appendix for reference. The survey itself was conducted using Sawtooth™ ACA software field disks [Ref. 15]. Each participant responded to questions provided by the software that adapt based on participant responses. The disks were then returned and the data analyzed by the project team.

The definitions of the attributes and levels are as follows:

1. Fee Structure: *How will the customer pay?*

- Level 1: Single Annual Fee: all members pay the same price. All services are included.
- Level 2: Scaled Annual Fee: larger corporations pay higher fees, scaled on total revenue. All services are included.
- Level 3: Minimum Fee + Menu: all members pay some minimum fee to participate, and then can choose from several service options to obtain the services in which they are interested.

2. Price Level: *How much will the customer pay?*

The price level is defined as the average annual cost, regardless of level set for Fee Structure. Thus, if “Scaled” was chosen, the cost would be a little less for smaller companies, slightly more for larger companies. If “Menu” was chosen, the price would reflect average cost including the chosen menu items.

- Level 1: \$2,000 average annual fee.
- Level 2: \$5,000 average annual fee.

- Level 3: \$10,000 average annual fee.
- Level 4: \$15,000 average annual fee.
- Level 5: \$25,000 average annual fee.
- Level 6: \$50,000 average annual fee.

3. Technical Direction: *What say will the customer have in project direction?*

- Level 1: One vote per member.
- Level 2: One vote per share: vote weight scales on financial contribution.
- Level 3: Additional fee to participate on committees.
(Technical and Steering Review Committee membership would require a fee)

4. Membership Composition: *Who will be allowed to join?*

- Level 1: Utilities Only.
- Level 2: All power generators / Transmission & Distribution.
Includes independent power producers and transmission system owners.
- Level 3: All power generators plus power plant contractors.
includes level 2 plus builders of power plants and/or transmission lines
- Level 4: Generators, contractors, banks, plus PV consultants.
includes level 3 plus PV and PV-related consulting groups or contractors.
- Level 5: Anybody.

Feedback for this attribute indicated that the levels could be reduced to incorporate levels 3 and 4 as a single level titled “power generators and energy companies”, and perhaps leave only one other category as “any PV-related business”.

5. Education & Workshops: *Will workshops and educational services be available and if so to whom?*

- Level 1: Available to members only.
- Level 2: Available to non-members for a fee.
- Level 3: No education/workshop activity.

6. Data Collection: *Will there be data collected and if so to whom will access be granted?*

Data collection includes data acquisition and access to archives.

- Level 1: For members only.
- Level 2: For non-members for a fee.
- Level 3: Data Available to general public.
Data acquisition services would be paid for as part of engineering services.
- Level 4: None (no data collection activity).

7. Analysis and Reporting: *Will there be data synthesized into analysis and reports and if so to whom will they be available?*

- Level 1: For members only.
- Level 2: For non-members for a fee, after 2 years.
- Level 3: For general public, after 2 years.
- Level 4: For non-members for a fee (no delay).
- Level 5: For general public (no delay).

8. Engineering Services: *Will there be Engineering Services available and if so to whom?*

Engineering services include technical specifications, data acquisition systems installation, procurement help, system design critique, and other photovoltaic-related engineering consultation.

- Level 1: For members only.
- Level 2: For non-members for a fee.
- Level 3: None (no engineering services activity).

9. Breadth of Focus: *How broad will the scope of investigation be?*

- Level 1: Many diverse applications.
- Level 2: Several key tasks.
- Level 3: Few targeted tasks.

10. Typical Applications Scale: *How big will the typical systems under study be?*

There are a range of system sizes at PVUSA. Typical applications scale is intended to represent the primary focus of future work.

- Level 1: greater than 100 kW [approximately 1,000 m², 10,000 ft², or 1/4 acre].
- Level 2: 30 kW to 100 kW.
- Level 3: 10 kW to 30 kW.
- Level 4: less than 10 kW.

Issues relating to specific research tasks had been well characterized by previous analysis. PVUSA is already beginning to focus more on the tasks deemed important by most PV-interested utilities that had been surveyed. These tasks include new technology and new component evaluation, system reliability tracking, data standardization and implementation, operating cost tracking, and value determination. The degree to which these various activities receive emphasis may have significant impact on an individual utility's demand. These factors were left as fixed decision for the purpose of the study to focus on the more general strategic overall program design issues.

SURVEY RESULTS SUMMARY

There are two fundamental outputs from the conjoint analysis model: utility value and purchase probability. Utility value is a measure of the relative importance of specific attributes in determining the value of the product to a customer. Purchase probability is the likelihood of purchase for a particular product with a given set of product attributes.

The utility value units are arbitrary, scaled in such a way that the sum of the utilities for all attribute levels is 100 times the number of attributes, in this case the sum is 1000. The useful insights are obtained from the relative magnitude and direction of change for moving from one level to another. To first order, equal changes in utility value represent an acceptable or indifferent tradeoff to the customer. Thus, moving from a utility level of 50 to 30 in one attribute could be offset by moving from 20 to 30 in another. Strict reliance on such a linear model should be avoided, though, for two key reasons. First, these estimates are the result of linear regression fit to survey results from three expert respondents. Although each respondent does represent a well-informed opinion about a much larger number of particular customers, the reliability of such regression techniques improve with greater numbers of participants. Second, any synergy or interference between attributes is not accounted for specifically in the

model. However, inconsistent reasoning or preferences on the part of respondents was minimized by employing judicious correlation coefficient criteria in data analysis.

The fundamental outputs from the conjoint analysis survey are illustrated graphically in Figure 5 and Figure 6. The complete tabular data is included in the appendix, as are the utility values calculated for each individual respondent.

Figure 5 summarizes the model estimates of utility value to a potential PVUSA customer. Figure 6 summarizes the purchase probability model estimates for changes in individual attributes with all other attribute levels held fixed at the status quo base case. There are two key indicators for each set of data that are plotted in these figures. The first is the RANGE, or the maximum minus the minimum value for each attribute, shown as a striped bar. The larger range values represent the attributes with the greatest potential swing in either perceived value to the customer or in purchase probability. The second indicator is the sensitivity VALUE itself, which shows the magnitude and direction of change for selecting a different level of any single attribute while holding all the other attributes fixed at the fixed base case level. These data points are represented by the solid bars.

Table 2 below summarizes for each attribute the range, maximum increase, and maximum decrease for both utility and purchase probability estimates, as well as the rank (#1 being biggest) in each category. The nominal purchase probability for the base case scenario (today's program) is 20%. There is no real interpretive meaning of the nominal utility value, because the units are arbitrary to begin with and the real insights are from looking at the relative magnitudes of changes in utilities, not absolute or percentage changes.

Table 2: Conjoint Analysis Data Summary Table

Attribute	Nominal Utility = 2.99						P[Base Case]= 20%					
	Utility Estimates						Purchase Probability Estimates					
	Range		Max. Increase		Max. Decrease		Range		Max. Increase		Max. Decrease	
	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank
1. Fee Structure	3.7	8	3.7	3	0	8	6%	3	6%	3	0%	9
2. Price Level	6.7	1	1.1	5	-5.6	2	21%	7	1%	7	-20%	1
3. Technical Direction	4.8	5	4.8	1	0	8	3%	5	2%	5	0%	8
4. Membership Composition	5.8	3	4.0	2	-1.8	7	6%	8	0%	8	-6%	4
5. Education & Workshops	5.2	4	0	8	-5.2	3	9%	4	3%	4	-5%	5
6. Data Collection	2.8	9	2	7	-2.6	6	20%	8	0%	8	-20%	1
7. Analysis and Reports	4.2	7	1.1	5	-3.1	5	2.6%	2	6%	2	-20%	1
8. Engineering Services	1.2	10	1.2	4	0	8	40%	1	40%	1	0%	9
9. Breadth of Focus	6.0	2	0	8	-6.0	1	6%	6	2%	6	-4%	6
10. Applications Typical Scale	4.3	6	0	8	-4.3	4	3%	8	0%	8	-3%	7

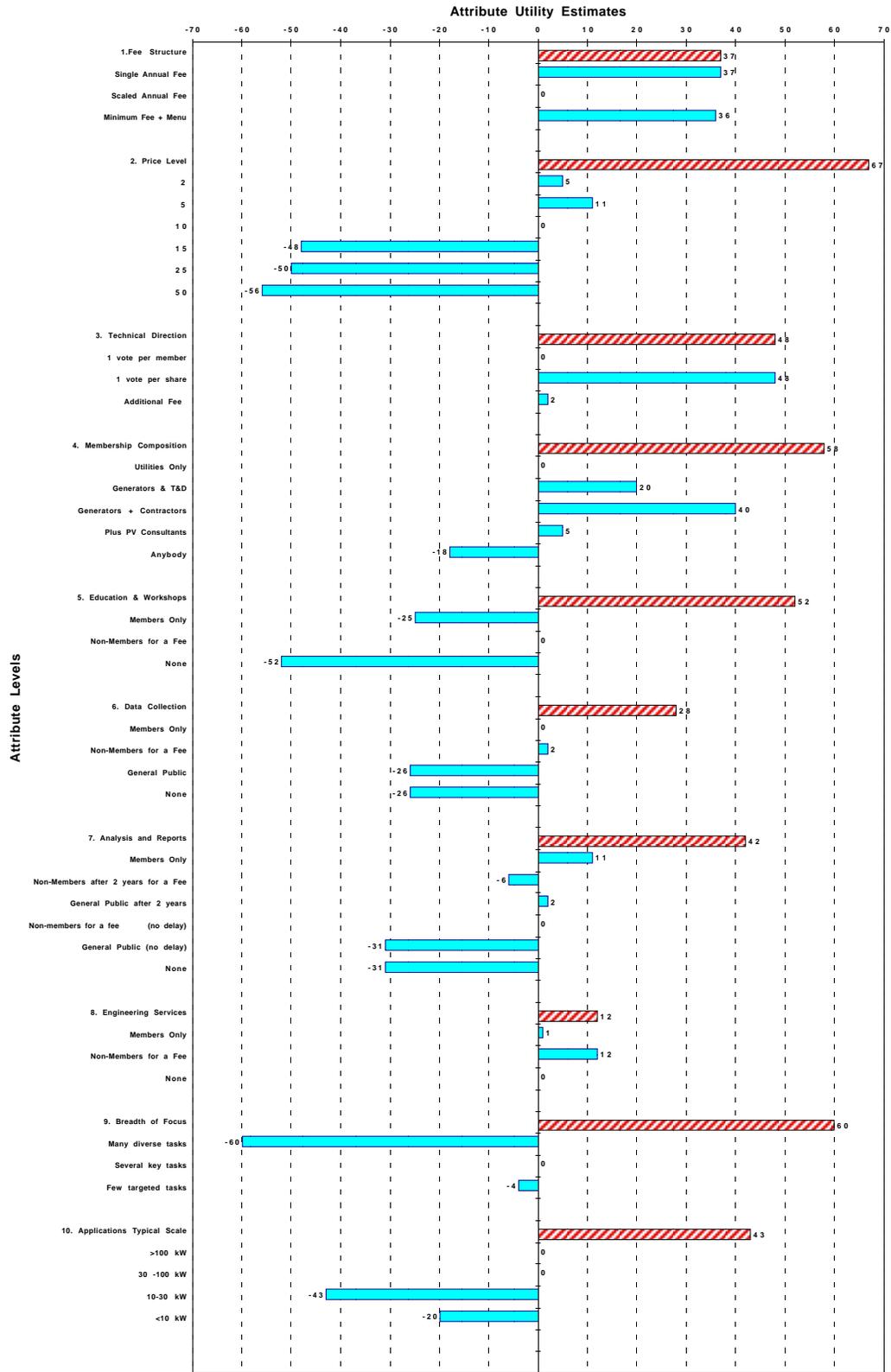
The most important observations are as follows. More detailed discussion of these observations and their implications is provided in the discussion section.

Most Sensitive

The most sensitive attributes (greatest range) in terms of utility value were price level and breadth of focus. The most sensitive for purchase probability were engineering services and analysis and reports.

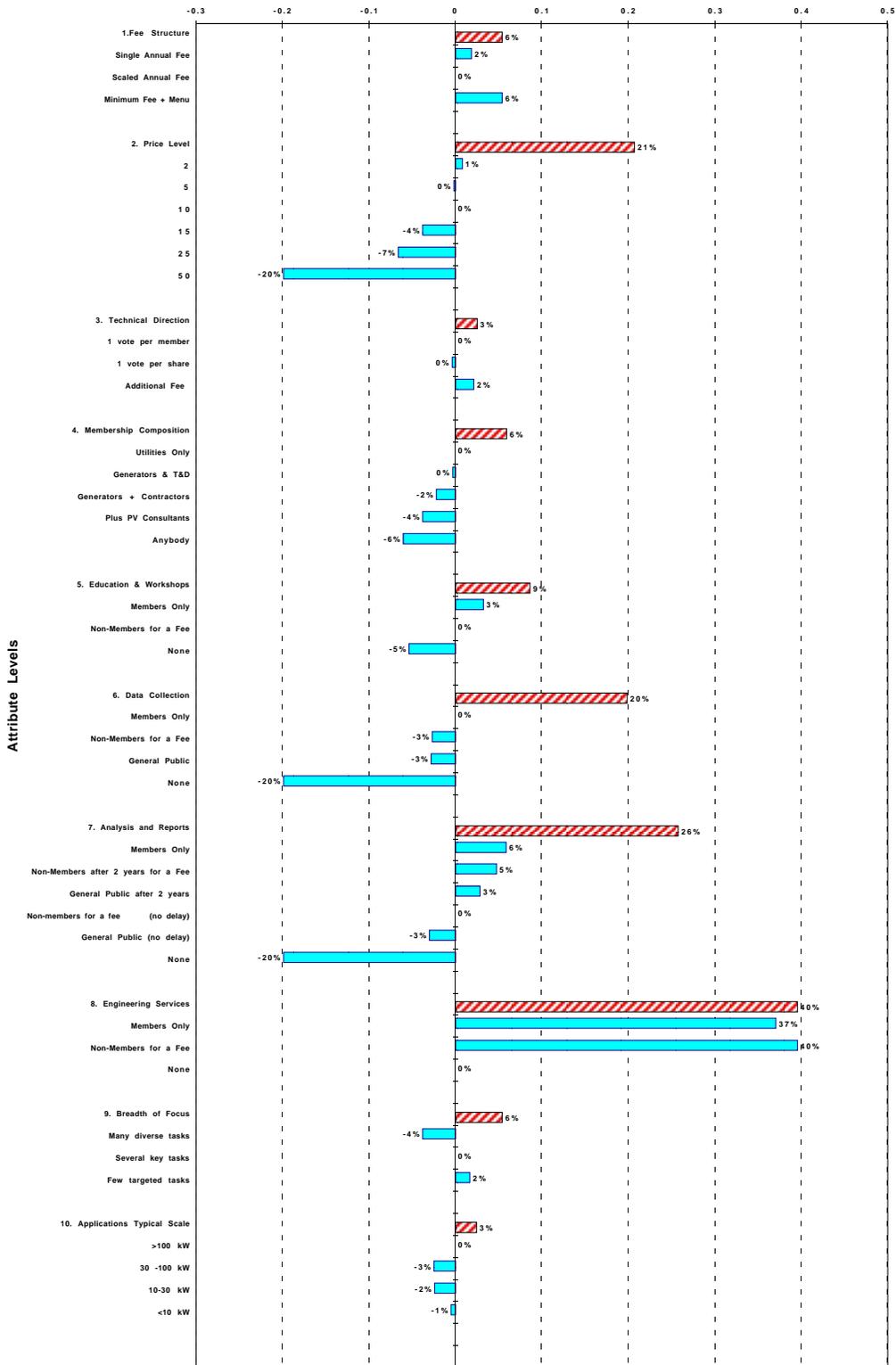
The greatest increases in utility value are due to technical direction and membership composition. For purchase probability the greatest increase is from having engineering services. The projected increase is dramatic, jumping from 20% to 60%. See discussion section.

Change From Base Case Range = Max-Min



Change From Base Case Range = Max-Min

Purchase Probability Estimates



The greatest decrease from the base case was breadth of focus and price level for utility value. The greatest decrease for purchase probability came from analysis and reports, data collection, and price level. Basically, selecting poor choices for either of these drove the purchase probability to zero.

Optimal Utility Value Program

The conjoint analysis model simulation was repeated for predicting the probability of purchase for the optimal utility program, wherein the levels with the maximum utility values for each attribute were selected for the program design. The model estimates a purchase probability over 80% for this program, compared to 20% for the base case status quo program. The two cases are summarized in Table 3. For comparison, the highest average directly assessed purchase probability for the status quo program was 58% (discussed in the next section).

Table 3: Status Quo vs. Optimal Utility Value Program

Attribute	Status Quo	Utility Optimum
1. Fee Structure	Scaled annual fee	Single annual fee
2. Price Level	\$10,000	\$5,000
3. Technical Direction	1 vote per member	1 vote per share
4. Membership Composition	Utilities only	Generators + contractors
5. Education & Workshops	Non-members for a fee	Non-members for a fee
6. Data Collection	Members only	Non-members for a fee
7. Analysis and Reports	Non-members for a fee	Members only
8. Engineering Services	None	Non-members for a fee
9. Breadth of Focus	Several key tasks	Several key tasks
10. Applications Typical Scale	> 100 kW	30-100 kW
Projected Purchase Probability	20%	84%

Digital Behavior

Some attributes exhibited more or less digital on-off behavior. For example, for both engineering services and education/workshops, it was more important whether these services were offered or not than how they were offered if available. Having them was important. Protecting information access was also important, evident in the digital behavior of both analysis and reports data collection attributes, wherein making these services available to the general public was viewed as essentially equivalent to not taking the data or writing reports at all as far as the customer value is concerned.

Surprises

There were a few surprises in the model estimates. These had to do with the preferred applications scale, membership composition, and price level.

The preferred typical applications scale was bimodal, with stronger preference for either of the larger scale operations [greater than 30 kW], or a weaker preference for the very small scale [less than 10 kW] over the mid-range [10 kW to 30 kW]. This trend suggests that for smaller-scale operations experiments, emphasis should be placed on the very small systems rather than “splitting the difference” to best accommodate the interests of utilities. The second surprise

was that opening membership to more than just utilities was preferred over keeping the program “utilities-only”.

Expansion of membership eligibility to include independent power producers and energy-related companies such as power plant contractors could actually increase the perception of value by electric utilities according to the survey results. Projected purchase probability, though, was lower for expanded membership eligibility; although the perception of value may be higher, participation may be lower. The relationships between value and probability estimates are discussed below.

The lowest price level did not generate the highest value, and projected very little change in purchase probability moving from \$10,000 down to \$2,000. This effect could be due to several factors. First is the uncertainty in the regression model itself (see appendix). If the model is a reasonable estimate of behavior, such a response could be due to either prices lower than \$10,000 being considered similarly “small” to be roughly equivalent, or the lower prices could be seen as reflecting a lower quality product, countering the price sensitivity effect. This second effect has been noted in literature concerning conjoint analysis; for a good discussion about this effect, please refer to Zicha [Ref. 16] or Kalish [Ref. 17].

SURVEY RESULTS DISCUSSION

In general, one would expect increased customer value to increase purchase probability. The method used to fit the survey response data to such a model can produce purchase probability projections counter to this expectation. These results can arise from two fundamental sources: inconsistent respondent answers and the natural variance in the respondent answers. The first is a human effect, the second is mathematical. These effects are most strongly evident in the estimated effects due to engineering services and membership composition. Engineering services impacts both move in the same direction, but the magnitude of the purchase probability change is enormous while the increase in utility value is minuscule. The two effects due to membership composition, on the other hand, actually move opposite to each other: fairly substantial increases in estimated utility value correspond to decreases in purchase probability.

There are a number of biases present and heuristic rules applied to making choices when faced with uncertainty. For an excellent treatise on how these effects can influence survey results and interpretation, see Tversky [Ref. 18]. There are several ways the analyst can minimize this kind of inconsistency. The first is clarity of the definitions for each attribute and level. Feedback from our interview respondents indicated that there was some difficulty in discerning between “several key tasks” and “few targeted tasks”, or were not sure what was meant by the price level for different fee structure choices. The second method is to minimize the number of attributes and levels. People in general have difficulty in assimilating combinations of many attributes in making choices, and including more than needed is likely to produce less consistent responses. The third important factor is the length of the interview itself. Fewer levels and attributes can reduce the total interview time, but making both the interview and the instructions concise and clear will also improve the result. Average time to complete the survey was 20 minutes. Personal interaction and follow-up is suggested to help the clarity issue and to incorporate immediate feedback from the participant. The software itself could be improved by providing some indicator as to how far along the participant is in the survey to minimize this weariness. Simpler survey design and instructions as well as longer lead times for participants could also improve participation rates. Our survey data consists of three expert respondents out of seven delivered surveys. The incorporation of the additional data once it is received is straightforward.

There is, of course, natural variation in the responses between survey participants. The model used employs statistical methods to obtain a best fit to the data. For few respondents, the variance can be large relative to the prediction itself. The technique is better suited to larger numbers of actual potential customers than to a few experts. However, each expert represents a different perspective on a large number of actual customers. The standard error in the projection is thus likely to be much lower than calculated. Furthermore, the trends in the data with respect to relative changes in program design do reflect the opinions of the experts involved, and the insights gained have been valuable in developing recommended changes to follow-up data gathering and specific marketing strategy recommendations. The best source of information about the methods applied to determine the model projections is contained in the appendices of the Sawtooth™ software manual [Ref. 15]. The specifics of the regression analysis are outlined in the appendix for reference.

Conjoint analysis is a valuable technique for this type of information gathering process. Zicha [Ref. 16] concludes that conjoint analysis is effective in isolating the effects of each attribute and that it does provide data capable of employing market simulation models to predict preferences in marketplace conditions. Other market assessment techniques such as focus groups or open-ended elicitation, for example, may provide alternative perspectives and interpretations. Six different such techniques are compared in Jaccard [Ref. 19], in which the author concludes that different techniques can lead to different interpretations of attribute importance. Focus groups composed of representative customer cross-sections may be a better method for PVUSA's next step. The focus group approach was impractical for the first cycle of analysis in this case due to the timing of the study and the geographical diversity of the focus group base. The feedback from such a focus group and from the respondents from this survey cycle can be used to produce an improved conjoint study if the analysis determines that it is worth the investment of further resources.

INCORPORATING UNCERTAINTY:

Comparison Of Conjoint Analysis Model With Direct Assessment

The main objective of this project was to develop a structured framework with which to approach the complex issues facing PVUSA. The conjoint survey itself was intended to clarify the important distinctions for decision-making and gain insights from the relative magnitude and projected direction of impact attributable to specific program design features. As discussed above, there remains considerable uncertainty in the estimates of possible customer behavior. This section describes the application of a simple decision analysis approach to incorporating the uncertainty, and can be used effectively as updated information is obtained from further data collection, through direct assessment, contingent valuation, conjoint analysis, or focus groups. As there will always be some degree of uncertainty in events as long as they are in the future (many past events have significant uncertainty associated, as well, of course), it is useful and advisable to incorporate this uncertainty into the decision-making process.

After the conjoint analysis questionnaires were completed, the same experts were asked to estimate the fraction of electric utilities that would join PVUSA, given that today's program would be offered, but varying the price over the same range as used in the conjoint analysis (\$2,000 to \$50,000). The population to be considered for this fraction would be those utilities that are presently members of UPVG [present membership is 86 electric utilities].

The conjoint model predictions and the directly assessed purchased probabilities are plotted versus price in Figure 7. These curves are fundamentally estimated demand curves for today's base case program design. The specific response data are included in the appendix. The direct expert opinion diverges significantly from the model at the low price end, predicting much

higher participation rates. If we take these estimates as representative of the fraction of the 86 utilities that would join at the given prices, we can estimate the expected revenue by multiplying the number of potential customers (86) times the purchase probability times the price. These expected revenue curves for the different customer preference estimates is shown in Figure 8.

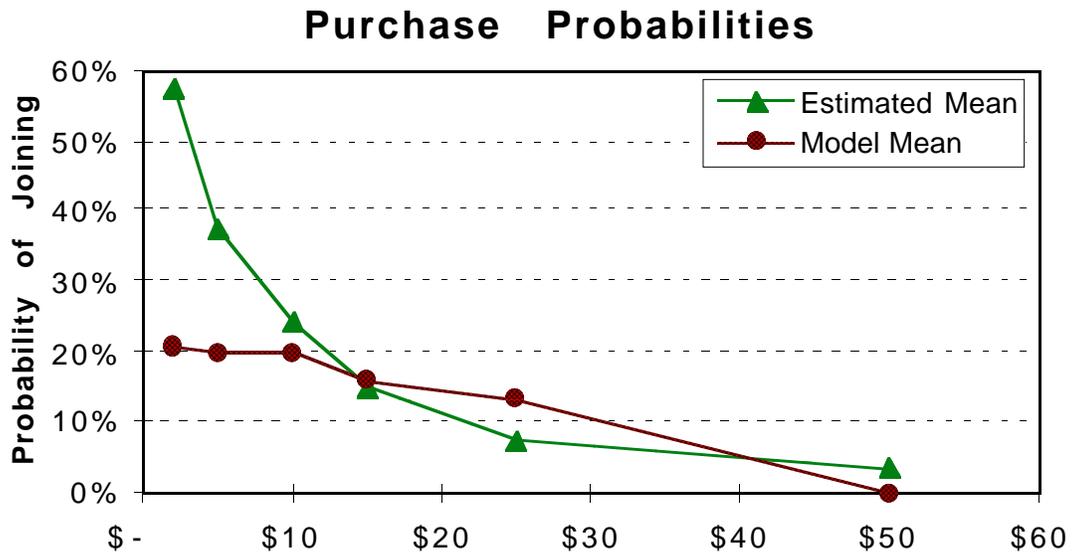


Figure 7: Purchase Probability vs. Price for Status Quo Base Case

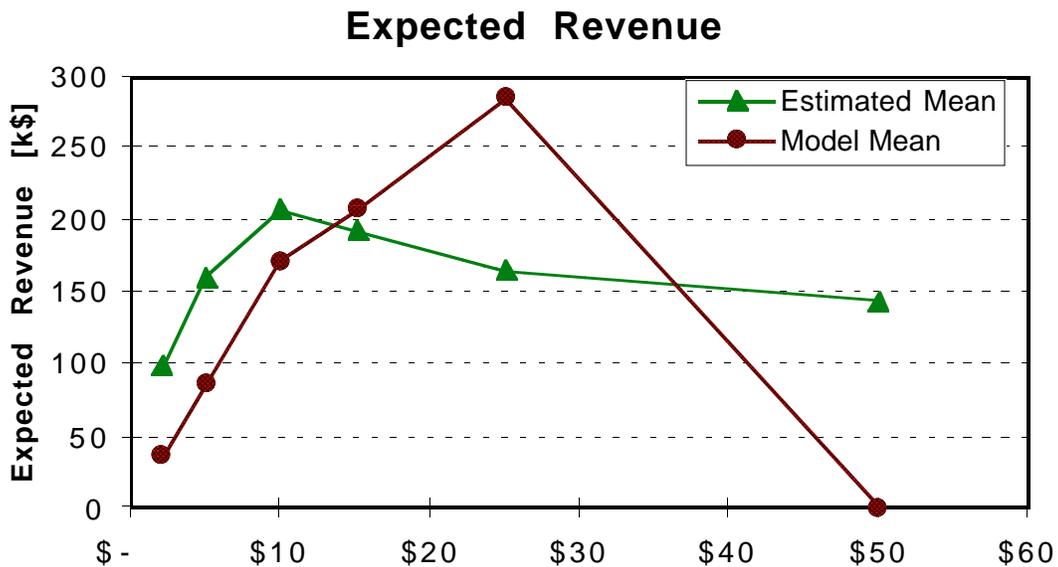


Figure 8: Expected Revenue vs. Price for Status Quo Base Case

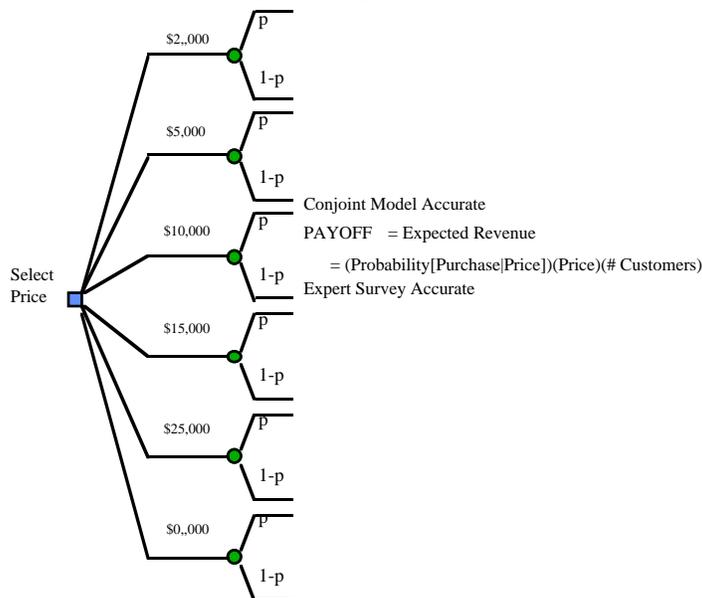
It is evident from these graphs that the optimal choice for price level depends on which customer preference model best represents actual behavior. If we believe the conjoint model, the optimal price is \$25,000. If we believe the expert survey, the optimal price is \$10,000. We can incorporate this uncertainty into the price level decision with a simple decision analysis model.

Assume that these two estimates represent two possible futures, but we are uncertain about which is correct. There are, of course, many other possible representations of the demand curves, but these represent our current state of information. Additional data gathering activities could improve the confidence level in either model or provide an entirely new possible response. The two demand curves represent the different possibilities for the fundamental uncertainty depicted in Figure 2.

Both the optimal choice and the value of obtaining updated information can be determined as a function of the confidence level that the decision-maker has in the two possibilities: the probability assigned that one model is right as opposed to the other. Note that this analysis is only valuable because the price decision would change if the uncertainty were resolved. If the optimal choice were the same in each case, there would be no need to compare the models because the decision is independent of which model is right, even though the absolute value of the purchase probabilities and expected revenue may differ significantly.

The decision situation is represented graphically in Figure 9. In this process, the decision-maker chooses a price level, the response to which is uncertain. Dividing the possible futures into the two model representations discussed above for this example, we then assign a probability p that the conjoint model is correct, and $(1-p)$ that the expert survey is correct. This probability reflects the decision-maker's confidence level, not the analytical team's. Assuming risk neutrality over this range of interest, we then model the decision based on the expectation of the payoff, which in this case is the expected revenue. This expectation is also referred to as the Certain Equivalent of the decision, by

$$CE = p (\text{Conjoint Expected Revenue}) + (1-p) (\text{Expert Survey Expected Revenue})$$



The optimal choice is the price selection that maximizes the certain equivalent for any given probability p . The certain equivalent of the two optimal choices as a function of the probability p are plotted in Figure 10. The values for the other four price level choices lie below each of these options and are left off for clarity. The figure illustrates that the optimal decision changes at a probability that the conjoint model is correct of about 27%. If the confidence level is higher than this, the optimal choice is \$250,000, if below then the optimal choice is \$10,000.

Figure 9: Decision Tree

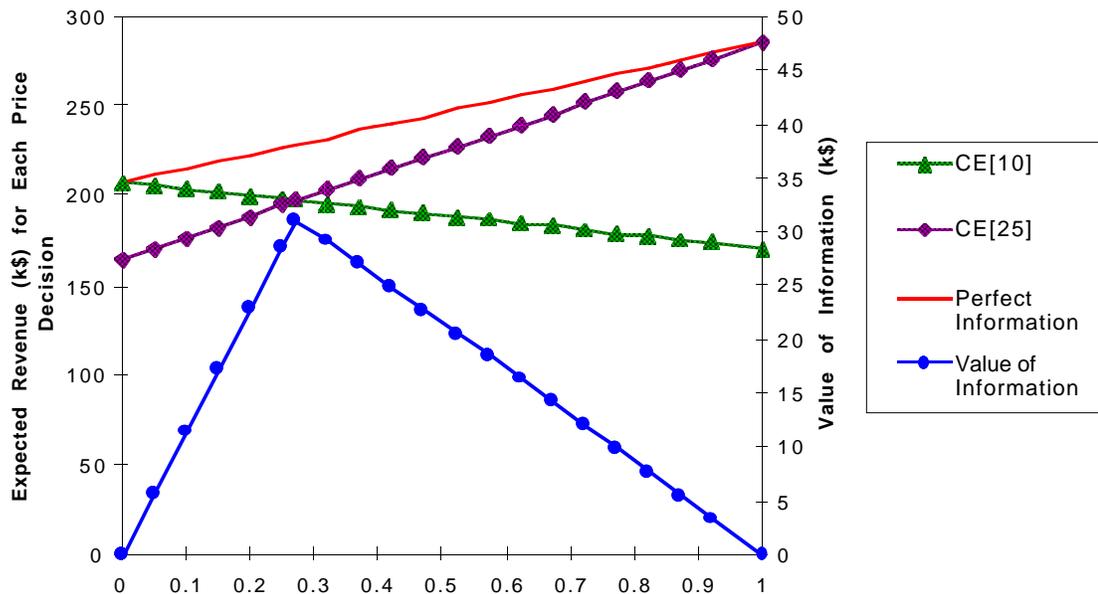


Figure 10: Sensitivity to Probability and Value of Information

Another capability of the decision analysis model is to estimate an upper bound on the value to the decision maker of gathering more information. If PVUSA wants to have better information about their customers' demand, what is the most they should pay to get it? For the risk-neutral decision maker, the value of resolving which model is correct (assuming one of them is correct) is represented by the height in Figure 10 between the line connecting the two endpoints of the optimal choices and the best alternative at probability p . This difference is plotted using the right axis. This value of perfect information (sometimes referred to as value of clairvoyance) peaks at the decision switching point of 27% at a value of about \$30,000. Note that there is no value if the decision maker is already certain that one or the other is correct (probabilities of zero or one). For market surveys that are less than 100% perfect, the value will be less than this upper bound. Estimating the value of less-than-100% accurate information gathering activities can be calculated using decision analysis as well. For more background and discussion about the decision analysis techniques employed, including sensitivity to probability and value of information calculation, see Lowell [Ref. 20] and Matheson [Ref. 21].

V. THE ELECTRIC POWER RESEARCH INSTITUTE (EPRI) : LESSONS IN RESEARCH ORGANIZATIONS FOR PVUSA

The Electric Power Research Institute (EPRI) is a research consortium that serves as an electricity research and development (R&D) arm for the utility industry. In this respect, EPRI is similar to PVUSA; thus, it would be worthwhile to learn from the experiences of EPRI as a research firm funded by the electric utility industry. The ideas in the following paragraphs were taken from articles on EPRI and interviews with EPRI management.

An issue of concern for EPRI is the inconsistent membership of some of its utility members; this is also known as the “entry-exit problem.” As implied by the aforementioned phrase, some EPRI members may join for a year and then leave, renewing their membership every three or four years. In doing so, they receive the R&D benefits from previous years without paying membership dues for that time period. Left unchecked, this practice can lead to an appearance of unfairness that will undermine EPRI’s efforts at increasing its membership list. This situation can be alleviated by instituting policies to encourage long-term membership, such as discounted multi-year memberships, restricted access to previously-performed R&D work, etc.

The ownership of intellectual property is also an important issue for EPRI. Generally, a member utility’s ownership of R&D technologies is proportional to their contributions to the corresponding program/s. Nevertheless, it is important for EPRI (and all other research organizations) to clearly define the ownership of any R&D findings with respect to membership status and periods, contributions, and other relevant issues. The distribution of R&D work should also be well-structured, most especially with respect to information access. The systematic development of rules concerning ownership and distribution of intellectual property will prove useful when dealing with the dissemination of valuable technological information.

The “unbundling” of EPRI contributions refers to the research organization’s policy of allowing its members to direct their contributions towards certain preferred research programs, while maintaining a core program in which all members must invest. This structure offers members the freedom to invest in the program/s of their choice. In a further illustration of the “bang for the buck” principle, EPRI confers greater ownership of research work to firms that provide a greater investment in the corresponding EPRI programs. This policy would prevent members with little or no investment in certain programs from controlling the R&D agenda in those fields (and possibly stifling R&D efforts).

Because of the nature of research institutes, these organizations often suffer from the inefficiencies resulting from lack of competition (also known as X-inefficiencies, coined by economist Harvey Leibenstein). This refers to the problems of weak motivation and resource misallocations internal to firms that are not subject to enough competition. In particular, the “career service” nature of most research organizations may lead to vested bureaucratic interests, invariably stifling flexibility and the development of new ideas. With respect to EPRI, recommendations have been suggested to staff the organization with more people on temporary loan from utilities, regulatory commissions and other entities, thus fostering a constant renewal of intellectual talent at EPRI.

A counterargument to opening EPRI up to competition is the contention that it would lead to a short-term focus in research work. Most researchers and research managers argue that they need to be somewhat insulated from the demands of the businesses that they serve. However, Peter Drucker has noted that “... the successful innovations in both pharmaceuticals and computers--and in other fields--are now being turned out by cross-functional teams with

people from marketing, manufacturing and finance participating in research work from the beginning.”[Ref. 22] Thus, Peter Drucker makes a compelling argument that EPRI and R&D entities would be helped by being forced to “sell” their research products like a competitive firm.

With the upcoming deregulation of the electric utility industry, EPRI may face increased competition from the National Regulatory Research Institute, the national laboratories, state-sponsored R&D organizations and other similar entities, as well as the internal R&D programs of its members. Thus, EPRI may indeed be forced into learning to operate as a competitive firm, selling its research services in the free market. Operating as a free-standing business, EPRI can engage in contractual research work, technical and environmental consulting, investments into energy-related projects (with an eye towards maximizing their expected returns), and other revenue-generating activities. Such a profit orientation may result in increased short-term versus long-run focus, but an equitable balance between the two can be found that would not compromise the commitment of EPRI towards basic R&D in the electric power industry. The increased competition will eventually lead (possibly with some huge sacrifices on EPRI’s part) to greater efficiency, and should prove favorable to EPRI in the long-run.

PVUSA is facing many of the same challenges as EPRI. While not as diversified as EPRI, PVUSA can benefit from EPRI’s experience and adopt those approaches that apply.

VI. INSIGHTS AND RECOMMENDATIONS

Our primary recommendation for PVUSA is to maintain a competitive attitude in its efforts to maximize the amount of contributions from its members. This recommendation involves developing a for-profit approach towards “selling” its R&D services, and requires a customer-oriented focus. Therefore, PVUSA must strive to provide a competitive advantage for its members, which they can accomplish by providing a unique, cost-effective program relating to a topic of interest (namely, photovoltaics) that protects access to information. In communications with members, as well as in recruiting literature, PVUSA should emphasize the usefulness of learning about the future potential of photovoltaics.

We have also developed specific recommendations, centered around the notion of fostering a competitive approach, regarding certain key areas in PVUSA’s market strategy.

(1) PRICE

PVUSA should consider more enticing payment policies that would encourage long-term memberships. Examples of such policies would be discounted multi-year membership deals and joint membership fees with other PV-related organizations (such as the Utility Photovoltaics Group). No change is recommended from the current price level.

(2) TECHNICAL DIRECTION and INFORMATION ACCESS

PVUSA must clarify its stance concerning the rights to ownership of information regarding its R&D work to its members. These policies must be well-defined and systematically organized. Also, a member’s information access (as well as voice in technical direction) should be proportional to their share of total contribution. Access to previously-performed work should be restricted, with late-comers required to pay for such access.

(3) SERVICES

PVUSA should institute an engineering services program as part of the overall package for its members. Such a program would include specifications, data acquisition system installation, procurement, system design critique, etc. Also, PVUSA should add emphasis on small-scale systems in their R&D efforts, or at least avoid the mid-range scale systems. Selecting “in-between” scale appears to be less preferred than the extremes.

(4) MEMBERSHIP

PVUSA should consider expanding membership eligibility in their program beyond just electric utilities. In particular, they should consider other electric power generators and power plant contractors.

(5) JOINT EFFORT with UPVG

In our recommendations on PVUSA’s pricing structure, mention was made of joint membership fees with the Utility Photovoltaics Group (UPVG). Like PVUSA, UPVG also concentrates on photovoltaics and PV-related issues, but its approach is marketing-oriented, as compared to PVUSA’s emphasis on technical R&D. It would be to PVUSA’s advantage to negotiate with UPVG and design a joint program that

would combine the technical expertise of PVUSA with the marketing knowledge of UPVG in order to have greater efficacy in the technological and marketing development of photovoltaics. The programs could remain separate, but both benefit from the potential synergy if interaction. It may be necessary to request a mandate from the utility participants of the governing boards for the two projects in order to stimulate such a cooperative relationship.

(6) NEXT STEPS

We feel that improved information upon which to base the program design would best be obtained first by focus group discussions of the important program attributes as mentioned in this study. Some of the less important ones can be eliminated, and some new ones may be added. The important point is to stimulate the program design decision makers to think with a customer-focused frame of mind. A few groups of 8-12 actual utility decision-makers, combined with technical or steering committee members, could quickly shed light on the issues at hand with which our team may be unfamiliar. Only when these critical issues have been flushed will attempts to quantify the demand response provide additional value. Once the important program attributes and levels are clarified, conjoint analysis does provide a means for accurately estimating the impacts of various program designs. Such a survey may be superfluous, though, because the optimal choice may be obvious once the discussion has become clear enough to attempt such a survey.

VII. CRITIQUE

Several issues of problem formulation remain to be examined for further study. In this section, we discuss the pros and cons regarding our study presented so far. The discussion is centered around the use of Conjoint Analysis, especially issues related to attributes and levels and issues related to underlying assumptions.

The setting of attributes and levels is one of the most important parts of our problem formulation. They should be clear and parsimonious. In the early stage of our study, we referred to reports by PVUSA, which helped us identify attributes and levels in the right manner. However, we still admit that the procedure needs to be reviewed in some sense. The important issues are the following.

Numbers Of Attributes And Levels:

Attributes and levels must balance human ability to assimilate with desire to fully characterize the problem. If too many attributes and levels are presented, interviewees may become confused or overwhelmed and lose their judgment capabilities. Too many attributes also leads to a long questionnaire where weary interviewees may respond inconsistently. On the contrary, if attributes and levels are not enough to describe the problem, the results that the analysis produces can not shape the important aspects of the problem.

Clarity Of Distinctions:

It is essential that the distinctions and definitions are clear for the interviewees. In order to ensure this clarity, interactive procedures from the early stage of conjoint modeling through the completion of interviews might be of great help. Personal interaction and follow-up is important. Also, some issues could be clarified early using focus group.

Assumptions that underlie our modeling procedure should be questioned for further development of the study, too. Issues are discussed below.

Separable Utilities:

We implicitly assumed in our study that utilities for attributes were separable and that there were no interactions between them. The total utility value for a product is therefore described as the sum of utilities for each attribute. Although this assumption is common in Conjoint Analysis, it may not hold in some cases. Interactions between attributes need to be examined and addressed.

Customer Segmentation:

In our study, no segmentation or expansion of customer base beyond utilities was considered. However, customers are not a single entity and there is no single customer who represents the whole picture of them. Thus customer segmentation or classification must be considered.

Objectives:

Although our study focused upon expected revenue, other objectives may be more appropriate. Possible options are profit for PVUSA and social welfare in an economic sense. Long-term objectives should be considered, as well. For profit or social welfare, estimation of costs or modeling of cost structure is required because profit (social welfare) is revenue (utility) minus cost. Although it will bring a lot of difficulties into our analytical framework,

cost structure modeling will definitely provide us another deep insight into the problem. Qualitative analysis is discussed in the appendix.

Our study nevertheless has the advantage in that it presented a complete cycle of pilot analysis. The pilot cycle helped identify some attributes that are not sensitive to customer preference. Further work can begin by eliminating these insensitive attributes. Unclear distinctions and instructions for interviewees were also identified through the feedback of participants. This experience will be of great help to develop more detailed models. The pilot cycle also highlighted several practical limits and expectations of the use of Conjoint Analysis.

VIII. CONCLUSION

We were quite pleased that we were able to meet our stated objectives for the project.

- Bring structure to the complex issues facing PVUSA.
- Improve the understanding of PVUSA's customers' perspective.
- Use simple models and assumptions to complete a *pilot cycle* through the analysis process in order to capture and represent the conventional wisdom and validate the basic approach.
- Provide specific marketing strategy recommendations to PVUSA management.

The basic approach proposed here provides a sound framework for a structured approach to this particular strategic planning problem.

- Use a market survey approach to determine customer response sensitivity to program design features.
- Maximize an appropriate objective (expected revenue in this case).
- Incorporate uncertainty in survey results into the program design decisions.

Where to next? Our fundamental recommendations are:

1. Improve the understanding of PVUSA's customers' perspective by improving the information base about PVUSA's customer preferences. We recommend making use of focus groups to better identify and define the important program design attributes and levels, then if necessary THEN attempt additional market analysis. In doing so, incorporate some of the lessons learned in this study.
 - Eliminate insensitive attributes and reduce the number of levels.
 - Include the effects of the interactions between attributes.
 - Keep interviews, surveys and instructions brief and interesting.
2. Clarify PVUSA's stance on protection of intellectual property.
3. Institute an Engineering Services feature.
4. Reorient PVUSA's marketing literature to add more emphasis on why photovoltaics is a good thing for potential members to understand. The current information sets a frame of, "if you're interested in PV, you should talk to us". More appropriate is something more like, "you *should* be interested in PV, here's *why*, and you should talk to us".

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Appendix A. ACA Results Table

ATTRIBUTES	1	2	BASE CASE IN BOLD OUTLINE			6	7	8	9	10
Level	Fee Structure	Price Level	Technical Direction	Membership Composition	Education & Workshops	Data Collection	Analysis and Reports	Engineering Services	Breadth of Focus	Applications Typical Scale
1	Single Annual Fee	2	1 vote per member	Utilities Only	Members Only	Members Only	Members Only	Members Only	Many diverse tasks	>100 kW
2	Scaled Annual Fee	5	1 vote per share	Generators & T&D	Non-Members for a Fee	Non-Members for a Fee	Non-Members after 2 years for a Fee	Non-Members for a Fee	Several key tasks	30 -100 kW
3	Minimum Fee + Menu	10	Additional Fee	Generators + Contractors	None	General Public	General Public after 2 years	None	Few targeted tasks	10-30 kW
4	-	15	-	Plus PV Consultants	-	None	Non-members for a fee (no delay)	-	-	<10 kW
5	-	25	-	Anybody	-	-	General Public (no delay)	-	-	-
6	-	50	-	-	-	-	None	-	-	-
# Levels:	3	6	3	5	3	4	6	3	3	4
Total Levels =	40								Permutations=	699,840
AVERAGE UTILITIES										
Level	Fee Struct	Price	Direction	Membership	Education	Data	Reports	Engineering	Focus	Scale
1	37	61	6	18	27	26	42	2	6	43
2	0	67	54	38	52	28	25	13	66	43
3	36	56	8	58	0	0	33	1	62	0
4	0	8	0	23	0	0	31	0	0	23
5	0	6	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0
RANGE	37	67	54	58	52	28	42	13	66	43
RANK	8	1	4	3	5	9	7	10	2	6
PURCHASE PROBABILITIES										
Values for change from base case										
	0.218	0.208	0.199	0.199	0.232	0.199	0.258	0.57	0.161	0.199
	0.199	0.197	0.195	0.196	0.199	0.172	0.247	0.595	0.199	0.174
	0.254	0.199	0.221	0.177	0.145	0.171	0.228	0.199	0.216	0.175
		0.161		0.161		0	0.199			0.194
		0.133		0.139			0.169			
		0					0			
RANGE	0.055	0.208	0.026	0.06	0.087	0.199	0.258	0.396	0.055	0.025
RANK	7	3	9	6	5	4	2	1	7	10
MAX	0.254	0.208	0.221	0.199	0.232	0.199	0.258	0.595	0.216	0.199
RANK	3	7	5	8	4	8	2	1	6	8
MIN	0.199	0	0.195	0.139	0.145	0	0	0.199	0.161	0.174
RANK (smallest)	9	1	8	4	5	1	1	9	6	7
				U[max]=	460					
				U[Base Case]=	299					
SENSITIVITY UTILITIES:										
Deltas from base case										
	37	5	0	0	-25	0	11	1	-60	0
	0	11	48	20	0	2	-6	12	0	0
	36	0	2	40	-52	-26	2	0	-4	-43
		-48		5		-26	0			-20
		-50		-18			-31			
		-56					-31			
MAX Increase	37	11	48	40	0	2	11	12	0	0
RANK	3	5	1	2	8	7	5	4	8	8
Max Decrease	0	-56	0	-18	-52	-26	-31	0	-60	-43
RANK	8	2	8	7	3	6	5	8	1	4
				P[max]=	0.595					
				P[Base Case]=	0.199					
SENSITIVITY PROBABILITIES										
Deltas from base case										
	0.019	0.009	0	0	0.033	0	0.059	0.371	-0.038	0
	0	-0.002	-0.004	-0.003	0	-0.027	0.048	0.396	0	-0.025
	0.055	0	0.022	-0.022	-0.054	-0.028	0.029	0	0.017	-0.024
		-0.038		-0.038		-0.199	0			-0.005
		-0.066		-0.06			-0.03			
		-0.199					-0.199			
MAX Increase	0.055	0.009	0.022	0	0.033	0	0.059	0.396	0.017	0
RANK	3	7	5	8	4	8	2	1	6	8
Max Decrease	0	-0.199	-0.004	-0.06	-0.054	-0.199	-0.199	0	-0.038	-0.025
RANK	9	1	8	4	5	1	1	9	6	7

Appendix B. Individual Values

Respondent I.D.	Aggregate		21		101		121		121b		81	
			Brian Farmer		Chris Eberspacher		Tom Hoff		Charlie Gay		Mike DeAngelis	
Time to complete survey (minutes)	19		28		16		17		15			
Correlation Coefficient			0.624		0.943		0.806		0.801		0.825	
PVUSA Status Quo Purchase Probability	12%		0%		0.03%		60%		0%		0%	
	Utility Value	Percent Unacceptable	Utility Value	Unacceptable	Utility Value	Unacceptable	Utility Value	Unacceptable	Utility Value	Unacceptable	Utility Value	Percent Unacceptable
1. Fee Structure												
Single Annual Fee	26	0%	36	0%	57	0%	18	0%	21	0%	0	0%
Scaled Annual Fee	2	0%	0	0%	0	0%	0	0%	2	0%	8	0%
Minimum Fee + Menu	22	0%	13	0%	37	0%	57	0%	0	0%	4	0%
2. Price Level												
\$2,000	62	0%	105	0%	11	0%	68	0%	39	0%	86	0%
\$5,000	59	0%	87	0%	56	0%	58	0%	58	0%	35	0%
\$10,000	44	0%	57	0%	52	0%	59	0%	0	0%	51	0%
\$15,000	20	0%	0	0%	0	0%	25	0%	8	0%	68	0%
\$25,000	7	40%	0	100%	19	0%	0	0%	0	100%	17	0%
\$50,000	0	80%	0	100%	0	100%	0	100%	0	100%	0	0%
3. Technical Direction												
1 vote per member	5	0%	8	0%	6	0%	3	0%	0	0%	8	0%
1 vote per share	39	0%	74	0%	87	0%	0	0%	33	0%	0	0%
Additional Fee	7	0%	0	0%	0	0%	24	0%	7	0%	4	0%
4. Membership Composition												
Utilities Only	14	0%	0	0%	0	0%	54	0%	0	0%	14	0%
Generators & T&D	40	0%	32	0%	31	0%	51	0%	61	0%	25	0%
Generators + Contractors	62	0%	66	0%	74	0%	34	0%	104	0%	34	0%
Plus PV Consultants	48	20%	50	0%	0	100%	20	0%	121	0%	51	0%
Anybody	25	40%	0	100%	0	100%	0	0%	126	0%	0	0%
5. Education & Workshops												
Members Only	16	20%	0	0%	0	0%	82	0%	0	100%	0	0%
Non-Members for a Fee	55	0%	57	0%	49	0%	49	0%	105	0%	15	0%
None	0	60%	0	100%	0	100%	0	0%	0	0%	0	100%
6. Data Collection												
Members Only	15	20%	24	0%	28	0%	25	0%	0	100%	0	0%
Non-Members for a Fee	29	20%	83	0%	0	0%	0	0%	0	100%	60	0%
General Public	43	20%	0	0%	0	100%	0	0%	154	0%	62	0%
None	0	80%	0	100%	0	100%	0	100%	0	0%	0	100%
7. Analysis and Reports												
Members Only	32	20%	37	0%	0	0%	89	0%	0	100%	33	0%
Non-Members after 2 years for a Fee	25	40%	0	0%	0	100%	75	0%	0	100%	50	0%
General Public after 2 years	33	40%	45	0%	0	100%	55	0%	0	100%	62	0%
Non-members for a fee (no delay)	19	0%	18	0%	50	0%	27	0%	0	0%	0	0%
General Public (no delay)	7	40%	0	100%	0	100%	0	0%	22	0%	11	0%
None	0	100%	0	100%	0	100%	0	100%	0	100%	0	100%
8. Engineering Services												
Members Only	5	20%	0	0%	4	0%	1	0%	0	100%	17	0%
Non-Members for a Fee	8	0%	39	0%	0	0%	0	0%	0	0%	0	0%
None	3	60%	0	100%	0	100%	2	0%	12	0%	0	100%
9. Breadth of Focus												
Many diverse tasks	21	0%	19	0%	0	0%	0	0%	0	0%	88	0%
Several key tasks	45	0%	50	0%	115	0%	34	0%	27	0%	0	0%
Few targeted tasks	57	0%	0	0%	137	0%	50	0%	85	0%	14	0%
10. Applications Typical Scale												
>100 kW	39	20%	8	0%	100	0%	22	0%	0	100%	67	0%
30 -100 kW	32	0%	41	0%	89	0%	0	0%	15	0%	14	0%
10-30 kW	20	0%	0	0%	0	0%	1	0%	0	0%	102	0%
<10 kW	14	40%	51	0%	0	100%	18	0%	0	100%	0	0%

APPENDIX C. Instructions Provided to Survey Participants

May 19, 1995

Dear Expert,

Thank you for agreeing to participate in our project. Enclosed is a 3.5" IBM-formatted diskette containing a questionnaire program designed to provide useful data about electric utility attitudes and perceptions with respect to photovoltaics and the PVUSA program.

To start the program,

- 1.) Insert the diskette into your drive.
- 2.) If you are in Windows, shell to DOS by double-clicking on the MS-DOS icon (usually in the MAIN window).
- 3.) At the DOS prompt, type A:, then ENTER
- 4.) Type ACQ, then ENTER
- 5.) Follow the instructions (there is additional explanatory text attached).

At any time during the program, you can exit by hitting Ctrl-End.

When you're all done, just eject the disk and send it back to us.

Depending on the speed with which you make your choices, the interview should take 20-30 minutes.

Clearly, not all possible attributes of a PVUSA program design are included. The first pass is intended primarily to sort out high-level strategic issues. Attitudes about many of the more specific program tasks have been evaluated and tabulated in earlier studies (i.e. UNISUN), although there is some intentional overlap to help us assess our calibration.

This first questionnaire will assess a number of utility experts as to how they believe electric utilities would respond to the questions. We would like you to answer the questions based on your knowledge of the electric utility industry. The population we feel should be represented by your answers are those utilities that are current UPVG members, as they have by so joining indicated some market-verifiable level of interest in PV.

We do not expect that there is actually a "typical utility" in this population. If you have the interest and the time, we would like to actually obtain similar results assuming different respondent demographics. The easiest would be to run answer the questionnaire from three different perspectives:

1. A large utility (revenues >\$5 billion)
2. A medium utility (revenues \$500 million-\$5 billion)
3. A small utility (revenues <\$500 million)

We are not considering non-utility opinions in this evaluation.

Thank you again for taking the time to participate. We think that useful insights will result.

Sincerely,

Karl E. Knapp, Akira Maeda, David Wang, John Ang
Stanford University, Department of Engineering-Economic Systems

enc: Expanded Questionnaire Explanations

- In general, just follow the on-screen instructions. For ACQ.

Notes:

- Please record your Respondent Number (first screen), especially if you try the interview more than once to simulate different potential points of view or just want to try a couple of times.
- To **back up** a keystroke at any time (oops key), use the **ESC**ape key.
- To **quit** at any time, push **Ctrl-End** (Ctrl and End keys simultaneously)

There are five sections of the questionnaire:

- I. ELIMINATE any UNACCEPTABLE choices of program options.
Select the numbers of any options unacceptable under ANY circumstances.
- II. RANK ORDER your preferences for the levels of each program attribute.
Select the numbers for most preferred, next most, etc.
- III. Assign RELATIVE IMPORTANCE to each attribute.
Select a number from 1 to 9 that represents the relative importance in your decision to join PVUSA.
- IV. Select MOST PREFERRED options from pairs of options presented.
Select a number from 1 to 9, 5 representing indifference.
Assume EVERYTHING ELSE is EQUAL.
This part of the program is the meat of the interview and takes the longest.
Be honest.
- V. Estimate your PROBABILITY of subscribing to PVUSA for each program presented.

- Then just finish, remove the disk, and send it back. Or try again with a different attitude!

A PROGRAM is composed of ten program ATTRIBUTES, each of which has several LEVELS from which to choose. There are ten attributes included in this study, summarized below.

Attribute 1: Fee Structure (How would fees be set?)

- Level 1: Single annual fee, all services included
- Level 2: Annual fee scaled on revenue, all services included
- Level 3: Minimum annual fee plus per-service price menu
e.g. can get all workshops only for \$X, reports only for \$Y.

Attribute 2: Price Level (average annual cost, regardless of level set for Fee Structure)

- Level 1: \$2,000 average annual fee
- Level 2: \$5,000 average annual fee
- Level 3: \$10,000 average annual fee
- Level 4: \$15,000 average annual fee
- Level 5: \$25,000 average annual fee
- Level 6: \$50,000 average annual fee

Attribute 3: Technical Direction (say in the priorities and management of the program)

- Level 1: One vote per member
- Level 2: One vote per share: vote weight scales on financial contribution
- Level 3: Additional fee to participate on committees
(Technical and Steering Review Committee membership require a fee)

Attribute 4: Membership Composition (who is allowed to participate?)

Level 1: Utilities Only

Level 2: All power generators / T&D

includes IPP's, munis, transmission system owners, etc.

Level 3: All power generators plus power plant contractors

includes level 2 plus builders of power plants and/or transmission lines

Level 4: Generators, contractors, banks, plus PV consultants

includes level 3 plus PV and PV-related consulting groups or contractors

Level 5: Anybody (who pays)

Attribute 5: Education and Workshops

Level 1: Available to members only

Level 2: Available to non-members for a fee

Level 3: No education/workshop activity

Attribute 6: Data Collection (includes Data Acquisition and access to archives)

Level 1: For members only

Level 2: For non-members for a fee

Level 3: Data Available to general public

Data acquisition services would need to be paid for

Level 4: None (no data collection activity)

Attribute 7: Analysis and Reporting

Level 1: For members only

Level 2: For non-members for a fee, after 2 years

Level 3: For general public, after 2 years

Level 4: For non-members for a fee (no delay)

Level 5: For general public (no delay)

Attribute 8: Engineering Services (specifications, DAS installation, procurement, critique, etc.)

Level 1: For members only

Level 2: For non-members for a fee

Level 3: None (no engineering services activity)

Attribute 9: Breadth of Focus

Level 1: Many diverse applications

Level 2: Several key tasks

Level 3: Few targeted tasks

Attribute 10: Applications Scale (typical installation size under investigation)

Level 1: greater than 100 kW

Level 2: 30 kW to 100 kW

Level 3: 10 kW to 30 kW

Level 4: less than 10 kW

APPENDIX D. Summary Of Sawtooth™ ACA Utility Estimation And Regression Analysis.

This appendix provides a concise summary of the conjoint analysis methodology employed in the conjoint analysis software tools used for this project. It represents the most pertinent information from the software manual as it applies to this specific project.

The best source for detailed information about conjoint analysis as a tool for management is Green and Kreiger [Ref. 24]. For more discussion about the specifics of the Sawtooth™ Adaptive Conjoint Analysis software package, refer to the software manual itself (particularly the appendices) [Ref. 15].

Initial Utility Estimates: *Prior* Utility Values

There are two types of utility values later used to estimate the purchase probabilities. These are designated as *prior* utilities and *pairs* utilities. The prior utilities are estimated before the pairs trade-off questions in the survey. The pairs utilities are updated values based on the answers to pairs trade-off questions.

Prior utilities are initial estimates, constructed as follows:

- If rank orders of preferences are asked, ACA converts them to relative desirabilities by reversing them. For example, ranks of 1, 2, 3 would be converted to values 3, 2, and 1 respectively. If desirability ratings are asked, those are retained “as is”. The survey employed in this project used rank ordering.
- The average for each attribute is subtracted to center its values at zero. For example, desirability values of 3, 2, 1 would be converted to 1, 0, -1, respectively.
- The values for each attribute are scaled to have a range of unity. For example, desirability values of 1, 0, -1 would be converted to .5, 0, -.5.
- The importance ratings for each attribute are scaled to range from 1 to 4, and then used as multipliers for the unit-range desirability values. Thus, if an attribute has desirabilities of .5, 0, and -.5 and an importance of 3, the result is 1.5, 0, -1.5.

The resulting values are initial estimates of utilities, with these characteristics:

- For each attribute the range of utility values is proportional to the stated importance, and attribute importances differ at most by a factor of 4.
- Within each attribute the values have a mean of zero, and differences between values are proportional to the differences in desirability ratings or rank orders of preference.

Updating: Paired-Comparison Utility Values

The participant is asked to indicate the relative desirability on a scale of 1 to 9 facing two choices, called Pairs questions. Estimates of the respondent’s utilities are updated after each Pairs response.

this updating is accomplished through a series of linear regression techniques that includes both the prior utilities and the latest updated utility values. The details will be excluded from this summary.

Attributes or levels which the respondent considers unimportant, unacceptable, or unlikely to be considered when actually making a purchase are not represented in the Pairs section of the questionnaire. After that section is concluded, rough estimates are provided for any missing values.

Any level judged “totally unacceptable” is given a large negative value. The default is -9.999, but a different value can be chosen by the user when setting up simulations.

Rank orders of preference or desirabilities are available for all attribute levels. If missing levels have desirabilities between levels for which utilities have been estimated, then missing values are estimated by interpolation. Special rules apply for extrapolation, which were not needed for this project.

Calibration Concepts: Purchase Probability Regression

The use of ACA’s Calibration Concepts permits scaling of utilities in a non-arbitrary way. In any product category, some respondents will be more interested and involved than others. ACA attempts to measure each respondent’s degree of involvement by asking “likelihood of purchase” questions for several concepts that differ widely in attractiveness. The data obtained from those questions are used by the Market Simulator module of the software in these ways:

- Correlations between utilities and likelihood responses can be used to identify unmotivated or confused respondents. Respondents whose likelihood responses are not related to their utilities should probably be excluded from simulations by using a cutoff value greater than zero when setting up the simulation (we used a cutoff value of 0.4).
- The level of likelihood responses can identify respondents who are more or less interested in the product category. Respondents who give low likelihood responses even to concepts custom-designed for them are automatically assigned low weights in simulations.
- Variation in likelihood responses can also identify respondents who are “tuned in” to, or highly involved in, the product category. A respondent who gives a low likelihood rating to the least attractive concept and a high rating to the most attractive is automatically made to respond sensitively in preference simulations, whereas someone who gives every concept similar likelihood values is automatically made to respond insensitively in simulations.

In the Calibration Concepts section, each respondent is first shown what should be the least attractive possible concept followed by the most attractive possible concept, as determined from the respondent’s own answers. Those two concepts establish a frame of reference. The remaining concepts are of middling attractiveness, but differ most strongly in the two components of respondent utility from the initial and paired-comparison sections of the questionnaire. ACA determines an intercept and two regression coefficients to apply to utilities to best predict likelihood responses.

Those parameters are then used in a final scaling of utilities, which are therefore no longer arbitrarily scaled. The procedure is as follows:

Let:

- p = the predicted likelihood of buying a concept
- x_1 = the concept’s utility scored using the initial or “prior” estimates
- x_2 = the concept’s utility scored using the component of utility derived from the pairs questions

b_1 = the coefficient used to weight prior utilities
 b_2 = the coefficient used to weight the utilities derived from the pairs questions
 a = an intercept parameter

The actual likelihood response is a single digit on a scale with n points. If we divide by $n+1$ we may regard the result approximately as the probability p . Then, using the logit transformation, we model buying likelihood as a function of the respondent's utilities as:

$$\ln\left[\frac{p}{1-p}\right] \approx a + b_1x_1 + b_2x_2$$

If the two regression coefficients differ too widely, more conservative estimates are applied. The utilities are scaled so their sums are logits. The intercept is divided by the number of attributes, and the quotient is added to the utility for every attribute level. The utilities can be added up and antilogs of their sums are predictions of odds ratios for claimed likelihood of purchase of any concept.

Standard Error

Standard error is associated with sampling. In ACA, the standard errors reflect the uncertainty in the preference estimates due to sampling. The standard error is the standard deviation divided by the square root of the sample size. The standard error is a measure of the precision of the estimate of the mean. Standard errors decrease as sample sizes increase. Quadrupling the sample size cuts the standard error in half.

The mean purchase probability for the PVUSA status quo base case was 20%, with an ACA-reported standard error of 16%. Because the sampling in our case was carried out with each respondent representing an estimate of the entire population, the standard error is likely to actually be much smaller. If each of the three experts accurately represented one-third of the 86 electric utilities considered, the standard error would be cut by a factor of five. This discussion points out the importance of using larger samples when relying on statistical methods for predicting events.

APPENDIX E. Critique (Cost Modeling)

In the Critique section, we have discussed profit for PVUSA and social welfare as other options for objectives. In both cases, quantifying the cost required for a product (or service) configuration will bring difficulties into our analytical framework. Due to lack of information and data available, we cannot provide a quantitative analysis on this issue at this stage. However, some qualitative analysis can be possible, which provides us another deep insight into the problems that PVUSA is facing.

The following is a qualitative analysis of cost structure for each attribute. We believe that it would help us develop more realistic cost models if we have had an access to detailed data and information. Table E1 summarizes the expensive orders of level choices for each attribute.

	Attribute 1	Attribute 2	Attribute 3	Attribute 4	Attribute 5	Attribute 6	Attribute 7	Attribute 8	Attribute 9	Attribute 10
Level 1	3	-	1	6	1	1	3	1	1	1
Level 2	2	-	1	5	3	4	4	3	2	2
Level 3	1	-	3	4	2	3	2	2	3	3
Level 4	-	-	-	3	-	2	5	-	-	4
Level 5	-	-	-	2	-	-	1	-	-	-
Level 6	-	-	-	1	-	-	-	-	-	-

(For each attribute, “1” indicates the corresponding level is the most expensive. “2” is the second, etc.)

Table E1. Cost Structure that is Subject to Service Options and Management Policies.

Attribute 1: Fee Structure

Complicated fee structures cost much more than simple structures do. Thus “minimum annual fee plus per-service price menu” costs more and “single annual fee” costs less. However, the difference is not expected to be large. It may be negligible compared to other attributes.

Attribute 3: Technical Direction

This attribute may make little difference in terms of costs, too. Or, the “additional fee to participate on committee” option may cost more little bit due to complicated management procedures.

Attribute 4: Membership Composition

Larger organizations require much more operating costs. As long as the PVUSA is operated with a small number of utilities, it does not have to be concerned with advertisement, sales promotion, information disclosure, public relations, etc., which costs less. On the contrary, opening itself to anybody who is willing to pay for it will require more expenditures.

Attribute 5: Education and Workshops

These services to members with no additional fee seem expensive. If the PVUSA opens these services to non-members with some fee, they may help its budget. Clearly, no service costs nothing.

Attribute 6: Data Collection

The same discussion applies to the data acquisition and access service. The “data available to general public” option needs the highest expense. The “members only” option comes next because of the service size.

Attribute 7: Analysis and Reporting

This service also costs much depending on the level of open access to the public. Reporting for general public with no fee and no delay will be very expensive. However, if fees for the services are paid, the cost required gets lower.

Attribute 8: Engineering Service

The cost for engineering service is expected to be high. At the same time, offering this service requires a lot of knowledge and skills. This indicates that the PVUSA can differentiate itself and compete with energy service companies. In that case, this service can create another source of revenue. Thus the “for non-member for a fee” option can make a profit rather than reduce the PVUSA’s cost.

Attribute 9: Breadth of Focus

It is clear that diversified applications cost much more than narrow targeted tasks do.

Attribute 10: Applications Scale

The greater the scale is, the higher the total cost is. Large scale installation boosts the cost for the PVUSA that is basically proportional to the number of PV cells required. Thus this attribute seems the most critical in light of cost-benefit tradeoff.