STATE OF CALIFORNIA

ARNOLD SCHWARZENEGGER, *Governor*

PUBLIC UTILITIES COMMISSION

505 VAN NESS AVENUE
SAN FRANCISCO, CA 94102-3298

Tel. No. (415) 703-1691

May 3, 2005

Advice Letter 2616-E

Rose de la Torre
Pacific Gas & Electric
77 Beale Street, Room 1088
Mail Code B10C
San Francisco, CA 94105

Subject: PG&E's value of service study and proposed budget in compliance with Decision 04-10-034

Dear Ms de la Torre:

Advice Letter 2616-E is effective April 22, 2005 by Resolution E-3922. A copy of the advice letter is returned herewith for your records.

Sincerely,

Sean H. Gallagher, Director
Energy Division

jjr

PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA

ENERGY DIVISION

RESOLUTION E-3922
APRIL 21, 2005

RESOLUTION

Resolution E-3922. Pacific Gas and Electric (PG&E) proposed a market-based method for a customer value of service (VOS) study. The Commission denies the request and requires PG&E to use a survey-based method instead.

By Advice Letter 2616-E Filed on January 21, 2005.

SUMMARY

This Resolution denies PG&E's proposal to use a market-based approach for a value of service (VOS) study. PG&E was directed to update prior VOS estimates and to determine how they have changed since PG&E last conducted a VOS study for each customer class in 1993.

If the market-based approach were used for this study the results could not be compared or combined with the 1993 study because the data, assumptions and methods all differ. Instead PG&E is directed to use the alternative survey-based approach it also describes in AL 2616-E, in order to leverage the 1993 survey-based results.

PG&E may record debit entries to a Streamlining Residual Account equal to the amounts of study's invoices. However, invoices are limited to scope of work required under D.04-10-034, and the Streamlining Residual Account is subject to review before recovery in rates.

BACKGROUND

D.04-10-034 in PG&E's 2003 General Rate Case Ordered a VOS Study

In Application (A.) 02-11-017, Pacific Gas and Electric's (PG&E) Test Year (TY) 2003 General Rate Case (GRC) application the Commission issued Decision (D) 04-10-034. Ordering Paragraph 6 of the decision required PG&E to perform a customer VOS study prior to their next GRC. The Decision also specified that the new VOS study, at a minimum, should include a "willingness to pay (WTP)" element. It also ordered PG&E to file an Advice Letter with the Commission within 90 days or by February 8, 2005, detailing its proposed VOS study approach and cost estimate for Commission review and approval. PG&E submitted an Advice Letter on January 21, 2005 and recommended the Commission choose a market-based method over a survey-based method for it to conduct the required customer VOS study.

VOS Results Allow PG&E and the Commission to Make Informed Decisions

This study is intended to update prior VOS estimates and determine how these values have changed since the last PG&E VOS study conducted for each customer class in 1993. Value of Service information allows PG&E to make cost effective decisions in resource planning and revenue allocation that are consistent with customer's desires. It also allows the Commission to better evaluate performance incentive mechanisms and funding proposals.

Three Methods of Doing a VOS Study are 1) Proxy; 2) Survey (Contingent Valuation); and 3) Market-Based

A Value of Service study (also called an outage cost study) provides a means to quantify the value customers place on reliable electric service. According to the AL, the economic value of utility service reliability is equal to the economic losses resulting from service interruptions and power quality problems. The three methods commonly used to quantify VOS are:

- The **Proxy** method involves simple calculations to infer customer Willingness-to-Pay (WTP) using secondary data such as average electricity rates, cost of owning and operating backup generation, wage rates, and Gross Domestic Product (GDP) per kWh.
- **Contingent Valuation (CV or Survey-based)** methods use surveys to elicit customer response. There are three valuation methods depending on

customer segment: 1) the amount a customer is willing to pay to avoid an outage (Willingness-to-Pay or WTP), 2) the amount a customer is willing to receive in order to accept an outage (Willingness-to-accept or WTA), and 3) the specific costs and savings from an outage (Direct Costs). Outage costs are the costs minus the savings from an outage.

- Market-based methods infer WTA and/or WTP based on: 1) consumer surplus (area under the demand curve net of bill payment), 2) customer choice of non-firm rate options, 3) customer backup generation ownership, 4) industrial firm lost profit due to power outages.

Of the three methods PG&E recommended the Commission consider either the survey-based method proposed by the Freeman, Sullivan & Company (FSC) or the market-Based method proposed by the Energy and Environmental Economics Inc. (E3).

The VOS study is to address the customer classes of residential, small/medium commercial/industrial, large commercial/industrial, and agricultural. Because the Proxy method would not be able to do so PG&E did not propose using it.

The Survey-based Method Proposed by FSC Would Compare Data from Prior Surveys with Data from New Surveys

FSC conducted a recent study for the Lawrence Berkeley National Laboratory to create a meta-database by combining 24 individual VOS studies conducted by electric utilities across the United States. The approach is valid because all the studies used a common methodology. FSC proposed to integrate results of the last PG&E survey with datasets available from the California market to develop a description of customer value of service prior to year 2000 for all of California, particularly PG&E customers. FSC also suggested that information from the meta-data base can be used to develop preliminary estimates of outage costs, to project probable results, and to fine tune sampling and data collection strategies of the 2005 VOS study.

The actual customer responses collected during the 2005 PG&E VOS surveys then will be added to the model to identify the extent of change in customer outage costs since the 1993 PG&E survey study.

FSC also proposed to develop separate surveys for each customer class. Data collection instruments and approaches would be tailored specifically for each of these customer segments.

The table on the following page shows the research approach and data collection strategies proposed by FSC for each customer segment:

Value of Service Survey Proposed by Freeman, Sullivan & Company (FSC)

Customer Segment	Sample Size	Data Collection Approach	Valuation Method
Residential	1,000	Mail	Direct Cost & Willingness to Pay
Small/Medium Commercial/Industrial	800	Telephone recruit, Mail	Direct Cost & Willingness to Pay
Large Commercial/Industrial	150	Telephone recruit, In-person Interview	Direct Cost
Agricultural	400	Telephone recruit, Mail	Direct Cost & Willingness to Pay

FSC proposed to analyze these data to produce and report outage cost estimates system-wide and by customer segments. FSC would present results in summary analysis tables and customer damage functions in the form of multiple regression equations. Then FSC would compare results of the 2005 surveys with their initial meta-data base projections.

FSC projected completing the study by September 1, 2005 with a total budget of $540,000.

FSC stated in response to a staff request to PG&E that the sample sizes proposed for the 2005 PG&E VOS study are designed to produce reliability in the +/- 15-20 percent range of the true population mean with 90 percent confidence depending on customer segment.

E3's Market-based Study Would Use Two Methods to Estimate WTP

<u>For Residential Customers the "Net Benefit of Consumption with Supply Availability Changes" Method Measures WTP</u>

Consumer surplus or net benefit is the area under the demand curve, minus the bill payment quantity times price. Consumer surpluses can be calculated for demand curves of high and low availabilities. The difference in consumer surpluses is WTP for the decline in availability. This method based on the idea that as reliability of electricity supply decreases, customers can not use as much electricity as they would under high reliability. Customer may be able to make up some of the lost usage at the end of an outage, but there still would be a net loss in electricity usage. Hence, there is a loss in the customer's value of service.

For NonResidential Customers the "Cost of Production" Method Measures WTP
PG&E's AL states that this approach assumes that a cost-minimizing firm uses variable inputs like labor and electricity to produce an output, subject to electricity availability. When outages decrease and electric supply availability improves, a firm's variable product cost declines. WTP is the percentage change in average product cost per percentage change in electricity supply times the initial total product cost.

E3 would complete the entire project within six months of the contract award date with a total budget of $249,200.

E3 indicated that its study and the survey study likely have comparable confidence intervals. The 90% and 95% confidence intervals, however, are commonly cited.

NOTICE

Notice of AL 2616-E was made by publication in the Commission's Daily Calendar. PG&E states that a copy of the AL was mailed and distributed in accordance with Section III-G of General Order 96-A.

PROTESTS

PG&E's AL 2616-E was timely protested by the Aglet Consumer Alliance (Aglet), the Agricultural Energy Consumers Association (AECA), the Coalition of California Utility Employees (CUE), and The Utility Reform Network (TURN).

The protests raised the following major issues. PG&E's response on February 16, 2005 appears below each issue it addressed.

Reliability Hardly Affects Demand for Residential Customers

CUE and TURN suggested that since PG&E has a 99.95% reliable electric system, it would be almost impossible for E3 to determine the extent which changes in the frequency of very infrequent outage events cause demand curves to change, while at the same time excluding the effects of larger drivers of electricity demand.

PG&E responded:

- There exists large variation in outage rates at a division level, even PG&E has an overall reliable electric system. E3 believes that the variation in usage due to outages will be statistically significant in a demand analysis using monthly consumption data by area.

CUE and TURN claimed that the market-based approach was based on an invalid assumption; namely, that residential customers are willing to pay more per unit of electricity, with increased electricity supply reliability.

PG&E responded:

- "Net Benefit of Consumption with Supply Availability Changes" Method for Residential Customers is based on the idea that customer net loss in electricity usage equates to loss in the customer's value of service. It doesn't mean that customers are willing to pay more for electricity just because they have higher reliability.

CUE and TURN disagreed with E3's assumption that "interruption-minutes per customer" are one of the major drivers of electricity demand. They questioned the impact of outages on electricity demand, compared to other factors such as income, electricity rates, and weather. Also, E3 did not explain how it would extract the impacts of reliability differences on demand curves from all other known causes.

PG&E responded:

- As long as usage varies with outage minutes, outage rate does not need to be a "major "driver to apply this method.

CUE and TURN indicated that customer behavior is not driven purely by economic theory. Aglet Consumer Alliance (Aglet) agreed with CUE and TURN that the VOS study should be based on actual customer responses, not a theory.

PG&E responded:

- E3's principal investigator has extensive electric industry experience in general and in VOS estimation. His publication records, especially in VOS estimation, mirrors the rigor and quality of his VOS research. E3 proposal contains a list of references and copies of key E3 papers cited in their proposal.

The Market-Based Approach May Exclude Results from Two-Thirds of PG&E's Customers

The demand curves produced by the VOS study reflect customer response to rate changes. CUE and TURN alleged that customers who use less than 130% of the baseline quantity would be excluded from the market-based study because their rates have not changed since before the passage of AB1x1. These customers form some 2/3 of PG&E's customer base.

PG&E responded:

- There is only 1/3 of PG&E's residential customers had bills that remained at or below the 130% baseline for the entire year. At the aggregate level of operating area, division, or county; the fact that rates have not changed for a subset of the population is not an issue. The usage and cost data for the small customers remain valid components of the area averages.

Under the Market-Based Approach PG&E Could Not Measure Changes since the Energy Crisis, or Compare Current VOS Study Results with Past Results

CUE and TURN indicated that E3 using historical data before and after the California energy crisis in the market-based study would not produce current VOS results, and would not be able to measure changes in VOS since the energy crisis. Furthermore, since the market-based approach is a new method, the results could not be compared with the past survey-based VOS study. Hence, it would violate the order and intentions of D.04-10-034.

PG&E responded:

- E3's market-based approach will be implemented using data that includes consumption and outage data in recent years. The use of historic data is necessary to assess the trend in consumption behavior and the related VOS. Once completed, however, the VOS estimation models can be used to make VOS predictions using data assumptions that reflect current and future consumer behavior.

Electric Supply Availability May Not Be a Major Determinant in Non-Residential Production Costs

Both CUE and TURN stated that electric supply availability may not be a "key driver" of non-residential production costs. Furthermore, supply could not be disentangled easily from other major determinants such as output level and input price.

A Market-Based Approach Does Not Take into Account the Detailed Outage Attributes Needed to Calibrate Performance Incentives

CUE and TURN also maintained that the market-based approach does not distinguish among outage characteristics such as frequency and duration needed to support CPUC outage performance incentive programs.

CUE and TURN Recommend the Meta-Study Proposed by FSC

CUE and TURN recommended that the Commission adopt FSC's proposal that would combine PG&E's data with data from the meta-study to estimate PG&E's VOS in 2005.

Tiered and Regulated Rates Affect the Market-Based Approach

The Agricultural Energy Consumers Association (AECA) alleged that using billing data in the market-based approach could lead to misleading results. This is because: 1) rates are tiered to usage, particularly for residential customers, hence, a customer essentially chooses a marginal price in which to charge his consumption and this would create an endogenous variable problem in estimation; and 2) rates are set by regulation, not the market. Hence, they do not float with changes in demand.

PG&E responded:

- There are well-known solutions that tests for the presence of and proposes remedy for the endogenous variable problems.
- Since regulation and not an individual customer's consumption that sets the tier rate structure and each tier's rate level, the tier rate structure and its associated rate levels do not have the endogeneity problem described by AECA.

A Market-Based Approach may not Produce the Necessary Short-Run Price Elasticity Estimates for NonResidential Customers

AECA stated that the Statewide Pricing Pilot (SPP), which is testing critical peak pricing (CPP), has developed appropriate measures of short-term price elasticities. However, the SPP focuses almost solely on residential customers. Hence, if a VOS study did not use a survey it could rely on the SPP results for residential customers but still would need to develop comparable data for the other rate classes.

PG&E responded:

- E3 will investigate using CPP price elasticity results to infer residential VOS.

A Market-Based Approach will Not Capture the Likely Dynamic Effect Associated with How a Customer Values Reliability

AECA pointed out that an outage in one hour may affect electricity usage in subsequent hours. A full outage has a different effect than reduced or partial usage. Hence, the Market-based approach would estimate the demand elasticity for a single unit of use and would not capture this interdependence of use across units, or the implications of full outages.
PG&E responded:

- VOS estimates are for full outages. The billing data reflects monthly consumption; and therefore it accounts for a customer's consumption response to outages over the course of a month. Hence, the resulting VOS estimate capture the net effect of outages on monthly consumption, allowing for the possibility that a customer may make up consumption after an outage.

AECA Recommends Considering Other VOS Studies

AECA states PG&E should investigate using one of the following methods:

- Examine how participation in interruptible tariffs changed before and after the 2000-2001 energy crises. The difference in participation before and after interruptible tariff would reveal their WTP for enhanced service.
- Analyze by location and industry their likelihood of having a backup generator could reveal a WTP for added reliability.

PG&E's responses to these two suggestions appear at the end of the following DISCUSSION section.

DISCUSSION

Energy Division reviewed the Advice Letter and protests, along with PG&E's response to these protests, and to Energy Division's questions.

The Selected VOS Study Method Should Yield Responsive, Timely, Comparable and Understandable Results

Energy Division's recommendation is based on the following criteria:

- The selected study should produce the **results ordered** by the CPUC using available data.
- The study should yield **results in time** for PG&E's next GRC.
- The selected study should yield **results that can be compared** with prior studies.
- The accepted methodology should have a **reasonable cost** as compared to its potential benefits.
- **Understanding** the study method and results should not require a technical background.

The Proxy Method

The Proxy method is low cost but too simple to link important outage details with value of service.

The Survey approach

Contingent Valuation (CV or Survey) methods have been long used in VOS literature. The proposal by FSC was for a survey-based study that it would complete by September 1, 2005 for $540,000. PG&E's last VOS Study in 1993 used a survey-based method. Some questions in a survey are difficult for the survey respondent customers to answer with a dollar value, and to some questions the responder will have an incentive to answer higher or lower than actual behavior.

- Advantages
  - It is a well known approach
  - There is an extensive amount of survey-based VOS literature.
  - It can yield detailed outage attribute information (WTA and WTP).
- Disadvantages
  - Lengthy and costly process.
  - Responses to survey questions vary widely.
  - If customers give "protest" or "strategic" responses then survey results may not match actual customer behavior.
  - It may be difficult for residential customers to place a dollar-value service interruptions since they do not buy and sell them.

The Market-based approach

The Market approach was developed more recently than the Survey method. Because it involves economic theory it is more complex but it has been evaluated in scholarly journals and is often applied. The proposal by E3 for a Market approach would yield results within six months, for $249,200 or less than half the cost of the Survey-based proposal.

Protesters raised concerns about Market method results not reflecting the bulk of PG&E's customers and about being unable to compare those results with existing prior pre-energy crisis results.

- Advantages
  - It uses data that reflects actual customer behavior.
  - The market-based model may be updated by utility staff without incurring future data collection costs.
- Disadvantages
  - It is a more complex approach.
  - It yields limited Outage attributes (WTA and WTP)
  - It is a less well-known and utilized approach.
  - The data may not support solid conclusions.
  - Constraints in customer billing and interruption data may impact the analysis.

Two Other Approaches as Proposed by AECA Appear Unlikely to Yield a Broad Representative Study

Examine whether lower participation in interruptible tariffs after the 2000-2001 energy crisis reveals a WTP for firm service

Participation in interruptible tariffs changed after the energy crisis but interruptible customers are only a small part of the total customer base. PG&E's protest response stated that this approach is limited and cannot produce useful data, because it can only produce VOS estimates for customers who had volunteered to join the interruptible/curtailable rate programs before the energy crisis. Obtaining VOS estimates from this small sample would not be representative of PG&E's large customer population.

An analysis by location and industry of backup generator installations could reveal a WTP for added reliability

While this approach could yield WTP data, PG&E explained in its protest response that most customers owning backup generation prefer not to reveal their generation cost data. Therefore the data collected could not readily be used to infer trade-off between cost and reliability from a customer's perspective.

CONCLUSION

Market-Based Study Results Cannot Be Compared with Survey-Based Study Results

Both the Survey- and Market-based methods offer benefits. The cost difference is not significant considering the potential improvement in managing and allocating PG&E's electric distribution revenue requirements, which was $2.493 billion for Test Year (TY) 2003. However, it would be a challenge to do a credible comparison of new market-based VOS study results with the 1993 survey results, since they are based on different sets of assumptions and methodologies.

The Survey-based Approach Meets All the Criteria

Staff received no comments opposing the Survey-based methodology. Only the Survey-based VOS would allow the comparison with PG&E's existing 1993 survey results and result in the best analysis of changes in VOS perceptions since the California energy crisis. The survey-based approach has its limitations, but it would best meet our overall objectives. It also allows ratepayers to directly voice their opinions and to participate in our decision process. Energy Division recommends that the Commission deny Advice Letter 2616-E and direct PG&E to conduct a Survey-based VOS study.

COMMENTS

Public Utilities Code section 311(g)(1) provides that this resolution must be served on all parties and subject to at least 30 days public review and comment prior to a vote of the Commission. Section 311(g)(2) provides that this 30-day period may be reduced or waived upon the stipulation of all parties in the proceeding.

The 30-day comment period for the draft of this resolution was neither waived nor reduced. Accordingly, this draft resolution was mailed to parties for comments, and will be placed on the Commission's agenda no earlier than 30 days from today.

PG&E submitted the following comments on the draft resolution in a letter dated April 6, 2005:

- It accepted the decision to proceed with a survey-based VOS study.
- It proposed to extend the study completion date from September 1, 2005, to allow FSC to complete the study before PG&E files its 2007 GRC application.
- It requested authorization to record costs associate with the VOS study in a Streamlining Residual Account pending review and rate recovery.

The Energy Division finds that it is reasonable to extend the completion date beyond September 1, 2005, as long as PG&E submits results of the VOS study with its 2007 GRC application.

A Streamlining Residual Account (SRA) is a cost recovery account that tracks intervenor compensation payments and Commission imposed rate case expense obligations. Each payment has been authorized by a Commission decision. Electric Preliminary Statement Part BF shows the specific entries into this account. The Energy Division recommends the Commission to allow PG&E to record debit entries to the SRA equal to the amounts of study's invoices. However, invoices are limited to scope of work required under D.04-10-034, and the Streamlining Residual Account is pending review and rate recovery.

FINDINGS

1. Commission Decision 04-10-034 directed PG&E to file an Advice Letter to recommend a method to conduct a customer VOS study.
2. The Decision also specified that the new VOS study, at a minimum, should include a "willingness to pay (WTP)" element.
3. PG&E submitted an Advice Letter on January 21, 2005 and recommended a market-based method to conduct a customer VOS study.

4. A Value of Service study (also called an outage cost study) provides a means to quantify the value customers place on reliable electric service.
5. Proxy, Contingent Valuation (CV), and Market-based are three categories of methods commonly used to quantify VOS.
6. Each approach to the VOS study has advantages and disadvantages.
7. The study would address customer classes in residential; small/medium commercial/industrial, large commercial/industrial, and agricultural.
8. The last PG&E VOS study of each customer class was made in 1993.
9. Freeman, Sullivan & Company (FSC) proposed a survey-based VOS study method and Energy and Environmental Economics Inc. (E3) proposed a market-based method.
10. FSC proposed to use historic data from prior surveys to compare and project new survey results, to conduct new customer surveys, and to present results in analysis tables and customers damage functions.
11. FSC proposed to complete the study by September 1, 2005 with a total budget of $540,000. However, in its comments on the draft resolution dated April 6, 2005, PG&E recommended extending the study completion date beyond September 1, 2005, as long as FSC completes the study before PG&E files its 2007 GRC application.
12. E3 recommended using economic theory and billing data and two separate methods in order to estimate WTP.
13. E3 would complete the entire project within six months of the contract award date with a total budget of $249,200.
14. Pacific Gas and Electric's Advice Letter AL 2616-E was timely protested by the Aglet Consumer Alliance (Aglet), the Agricultural Energy Consumers Association (AECA), the Coalition of California Utility Employees (CUE), and the Utility Reform Network (TURN).
15. Pacific Gas and Electric responded to the protests of the above parties on February 16, 2005.
16. It would be difficult to compare or combine market-based study results with survey-based results since they are based on totally different assumptions and methodologies.
17. Energy Division recommends that the Commission:
    - Deny Advice Letter 2616-E and instead order PG&E to conduct a survey-based VOS study.

- Extend the study completion date beyond September 1, 2005, as long as PG&E submits results of the VOS study with its 2007 GRC application.
- Allow PG&E to record the study invoices as debit entries to a Streamlining Residual Account. However, invoices are limited to scope of work required under D.04-10-034, and the Streamlining Residual Account is subject to review before recovery in rates.

THEREFORE IT IS ORDERED THAT:

1. The request of Pacific Gas and Electric (PG&E) in Advice Letter AL 2616-E to perform a customer value of service study using a market-based method is denied. PG&E is directed to file in its next General Rate Case the results of the survey-based value of service study also described in AL 2616-E. PG&E may record debit entries to a Streamlining Residual Account equal to the amounts of study's invoices. However, invoices are limited to scope of work required under D.04-10-034, and the Streamlining Residual Account balance is subject to review before recovery in rates.

This Resolution is effective today.

I certify that the foregoing resolution was duly introduced, passed and adopted at a conference of the Public Utilities Commission of the State of California held on April 21, 2005; the following Commissioners voting favorably thereon:

STEVE LARSON
Executive Director

MICHAEL R. PEEVEY
PRESIDENT
GEOFFREY F. BROWN
SUSAN P. KENNEDY
DIAN M. GRUENEICH
Commissioners

Pacific Gas and
Electric Company

Brian K. Cherry
Director
Regulatory Relations

77 Beale Street, Room 1087
San Francisco, CA 94105

Mailing Address
Mail Code B10C
P.O. Box 770000
San Francisco, CA 94177

415.973.4977
Internal: 223.4977
Fax: 415.973.7226
Cellular: 415.517.5067
Internet: BKC7@pge.com

January 21, 2005

Advice 2616-E
(Pacific Gas and Electric Company ID U39 E)

Public Utilities Commission of the State of California

Subject: **PG&E's Value of Service Study and Proposed Budget in Compliance with Decision 04-10-034**

Pacific Gas and Electric Company (PG&E) hereby submits its proposed plan to complete a value of service (VOS) study and the associated budget for approval. This filing is made in compliance with Decision (D.) 04-10-034, dated October 28, 2004.

Purpose

In D.04-10-034, the Commission ordered PG&E to perform a new VOS study before its next general rate case and directed PG&E to file an Advice Letter detailing its proposed study approach and cost estimate (p. 105, OP 6).

As explained below, PG&E recommends hiring Energy and Environmental Economics, Inc. ("E3") to perform a market-based VOS study. Based on E3's proposal, PG&E recommends budgeting $300,000, which is 20 percent above E3's bid, to allow for change orders if, for example, Commission staff requests additional work.

Background

PG&E considered two different VOS methodologies, survey and market based, both of which address the Commission's directive to include a "willingness to pay" element (D.04-10-034, p.54) for four main customer classes: residential, small commercial/industrial, large commercial/industrial, and agricultural.

The survey method involves sampling PG&E customers to obtain information regarding the cost of an outage via a questionnaire or an interview (in-person or phone based). Analysis of the survey responses yields an average value of service for each customer class. Both the amount a customer is willing to pay to avoid an outage (willingness-to-pay or WTP) and the amount a customer needs to receive in order to accept an outage (willingness-to-accept or WTA) can be estimated if the survey includes the appropriate questions.

The survey method offers the following potential advantages:

- It is a well known approach;
- There is an extensive amount of survey-based VOS literature;
- The survey method yields WTP and WTA values;

The survey method has the following potential disadvantages:

- It can be a lengthy and costly process;
- The study can sometimes produce a wide-range of results;
- Customers may offer "protest" or "strategic" responses;
- Service interruptions are a non-market good (i.e., a customer does not buy or sell outages) that are difficult for many customers to value;
- It is unclear if survey results matches actual customer behavior.

The market-based method, on the other hand, uses actual transaction data to infer customer consumption behavior and estimate electricity demand under alternative supply reliability. Reliability deterioration results in customer loss, while reliability improvement results in customer gain. The loss represents the WTA to tolerate the deterioration. The gain represents the WTP for the improvement. For the residential sector, the WTA/WTP values can be inferred from the change in consumer surplus due to a reliability change.[1] For the non-residential sector, the WTA/WTP values can be inferred from the change in production cost due to a reliability change.

The market-based method offers the following potential advantages:

- The market-based approach uses data that reflects actual customer behavior;
- The market-based method yields WTA and WTP values that are consistent with the theory and practice of applied economics;
- Once a market-based model is constructed, it is practical to update the results using new data without the need for additional customer surveys, interviews, etc.

The market-based method has the following potential disadvantages:

- It is a more complicated approach;
- It is a less well-known and utilized approach;
- Some parties are concerned that constraints in customer billing and interruption data may impact the analysis.

As required by D.04-10-034 (p. 54), PG&E met with ORA and other interested parties in December 2004 to give them an overview of the market-based method and obtain their input. (Due to time constraints and because the parties are

[1] Consumer surplus measures the gross benefit from electricity consumption, net of bill payment. It can be approximated by the area under a demand curve, net of bill payment.

familiar with the survey method, PG&E did not arrange a similar overview of the survey method.)

While each method has potential advantages and disadvantages, PG&E believes both approaches are reasonable. PG&E is mindful that, regardless of the methodology employed, parties may contest the study if it yields undesirable results. Therefore, PG&E's criteria for deciding what approach to recommend is:

- The ability of the consultant to deliver a quality study;
- Cost;
- Schedule

Consistent with these criteria, PG&E recommends hiring E3 to perform the VOS study for the following reasons:

- E3's bid is less than half the cost of the best survey-based proposal PG&E received (from Freeman, Sullivan & Company);
- E3 can complete the work in-time for PG&E's GRC application
- E3's method is consistent with the theory and practice of applied microeconomics;
- The E3 project manager, Dr. C.K. Woo, has over 20 years of electric industry experience and has published over 70 articles in numerous scholarly energy and economic journals;
- Once the market-based model is constructed, it can be potentially updated by PG&E staff.

Attached are the proposals from E3 and Freeman, Sullivan & Company. The proposals contain specific details regarding methodology, individuals performing the work, their qualifications and other relevant information.

PG&E urges the Commission to approve this advice letter in a timely manner. In order to fulfill the requirement of D.04-10-034, PG&E needs to execute a contract with E3 so work can start as soon as possible.

This filing will not increase any other rate or charge, cause the withdrawal of service, or conflict with any rate schedule or rule.

Pursuant to D. 04-10-034, Ordering Paragraph 6, the Energy Division must review and approve this filing prior to it becoming effective.

Protest Period

Anyone wishing to protest this filing may do so by sending a letter by **February 10, 2005,** which is 20 days from the date of this filing. The protest must state the grounds upon which it is based, including such items as financial and service impacts and should be submitted expeditiously. Protests should be mailed to:

IMC Branch Chief
Energy Division
California Public Utilities Commission
505 Van Ness Avenue, Room 4th Floor
San Francisco, California 94102
Facsimile: (415) 703-2200
E-mail: jjr@cpcu.ca.gov

Copies should also be mailed to the attention of the Director, Energy Division Room 4005 and Jerry Royer, Energy Division, at the address shown above. PG&E also requests that a copy of the protest be sent to Pacific Gas and Electric Company via e-mail and facsimile on the same date it is mailed or delivered to the Commission at the address shown below:

Pacific Gas and Electric Company
Attention: Brian K. Cherry
Director, Regulatory Relations
77 Beale Street, Mail Code B10C
P.O. Box 770000
San Francisco, California 94177
Facsimile: (415) 973-7226
E-mail: RxDd@pge.com

Effective Date

PG&E requests that this advice filing is effective **Upon Commission Approval.**

Notice

In accordance with General Order 96-A, Section III, Paragraph G, a copy of this advice letter is being sent electronically and via U.S. mail to parties shown on the attached list, and parties on the service list for PG&E's 2003 General Rate Case, Application (A.) 02-11-017. Address change should be directed to Rose De La Torre (RxDd@pge.com) at (415) 973-4716. Advice Letter fillings can also be accessed electronically at:

http://www.pge.com/tariffs

Brian K. Cherry/RX
Director - Regulatory Relations

Attachments

cc: Service List – A. 02-11-017

PG&E Electric Advice Filing List
General Order 96-A, Section III(G)

ABAG Power Pool
Aglet Consumer Alliance
Agnews Developmental Center
Ahmed, Ali
Alcantar & Elsesser
Anderson Donovan & Poole P.C.
Applied Power Technologies
APS Energy Services Co Inc
Arter & Hadden LLP
Avista Corp
Barkovich & Yap, Inc.
BART
Bartle Wells Associates
Blue Ridge Gas
Bohannon Development Co
BP Energy Company
Braun & Associates
C & H Sugar Co.
CA Bldg Industry Association
CA Cotton Ginners & Growers Assoc.
CA League of Food Processors
CA Water Service Group
California Energy Commission
California Farm Bureau Federation
California ISO
Calpine
Calpine Corp
Calpine Gilroy Cogen
Cambridge Energy Research Assoc
Cameron McKenna
Cardinal Cogen
Cellnet Data Systems
Childress, David A.
City of Glendale
City of Healdsburg
City of Palo Alto
City of Redding
CLECA Law Office
Constellation New Energy
Cooperative Community Energy
CPUC
Creative Technology
Crossborder Inc
CSC Energy Services
Davis, Wright Tremaine LLP
Davis, Wright, Tremaine, LLP
Defense Fuel Support Center
Department of the Army
Department of Water & Power City
DGS Natural Gas Services
DMM Customer Services
Douglass & Liddell
Downey, Brand, Seymour & Rohwer
Duke Energy
Duke Energy North America
Duncan, Virgil E.
Dutcher, John
Dynegy Inc.
Ellison Schneider
Energy Law Group LLP
Energy Management Services, LLC
Enron Energy Services
Exeter Associates
Foster, Wheeler, Martinez
Franciscan Mobilehome
Future Resources Associates, Inc
G. A. Krause & Assoc
Gas Transmission Northwest Corporation
GLJ Energy Publications
Goodin, MacBride, Squeri, Schlotz &
Hanna & Morton
Heeg, Peggy A.
Hogan Manufacturing, Inc
House, Lon
Imperial Irrigation District
Integrated Utility Consulting Group
International Power Technology
J. R. Wood, Inc
JTM, Inc
Kaiser Cement Corp
Korea Elec Power Corp
Marcus, David
Masonite Corporation
Matthew V. Brady & Associates
Maynor, Donald H.
McKenzie & Assoc
McKenzie & Associates
Meek, Daniel W.
Mirant California, LLC
Modesto Irrigation Dist
Morrison & Foerster
Morse Richard Weisenmiller & Assoc.
New United Motor Mfg, Inc
Norris & Wong Associates
North Coast Solar Resources
Northern California Power Agency
PG&E National Energy Group
Pinnacle CNG Company
PITCO
PPL EnergyPlus, LLC
Praxair, Inc.
Price, Roy
Product Development Dept
R. M. Hairston & Company
R. W. Beck & Associates
Recon Research
Regional Cogeneration Service
RMC Lonestar
Sacramento Municipal Utility District
SCD Energy Solutions
Seattle City Light
Sempra
Sempra Energy
Sequoia Union HS Dist
SESCO
Sierra Pacific Power Company
Silicon Valley Power
Simpson Paper Company
Smurfit Stone Container Corp
Southern California Edison
SPURR
St. Paul Assoc
Stanford University
Sutherland, Asbill & Brennan
Tabors Caramanis & Associates
Tansev and Associates
Tecogen, Inc
TFS Energy
Transwestern Pipeline Co
Turlock Irrigation District
U S Borax, Inc
United Cogen Inc.
URM Groups
Utility Cost Management LLC
Utility Resource Network
Wellhead Electric Company
Western Hub Properties, LLC
White & Case
WMA

2005 Value of Service Study
Pacific Gas and Electric Company

FREEMAN, SULLIVAN & CO.

A MEMBER OF THE FSC GROUP

2005 Value of Service Study

Pacific Gas and Electric Company

January 7, 2005

Prepared for:
John Carruthers
Pacific Gas and Electric Company
123 Mission St, Rm 1657-H16B
San Francisco, CA 94105

Prepared by:
Freeman, Sullivan & Co.
100 Spear St., 1700
San Francisco, CA 94105

Table of Contents

Tables

Figures

1. Introduction

1.1 Background

Pacific Gas and Electric Company (PG&E) is seeking a firm to conduct a Value of Service (VOS) study. The study is a response to a directive by the California Public Utilities Commission to provide updated VOS estimates prior to PG&E's next General Rate Case. This study is intended to update prior VOS estimates and establish how these values have changed in the intervening years since the last PG&E VOS studies were conducted for each customer class. The study should address VOS in all customer classes and the directive also indicates that a new VOS study should include estimation and analysis of customers' "willingness to pay" for service reliability.

Much of the debate in the proceeding that led the commission to instruct PG&E to conduct its Value of Service study centered on the need to know whether customer value of service and reliability preferences changed since PG&E's last study was published in 1993. It is likely that during the last 11 years that the individual customer characteristics driving outage cost estimates and/or the valuation balance between customer classes changed. To address these issues effectively, it is necessary to compare historical PG&E Value of Service measurements with VOS measurements obtained in 2005 using comparable sampling and survey methodologies.

Freeman Sullivan and Company (FSC) proposes to conduct a comprehensive VOS study for PG&E. This proposal provides an overview of VOS studies and detailed discussion of the tasks to be completed as part of the project.

1.2 Overview of VOS studies

Value of Service (VOS) studies -- also called outage costs studies -- measure the economic value customers assign to service reliability. Under the general theory of welfare economics, the economic value of utility service reliability is equal to the economic losses they will experience as a result of service interruptions and power quality problems. The economic losses experienced by customers as a result of reliability and power quality problems can be described by what is known as a Customer Damage Function (CDF). Generally, the CDF can be expressed as:

Loss = f {outage attributes, customer characteristics, environmental attributes}.

The economic loss (or outage cost) in the above function is expressed in dollars per event. Outage costs are a function of a number of factors, including: outage attributes customer characteristics and environmental attributes. Outage attributes are factors such as duration, season, onset time, notice and day of the week. Customer characteristics include such things as: type of customer, size of customer, type of business, household family structure, presence of outage sensitive equipment, presence of backup equipment, and other customer characteristics. Environmental attributes include: temperature, humidity, frequency of storms and other conditions that tend to be constant for all of the customers within a given geographic location for any outage.

A customer damage function predicts the average loss expected to occur under a given set of outage conditions, for customers with a given set of characteristics, under particular environmental circumstances. The resulting outage costs measured on a per event basis can then be converted into outage costs per kWh or KW unserved by estimating the energy or demand associated with events.

The most widely used approach to estimating customer outage costs and customer damage functions is the customer outage cost survey. In a customer outage cost survey, a representative sample of customers is asked to estimate the costs they would experience given a number of hypothetical outage scenarios. In these hypothetical outage scenarios, the outage attributes that affect customer outage costs are systematically varied. Regression techniques are then used to identify and describe the relationships between customer economic losses, outage attributes, customer attributes and environmental conditions.

There are a number of key methodological issues surveying customer outage costs that must be resolved including what method of surveying is appropriate, the number and nature of the hypothetical outage scenarios to include, and what specific form of outage cost question should be used. Our approach to these issues varies by sector and so they are discussed in our approach to each sector below. With regard to the form of the survey questions, over the past twenty years, three general approaches have been employed. These are:

Direct Costs—For a given scenario customers describe or provide their specific dollar costs and their savings from the outage. Outage costs are the costs minus the savings.

Willingness to Pay—For a given scenario customers are asked to indicate what they would be willing to pay to avoid the outage.

Willingness to Accept—For a given scenario customers are asked to indicate what they would be willing to accept as compensation to have the outage.

There has been a good deal of debate over the strengths and weaknesses of each approach and its application to various customer sectors. In general, direct costing has been most widely used in the commercial, industrial, and agricultural sectors because it is an effective method to estimate "lost profits" which represent the costs of an outage to a typical business. Large nonresidential customers tend to incur much greater costs per outage than small customers, so is desirable to divide the nonresidential customers into small/medium and large businesses and tailor the questions to best suit each segment.

In the residential sector, the willingness to pay measure has been most frequently used because it allows consumers to factor in inconvenience and other considerations in calculating their costs and these non-monetary considerations may be the largest component of their expressed costs since the actual out of pocket expenses may be relatively trivial. Recent trends in VOS research blend the direct costing and willingness to pay methods for residential, and sometimes, small/medium nonresidential customers. This technique lends a degree of structure to the valuation questions and enables respondents to more easily estimate their willingness to pay to avoid an outage based on a thorough, stepwise consideration of costs and inconveniences during an outage.

The choice of hypothetical outage scenarios is also a key element of VOS studies and will influence the use of the results. Studies that are constructed to provide input to generation planning studies will include hypothetical outage scenarios that are described as occurring at the time of system peak and usually involve a described warning required by emergency contingency planning. Studies designed to inform transmission planning will include, in addition, hypothetical scenarios that describe circumstances representing more typical transmission and distribution systems events such as storm related outages that may occur in certain seasons or more randomly during the day or night. Once estimates have been developed for each customer segment, these data can be used to conduct system-wide analyses.

1.3 Recent Developments in Value of Service Research — Outage Cost Meta-Analysis

Over the last 20 years, there have been a number of customer outage cost surveys. These studies have been undertaken primarily by electric utilities seeking to quantify the economic value of service reliability for planning purposes. Until recently, most utility sponsors of valid customer outage cost surveys have treated the results of these surveys as proprietary and confidential and as a result it has been impossible to assemble a comprehensive analysis of customer outage costs on a regional or nationwide basis.

However, in a recent study conducted for Lawrence Berkeley National Laboratory by Freeman, Sullivan & Co., data from 24 available outage cost studies were combined into a single meta-dataset describing customer outage costs across time and the geography of the United States. This research was possible largely because the data from the 24 studies were originally collected using a common methodology, described in Sullivan and Keane's (1995) Outage Cost Estimation Guidebook. Results from this research include customer damage functions using multiple regression (Tobit) models for estimating outage costs controlling for a variety of variables commonly available in existing VOS study datasets (e.g., customer class, region, outage duration, business type and size for nonresidential customers). These statistical models can be used to predict outage costs for outages of varying durations for representative customers in different geographic regions and customer classes. PG&E did not participate in the development of the meta-dataset, but information is available in this dataset from other California utilities.

1.4 Issues for 2005 PG&E VOS Study

PG&E's last outage cost study was published more than a decade ago, in 1993, long before California's experience with a restructured energy market and the resulting "energy crisis" in 2000-2001. Regulatory and utility decision-makers rely on having current outage cost information in order to determine ratepayers' willingness to pay for increased reliability. To serve this purpose effectively, the PG&E VOS estimates must be updated -- especially in light of changes in the California market. A key issue for the 2005 PG&E VOS study is whether, and by how much, outage costs and the commensurate value of service reliability has changed for PG&E customers since 1993 (beyond standard adjustments for population and Consumer Price Index (CPI)).

The 24-study meta-analysis of VOS research described in the last section can serve as a rich source of information to augment PG&E's 2005 VOS study in order to address these and other relevant questions. By integrating customer outage cost information from PG&E's prior interruption cost surveys with the other datasets available from the California market, we will be able to develop a highly robust description of customer value of service prior to the year 2000 for all of California and PG&E customers in particular. This will provide a highly reliable basis of comparison for evaluating the changes that have occurred in customer value of service since the year 2000. Moreover, information from the meta-data base can be used to develop preliminary estimates of outage costs to identify the range of probable results that will be obtained from the 2005 PG&E VOS customer surveys. This information can be used to identify areas where adjustments to sampling or data collection strategies for the current study would be beneficial. The pattern of results can also indicate where opportunities exist for minimizing the complexity and/or number of outage scenarios that need to be tested in the field. Doing so reduces confusion and burden for survey respondents -- crucial considerations for obtaining valid VOS results.

1.5 2005 PG&E VOS Study Approach

With these issues in mind, we propose the following steps for conducting PG&E's 2005 VOS study. First, historical data from PG&E's prior VOS studies will be combined with the VOS meta-analysis dataset (described above). The resulting dataset will be analyzed and a PG&E-specific forecast of outage costs will be projected for 2005. These estimates will be developed by customer class, under several outage scenarios and controlling for a variety of customer and environmental attributes. This information will be used to fine-tune sampling strategies and data collection instruments for the 2005 PG&E VOS, in order to target project resources most effectively for the current study. Later, the actual customer responses collected during the 2005 PG&E VOS will be added to the model to identify the extent of change that has occurred in customer outage costs since the last time these measurements were taken

Customer outage cost surveys for the 2005 PG&E VOS will be developed separately for four customer segments: residential, small/medium commercial/industrial, large commercial/industrial and agricultural. Data collection instruments and approaches will be tailored specifically for each customer segment. Customers' direct cost estimates and/or willingness to pay for increased service reliability will be assessed through a combination of mail and telephone surveys, with in-person interviews for large nonresidential customers. The outage cost estimates will be collected for outage scenarios that vary in terms of duration, advance notice and environmental conditions including season, day of week, time of day and presence of backup generation. Customers will also be asked a battery of choice questions designed to measure their preferences among trade-offs between changes in overall reliability levels and rates. Information regarding each customer's demographic or firmographic characteristics such as family size, business type and size, location, number of employees and presence of medical equipment and back-up generators will be recorded. The research approach and data collection strategies for each segment are presented in Table 1—1 below.

Table 1-1: Proposed Data Collection Approach for 2005 PG&E VOS Study

	Sample size	Data Collection Approach	Valuation Method
Residential	1,000	Mail	Direct Cost & Willingness to Pay
Small/Med C&I	800	Telephone recruit, Mail	Direct Cost & Willingness to Pay
Large C&I	150	Telephone recruit, In-person Interview	Direct Cost
Agricultural	400	Telephone recruit, Mail	Direct Cost & Willingness to Pay

These data will be compiled and analyzed to produce outage cost estimates by customer segment. These estimates results will be reported both separately by segment, and combined and scaled to represent system-wide figures. Outage cost results for each scenario will be presented using a variety of metrics such as total average cost per event, per kWh of unserved electricity, and as a function of customer usage. Results will be developed and presented in two basic formats: (1) summary (bi-variate) analysis tables and (2) customer damage functions in the form of multiple regression (Tobit) equations of the kind described in (cite DOE study).

Finally, results from the 2005 surveys will be compared with projections of 2005 customer outage costs and customer damage functions obtained in the initial modeling effort.

1.6 Scope of Work

FSC will perform the study pursuant to the research objectives discussed above and the detailed tasks and deliverables described in this section. FSC is proposing to conduct the following tasks as part of the 2005 PG&E's VOS study:

Task 1: Meta-Analysis of Prior PG&E Outage Cost Data.
Task 2: Outage Scenario Development
Task 3: Residential Outage Costs Estimation
Task 4: Small/Medium Commercial and Industrial Outage Costs Estimation
Task 5: Large Commercial and Industrial Outage Costs Estimation
Task 6: Agricultural Outage Costs Data Estimation
Task 7: Customer Segment Specific and System-wide Outage Cost Estimation
Task 8: Project Management and Reporting

Each of these tasks is described in detail in the next section.

2. Scope of Work

2.1 Task 1: Meta-Analysis of Prior PG&E Outage Cost Data.

In 2003 and 2004, FSC combined the results of 24 customer interruption cost studies carried out in the US between 1987 and 2002 into a single meta-data set. The dataset contains the responses of over 8,700 residences and businesses to various outage scenarios observed over a 15 year period in utilities in most regions of the US. From this dataset a general set of customer damage functions was estimated expressing interruption cost as a function of interruption duration for different types of customers in locations around the US. PG&E was not one of the participants in this study.

The first step in the 2005 PG&E VOS will be to develop an estimate of current outage costs for PG&E customers using the predictive statistical models developed by FSC in the meta-analysis of VOS studies described above.[1] Data from PG&E's prior VOS studies (conducted from 1987 though 1993) will be combined with data from the other outage cost studies used in the meta-analysis; and the models will e re-estimated. The objective will be to develop detailed customer damage functions for PG&E customers in 2005 based on the trends in interruption costs that have been observed over the past 15 years. The models can be estimated for California utilities only. The results of this forecast will enable us to better tailor the overall approach and data collection strategies for the 2005 PG&E VOS study to address issues specific to PG&E customers and service territory and to target project resources most effectively.

Steps:
1. Prepare detailed data request to PG&E
2. Obtain datasets, codebooks and original survey instruments from prior VOS studies
3. Standardize the form of these data to match the structure and common metrics used in the meta-analysis datasets (e.g., outages are described in terms of minutes rather than hours or days)
4. Review and clean historical PG&E data.
5. Merge the PG&E datasets with the main meta-database.
6. Normalize outage costs to 2005 dollars
7. Re-estimate Tobit regression models with inclusion of PG&E VOS data
8. Report projected outage cost results separately for PG&E customers vs. the overall dataset or other breakout attributes

Task 1 Deliverables:
- Preliminary 2005 outage cost forecasts for PG&E customers, by customer segment, in current dollars
  - Due: March 15, 2005
- Recommended scenario combinations for 2005 VOS
  - Due: March 15, 2005

Task 1 Budget
$37,800

---

[1] A Framework and Review of Customer Outage Costs: Integration and Analysis of Electric Utility Outage Cost Surveys; Lawton Leora , M. Sullivan, K. Van Liere, A. Katz and J. Eto, 2003; LBNL-54365

2.2 *Task 2: Outage Scenario Development*

The second task for the study will be to develop a set of outage scenarios that will be used in the research. Recruited respondents from all customer classes will be presented with descriptions of different outage scenarios and asked to estimate the direct costs that would result from such an outage and/or their willingness to pay to avoid the event. The scenarios will vary with respect to several characteristics of the hypothetical outage. An example demonstrating common outage scenario attributes is presented in Table 2—1.

Table 2-1: Attributes for Outage Scenarios -- Example

Outage Attribute	Scenario Dimensions
Duration	Momentary, 1 hour, 4 hour
Season	Summer, Winter
Time of day	Daytime, Evening, Night
Day of week	Weekday, Weekend
Advanced notice	1 hour notice, no notice

The dimensions described in Table 2—1 yield 72 possible permutations describing different outage cost scenarios. It is practically impossible to collect responses to all of the above permutations from all respondents because the respondent burden in such a study is too high. Some of the above combinations may be eliminated in consultation with PG&E and other interested parties because they are not necessary. For example, it may be that there is no need to develop specific outage cost estimates for off-peak hours; or that weekend outage costs are irrelevant for utility planning purposes. It may also be appropriate to add specific outage combinations that are not reflected in Table Two to answer specific issues (e.g., severe storm related outages lasting 24 or more hours). The appropriate minimum subset of outage scenarios will be chosen in consultation with PG&E. If the number of scenarios chosen for analysis exceeds the number that individual respondents can complete, the sample populations will be partitioned and respondents will be given randomly chosen subsets of the scenarios of interest to allow estimation of all of the needed outage costs.

The design of the final questionnaire booklet will vary between customer segments to address specific issues for each customer type. Respondents will be instructed to assess the costs they would incur for a specific site during an outage (and/or willingness to pay for avoiding the outage event). For residential customers and small to medium nonresidential customers, this essentially means a dwelling – the site of their home or business. However, establishing a consistent definition of "the site" can become more complicated with larger customers whose premise may contain several buildings or accounts, and with agricultural customers whose site often includes dispersed buildings and pumps that may not be metered consistently. However, descriptions of the outage scenarios selected for study will be held constant across all segments to allow for comparison and aggregation of outage cost results in the final analysis.

Virtually all of the combinations of outage conditions that will be included in the study have been used in prior outage cost surveys by PG&E and others. We will employ specific scenario descriptions that have been used in the past and have been demonstrated to be valid and understandable by utility customers.

Steps:
1. Meet with PG&E to discuss appropriate scenarios for study
2. Select outage scenarios for use in the study
3. Prepare scenario descriptions

Task 2 Deliverable:
- Outage scenario descriptions
  - Due: April 1 , 2005

Task 2 Budget
$21,600

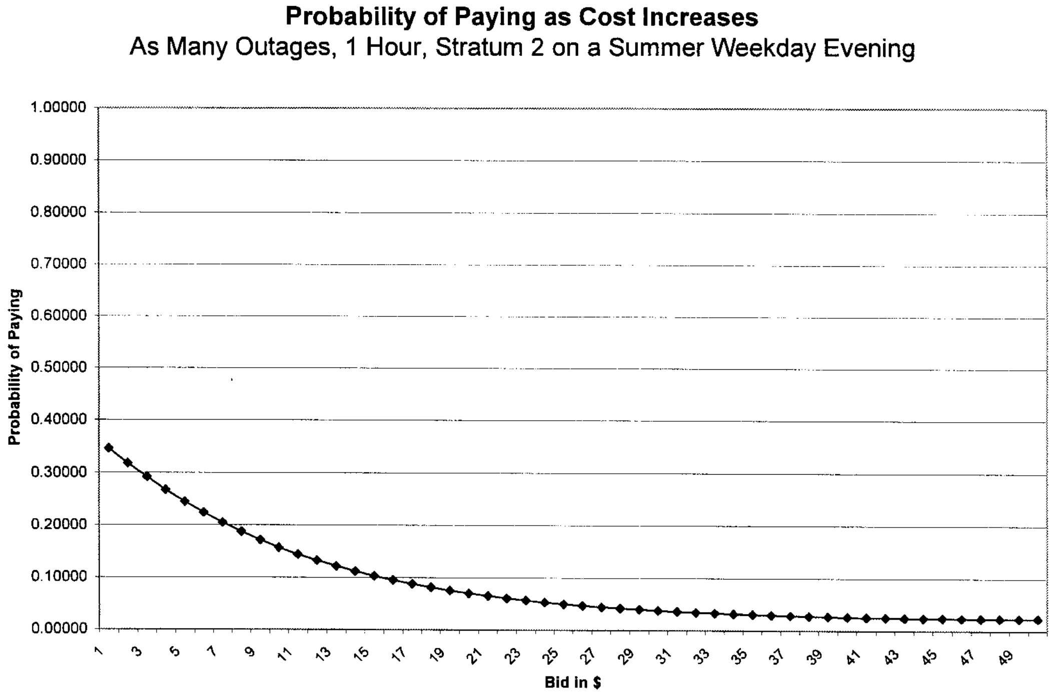
2.3 Task 3: Residential Outage Costs Estimation

Historically PG&E has used various approaches to estimating customer interruption costs for residential customers. In 1986, it used direct worth and willingness to pay measurements. The willingness to pay questions was open-ended. In 1993, both measures were used again, but the open-ended questions were replaced with response scales ranging from $0 to an upper limit that varied by outage scenario.

Since 1993, a more reliable willingness to pay measurement technique has been developed which involves the use of a single bounded consumer choice experiment carried out on a stratified random sample of residential customers. Using this approach each sampled customer is asked to indicate whether they would pay a given (randomly assigned) amount to avoid an outage of the kind described in a given scenario. Each customer is asked to respond to 4 or 5 scenarios. The offered prices are varied randomly over customers and scenarios in such a way as to allow estimation of the fraction of customers who will pay to avoid a given outage scenario at a given price. Sufficiently large numbers of customers are asked their willingness to pay to avoid each outage scenario to allow relatively precise estimates (i.e., to within plus or minus 10%). The figure below shows an example of the outcome of a consumer choice experiment in which residential customers were asked their willingness to pay (randomly chosen amounts) to avoid a one hour outage on a summer weekday evening.

We recommend using a combination of the direct worth and consumer choice experiment for the 2005 PG&E VOS to preserve continuity with prior measurements and to obtain the most valid measurements of customer willingness to pay available today. An example of the format we propose (without the direct worth component) is found in Appendix A—Example 1.

Figure 2-1 Probability of Paying as Cost Increases



In the proposed outage cost survey, residential customers will receive packages containing:

- A letter explaining the purpose of the research
- Clear and easy-to-understand instructions for completing the survey questions
- A telephone number they can call if they have questions about the research or wish to verify its authenticity
- The survey booklet
- Return envelope with pre-paid postage

Sample design

There are two sample design issues in the proposed residential VOS survey. The first is the sample design used to select customers for study. For this sampling effort we propose to select a simple random sample of customers sufficiently large to provide for 1,000 completed surveys. These customers will be sampled from PG&E's customer information system.

The second sample design problem involves development of a balanced experimental design for distributing the "bid" prices across the groups of customers that experience each scenario. This is called the "Bid Design". The Bid Design is chosen in such a way as to ensure that sufficient consumer choices are offered in each scenario to allow for estimation of the interruption costs. An example of a Bid Design in also found in Appendix A.

Survey Procedures

The survey will be carried out in the mail and will be distributed to the target respondents in three waves. In the first wave respondents will receive a cover letter on PG&E stationary explaining the purpose of the study and requesting their participation. The first wave will also contain a copy of the survey form along with an explanation of how to complete it. Ten days after the first wave has been mailed, all respondent will be sent a reminder postcard. Ten working days later, all respondents who have not returned their surveys will be sent a second letter and survey form reminding them of the importance of the survey and requesting that they complete it and send it back as soon as possible.

An incentive of $10 will be mailed to participants who return the completed survey form.

The survey packets will include an 800 number that respondents can call to verify the legitimacy of the survey and ask any questions they may have. The 800 number will be staffed during business hours on the West Coast with a live operator and an answering machine will be available during non-business hours.

Steps:
1. Develop Survey forms and correspondence
2. Sample customers and finalize Bid Design
3. Print custom surveys containing randomized bids
4. Distribute Wave One
5. Distribute Wave Two
6. Distribute Wave Three
7. Clean and digitize returned forms
8. Analyze and summarize customer interruption costs

Task 3 Deliverables:
- Survey instruments and materials
  - Due: April 1, 2005
- Clean survey datasets
  - Due: July 15, 2005
- Analysis of residential customer interruption costs
  - Aug 1, 2005

Task 3 Budget
$91,800

2.4 Task 4: Small/Medium Commercial and Industrial Outage Costs Estimation

Most studies of commercial and industrial value of service have focused entirely on measuring the direct worth of interruption cost experienced by these customers. That is, they have not attempted to measure customer willingness to pay for service reliability. The reasons for this decision were discussed in detail in the Outage Cost Estimation Guidebook by Sullivan and Keane in 1995. However, the Commission has specifically instructed PG&E to measure customer willingness to pay for service reliability for all customers in this case. To comply with this order, we will have to develop valid survey measurements of customer willingness to pay for commercial and industrial customers.

Therefore, the approach we recommend for the small/medium segment is similar to the method described above for residential customers. We propose to use a combination of the direct worth and consumer choice valuation methods. This will preserve continuity with prior measurements for purposes of comparison with earlier research, and provide the willingness to pay measurements required by the commission.. Survey instruments for two types of customers will be developed. Our experience suggests that customers with businesses that "produce" output have a different valuation function than customers who primarily provide services. The proposed research will be designed to reflect that difference. Examples of business that produce output include not only manufacturing companies, but, conceptually, any businesses that generate revenue via throughput. For example, retail stores generate revenue in terms that can be expressed as sales/hour. Businesses or organizations like schools, on the other hand, do not count on average hourly production as their primary source of funding, so they experience outage costs differently. An example of the survey format we propose to begin with (without the willingness to pay component) is found in Appendix A — Example 2.

In the research design we are suggesting, small and medium commercial and industrial customers will first be recruited by telephone to ensure that we have identified the appropriate individual to answer questions related to energy and outage issues for that company and to secure a verbal agreement from them to complete the survey. Telephone interviewers will explain the purpose of the survey and mention that an incentive will be provided to thank the respondent for their time. The individual will then be mailed a package containing:

- A letter re-explaining the purpose of the research
- Clear and easy-to-understand instructions for completing the survey questions
- A telephone number they can call if they have questions about the research or wish to verify its authenticity
- The survey booklet
- Return envelope with pre-paid postage

Sample design

For this sampling effort we propose to select a random sample of customers sufficiently large to provide for 800 completed surveys. These customers' contact information will be sampled from PG&E's customer information system, by rate class to distinguish small from medium-sized accounts. To efficiently sample from the population of small and medium commercial and industrial customers we propose to stratify the sample into 5 usage categories optimally defined using the Delanius-Hodges technique for identifying optimal stratum boundaries. We will be sampling small and medium commercial and industrial sites within size categories. Using this technique, we will be able to measure the average customer outage costs for outages of 4 hour's duration to within plus or minus 20%. The sample may also be stratified to provide statistically reliable outage cost estimates that can be characterized by attributes such as geography, business type, and by to address topics of interest that may include transmission congestion, regions with historically high outage frequencies or business types known to experience high outage costs. The sampling plan will also entail development of a Bid Design to elicit the willingness to pay valuations, as described above for residential sectors, but tailored to the needs and cost ranges best suited to small/medium nonresidential customers.

Survey Procedures

The survey will be carried out in the mail following recruitment of assigned respondents by telephone and will be distributed to the target respondents in three waves. In the first wave respondents will receive a cover letter on PG&E stationary explaining the purpose of the study and requesting their participation. The first wave will also contain a copy of the survey form along with an explanation of how to complete it. Ten days after the first wave has been mailed, all respondent will be sent a reminder postcard. Ten working days later, all respondents who have not returned their surveys will be sent a second letter and survey form reminding them of the importance of the survey and requesting that they complete it and send it back as soon as possible.

An incentive of $50 will be mailed to participants who return the completed survey form.

The survey packets will include an 800 number that respondents can call to verify the legitimacy of the survey and ask any questions they may have. The 800 number will be staffed during business hours on the West Coast with a live operator and an answering machine will be available during non-business hours.

Steps:
1. Develop valid willingness to pay questions
2. Develop Survey forms and correspondence
3. Sample customers and finalize Bid Design
4. Print custom surveys containing randomized bids
5. Distribute Wave One
6. Distribute Wave Two
7. Distribute Wave Three
8. Clean and digitize returned forms
9. Analyze and summarize customer interruption costs

Task 4 Deliverables:
- Survey instruments and materials
  - Due: April 1, 2005
- Clean survey datasets
  - Due: July 1, 2005
- Analysis of small/medium Commercial and Industrial customer interruption costs
  - Due: August 1, 2005

Task 4 Budget
$97,200

2.5 *Task 5: Large Commercial and Industrial Outage Cost Estimation*

FSC has conducted Large Commercial and Industrial VOS studies for a number of years and has developed a well defined process for carrying them out. For purposes of this research, Large C&I customers are those with on-peak annual demand in excess of 1 MW. Typically, Large C&I customers operate businesses that are relatively complex, often with many buildings at a site and facilities sometimes served by multiple accounts and even multiple service drops. To sort out the details of the complex situations it is necessary to conduct interruption cost surveys of these customers using a highly trained interviewer on site.

FSC proposes to survey 150 Large C&I customers using a two-stage process in which an experienced telephone recruiter first locates and recruits an appropriate representative at each of the sampled locations. Normally, the target respondent is a plant manager or plant engineering manager – someone who is highly familiar with the cost structure of the enterprise. The recruiter first identifies the target respondent by calling the name of the company representative provided by PG&E (if available). Otherwise the recruiter will cold call into the plant manager's office to get started. In some cases, it has been helpful for the utility's representative to advance the call to his contact at the site, but this not necessary.

Once the target respondent is located, the telephone recruiter faxes or emails them a written description of the study and explanation of what they are being asked to do. The recruiter calls back within the next couple of days to try to set up an appointment for the field interviewer. The interview is scheduled at the convenience of the target respondent and a financial incentive of $100 is offered for completion of the information.

On the agreed upon date FSC's field interviewer visits the sampled site and conducts the in-person interview. FSC has developed a widely used survey instrument for carrying out these in-person interviews. The survey form concentrates on obtaining detailed measurements of the direct worth of 5 different outage scenarios. An example of this interview schedule and interviewer's guide are found in Appendix A — Example 4.

We propose to modify the interview forms and procedures as outlined in Appendix C for use in the 2005 PG&E VOS. As was the case with small and medium commercial and industrial customers it will be necessary to develop willingness to pay measurement protocols for large customers.

Sample Design

Outage costs are correlated with customer energy usage for industrial customers – to some extent. To efficiently sample from the population of Large Commercial and Industrial customers we propose to stratify the sample into 5 usage categories optimally defined using the Delanius-Hodges technique for identifying optimal stratum boundaries. We will be sampling commercial and industrial sites within size categories. Using this technique, we will be able to measure the average customer outage costs for outages of 4 hour's duration to within plus or minus 20%.

Steps:

1. Develop appropriate willingness to pay measurement protocols
2. Finalize survey forms and correspondence
3. Design Sample
4. Select Sample
5. Recruit and interview target respondents
6. Clean and digitize completed forms
7. Obtain and analyze usage and demand data for Large C&I customers
8. Analyze and summarize customer interruption costs

Task 5 Deliverables:

- Survey instruments and materials
  - Due: April 1, 2005
- Clean survey datasets
  - Due: July 1, 2005
- Analysis of large Commercial and Industrial customer interruption costs
  - Due: August 1, 2005

Task 5 Budget
$113,400

2.6 *Task 6: Agricultural Outage Cost Estimation*

Methods for establishing outage cost estimates for agricultural customers are similar to those used for the small commercial and industrial segment. As with the small/medium customers, we propose to use a combination of the direct worth and consumer choice valuation methods. However, agricultural businesses differ from other nonresidential customers in a number of dimensions that require differential treatment in the content and design of the survey instruments. It is important to distinguish the agricultural customers from other nonresidential customers because previous research indicates that their operating processes can produce interruption costs that are significantly lower than those of other business customers. The bulk of electricity used by this sector is for pumping to water crops. An outage that affects pumping for an hour or a few hours has negligible adverse economic affect – it is a relatively simple matter to make up for the lost watering time. As a result, these customers willingness to pay for reliability improvements also is thought to be lower on average than other nonresidential customer classes. Pumping is the largest, but not the only end use of significance in the agricultural sector. These customers also use energy for other uses such as refrigeration, lighting and motors. Service interruptions are more likely to affect these activities, and tend to drive outage costs for customers using these technologies higher.

A second issue that bears attention for agricultural customers is defining the scope of the "site" respondents should have in mind when evaluating the outage cost scenarios. For residential and small commercial/industrial customers, defining the term "site" for the purpose of outage cost research is reasonably straightforward – it is usually a building or dwelling. Large customers' and agricultural customers' "site" tend to cover larger physical areas and typically are served by more than one meter and/or account. Obtaining clean outage estimates from agricultural customers given these issues requires preparing a distinct and carefully crafted set of instructions and questions. An example of the survey format we intend to use (without the direct worth feature) is found in Appendix A – Example 3.

As with the small/medium commercial and industrial segment, agricultural customers will first be recruited by telephone to ensure that we have identified the appropriate individual to answer questions related to energy and outage issues for that business and to secure a verbal agreement from them to complete the survey. Telephone interviewers will explain the purpose of the survey and mention that an incentive will be provided to thank the respondent for their time. The individual will then be mailed a package containing:

- A letter re-explaining the purpose of the research.
- Clear and easy-to-understand instructions for completing the survey questions.
- A telephone number they can call if they have questions about the research or wish to verify its authenticity.
- The survey booklet.
- Return envelope with pre-paid postage.
- An incentive to encourage participation and thank respondents for their time.

Sample design

For this sampling effort we propose to select a simple random sample of customers sufficiently large to provide for 400 completed surveys. These customers' contact information will be sampled from PG&E's customer information system.. The sample will be stratified to provide statistically reliable outage cost estimates that can be characterized by attributes such as customer size, geography, and to address other topics of importance. The sampling plan will also entail development of a Bid Design to elicit the willingness to pay valuations, as described previously, but tailored to the needs and cost ranges best suited to the agricultural segment.

Survey Procedures

The survey will be carried out in the mail following recruitment of assigned respondents by telephone and will be distributed to the target respondents in three waves. In the first wave respondents will receive a cover letter on PG&E stationary explaining the purpose of the study and requesting their participation. The first wave will also contain a copy of the survey form along with an explanation of how to complete it. Ten days after the first wave has been mailed, all respondent will be sent a reminder postcard. Ten working days later, all respondents who have not returned their surveys will be sent a second letter and survey form reminding them of the importance of the survey and requesting that they complete it and send it back as soon as possible.

An incentive of $50 will be mailed to participants who return the completed survey form.

The survey packets will include an 800 number that respondents can call to verify the legitimacy of the survey and ask any questions they may have. The 800 number will be staffed during business hours on the West Coast with a live operator and an answering machine will be available during non-business hours.

Steps:
1. Develop Survey forms and correspondence
2. Sample customers and finalize Bid Design
3. Print custom surveys containing randomized bids
4. Distribute Wave One
5. Distribute Wave Two
6. Distribute Wave Three
7. Clean and digitize returned forms
8. Analyze and summarize customer interruption costs

Task 6 Deliverables
- Survey instruments and materials
  - Due: April 1, 2005
- Clean survey datasets
  - Due: July 1, 2005
- Analysis of agricultural customer interruption costs
  - Due: August 1, 2005

Task 6 Budget
$81,000

2.7 Task 7: Systemwide Outage Cost Estimation

Data will be compiled and analyzed to produce outage cost estimates by customer segment. The results will be reported both separately by segment, and combined and scaled to represent systemwide figures.

Outage cost results for each scenario will be presented using a variety of metrics including total average cost per event, per kWh of unserved electricity, and as a function of customer characteristics.

Results will be developed and presented in two basic formats: (1) summary (bi-variate) analysis tables for various scenario factors and customer demographics, and (2) customer damage functions using multiple regression (Tobit) models to estimate customer damage functions controlling for different outage characteristics and customer attributes.

Task 7 Deliverables
- Systemwide outage cost estimation report
  - Due: August 1, 2005

Task 7 Budget
$54,000

2.8 *Task 8: Project Management and Reporting*

Project Initiation

FSC will hold a project initiation meeting at a time place to be determined by the PG&E Project Manager. The meeting will include the FSC team, the PG&E Project Manager and other staff and stakeholders per the request of the PG&E Project Manager. The purpose of the project initiation meeting will be to refine the research objectives, project design, study issues, data requirements, final reports, and other issues.

Research Plan

Based on the discussion during the project initiation meeting, FSC will prepare a detailed research plan for review and approval by the PG&E Project Manager. The research plan will describe the study research methodology in detail, refining the method and approaches outlined in the initial proposal. FSC will deliver a draft research plan to the PG&E Project Manager. FSC will incorporate comments requested by the PG&E Project Manager into a final research plan and deliver the final research plan to the PG&E Project Manager.

The research plan will contain, at a minimum, the following sections:
- Introduction and key issues
- Description of study requirements
- Detailed workplan and schedule
- Project management plan
- Budget allocation
- Detailed specification of final deliverables.

Reporting and Electronic Databases

Following data collection and analysis, FSC will prepare a draft report for review and approval by the PG&E Project Manager. The final report will contain, at a minimum, the following sections:
- Executive Summary.
- Background and Introduction
- Methodology
- VOS Analysis Results By Customer Segment and Systemwide
    - Residential
    - Small/Medium Commercial/Industrial
    - Large Commercial/Industrial
    - Agricultural
- Systemwide
- Recommendations
- Appendices
- Electronic datasets and documentation

Project Management

On an agreed-upon time and day, the FSC Project Manager will have a bi-weekly conference telephone call with the PG&E Project Manager. The status of the research and other pending issues will be discussed.

Task 8 Deliverables

- Conduct project initiation meeting
  - Due: February 1, 2005
- Draft Research Plan
  - Due: February 15 , 2005
- Final Research Plan
  - Due: March 1, 2005
- Draft Report
  - Due: August 15, 2005
- Final Report
  - Due: September 1, 2005
- Electronic datasets and documentation
  - Due: September 1, 2005
- Bi-weekly project management telephone calls
  - Due: Ongoing

Task 8 Budget
$43,200

2.9 *Project Schedule*

Table 2-2: Project Schedule

Task	Deliverables
Task 1: Meta-Analysis of Prior PG&E Outage Cost Data.	♦ Preliminary 2005 outage cost forecasts for PG&E customers, by customer segment, in current dollars o Due: March 15, 2005 ♦ Recommended scenario combinations for 2005 VOS o Due: March 15, 2005
Task 2: Outage Scenario Development	♦ Outage scenario descriptions o Due: April 1 , 2005
Task 3: Residential Outage Costs Estimation	♦ Survey instruments and materials o Due: April 1, 2005 ♦ Clean survey datasets o Due: July 15, 2005 ♦ Analysis of residential customer interruption costs o Aug 1, 2005
Task 4: Small/Medium Commercial and Industrial Outage Costs Estimation	♦ Survey instruments and materials o Due: April 1, 2005 ♦ Clean survey datasets o Due: July 1, 2005 ♦ Analysis of small/medium Commercial and Industrial customer interruption costs o Due: August 1, 2005
Task 5: Large Commercial and Industrial Outage Costs Estimation	♦ Survey instruments and materials o Due: April 1, 2005 ♦ Clean survey datasets o Due: July 1, 2005 ♦ Analysis of large Commercial and Industrial customer interruption costs o Due: August 1, 2005
Task 6: Agricultural Outage Costs Data Estimation	♦ Survey instruments and materials o Due: April 1, 2005 ♦ Clean survey datasets o Due: July 1, 2005 ♦ Analysis of agricultural customer interruption costs o Due: August 1, 2005
Task 7: Customer Segment Specific and System-wide Outage Cost Estimation	♦ Systemwide outage cost estimation report o Due: August 1, 2005
Task 8: Project Management and Reporting	♦ Conduct project initiation meeting o Due: February 1, 2005 ♦ Draft Research Plan o Due: February 15 , 2005 ♦ Final Research Plan o Due: March 1, 2005 ♦ Draft Report o Due: August 15, 2005 ♦ Final Report o Due: September 1, 2005 ♦ Electronic datasets and documentation o Due: September 1, 2005 ♦ Bi-weekly project management telephone calls o Due: Ongoing

2.10 Budget Summary

Table 2-3: Budget Summary

Task Number	Amount
Task 1: Meta-Analysis of Prior PG&E Outage Cost Data.	$37,800
Task 2: Outage Scenario Development	$21,600
Task 3: Residential Outage Costs Estimation	$91,800
Task 4: Small/Medium Commercial and Industrial Outage Costs Estimation	$97,200
Task 5: Large Commercial and Industrial Outage Costs Estimation	$113,400
Task 6: Agricultural Outage Costs Data Estimation	$81,000
Task 7: Customer Segment Specific and System-wide Outage Cost Estimation	$54,000
Task 8: Project Management and Reporting	$43,200
Budget Total	**$540,000**

3. Project Team and Firm Qualifications

3.1 Project Team

The FSC project team will be lead by the premiere experts in outage cost and value of service research for electric and gas utilities nationally. This section introduces the senior staff responsible for completing all phases of the proposed research. Full resumes for each team member are included in Section 4.

Michael J. Sullivan, Ph.D., Principal, Freeman, Sullivan & Co. Dr. Sullivan is a nationally recognized authority in statistical analysis of utility data and program evaluation. He also has extensive experience as an expert witness on issues of statistical analysis and economic models of future liability and risk. He has published a number of works regarding customer response to service reliability issues and directed 23 customer outage cost surveys for various utilities in the United States for utilities including: Pacific Gas and Electric, SEMPRA Energy, SMUD, Puget Sound Energy, Duke Energy, Southern Company, Salt River Project, Cinergy and MidAmerican Power. He has testified before the California Public Utilities Commission on a number of topics including interruption cost survey estimates used by PG&E to establish marginal generation capacity costs for its 1996 General Rate Case. Dr. Sullivan completed his doctoral studies at Washington State University specializing in research methods and statistics.

Dr. Kent Van Liere, Senior Consultant, Freeman Sullivan & Co. Dr. Van Liere is a nationally recognized authority in the application of advanced statistical and survey methodologies to inform and support the measurement of customer, economic, and behavioral issues in the energy and natural resource fields. He is widely published in the areas of customer service reliability, as well as the economic measurement of value of service, and has conducted numerous outage cost studies, including several for PG&E. Dr. Van Liere completed his doctoral studies at Washington State University specializing in research methods and statistics.

Dr. Chris Ann Dickerson, Senior Consultant, Freeman, Sullivan & Co. Dr. Dickerson recently joined Freeman, Sullivan & Co. after serving as a project manager for nearly ten years in Pacific Gas & Electric Company's (PG&E) Customer Energy Efficiency Evaluation & Policy group and Demand-Side Resources Integrated Resource Policy group. Dr. Dickerson has managed numerous statewide and utility-specific research projects on topics including program impact and process evaluations, customer satisfaction, measure retention, market assessment, cost-effectiveness and risk management. Dr. Dickerson's PhD dissertation focused on cross-methodological comparisons between willingness-to-pay and willingness-to-accept valuation techniques commonly employed in outage cost estimation research. Her doctoral degree is from the University of California, in public policy with a focus on research methods and environmental economics.

Dr. Katrin Ewald, Director of Population Research Systems, A subsidiary of Freeman, Sullivan & Co. Dr. Ewald specializes in program outcome evaluation and quantitative data collection. Dr. Ewald manages all aspects of field, phone, mail and web based survey projects, including panel and longitudinal projects in a wide variety of fields including energy, air-quality, healthcare and education. A number of recent projects have focused on energy markets and programs, market barriers, and on assessing customer satisfaction with the programs. Recent research includes several telephone surveys for New York State Energy Research and Development Authority (NYSERDA). Dr. Ewald completed her PhD in Psychology at the University of Bielefeld.

The following section will detail specific firm qualifications related to outage cost estimation and value of service projects.

3.2 Project Descriptions

Outage Cost Estimation Guidebook
Electric Power Research Institute, System Planning Division, Palo Alto, CA
Dr. Michael Sullivan of FSC prepared a detailed technical report for EPRI summarizing the state of the art in engineering and economics concerning the application of value based reliability planning techniques to generation, transmission and distribution planning. The report described state of the art procedures for analyzing the costs and benefits of investments designed to achieve reliability and power quality improvements on electric systems. The report sold out within two months of its initial publication and is now in its fifth printing.

Circuit Level Outage Cost Estimation Project
Duke Power Company, Charlotte, NC, and Electric Power Research Institute, Palo Alto CA
Customer outage costs were estimated by FSC for all transmission customers and for each of the approximately 1,900 distribution circuits in the Duke Power service territory. FSC developed a statistical model for estimating circuit level outage costs using information it collected during a prior survey of Duke Power's customer outage costs. In addition to estimates of potential outage costs for all circuits, the project estimated actual outage costs experienced on circuits within one of Duke Power's planning regions to quantify the financial impacts (i.e., costs and savings to utility and customers) from adopting value based reliability planning criteria in distribution planning. Results of this effort were published by EPRI summarizing best current practices in value based reliability planning.

National Electric Customer Outage Cost Study
Lawrence-Berkeley Laboratories and the US Department of Energy.
FSC assembled the data from customer interruption cost surveys that had been conducted in various locations across the country since 1987 creating meta-data sets describing customer interruption costs for residential, small-medium commercial & industrial, and large commercial and industrial customers over time and geographical location within the continental United States. Using these databases, FSC developed general customer damage functions expressing customer damages as a function of outage type, duration, onset time, date of week and season as well as customer characteristics such as size, number of employees, and geographical location. Results

were presented to the US Department of Energy Task Force on Transmission Reliability and published by LBNL.

Customer Interruption Cost Study
Salt River Project, Phoenix, AZ
In this study FSC collected and summarized information from SRP's commercial and residential customers regarding outage interruption cost and willingness to pay to avoid outage consequences. Customer damage functions were estimated for all major customer classes. In the course of the work FSC demonstrated the application of value based reliability planning techniques to the evaluation of a number of distribution and planning decision making problems.

Customer Value of Service Study
Duke Power Company, System Planning Department, Charlotte, NC
Duke Power Company uses customer interruption costs in a number of reliability planning applications to represent the economic benefits obtained from decision alternatives. They revise these estimates every 5 years to ensure that parameters used in planning are accurate. FSC surveyed residential and small and medium sized commercial and industrial customers of Duke Power Company to update Duke Power's interruption costs in 1992 and 1997 and assisted in developing non-survey based interruption cost survey estimates in 2003.

Agricultural Value of Service
Pacific Gas and Electric Company, Rates Department, San Francisco, CA
FSC was responsible for overall project management of PG&E's Agricultural Value of Service Study. The study was used to determine outage costs of agricultural customers throughout PG&E's service area. The survey involved combined telephone and mail surveys of over 1,250 agricultural customers throughout Northern California.

Industrial Value of Service Study
Pacific Gas and Electric Company, Rates Department, San Francisco, CA
FSC was responsible for overall project management of PG&E's Large Industrial and Commercial Value of Service Study (LICVOS). This study included a survey of 600 of PG&E's largest customers. The objective of the survey was to measure the costs customers experienced during electric outages, and identify their actions in response to them. The survey involved an initial telephone contact designed to identify the person in the customer's organization most familiar with the financial impacts of electric outages, and a one-hour in-person interview in which detailed outage cost information was collected.

Large Commercial and Industrial Value of Service Study
Duke Power Company, Charlotte, NC
The purpose of this project was to develop interruption cost survey instruments and procedures to be used by Duke Power's marketing representatives in surveying their largest and most important customers. FSC provided a training seminar for the marketing representatives to calculate customer interruption costs from information provided on the survey. FSC attempted to reconcile the results obtained by Duke's marketing representatives in the 1997 survey with those obtained by FSC's interviewers in 1992.

Sensitive Customer Value of Service Study

Southern Company Services, Birmingham, AL
FSC developed and implemented an on-site survey of the costs its customers experience as a result of power quality and reliability problems and their willingness to pay for service improvements and equipment that would lower these costs. In the first stage of the project, 50 customers using six highly sensitive manufacturing processes were surveyed. In the second stage of the project, additional survey interviews will be carried out to refine the measurements that are taken in Stage 1 and expand the number of processes under study.

Value of Service Study
Duke Power Company, Customer Studies Dept, Charlotte, NC & Electric Power Research Institute, Palo Alto, CA
This two-year study, jointly funded by Duke Power and the Electric Power Research Institute, supported Duke Power Company's efforts to implement value-based reliability planning for generation, transmission and distribution investments. This planning effort required the development of outage cost estimates for all customer classes. FSC produced these estimates by designing and administering outage cost surveys to Duke Power's residential, commercial, and industrial customers, collecting and analyzing the data. To collect outage cost data from Duke's largest customers, plant managers at over 200 sites were interviewed in-person for more than two hours by FSC executive interviewers. To estimate outage costs for small and medium-sized commercial customers, 1,500 customers were surveyed using a mixed-mode (telephone/mail) approach. Finally, information on residential outage costs was obtained via a contingent valuation survey instrument sent to 2,400 customers.

Commercial Value of Service Study
Pacific Gas and Electric Company, Marketing and Sales Department, San Francisco, CA
PG&E calculates its target reserve margins and marginal capacity costs using outage cost estimates obtained from surveys of its customer classes. FSC recently completed a mixed-mode survey of PG&E's small and medium sized commercial and industrial customers to estimate their outage costs. The study involved recruiting 1,400 business operators to measure the costs they experience as a result of different types of electric outages. The survey methodology involved an initial phone call to identify the person in the customer's organization who was most familiar with the impacts of electric outages on operations. Once the target respondent was identified and the study had been explained, they were asked to complete a survey, which was sent in the mail. Repeated mailings were used to encourage respondents to return the survey. To measure and control for the effects of non-response bias, a random sample of 267 non-respondents to the mail survey were re-contacted and interviewed over the telephone to obtain the information normally obtained from the mail survey.

Commercial/Industrial Value of Service Study
Cinergy Corp., Power Quality Department, Plainfield, IN
This study, jointly funded by Cinergy Corp. and ABB Power Systems Inc. supports Cinergy's efforts to implement value-based reliability planning for transmission and distribution investments using ABB's NETREL program. This planning effort requires the development of outage cost estimates for major customer classes. FSC developed interruption cost estimates for commercial and industrial customers by designing and administering outage cost surveys to Cinergy's commercial and industrial customers. To collect outage cost data from Cinergy's largest customers, plant managers at over 200

sites were interviewed in-person for more than two hours by FSC executive interviewers. To estimate outage costs for small and medium-sized commercial customers, 400 customers were surveyed using a mixed-mode (telephone/mail) approach.

Residential Value of Service Study
San Diego Gas and Electric - Enova, Marketing Department, San Diego, CA
All investor owned gas utilities in California are required to carry out customer value of service surveys in conjunction with reliability planning and to file the results of those surveys with the California Public Utilities Commission. SDG&E-Enova retained FSC to survey its residential customers, and collaborated in designing and developing a specialized survey instrument for the project. FSC conducted a three-stage mail survey of 1,500 randomly selected residential customers. At the conclusion of the project, FSC provided a final report, which was filed with the CPUC.

Residential Power Outage Survey
Puget Sound Energy, Bellevue, WA
FSC investigated 3,729 residential customers of Puget Sound Energy with 40 different questionnaire versions for the customer's willingness to pay or to accept certain power outage scenarios. Using the Dillman method, participants were randomly mailed one of the questionnaire versions together with a cover letter and a one-dollar bill attached to it. This was followed by a reminder postcard, resulting in a compliance rate of 63% of the overall sample.

4. Resumes

This section contains detailed resumes for each of the senior staff members:

- Dr. Michael J. Sullivan, Principal.
- Dr. Kent Van Liere, Senior Consultant.
- Dr. Chris Ann Dickerson, Senior Consultant.
- Dr. Katrin Ewald, Director, Population Research Systems (PRS), a subsidiary of Freeman, Sullivan & Co.

Michael Sullivan, Ph.D.
Principal
Freeman, Sullivan & Co.

SELECTED PROJECT EXPERIENCE

Energy, Water, Utility Studies

US Department of Energy, Meta Analysis of Value of Service Studies
Directed FSC's meta-analysis of value of service studies carried out by utilities between 1987 and 2002. In this project, FSC researchers obtained survey responses from major utilities and other entities in the United States that had conducted customer interruption cost surveys between 1987 and 2002 and estimated customer damage functions describing the relationships between outage costs experienced by customers and outage characteristics (i.e., type, duration, time of day and season) and customer characteristics (i.e., customer type, geographical location, size and business activities).

SDG&E's 1997 Non-Core Customer Interruption Cost Study
FSC surveyed the non-core gas customers of the San Diego Gas and Electric Company to determine the economic costs they would experience given natural gas outages of different durations. These costs estimates were used to establish an appropriate level of investment in their gas distribution system, and were filed with the California Public Utilities Commission.

Cinergy's 1996 Customer Value of Service Studies
FSC surveyed 200 of the largest and most sensitive customers of Cinergy as well as 400 of their small and medium-sized commercial and industrial customers to determine their satisfaction with service, cost of interruptions and expectations for service reliability. Cinergy uses these costs estimates in targeted marketing and in evaluating transmission and distribution reliability investments.

1997 Customer Value of Service Study, Duke Power Company, System Planning Department, Charlotte, North Carolina. Duke Power Company uses customer interruption costs in a number of reliability planning applications to represent the economic benefits obtained from decision alternatives. FSC surveyed 1,500 residential, and 1,250 small and medium sized commercial and industrial customers of Duke Power Company to update Duke Power's interruption costs in 1997.

Sacramento Municipal Utility District's 1994 Power Quality Surveys
FSC conducted on-site interviews with selected large commercial and industrial customers to identify causes and costs of power quality problems for purposes of evaluating the economic benefits associated with enhanced transmission services.

PG&E's 1993 Commercial Value of Service Survey
FSC conducted a combined telephone and mail survey of 1,250 commercial customers to estimate interruption costs experienced under different conditions.

Duke Power's 1992 Customer Value of Service Study
FSC surveyed 210 of the largest and most sensitive customers of Duke Power Company, 1,250 of its small and medium-sized commercial and industrial customers and 1,500 of its residential customers to determine their satisfaction with service reliability, costs of interruption and expectations for service reliability. In addition, FSC developed a circuit level interruption cost data base for the utility which contained estimated costs for different kinds of service interruptions for all of the transmission and distribution circuits on the Duke Power System. The study was jointly funded by Duke Power and the Electric Power Research Institute.

PG&E's 1990 Agricultural Value of Service Survey
FSC designed and managed a combined telephone and mail survey of 1,500 agricultural customers to estimate interruption costs experienced under different conditions.

PG&E's 1989 Large Commercial and Industrial Value of Service Survey
FSC designed and managed an on site survey of 500 large commercial and industrial customers to estimate interruption costs under different conditions.

PG&E's 1987 Small and Medium Commercial and Industrial Value of Service Survey
FSC designed and managed a combined telephone and mail survey of 1,500 small and medium-sized commercial and industrial customers to identify outage costs experienced under different conditions.

Various Utilities, Customer Outage Cost Surveys
Directed 23 customer outage cost surveys for various utilities in the United States. In these studies, FSC researchers carried out surveys of representative samples of utility customers to identify the costs they experience as a result of forced outages occurring under different conditions. In these surveys, precise representative samples of residential, commercial and industrial customers were asked to estimate the costs they would experience under outages of varying duration, occurring at different times of the day, week and year. Since 1987, FSC has conducted such surveys for a number of utilities including: Pacific Gas and Electric, SEMPRA Energy, SMUD, Puget Sound Energy, Duke Energy, Southern Company, Salt River Project, Cinergy and MidAmerican Power.

Southern Company, Flywheel UPS Market Potential Study
Directed FSC's evaluation of the market for a new high-technology flywheel UPS in industrial applications throughout the Southeastern US. In this study, FSC researchers identified a representative sample of customers that could benefit from installation of the technology and interviewed plant engineering and management personnel to describe the technology with its benefits and costs, and determine their interest in purchasing it. Engineering and economic studies were carried out in the study at over 600 industrial locations located in Alabama, Georgia, Florida and Tennessee.

PacifiCorp, International Energy Services Market Assessment
Directed FSC's assessment of business customer interest in and willingness to pay for energy services under varying service design models. In the study, representative samples of business customers in the US, Australia and Britain were asked to identify their familiarity with and perception of PacifiCorp brands, their interest energy and financial services that were being considered for bundling with energy contracts, the amount they would be willing to pay for such services and the contract arrangements they would prefer. Results from the surveys were subsequently analyzed to estimate the incremental economic value customers assigned to energy services within various markets and to identify markets in which the company's offering were more or less competitive.

Pacific Gas and Electric, Smarter Energy Line Evaluation
Directed FSC's evaluation of Pacific Gas and Electric Company's Smarter Energy Line Program. For three years, FSC conducted quarterly surveys of PG&E customers who had contacted the Smarter Energy Line number to assess the effectiveness of the program at answering customers' questions and directing them to utility programs designed to encourage energy efficiency. FSC was responsible for identifying customers' reaction to the service and recommending restructuring and training based on results.

Southern Company, New Meter-Reading Service Concept Test Study.
FSC evaluated the technical and economic feasibility of providing meter reading services on an outsourced basis to electric, water and gas companies operating in the southeastern United States. The project involved identification of practical business models for acquisition of meter reads, including automated meter reading, and interviews with potential customers to identify their interest in buying the proposed services under various business and pricing models.

Confidential Clients, Assistance in Evaluating Distribution and Transmission Planning Initiatives.
Directed FSC' Dependability Excellence Project. FSC provided advice and consultation to distribution and transmission planning departments in several major utilities in developing statistical and economic models for prioritizing reliability investments among protection zones (within distribution feeders). The models simultaneously prioritized investments according to the impact of investments on customer satisfaction and interruption costs.

Regional Economic Valuation of Water Supply Studies (Various Water Utilities in California and Oregon)
Directed FSC's Regional Economic Valuation of Water Supplies. In this project, FSC interviewed representative samples of customers of water utilities in California and Oregon. The purpose of the study was to collect information on the respondents' economic valuation of water supply in the context of various water supply reduction scenarios. The project sponsor was a consortium of various government and water agencies in the San Francisco Bay Area, the Los Angeles Basin, and the Tri-County area surrounding Portland.

Metropolitan Water District of Southern California, Glendale, CA, Value of Water Quality Study.
Directed FSC's Value of Water Quality Study for the Metropolitan Water District of Southern California. FSC was hired by MWDSC to estimate the economic worth for both residential and commercial/industrial customers of lowering the salinity of the water provided by the water utility serving most of Southern California outside the city of Los Angeles. The study used mixed mode (mail and telephone) surveys to collect the data. Econometric models incorporating information about salinity of the water experienced by each household and other demographic and preference characteristics are being used to estimate the economic value of lowered salinity.

Aerosol Duct Sealing Market Transformation Study, Pacific Gas & Electric Company, San Francisco, California
FSC provided the survey design and data collection components for this project intended to track the potential for transformation in the market for residential duct sealing following the introduction of new improved technology.

Phase II Multi-client Retail Wheeling Study.
Directed this project for which FSC provided data collection services as a subcontractor to Xenergy. Four phone surveys were conducted among industrial, commercial and residential customers in California and Pennsylvania to provide data for modeling of customer behavior in a deregulated environment. Surveys were designed to gather data about the decision-making process used in choosing a new utility and to measure market share in markets where deregulation was sufficiently advanced.

Confidential Client 1997-98 Power Quality and Reliability Survey
Dr. Sullivan directed this project where FSC surveyed 150 of the largest and most sensitive customers of a major US utility to determine their satisfaction with service reliability, cost of outages, expectations for service reliability and willingness to pay for reliability improvements. Information from the study is being used in business and market planning.

State Water Resource Control Board, Sacramento, CA, Ground-water Information System Development
FSC designed and demonstrated a computer and database management system to assist geologists and hydrogeologists at various Water Resource Control Boards in identifying and analyzing ground-water contamination throughout California. Existing data sources and modeling techniques were cataloged, and the uses of these data and modeling techniques were demonstrated for two areas with known contamination. In addition to computer generated maps and other analysis results, hardware and software system specifications were prepared.

Cinergy, Projection of Asbestos Personal Injury Claims
Directed FSC's projection of future personal injury claims arising from asbestos exposures at Cinergy power plants. In the project FSC researchers identified the number of contractor employees exposed to asbestos over the more than 50 year lifespan of power plants built, operated and maintained by Cinergy; projected future asbestos claims and economic liability given the epidemiological considerations and trends in indemnity and defense costs; and evaluated available insurance coverage to identify uncovered economic exposure.

Duke Power Home Heating Study, Duke Power Company, Customer Studies Department, Charlotte, NC.
Directed this study carried out to ensure that marketing targets were realistic and high enough to reach corporate goals for the space and water heater market segments. FSC designed and analyzed data for a market assessment using a mail survey of a representative sample of 23,500 Duke Power residential customers. These data were used to estimate the share of the new construction and appliance replacement markets captured by the utility and its competitors in 1993.

Business Customer Opinion Survey, Pacific Gas and Electric Company, Marketing and Sales Department, San Francisco, CA. PG& E conducted telephone surveys with a random sample of customers quarterly. The survey includes questions regarding customers' likelihood of switching suppliers, likelihood of recommending the company, measurements of customer loyalty, and satisfaction scores on a variety of service dimensions. FSC provides quarterly written reports summarizing survey findings with the data compiled to identify improvement priorities and provide the information stratified by industry market segment and level of customer usage.

1996 Commercial/Industrial Value of Service Study, Cinergy Corp., Power Quality Department, Plainfield, Indiana. This study supports Cinergy's efforts to implement value-based reliability planning for transmission and distribution investments using ABB's NETREL program. This planning effort requires the development of outage cost estimates for major customer classes. FSC developed interruption cost estimates for commercial and industrial customers by designing and administering outage cost surveys to Cinergy's commercial, and industrial customers. To collect outage cost data from Cinergy's largest customers, plant managers at over 200 sites were interviewed in-person for more than two hours by FSC executive interviewers. To estimate outage costs for small and medium-sized commercial customers, 400 customers were surveyed using a mixed-mode (telephone/mail) approach.

1995 Customer Attitudes, Needs, and Opinions Survey, Sacramento Municipal Utility District, Rates Department, Sacramento, California. FSC conducted a series of mixed-mode surveys of residential, commercial, and industrial customers to determine their satisfaction with SMUD service and to obtain information about their willingness to pay for renewables, energy conservation programs, and SMUD activities which stimulate the local economy. The survey also collected information about customers' willingness to switch to alternative suppliers, should competitive options become available in the future.

Expert Testimony (related cases)

Dr. Sullivan has also testified before regulatory commissions in California regarding the use of value based planning techniques in generation, transmission and distribution planning. Most recently he testified before the California Public Utilities Commission regarding interruption cost survey estimates used by PG&E to establish marginal generation capacity costs for its 1996 General Rate Case. Dr. Sullivan understands utility systems, their daily operations, customer needs and demands, short and long term planning issues and investment financing considerations.

Bi-annual Hearings on Electric Reserve Margins before the California Energy Commission -- collection and analysis of statistical data and testimony describing electric utility customer outage costs.

California Energy Commission -- Research methods and statistical analysis related to measurement of utility customer outage costs.

California Public Utilities Commission -- Research methods and statistical analysis related to measurement of utility customer outage costs.

EMPLOYMENT HISTORY

Jan. 1, 2001	Founder, Population Research Systems (PRS), San Francisco
Jan. 1, 2001	Founder, Liability Management Systems (LMS), San Francisco
1984-Present	Founder, Freeman, Sullivan & Co. (FSC), San Francisco
1984,1988	Lecturer, Schools of Business Administration; University of California, Berkeley
1980-1981	Vice President, Kendall Associates, San Francisco
1979-1980	Program Coordinator, Seattle Energy Office, Executive Department, City of Seattle
1978-1979	Associate Senior Scientist, Kendall Associates, San Francisco
1974-1978	Joint Appointment in the Social Research Center and Sociology Departments at Washington State University, Survey Project Manager and Teaching Assistant
1972-1973	Research Associate, Office of Public Affairs, University of California, Riverside

EDUCATION

1984	Ph.D. Washington State University; Sociology – Research Methods and Statistics
1973	B.A. University of California, Riverside; Political Science

AWARDS

Highest Honors, College of Letters and Sciences, U.C. Riverside (1973)
National Science Foundation Summer Fellowship in Research (1972)
Associate Editor, Western Sociological Review (1975-1978) "Power Interruption Costs to Industrial and Commercial Consumers of Electricity," with Terry Vardell and Mark Johnson, IEEE Transactions on Industry Applications, Vol 33, December 1997.

PUBLICATIONS

Modeling Residential Customers' Heating System Choices, with Dennis Keane, Electric Power Research Institute, Final Report of Project 3902-02, EPRI Technical Report 106530, July 1996.

"Power Interruption Costs to Industrial and Commercial Consumers of Electricity," with Terry Vardell and Mark Johnson, Conference Record, IEEE and Commercial Power Systems Technical Conference, May 1996.

"Interruption Costs, Customer Satisfaction and Expectations For Service Reliability," with T. Vardell, N. Suddeth and A. Vogdani, IEEE Transactions on Power Systems, Vol. 11, May 1996.

Outage Cost Estimation Guidebook, with Dennis Keane, Electric Power Research Institute Final Report of Project 2878-04, EPRI Technical Report 106082, December 1995.

"Can Dispatchable Pricing Options Be Used To Delay Distribution Investments? Some Empirical Evidence" with D. Keane, and R. Cruz, in Proceedings Load Management: Dynamic DSM Options For the Future Electric Power Research Institute, May 1994.

"Reliability Service Options at PG&E," with D. Keane, in Service Opportunities For Electric Utilities: Creating Differentiated Products, S. Oren and S. Smith Eds., Kluwer Academic Publishers, 1993.

"Controlling Non-Response and Item Non-Response Bias Using Computer Assisted Telephone Interviewing Techniques," 1991 Sawtooth Software Conference Proceedings, June 1991 Reprinted in Quirks Market Research Quarterly, April 1992.

"Good Organizational Reasons for Bad Evaluation Research", with Michael Hennessy, Evaluation Practice, September 1989, Vol. 10, No. 4, pp. 41-50.

"Implementing Dispatchable Load Management Projects", with Michael Hennessy, Public Utilities Fortnightly, April 1988.

The Development of Social Power Structures in Small Groups, Ph.D. Dissertation, August 1983.

"Can You Create Structural Differentiation in Social Power Structures in the Laboratory?" with Louis N. Gray, Social Psychology, December 1978.

"Social Matching Over Multiple Reinforcement Domains: An Explanation of Local Exchange Imbalance" with Louis N. Gray, Max von Broembsen and Wanda Griffith, Social Forces, Vol 61, pp. 156-182, March 1982.

"Group Differentiation: Temporal Effects of Reinforcement" with Louis N. Gray and Max von Broembsen, Social Psychology Quarterly, Vol. 45 pp. 44-49, March 1982.

"Issues of Design and Analysis in Evaluation Research," with Duane Alwin, Sociological Methods and Research, August 1975.

Patterns of Geothermal Lease Acquisition in the Imperial Valley, University of California Press, 1974.

PROFESSIONAL SOCIETIES

American Association of Public Opinion Researchers
American Statistical Association
Defense Research Institute
Institute of Electrical and Electronic Engineers

Kent D. Van Liere, Ph.D.
Senior Consultant
Freeman, Sullivan & Co.

REPRESENTATIVE PROJECT EXPERIENCE

Energy, Telecom, Utility Planning Studies

Outage Cost Estimation Research
Led a team that designed and implemented new methods of measuring valuing service reliability by measuring outage costs for electricity and gas service using customer surveys. These surveys measured residential customers' perceived outage costs and their preferences for different scenarios of service reliability. Several projects were conducted as part of this research program. The studies involved several thousand surveys with all customer segments including residential, commercial, industrial, and agricultural customers. Studies included:

- Benefit-Cost Analysis of Electric Power System Reliability Project for Electric Power Research Institute (EPRI) using Bonneville Power Administration (BPA) and Florida Power and Light Company (FP&L)
- Priority Service Methods: Outage Cost Survey of the Small and Medium Commercial Sector for Electric Power Research Institute (EPRI)
- Outage Cost Survey of Large Industrial and Commercial Customers for Pacific Gas and Electric Company (PG&E)
- Value of Service Project for Southern California Edison Company (SCE)

Scoping Study for Assessing Residential Appliance Incentive Programs
Statistical analysis and report preparation of a measurement plan for PG&E's residential central air conditioning and refrigerator programs that would address the requirements of the California collaborative process. The plan laid out the research strategy for estimating first year savings, load shape, net-to-gross rate (free riders), rebound, persistence, and related impact parameters.

Impact Evaluation for Wisconsin Public Service Corporation's C&I Rebate and Programs
Study design and statistical analysis of an evaluation of the impacts of WPS's commercial and industrial energy efficiency programs. Measurement of quantitative results of the commercial and industrial programs, focusing on energy usage, demand, and load shape effects attributable to the programs. The estimate of annual load impacts relied on statistical analyses of customer billing data, both electric and gas. Customer surveys and previously calculated engineering estimates were also used.

Impact Evaluation Plan for Wisconsin Public Service Corporation's C&I Rebate and Programs
This evaluation plan describes the strategies and activities for the impact evaluation of WPS's commercial and industrial energy efficiency programs. The research objectives for this evaluation concerned the measurement of quantitative results of the commercial and industrial programs, focusing on energy usage, demand, and load shape effects attributable to the programs. The estimate of annual load impacts relied on statistical analyses of customer billing data, both electric and gas. Customer surveys and previously calculated engineering estimates were also used.

Demand-Side Management Evaluation Planning Materials
Dr. Van Liere assisted Wisconsin Power and Light in preparing a comprehensive set of evaluation planning reference materials for their 1990 demand-side management programs serving all customer sectors. The

final document also included a discussion of evaluation methods and examples of evaluation study prototypes.

Customers' Attitudes about Environmental Efforts for Madison Gas and Electric Company
Statistical analysis and design of surveys to measure residential and commercial/industrial customers' concern about environmental issues, to assess customers' familiarity with and evaluation of MGE's environmental efforts to date, to measure customers' attitudes about MGE and the environment, and to develop preliminary estimates of customers' willingness to pay for MGE's environmental efforts.

WPS Environmental Communications Project
Statistical analysis and survey design of baseline measurements of residential customers' environmental literacy, their awareness of Wisconsin Public Service's environmental communications, and segment customers based upon their environmental attitudes and behaviors.

Market Research on Media Effectiveness for Environmental and Energy Programs
Study design and statistical analysis of effectiveness of various media vehicles for communicating with customers using mail survey data and demographic characteristics. Seven types of media channels were examined and segmentation strategies were used to describe the specific market segments that could most successfully be reached through each of the media channels.

The High-Efficiency Laundry Metering and Marketing Analysis (THELMA)
This project was an innovative collaboration of utilities, manufacturers (Whirlpool, Maytag, Lever), and EPRI to analyze the impacts of wide spread adoption of horizontal axis washing machine technologies. Designed the study, survey methods and analysis The project included a national survey, focus groups, bench testing of the technology, in-home field monitoring of the washers, and a demonstration center.

In-home Interactive Energy Information Services
Pacific Gas and Electric, in cooperation with Microsoft and TCI Cable, developed an innovative service, Energy Information Services (EIS), by which residential households could monitor and program their household energy use using their television and a remote control. Led the team that defined the market and market potential for this system. Collected information through focus groups and market surveys of customers about their needs and reaction to such a system. In addition, in-home tests were set up and monitored to determine customer reactions to the systems. The energy saving impacts of the system were also evaluated.

Rock Valley Energy Efficiency Research Project
This project was an innovative community-based energy efficiency program. The research project assisted Iowa Public Service Company in planning, executing, and evaluating an innovative five-year pilot project designed to increase the energy efficiency of the entire community of Rock Valley, Iowa. The project used a coordinated, community-based approach involving extensive communications, improved energy audits, and a combination of several types of financial incentives, and extensive, individualized follow-ups that included energy use monitoring.

Evaluation of Customer Response to Pacific Gas & Electric Company's Real-Time Pricing and SCIP Programs
For this project, our team interviewed industrial customers participating in PG&E's Real-Time Pricing and Small Commercial/Industrial Load Management Service Option programs. The interviews examined customers' understanding of the rates, the decision processes used in deciding to respond (or not respond) to specific price signals, and behavioral responses to the price signals.

EMPLOYMENT HISTORY

2002-present	Senior Consultant, Freeman, Sullivan & Co., San Francisco
2000-2002	President and Chief Executive Officer, Primen
1997-2000	Senior Vice President, Hagler Bailly, Inc.
1995-1997	Director, Hagler Bailly Consulting, Inc.
1992-1995	President, HBRS, Inc.
1985-1992	Principal, HBRS, Inc.
1985	Visiting Associate Professor, Department of Rural Sociology, University of Wisconsin-Madison
1984-1985	Associate Professor (with tenure), Department of Sociology, University of Tennessee
1983-1984	Visiting Analyst, Strategic Planning Staff, Office of Planning and Budget, Tennessee Valley Authority
1978-1984	Assistant Professor, Department of Sociology, University of Tennessee

EDUCATION

1979	Ph.D. Sociology, Washington State University, specialization in research methods and statistics.
1976	M.A. Sociology, Washington State University,
1974	B.A. Sociology, Hamline University, with Honors

PUBLICATIONS

Dunlap, Riley E. and Kent D. Van Liere. 1977. "Further Evidence of Declining Public Concern with Environmental Problems: A Research Note." Western Sociological Review, 8: 110–112.

Dunlap, Riley E. and Kent D. Van Liere. 1977. "Land Ethic or Golden Rule." Journal of Social Issues, 33: 200–207.

Dunlap, Riley E. and Kent D. Van Liere. 1977. "Response to Heberlein." Journal of Social Issues, 33: 211–212.

Dunlap, Riley E. and Kent D. Van Liere. 1978. "The New Environmental Paradigm: A Proposed Measuring Instrument and Preliminary Results." Journal of Environmental Education, 9: 10–19.

Van Liere, Kent D. and Riley E. Dunlap. 1978. "Moral Norms and Environmental Behavior: An Application of Schwartz's Norm–Activation Model to Yard Burning." Journal of Applied Social Psychology, 8: 174–188.

Dunlap, Riley E. and Kent D. Van Liere. 1979. "Decline in Public Concern for Environmental Quality: A Reply." Rural Sociology, 44: 204–212.

Van Liere, Kent D. and Riley E. Dunlap. 1980. "The Social Bases of Environmental Concern: A Review of Hypotheses, Explanations, and Empirical Evidence." Public Opinion Quarterly, 44: 181–197.

Tremblay, Kenneth R., Jr., Don A. Dillman, and Kent D. Van Liere. 1980. "An Examination of the Relationship Between Housing Preferences and Community Size Preferences." Rural Sociology, 45: 509–519.

Van Liere, Kent D. and Benson H. Bronfman. 1981. "Beliefs About Social Control and Participation in a Load Management Project." Housing and Society, 8: 124–135.

Van Liere, Kent D. and Riley E. Dunlap. 1981. "Environmental Concern: Does it Make a Difference How It's Measured?" Environment and Behavior, 13: 651–676.

Van Liere, Kent D. and Frank P. Noe. 1981. "Outdoor Recreation and Environmental Attitudes: Further Examination of the Dunlap–Hefferen Thesis." Rural Sociology, 46: 505–513.

Ladd, Anthony E., Thomas C. Hood, and Kent D. Van Liere. 1983. "Ideological Themes in the Antinuclear Movement: Consensus and Diversity." Sociological Inquiry, 53: 252–272.

Lounsbury, John W., Kent D. Van Liere, and Gregory J. Meissen. 1983. "PsychoSocial Assessment." In Social Impact Assessment Methods, edited by K. Kinsterbush, L. Llewellyn, and C.P. Wolff, Beverly Hills, California, Sage, pp. 215–240.

Van Liere, Kent D. and Riley E. Dunlap. 1983. "Cognitive Integration of Social and Environmental Beliefs." Sociological Inquiry, 53: 333–341.

Dunlap, Riley E. and Kent D. Van Liere. 1984. "The Dominant Social Paradigm and Concern for Environmental Quality: An Empirical Analysis." Social Science Quarterly, 65: 1013–1028.

Hand, Carl M. and Kent D. Van Liere. 1984. "Religion, Mastery Over Nature and Environmental Concerns." Social Forces, 63: 555–570.

Van Liere, Kent D. and William Lyons. 1986. "Measuring Perceived Program Quality." In Performance Funding in Higher Education, edited by Trudy W. Banta, Boulder, Colorado, National Center for Higher Education Management System, pp. 85–94.

Van Liere, Kent D., Rick Winch, Kathleen Standen, Shel Feldman, and Dale Brugger. 1994. "The Design and Structure of a Statewide Sales Tracking System for Residential Appliances. In Energizing the Energy Policy Process, edited by Roberta W. Walsh and John G. Heilman, Westport, Connecticut, Quorum Books, pp. 199-216.

Malloy, Ken, Jamie Wimberly, and Kent D. Van Liere. 1999. "The Customer Stewardship Program: Successfully Linking Consumer Education and Corporate Strategy," The Electricity Journal, August/September 1999.

Dunlap, Riley E., Kent D. Van Liere, Angela G. Mertig, and Robert E. Jones. 2000. "Measuring Endorsement of the New Ecological Paradigm: A Revised NEP Scale." Journal of Social Issues, 56: 425-442.

Selected Published Reports and Monographs

Successful Residential Product and Service Development: Integrated Market Research and Evaluation. EPRI, Palo Alto, CA: 1996.

Market Tracking: Assessing Sources and Access to Appliance Sales Data, EPRI, Palo Alto, CA: 1997. TR-108928

Performance Measurement in Utilities: A Framework for Creating Effective Management Systems. EPRI, Palo Alto, CA: 1996. TR-106860 3269-34.

The High Efficiency Laundry Metering and Marketing Analysis (THELMA) Project. Volume 1: Final Research Plan. EPRI, Palo Alto, CA: 1997. TR-109147-V1

The High Efficiency Laundry Metering and Marketing Analysis (THELMA) Project. Volume 2: Laboratory Testing of Clothes Washers. EPRI, Palo Alto, CA: 1997. TR-109147-V2.

The High Efficiency Laundry Metering and Marketing Analysis (THELMA) Project. Volume 3: General Market Assessment. EPRI, Palo Alto, CA: 1998. TR-109147-V3.

The High Efficiency Laundry Metering and Marketing Analysis (THELMA) Project. Volume 4: Distribution Channels. EPRI, Palo Alto, CA: 1998. TR-109147-V4.

The High Efficiency Laundry Metering and Marketing Analysis (THELMA) Project. Volume 5: Product Demonstrations. EPRI, Palo Alto, CA: 1998. TR-109147-V5.

The High Efficiency Laundry Metering and Marketing Analysis (THELMA) Project. Volume 6: Product Users In-Home Interviews. EPRI, Palo Alto, CA: 1998. TR-109147-V6.

The High Efficiency Laundry Metering and Marketing Analysis (THELMA) Project. Volume 7: Product Users Field Monitoring. EPRI, Palo Alto, CA: 1998. TR-109147-V7.
PUBLICATIONS – Selected Published Reports and Monographs (Cont'd)

The High Efficiency Laundry Metering and Marketing Analysis (THELMA) Project. Volume 8: Product Benefits and Target Markets. EPRI, Palo Alto, CA: 1998. TR-109147-V8.

The High Efficiency Laundry Metering and Marketing Analysis (THELMA) Project. Volume 9: Product Users Further Evaluations. EPRI, Palo Alto, CA: 1998. TR-109147-V9.

The High Efficiency Laundry Metering and Marketing Analysis (THELMA) Project.Volume 10: Project Synthesis. EPRI, Palo Alto, CA: 1998. TR-109147-V10.

Predicting Customer Choices Among Electricity Options, Volume 1: Wholesale Markets, EPRI, Palo Alto, CA: 1998. TR-108864-V1

Dr. Chris Ann Dickerson
Senior Consultant
Freeman, Sullivan & Co.

Fifteen years experience in energy and environment, seasoned project manager overseeing increasingly high profile projects to plan and evaluate California's nearly $500 million annual investment in energy efficiency. Recognized for developing and leading cutting-edge research in energy efficiency planning and policy, evaluation methods, resource planning and cost-effectiveness assessment.

- Excellent working relationships with a broad range of stakeholders including utility staff, regulators, advisory boards, consulting community, municipalities, nonprofits, and others in the energy industry.
- Leadership in statewide committees to plan and oversee more than $15 million in annual research spending.
- Special expertise in market assessment and evaluation, strategic planning, resource planning, environmental economics, regulatory policy, cost-effectiveness assessment, research methods.

SELECTED PROJECT EXPERIENCE

Energy, Water, Utility Studies

Non-residential Customer Hard-to-Reach Study
The purpose of this study was to determine if there are nonresidential customer segments that are under-served (or hard-to-reach) with respect to PGC funded energy efficiency programs. A further objective of this study was to then identify potential program elements that can address the needs of these nonresidential customers to assist them in making decisions regarding energy efficiency and participating in the PGC funded programs. The research was managed by PG&E, for the California Public Utilities Commission, under the auspices of the California Measurement Advisory Committee.

Nonresidential Prescriptive Rebate Program Evaluation
Dr. Dickerson planned and managed a statewide study to examine the 2002 Express Efficiency Program, the largest energy efficiency program offered by the California investor owned utilities. The research consisted of several parts including examining the effects of recent program changes. The 2002 Express Efficiency study addresses several objectives: (1) assessing participation over time; (2) assessing the program process (including delivery, marketing and customer satisfaction), and; (3) benchmarking program success (longitudinal and across programs). Assessing participation of the hard-to-reach customer classes is a cross-cutting objective of this study. This report contains information and results for both program participants and non-participants of Express Efficiency. The research was managed by PG&E, for the California Public Utilities Commission, under the auspices of the California Measurement Advisory Committee. A Project Advisory Committee consisting of members from each of the investor-owned utilities, the California Energy Commission, the California Public Utilities Commission and National Resource Defense Council participated in the project.

Pacific Gas & Electric Company, Statewide Energy Efficiency Potential Summary Study
Dr. Dickerson planned and oversaw a $575,000 project to update the energy efficiency potential estimates for California's commercial, residential, industrial, new construction markets. These studies have been cited in numerous decisions and rulings by the California Public Utilities Commission, and serve as the foundation for California's recent near-doubling of statewide expenditures on energy efficiency – from $280 million to nearly $500 million in 2005. The team included a prime contractor and numerous sub-contractors. The research involved concurrent development with sector-specific studies for the industrial and new-

construction sector, and the addition of emerging technology benefit estimates. This study was managed by PG&E, for the California Public Utilities Commission, under the auspices of the California Measurement Advisory Committee. A Project Advisory Committee consisting of members from each of the investor-owned utilities, including the California Energy Commission, the California Public Utilities Commission and National Resource Defense Council participated in the research. This project is ongoing at PG&E.

California Statewide Commercial Sector Electric Energy Efficiency Potential Summary and Commercial Sector Gas Efficiency Study
As one component of a $2.1 million project that produced a number of studies and deliverables, Dr. Dickerson planned and oversaw development of the research which was published by PG&E and served as the basis for a frequently cited report entitled California's Secret Energy Surplus, conducted by Xenergy released by The Energy Foundation. This study, produced in 2002, was the first in a series of energy efficiency studies undertaken to estimate the availability of cost-effective energy efficiency potential in California in more than a decade, and the first to develop estimates for the combined investor-owned utility service territories. The research was managed by PG&E, for the California Public Utilities Commission, under the auspices of the California Measurement Advisory Committee. A Project Advisory Committee consisting of members from each of the investor-owned utilities, the California Energy Commission, the California Public Utilities Commission and National Resource Defense Council participated in the research.

A Framework for Planning and Assessing Publicly Funded Energy Efficiency
Dr. Dickerson planned and managed a California statewide study to develop a framework for measuring the cost-effectiveness of interventions designed to transform the market for energy efficient goods and services. This report has become industry-standard and is used as the basis for seminars given on the topic. The project involved selecting and assembling a team of nationally-recognized experts with a diversity of expertise regarding energy efficiency evaluation, and using the team to forge a set of measurement concepts that were, at the time, new. The research was managed by PG&E, for the California Public Utilities Commission, under the auspices of the California Measurement Advisory Committee. A Project Advisory Committee consisting of members from each of the investor-owned utilities, the California Energy Commission, the California Public Utilities Commission and National Resource Defense Council participated in the research.

Assessing the Risk Management Value of Energy Efficiency
Dr. Dickerson planned and managed a California Statewide pilot study designed to articulate a framework for valuing demand-side resources in the context of supply portfolio planning for a market environment. The research examined how to quantify and value the risk management effects of such resources and how assessment of energy efficiency and demand response can be couched in terms that are meaningful to a supply portfolio planner and risk manager. The research was managed by PG&E, for the California Public Utilities Commission, under the auspices of the California Measurement Advisory Committee. A Project Advisory Committee consisting of energy-efficiency experts and supply-side utility experts participated in the research. This project is ongoing at PG&E.

Cost-Effectiveness of Energy Efficiency Programs Serving Small Commercial Customers
Dr. Dickerson planned and managed a statewide study to estimate the incremental cost of providing utility-sponsored energy efficiency programs to small commercial customers, vs. large and medium customers. The study results indicated a 40 percent price differential for programs that focus exclusively on small commercial customers as opposed to previous programs that served a mix of customer sizes. The differential was attributed to increase in measure and administration costs. The research was managed by PG&E, for the California Public Utilities Commission, under the auspices of the California Measurement Advisory Committee. A Project Advisory Committee consisting of members from each of the investor-owned

utilities, the California Energy Commission, the California Public Utilities Commission and National Resource Defense Council participated in the project.

Small-Commercial Customer Wants and Needs Study
Dr. Dickerson planned and managed a statewide study of small commercial customers to ascertain their needs and wants from energy efficiency programs offered by California's investor-owned utilities. This report presents the results of interviews and focus groups of customers that make up California's under 500 kW population, conducted as part of a statewide study of the nonresidential sector. In addition to conducting a wants and needs study, the research extends a previous baseline description of small/medium customers' equipment changes, program participation and awareness to 2001. The study found that an overwhelming number of small/medium customers – 92% – are conserving in order to reduce their energy costs. small/medium customers are primarily adopting no cost conservation measures such as reduced lighting levels and thermostat adjustment. The research was managed by PG&E, for the California Public Utilities Commission, under the auspices of the California Measurement Advisory Committee. A Project Advisory Committee consisting of members from each of the investor-owned utilities, the California Energy Commission, the California Public Utilities Commission and National Resource Defense Council participated in the project.

California Statewide LED Traffic Light Study
Dr. Dickerson planned and managed a statewide study to estimate traffic signal usage in the absence of any LED program (baseline usage). Based on the distribution of measures in the average intersection and traffic signal technical data, an estimate of the full potential of LED traffic signal upgrades is then developed. Next, two separate methods are used to determine current LED traffic signal saturation levels. Finally, energy efficiency program commitments through PY2001 are used to estimate LED traffic signal penetration into the market, assuming that all committed projects will be implemented. The research was managed by PG&E, for the California Public Utilities Commission, under the auspices of the California Measurement Advisory Committee.

Statewide Residential Standard Performance Contracting Study
This evaluation tested the pilot residential standard performance contracting study, designed to bring performance contracting to the residential market in California for the first time. The results were used to re-design the program to focus on contractors for residential buildings. The research was managed by PG&E, for the California Public Utilities Commission, under the auspices of the California Measurement Advisory Committee.

PG&E's 1995 Residential Direct Assistance and Residential Energy Management Services Study
Dr. Dickerson planned and evaluated PG&E's 1995 programs. This study evaluated the gross and net load impacts from Pacific Gas & Electric's 1995 Residential Direct Assistance and Energy Management Services programs. Model structure and comparison group construction varied across the program. Billing analysis was the primary basis of the study supplemented with customer survey data collected by the program and weather data. This analysis was designed to give net savings directly without requiring separate net-to-gross adjustments. Nonparticipants were also surveyed. The research was managed by PG&E, for the California Public Utilities Commission, under the auspices of the California Measurement Advisory Committee.

Impact Evaluation of Pacific Gas and Electric Company's 1997 Residential Energy Management Services Programs
PG&E's 1998 Residential Energy Management Service Program (REMS) is a multi-faceted program designed to provide the residential sector with information on energy efficiency. This report presents a market baseline and the results of a near-term market effects study of the 1998 REMS program. The market baseline will enable future market effects studies of the REMS program to accurately measure market

effects. The market effects analysis is necessary to analyze the near-term effects of the 1998 program. Since no baseline existed prior to this study, the market effects study had to estimate effects by looking backward in time, using historical data and survey techniques.

Interim Evaluation: California Board for Energy Efficiency PY 98 Residential Standard Performance Contract Program

Early in the evaluation process for the PY98 program, it was suggested that immediate feedback on several critical areas of program design was desirable. As such, it was determined that a full and comprehensive evaluation, as initially planned for this program, would not meet the near-term needs of the CBEE. Given these time considerations, it was agreed that an interim report would be written to (1) summarize the history and current status of the program, (2) prioritize a disparate array of issues associated with the PY98 program, and (3) provide options and recommendations for the PY99 program.

Impact and Process Evaluation of PG&E's Residential Weatherization and Appliance Efficient Retrofit Incentives Programs

This study evaluated the gross and net load impacts from Pacific Gas & Electric's 1994 Residential Weatherization and Appliance Efficiency Retrofit Incentives programs covering refrigeration lighting heating/cooling. Data used was primarily through billing analysis. A telephone survey employing a sample of program participants and non-participants was also conduced as part of the evaluation. Results from the survey were used as input to the evaluations and to develop net-to-gross adjustments as necessary for certain program components. Refrigeration savings were evaluated using an engineering approach together with a net-to-gross adjustment developed through a statewide study for CADMAC.

1996 Residential Appliance Efficiency Incentives Programs: High Efficiency Refrigeration and Lighting Report and Appendices

Gross and net energy savings from high efficiency lighting and refrigeration measures for which PGE's Residential Appliance Efficiency Incentive Programs paid rebates. Used engineering estimates and on-site surveys, customer self-reporting. Realization rates (ex ante divided by ex post) for (1) refrigerators were 1.65 for kW and 1.93 for kWh while rates for savings from high efficiency lighting were only 0.36 for kW and 0.45 for kWh.

Retention Study of Pacific Gas and Electric Company's 1994 and 1995 Residential Appliance Efficiency Incentives Program: Fourth Year Retention

This study measures the effective useful life (EUL) of lighting, space conditioning and refrig. measures for which rebates were paid through PG&E 1994/95 residential appliance efficiency incentives program. Method for the study collected measure retention data from a sample of participants, and fit a parametric survival function to those data. For lighting measures, retention data were collected via onsite inspectons for a sample. For cenral A/C and refrig. studied, retention data were gathered via phone surveys. A supplemental 'new occupant' sample provided info on measure loss due to customer' leaivng the service territory with their rebated units.

Volume I: Phase I Statewide Residential Contractor Program Market Assessment
This study characterizes the residential market for retrofit services from general and specialized contractors. The report includes estimates of the number of contractors involved in each trade or market segment, their attitudes and promotion of energy effiicent alternatives, and recommends new program strategies to build consumer demand for their services.

Retention Study Of Pacific Gas And Electric Company's 1994 and 1995 Appliance Energy Efficiency Programs
Dr. Dickerson planned and oversaw this study designed to measure the Effective Useful Life (EUL) of lighting measures for which rebates were paid through PG&E's 1994 and 1995 Appliance Energy Efficiency Programs. Xenergy conducted this sixth year retention study.

Statewide LED Traffic Signal Saturation Study
Dr. Dickerson planned and oversaw this evaluation of the LED Traffic Signal Program. It starts with an estimate of traffic signal usage in the absence of any LED program (baseline usage). Based on the distribution of measures in the average intersection and traffic signal technical data, an estimate of the full potential of LED traffic signal upgrades is then developed. Next, two separate methods are used to determine current LED traffic signal saturation levels. Finally, energy efficiency program commitments through PY2001 are used to estimate LED traffic signal penetration into the market, assuming that all committed projects will be implemented.

EMPLOYMENT HISTORY

2004-	Senior Consultant, Freeman, Sullivan & Co., San Francisco
1995-2004	Sr. Project Manager, Market Assessment and Evaluation, Customer Energy Management, PG&E, San Francisco, CA
1993-1995	Senior Analyst, Synergic Resources Corporation, Oakland, CA
1993	Intern, Environmental Protection Agency, San Francisco, CA
1988-1993	Teaching Assistant, University of California, Santa Cruz; , University of California, Berkeley;

EDUCATION

2001	Ph.D. Public Policy, 1993 M.P.P, University of California, Berkeley, Berkeley CA
1993	M.S. Social Psychology, University of California, Santa Cruz, Santa Cruz CA
1986	A.B. Psychology, Stanford University, Stanford CA

AFFILIATIONS

Co-Chair, MAESTRO Market Assessment & Evaluation Statewide Team of Research Organizations
Website Committee Chair, CALMAC, California Measurement Advisory Council
CADMAC, California Demand Side Management Advisory Committee, Modeling and Base Efficiency Subcommittees

PUBLICATIONS

Cavalli, J., Myers, M., Flanagan, J., Rufo, M., Dickerson, C. "How to Cost-Effectively Serve Small Nonresidential Hard-to-Reach Customers." Pacific Gas & Electric Company, San Francisco, CA. 2003 Energy Program Evaluation Conference Proceedings, 2003.

Dickerson, C., Chamberlin, J., Goldberg, M., Bennett, D. "Exploratory Study of the Hedge Value of Energy Efficiency Investments." Pacific Gas & Electric Company, San Francisco, CA. Presentation to 2003 American Council for an Energy Efficiency Economy Conference on Energy Efficiency as a Resource, 2003.

Rufo, M., Coito, F., Dickerson, C., Shaw, P., Koomey, J, Friedmann, R. "Energy Efficiency in Post-Crisis California: Finding and Tapping the Surplus." Pacific Gas & Electric Company, San Francisco, CA. Proceedings from the 12th National Energy Services Conference, 2002.

Rufo, M., Coito, F., Dickerson, C. "California Statewide Commercial Sector Energy Efficiency Potential Study." Pacific Gas & Electric Company, San Francisco, CA, 2002.

Cavalli, J., Dickerson, C., Myers, M., Rufo, M. "California's Hard-to-Reach Nonresidential Segments: Who are They and What do They Want?". Pacific Gas & Energy Company, San Francisco, CA, 2002.

Myers, M., Dickerson, C. Rufo, M., Cavalli, J. Conservation and Demand Response: How is California Small Business Responding to the Energy Crisis? 12th Annual Association for Energy Services Professionals Conference, 2001.

Dickerson, C. "Rehabilitating the Willingness to Accept Measure in Contingent Valuation." Doctoral Thesis, University of California, Berkeley, 2001.

Sebold, F., Goldberg, M., Keating, K., Feldman, S., Peters, J., Skumatz, L., Dickerson, C., Fields, A. "A Framework for Planning and Assessing Publicly Funded Energy Efficiency." Proceedings from the 11th National Energy Services Conference., 2000.

Dickerson, C., Skumatz, L., Bordner, R., Landry, P. "Working Toward Market Transformation Through Residential and Non-Residential Standard Performance Contract (SPC) Programs – Lessons Learned on Delivery, Design, Participation and Needs." Proceedings from the 2000 American Council for an Energy-Efficient Economy (ACEEE) Summer Study on Energy Efficiency in Buildings, 2000.

Skumatz, L., Dickerson, C., Coates, B. "Non-Energy Benefits in the Residential and Non-Residential Sectors – Innovative Measurements and Results for Participant Benefits." Proceedings from the 2000 American Council for an Energy-Efficient Economy (ACEEE) Summer Study on Energy Efficiency in Buildings. 2000.

Skumatz, L., Dickerson, C. "What Do Customers Value? What Benefits Utilities? Designing to Maximize Non-Energy Benefits from Efficiency Programs in the Residential Sector." 1999 Energy Program Evaluation Conference Proceedings. 1999. 415-434.

Wirtshafter, R., Bordner, R., Dickerson, C., Kreitler, V. "Rethinking Performance-Based Measurement: Implications for Market Transformation Programs." 1999 Energy Program Evaluation Conference Proceedings. 1999. 539-562.

Skumatz, L., Bordner, R., Dickerson, C. "Transforming Markets to Get Efficiency into the Residential Sector: Where are the Contractors and What Do They Want and Need?" 1999 Energy Program Evaluation Conference Proceedings. 1999. 551-574.

O'Drain, M., Messenger, M., Richardson, V., Landry, P., Dickerson, C., Besa, A. "Changing the Evaluation Frame in California from Individual Customers to Market Players in Dynamic Energy Markets." Proceedings from the 9th National Energy Services Conference. 1998. 10-26.

Goldberg, M., Michelman, T., Dickerson, "Can We Rely on Self-Control?" 1997 Energy Evaluation Conference Proceedings, 187-197, 1997.

Skumatz, L., Dickerson, C. "Recognizing All Program Benefits: Estimating the Non-Energy Benefits of PG&E's Venture Partners Pilot Program (VPP)." 1997 Energy Evaluation Conference Proceedings, 279-292, 1997.

Dickerson, C., Thibodeau, R., Aronson, E., Miller, D. "Using Cognitive Dissonance to Encourage Water Conservation." Journal of Applied Social Psychology, 22, 11, 841-854, 1992.

Dr. Katrin Ewald
Director of Population Research Systems (PRS)
Freeman, Sullivan & Co.

RELATED PROJECT EXPERIENCE

Utility, Energy, Resource Studies

New Technology Awareness Study conducted for Southern California Edison (SCE), Los Angeles, CA.
Implemented and managed data collection for the PRS interviewed 913 participants to evaluate the market for energy efficient equipment and design practices in the Southern California area. Additionally investigated was the awareness of available energy saving technologies in professionals of different segments involved in the design and use of energy related equipment.

Woodburning Study for E.H. Pechan & Associates, Inc., Shingle Springs, CA.
Strategized, implemented and analyzed the entire project. A total of 1,905 residential interviews were completed concerning annual consumption of real wood and artificial logs within 11 states (Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, Connecticut) and the District of Columbia to fill 24 quota cells based on census tracts characteristics: land use/cover, latitude, and dwelling type.

Estimating the Demand for Alternative-Fueled Vehicles, Toyota and General Motors, Troy MI
Managed data collection process for Toyota and General Motors for a project estimating the demand for alternative-fueled vehicles. The goal of this study was to estimate the demand for alternative-fueled vehicles in California and the extent to which this demand was affected by the provision of detailed information about alternative-fueled vehicles and air quality issues. FSC, Toyota, and General Motors collaborated closely on the design and construction of the recruitment screener and data collection instrument. Using the CATI lab, 1,439 Californians were recruited to participate in the study and were mailed a unique set of 15 different vehicle choices with forced choices between three different subsets printed on a "choice exercise" sheet. After receiving their unique package, the participants were interviewed via telephone to review their vehicle choices, resulting in 1,037 completed interviews.

Selected Large Scale Surveys

Independent Evaluation of the California Tobacco Control Program
University of Southern California, Institute for Health Promotion and Disease Prevention Research, Los Angeles, CA and the Gallup Organization
The school-based component of the Independent Evaluation of California's Tobacco Control Program is a panel study conducted by the Gallup Organization and the Institute for Health Promotion and Disease Prevention Research at the University of Southern California (USC). The objective of this component was the evaluation of the effectiveness of tobacco control programs offered in California schools. PRS was responsible for Wave 2 data collection in the northern California counties in 1998. In Spring 2000, PRS completed Wave 3 data collection in eighteen selected counties of California. The survey was administered to students in randomly selected 5th, 8th, 10th, and 12th grade classrooms, including all students in the selected class. In the PRS organized and managed the complete data collection process and administered a total of 1,076 classroom surveys in the final wave.

Vietnamese Behavioral Risk Factor Survey
Santa Clara County Public Health Department, San Jose, CA
Since this population exhibits a prevalence of risky health behaviors in proportions higher than the general county population, Santa Clara County Public Health Department issued several surveys in the past years among their residents of Vietnamese ethnic origin to track the performance of programs targeted to this community and to guide development of new programs. Additionally, information was gathered about the Vietnamese population's general health status, health care access/coverage/utilization, prevalence of diabetes, alcohol and tobacco use, women's health issues, HIV/AIDS, sexual behaviors, use of preventive counseling services, and firearms in the home as well as demographic information such as age, marital and employment status, household income, education and degree of acculturation. Using 27 Vietnamese surnames as criterion for selection, PRS conducted 660 telephone interviews with Vietnamese residents using the Center for Disease Control Behavioral Risk Factor Survey (BRFS).

Medical Necessity Study
Stanford University, Center for Primary Care and Outcome Research
The Medical Necessity 2001 project was designed to survey medical directors and decision makers of 228 health plans in all fifty states and the District of Columbia concerning the definition and application of medical necessity decision-making within their health plans. The study objective was to answer questions concerning evaluation of: clinical effectiveness, cost-effectiveness, case scenario coverage, the impact of state regulations on medical decision-making. The mixed-mode approach, which used mail surveys, the Internet, and telephone interviews, resulted in a 66% return rate.

Violence Prevention Community Evaluation Surveys
Stanford University, Center for Research in Disease Prevention, Palo Alto, CA
This three-year project, funded by the California Wellness Foundation, was implemented to measure the effectiveness of violence prevention initiatives in eighteen disadvantaged communities in California. PRS was responsible for the data collection, which included annual telephone interviews with 1,800 adults, as well as on-site administration of surveys in high schools with 5,400 9th and 10th grade students, as well as telephone interviews with 360 community opinion leaders.

Alcohol Outlets and Violence Study
Prevention Research Center, Berkeley, CA
For this project, 1,541residential telephone interviews were conducted in English and Spanish in 96 California zip code areas using random digit dial (RDD) sample. Zip codes were selected based on hospital discharges due to violent assaults and subdivided into socioeconomic quintiles. Information was collected about respondent neighborhoods, perceived prevalence of crime and violence, and alcohol-related beliefs and behaviors. Nearly 15% of respondents were surveyed again one month later to validate data collected. Two annual follow-up surveys are planned.

Directed the Adolescent Sexuality and Media Study for the Prevention Research Center, Berkeley, CA.
PRS is conducting a three-year longitudinal study with 1,105 children recruited at the ages 12 through 16 to examine the impact of media – and especially TV series and day-time TV shows - in shaping attitudes and behaviors regarding sexuality. In the second wave, PRS has conducted 576 Computer Assisted Self-administered Interviews (CAPI) in 9 Bay Area counties as well as 527 interviews in Los Angeles. The CAPI is administered by trained field staff as a 60-minute laptop interview at the participant's home. A parent of the child or adolescent is asked to complete a 20-minute self-administered questionnaire to be filled out at the same time. The overall response rate after the first wave of data collection was 93%.

EMPLOYMENT HISTORY

1999-present	Director, Population Research Systems, Freeman, Sullivan & Co., San Francisco, CA.
1998-1999	Research Analyst, Ben Berman Center, Catholic Healthcare West, San Francisco, CA.
1996-1997	Program Coordinator, Project Public Health, NRW, Germany
1995-1996	Teaching Assistant, University of Bielefeld, Germany.

EDUCATION

1997	Ph.D. Psychology, University of Bielefeld
1995	M.A. Psychology University of Bielefeld, Adelphi University, NY
1991	Carl-Severing School of Economics - A-level Economics

PUBLICATIONS

Ewald, K. (1997). Computer assisted mnemonic strategy acquisition and tailored memory training approaches: A study with brain injured individuals. Logos Verlag: Berlin.

Markowitsch, H.J. & Ewald, K. (1997). Right-hemispheric fronto-temporal injury leading to severe autobiographical retrograde and moderate anterograde episodic amnesia - implications for the anatomy of memory. Neurology, Psychiatry, and Brain Sciences, 5, 1-7.

Markowitsch, H.J., Weber-Luxemburger, G., Ewald, K., Kessler, J., & Heiss, W. (1997). Patients with heart attacks are not valid models for medial temporal lobe amnesia. A neuropsychological and FDG-PET study with consequences for memory research. European Journal of Neurology, 4, 1-7.

5. Appendix: Survey Instrument Examples

The appendix contains four survey instruments that will be similar to instruments developed for each population studied in this project.

5.1 Survey Instrument Example 1: Residential Customers

1/17/00
WTP
Version #1A1

POWER OUTAGES AND YOUR RESIDENCE

An Important Issue Facing Your Home

This research is being conducted by

SALT RIVER PROJECT

Delivering More Than Power™

Section 1

SATISFACTION

1.1 How would you rate the basic electric service that SRP provides to your household? Please think of this in terms of both the reliability and quality of the power you receive.

- ☐1 Excellent
- ☐2 Very Good
- ☐3 Good
- ☐4 Fair
- ☐5 Poor
- ☐6 Don't Know

Experience

1.2 In the **past 12 months**, about how many outages of the durations listed below have you had at your home in the Valley? Write in the number of outages on the blanks. (Use 0 if none.)

A moment (1-2 seconds in length)	☐1_____
Longer than a moment and up to 1/2 hour	☐2_____
Longer than 1/2 hour and up to 1 hour	☐3_____
Longer than 1 hour and up to 4 hours	☐4_____
Longer than 4 hours and up to 24 hours	☐5_____
Over 24 hours	☐6_____

1.3 What items do you keep in your home in order to respond to power outages and power quality disturbances? (Please check all that apply.)

- ☐1 Candles and flashlights
- ☐2 Battery back-ups in clocks, VCRs, and other appliances
- ☐3 Surge protectors or power conditioners for computers and other sensitive equipment
- ☐4 A back-up generator
- ☐5 An uninterruptible power supply (battery backup) for your household's computer
- ☐6 Is there anything else? ____________________________

Section 2

Please read this carefully before going on to the next page.

As part of our continuing efforts to supply you with the best possible electric service, Salt River Project needs to know how much we should be spending to prevent power outages. To do this, we need to know how different types of power outages affect your household.

This survey asks about your reaction to **four kinds of power outages (starting at different times of day and lasting different amounts of time)**. **Therefore, each of the following four pages describes a different situation.** We ask about these different outages because we know they may cause you to experience different amounts of inconvenience and "out of pocket" costs.

Electric outages can be avoided by installing a backup power supply service or uninterruptible power supply service at your home. These services can meet all of your household's electrical needs during power outages, but they will cost more than your current service. In this survey, we will be asking you whether you would prefer to pay a fee to use these services to avoid future outages or whether you would prefer to continue to experience outages about as often as you have in the past.

By answering the questions on the following pages, you will help Salt River Project devise more reliable and cost-effective service programs in the future. There are no wrong or right answers. We simply want the best responses you can provide. So please take a few moments and answer the survey now. Thank you.

Outage Situation 1 -- Summer Weekday Evening

7 PM – ½ hour
On a Summer weekday evening a power outage occurs at **<u>7:00 p.m.</u>** without any warning. You do not know how long it will last, but after **<u>30 minutes</u>** your household's electricity is fully restored.

2.1 Please take a minute to think about how you would react to the above power outage.

2.2 Considering the costs and inconvenience that normally result from this type of outage, which of the following alternatives would you **most** prefer? (Check the box next to your choice.)

❑1 In return for the protection provided by the backup power supply service described below, you pay a fee of **0.25 each time** the backup system supplies power during this type of outage.

→ *Go to Outage Situation 2 on the next page*

OR

❑2 You continue to experience outages of this kind **about as often** as you have in the past and your electricity costs remain about the same.

→ 2.3 Is that because (please check the **one** answer that fits best):

❑1 Outages of this kind are not really that bothersome.
❑2 The backup service is not worth the extra cost.
❑3 You don't think the backup service will work.
❑4 Bills are already too high.
❑5 You can't afford to pay more.
❑6 You think the utility should supply reliable service for the price.
❑7 Other (explain) ______________________________

Go to Outage Situation 2 on the next page

Backup Service:
This service will meet all of your household's electrical needs during this type of power outage. You activate the backup system with a switch installed in your home. You can turn the backup system on after an outage has started or leave it on continuously to automatically protect you from outages. You will be billed by the supplier only when the service provides you with backup electricity.

Outage Situation 2 -- Summer Weekday Evening

7 PM – 1 Hour
On a Summer weekday evening a power outage occurs at **7:00 p.m.** without any warning. You do not know how long it will last, but after **1 hour** your household's electricity is fully restored.

2.4 Please take a minute to think about how you would react to the above power outage.

2.5 Considering the costs and inconvenience that normally result from this type of outage, which of the following alternatives would you **most** prefer? (Check the box next to your choice.)

❑1 In return for the protection provided by the backup power supply service described below, you pay a fee of **0.50 each time** the backup system supplies power during this type of outage.

→ *Go to Outage Situation 3 on the next page*

OR

❑2 You continue to experience outages of this kind **about as often** as you have in the past and your electricity costs remain about the same.

→ 2.6 Is that because (please check the **one** answer that fits best):

❑1 Outages of this kind are not really that bothersome.
❑2 The backup service is not worth the extra cost.
❑3 You don't think the backup service will work.
❑4 Bills are already too high.
❑5 You can't afford to pay more.
❑6 You think the utility should supply reliable service for the price.
❑7 Other (explain) ________________________

Go to Outage Situation 3 on the next page

Backup Service:
This service will meet all of your household's electrical needs during this type of power outage. You activate the backup system with a switch installed in your home. You can turn the backup system on after an outage has started or leave it on continuously to automatically protect you from outages. You will be billed by the supplier only when the service provides you with backup electricity.

Outage Situation 3 -- Summer Weekday Night

Midnight – 1 Hour
On a Summer weekday evening a power outage occurs at **12 midnight**. without any warning. You do not know how long it will last, but after **1 hour** your household's electricity is fully restored.

2.10 Please take a minute to think about how you would react to the above power outage.

2.11 Considering the costs and inconvenience that normally result from this type of outage, which of the following alternatives would you **most** prefer? (Check the box next to your choice.)

❑1 In return for the protection provided by the backup power supply service described below, you pay a fee of **0.25 each time** the backup system supplies power during this type of outage.

→ *Go to Outage Situation 4 on the next page*

OR

❑2 You continue to experience outages of this kind **about as often** as you have in the past and your electricity costs remain about the same.

→ 2.12 Is that because (please check the **one** answer that fits best):

❑1 Outages of this kind are not really that bothersome.
❑2 The backup service is not worth the extra cost.
❑3 You don't think the backup service will work.
❑4 Bills are already too high.
❑5 You can't afford to pay more.
❑6 You think the utility should supply reliable service for the price.
❑7 Other (explain) ____________________

Go to Outage Situation 4 on the next page

Backup Service:
This service will meet all of your household's electrical needs during this type of power outage. You activate the backup system with a switch installed in your home. You can turn the backup system on after an outage has started or leave it on continuously to automatically protect you from outages. You will be billed by the supplier only when the service provides you with backup electricity.

Outage Situation 4 -- Summer Weekday Evening

7 PM – 10 seconds
On a Summer weekday evening a power outage occurs at **7 p.m.** without any warning. You do not know how long it will last, but after **10 seconds** your household's electricity is fully restored.

2.13 Please take a minute to think about how you would react to the above power outage.

2.14 Considering the costs and inconvenience that normally result from this type of outage, which of the following alternatives would you **most** prefer? (Check the box next to your choice.)

- ❑1 In return for the protection provided by the uninterruptible power supply service described below, you pay a fee of **0.10 each time** the system supplies power during a momentary outage of the kind described above.

  → *Go to Section 3 on the next page*

OR

- ❑2 You continue to experience momentary outages **about as often** as you have in the past and your electricity costs remain about the same.

  → 2.15 Is that because (please check the **one** answer that fits best):
  - ❑1 Outages of this kind are not really that bothersome.
  - ❑2 The backup service is not worth the extra cost.
  - ❑3 You don't think the backup service will work.
  - ❑4 Bills are already too high.
  - ❑5 You can't afford to pay more.
  - ❑6 You think the utility should supply reliable service for the price.
  - ❑7 Other (explain) ______________________________

Go to Section 3 on the next page

Uninterruptible Power Supply Service:
This service will meet all of your household's electrical needs during momentary electric outages. The system is completely automatic and will protect you from all momentary outages. You may deactivate the system whenever you like (for example when you go on vacation). You will be billed by the supplier for each momentary outage that is avoided while the system is in operation.

Section 3

ACCEPTABLE LEVEL OF RELIABILITY

SRP works hard to prevent power outages, but eliminating all outages would be very costly, if not impossible. The next questions help us understand what you consider an acceptable level of service reliability from SRP.

If each of the following occurred, would you think you were getting an acceptable or unacceptable level of service reliability from Salt River Project?

3.1 An outage lasting **less than a minute** ... (Check one box on each line.)

	Acceptable Level of Service	Unacceptable Level of Service	Don't know/ No opinion
a.) Once weekly	❑1	❑2	❑3
b.) Once monthly	❑1	❑2	❑3
c.) Once quarterly	❑1	❑2	❑3
d.) Once semi-annually	❑1	❑2	❑3
e.) Once annually	❑1	❑2	❑3

3.2 An outage lasting a **few minutes to half an hour** ... (Check one box on each line.)

	Acceptable Level of Service	Unacceptable Level of Service	Don't know/ No opinion
a.) Once weekly	❑1	❑2	❑3
b.) Once monthly	❑1	❑2	❑3
c.) Once quarterly	❑1	❑2	❑3
d.) Once semi-annually	❑1	❑2	❑3
e.) Once annually	❑1	❑2	❑3

3.3. An outage lasting **about an hour** ... (Check one box on each line.)

	Acceptable Level of Service	Unacceptable Level of Service	Don't know/ No opinion
a.) Once weekly	❑1	❑2	❑3
b.) Once monthly	❑1	❑2	❑3
c.) Once quarterly	❑1	❑2	❑3
d.) Once semi-annually	❑1	❑2	❑3
e.) Once annually	❑1	❑2	❑3

3.4. An outage lasting **from one to four hours** ... (Check one box on each line.)

	Acceptable Level of Service	Unacceptable Level of Service	Don't know/ No opinion
a.) Once weekly	❑1	❑2	❑3
b.) Once monthly	❑1	❑2	❑3
c.) Once quarterly	❑1	❑2	❑3
d.) Once semi-annually	❑1	❑2	❑3
e.) Once annually	❑1	❑2	❑3

3.5 Please **rank** the following choices in terms of their attractiveness to you.

(Write **one** number on each line: 1 = most preferred; 2 = next most preferred; 3 = least preferred. Please use each number just once.)

❑1___ Half as many outages as you receive currently with a 10% price increase.

❑2_____The number of outages you currently receive with the same price.

❑3_____Twice as many outages as you receive currently with a 10% price reduction.

Comments:

____

____

____

The electric utility industry in Arizona is undergoing change to allow for more competition. Soon, you may be able to choose which electricity company actually produces or generates the electricity for your household. Under deregulation, SRP would still be responsible for transmitting and distributing the electricity from whichever company that produces it directly to your home.

Please answer the following questions by circling a number from one to five, where 1 means you "definitely would not" and 5 means you "definitely would."

If you could choose your electric power provider, what is the likelihood that you would…?

3.6 Review rate and service information that is mailed to you by other electricity providers, to compare this to what SRP offers.

Definitely would not				Definitely would
1	2	3	4	5

3.7 Actually switch electric power companies from SRP to someone else.

Definitely would not				Definitely would
1	2	3	4	5

3.8 Agree to speak or meet with another electricity provider to discuss the possibility of switching your electric service away from SRP.

Definitely would not				Definitely would
1	2	3	4	5

3.9 Take the initiative to request rate and service information from other electricity providers, to compare this to what SRP offers.

Definitely would not				Definitely would
1	2	3	4	5

3.10 If another electric company offered you electric service that was **comparable** to SRP's, and at the **same price** as SRP, would you be likely to discontinue your service with SRP?

Yes, would discontinue with SRP .... ❑1
No, would not discontinue .... ❑2
Don't Know .... ❑3

3.11 If another electric company offered you electric service that was **comparable** to SRP's, but they offered you **lower rates**, at what percentage would you be likely to discontinue your service with SRP?

	Yes	No	Don't Know
a) 2% lower than SRP's	❑1	❑2	❑3
b) 5% lower than SRP's	❑1	❑2	❑3
c) 10% lower than SRP's	❑1	❑2	❑3
d) 15% lower than SRP's	❑1	❑2	❑3
e) 20% lower than SRP's	❑1	❑2	❑3
f) 30% lower than SRP's	❑1	❑2	❑3
g) 40% lower than SRP's	❑1	❑2	❑3

Please continue on to the next page.

Section 4

ABOUT YOUR HOME

4.1 How long have you lived in your current residence?

❑1_____ years

if less than 1 year, ❑2_____ months

4.2 Do you own or rent your home?

❑1 Own ❑2 Rent

4.3 What type of dwelling do you live in?

❑1 Single-family home
❑2 Condo or apartment (4 or more units)
❑3 Manufactured home
❑4 Duplex or triplex
❑5 Other (explain) ______________________________

4.4 What kind of air conditioning system do you have in your residence?
(Please check all that apply.)
❑1 Central air conditioning or heat pump
❑2 Window-mounted unit
❑3 Other ______________________________
❑4 None

4.5 Is your home in the Valley occupied throughout the entire year?

❑1 Yes - ⇨ Skip to Question 4.7 ❑2 No ⇩

4.6 During which months of the year is your home usually <u>not</u> occupied?

❑1 January	❑2 February	❑3 March	❑4 April
❑5 May	❑6 June	❑7 July	❑8 August
❑9 September	❑10 October	❑11 November	❑12 December

4.7 Does anyone in this household use your residence as a place of business?

☐1 Yes ☐2 No

4.8 Is anyone in your household using electrical medical equipment such as a respirator or heart monitoring equipment?

☐1 Yes ☐2 No

4.9 Does anyone in your household stay at home during most of the day?

☐1 Yes ☐2 No

4.10 Including yourself, how many people in each of the following age groups live in your household year-round? Write in the number of people on each line. Use 0 if none.

Under 6 years of age ☐1_____
6-18 ☐2_____
19-24 ☐3_____
25-49 ☐4_____
50-64 ☐5_____
65 years or older ☐6_____

4.11 Are you:

☐1 Male ☐2 Female

4.12 What is the last grade you completed in school?

☐1 Some grade school
☐2 Some high school
☐3 Graduated high school/GED
☐4 Some college/technical school/junior college degree
☐5 Graduated college
☐6 Graduate/Professional school

4.13 What was your total household income before taxes last year?

☐1 Under $20,000
☐2 $20,000 to just under $30,000
☐3 $30,000 to just under $40,000
☐4 $40,000 to just under $50,000
☐5 $50,000 to just under $60,000
☐6 $60,000 to just under $70,000
☐7 $70,000 to just under $80,000
☐8 $80,000 to just under $90,000
☐9 $90,000 and over

5.1 If you have any additional comments, please write them below.

THANK YOU FOR YOUR HELP

Please return this questionnaire in the enclosed postage-paid envelope to:

Salt River Project Study
c/o Freeman, Sullivan & Co.
131 Steuart Street., Suite 500
San Francisco, CA 94105-9582

5.2 Survey Instrument Example 2: Small to Medium Commercial Customers

POWER OUTAGES
AND YOUR BUSINESS

An Important Issue Facing Your Organization

This research is being conducted by

SALT RIVER PROJECT

Instructions

Please answer each of the questions in this survey to the best of your ability. We understand that it might be difficult to calculate some of these values—in these cases, please just give us your best estimate. If you do not know the answer to a question and cannot learn the answer from anyone else in your organization, please simply write in "DK" for "don't know." If an answer to a question is "none" or "zero," please write in "0."

Before you start, please read these definitions.

Definitions

Outages: A power outage refers to a complete loss of electricity to your organization. Power outages can be caused by many factors, such as bad weather, traffic accidents, or equipment failure.

"This site" or "this location": Salt River Project is interested in the building or buildings that your organization occupies at this site. (Some organizations have more than one building at a location, while others have buildings in several locations.) Please confine your cost estimates to the costs experienced at this site.

Survey responses will be strictly confidential.

Thank you for your participation.

Please continue on next page ⇨

SATISFACTION

1.1 How would you rate the basic electric service that SRP provides to your business? Please think of this in terms of both the reliability and quality of the power you receive. (Please circle one answer.)

1 Excellent
2 Very Good
3 Good
4 Fair
5 Poor
6 Don't Know

1.2 Do you feel the number of outages your firm experiences **at this site** is (please circle one):

Very Low						Very High
1	2	3	4	5	6	7

1.3 In the **past 12 months**, about how many outages of each length listed below has your firm experienced? (Fill in the blanks. Use 0 if none.)

Length of Outage	Number in past 12 months
A moment (1-2 seconds)	_____
1 to 15 minutes	_____
15 minutes to 1 hour	_____
1 to 2 hours	_____
2 to 4 hours	_____
4 to 12 hours	_____
12 to 24 hours	_____
Over 24 hours	_____

1.4 How disruptive have you found outages of these lengths to be?
(Please circle one number for each. Leave blank if no outages of this type in past year.)

Length of Outage	Not at all disruptive						Very disruptive
A moment (1-2 seconds)	1	2	3	4	5	6	7
1 to 15 minutes	1	2	3	4	5	6	7
15 minutes to 1 hour	1	2	3	4	5	6	7
1 to 2 hours	1	2	3	4	5	6	7
2 to 4 hours	1	2	3	4	5	6	7
4 to 12 hours	1	2	3	4	5	6	7
12 to 24 hours	1	2	3	4	5	6	7
Over 24 hours	1	2	3	4	5	6	7

Please continue on next page ⇨

1.5 At this location, has your organization experienced power outages lasting more than one or two seconds?

❑ No ➡ *If no, please skip to Question 1.9*
❑ Yes ⬇

1.6 Have you called *Salt River Project* to report an outage?

❑ No ➡ *If no, please skip to Question 1.8*
❑ Yes ⬇

1.7 How satisfied were you with the way your call was handled?

Not at all Satisfied						Completely Satisfied	Don't Recall
1	2	3	4	5	6	7	❑

1.8 Overall, how satisfied are you with SRP's efforts to restore your power after outages?

Not at all Satisfied						Completely Satisfied
1	2	3	4	5	6	7

1.9 How long can you wait for the power to be restored after a power outage before the costs to your organization become significant? (Fill in either blank, or both blanks, as needed.)

_______ : _______
hours **min**

1.10 Generally, when would be the *most inconvenient* time for an unannounced 4-hour outage to occur at your organization?

Day of week: Sun Mon Tues Wed Thurs Fri Sat
(Circle all that apply.)

Time of day outage begins: ____________ AM or ____________ PM

Please continue on next page ⇨

HOW POWER OUTAGES AFFECT YOUR ORGANIZATION

Salt River Project (SRP) wants to learn more about how electric power outages affect your organization. This knowledge will help them plan for energy needs. SRP wants to provide customers with the reliability they need, reduce wasteful investments and avoid higher costs and higher rates.

This section is about a series of possible electric power outage situations. Please indicate how each power outage situation, if it were to occur, would affect your organization.

Please continue on next page ⇨

We would like you to calculate the cost per hour of lost production or sales that would occur because of an *unexpected power outage*. Complete Question 2A below to find the value of lost production or sales for your organization. Then complete Question 2B to find the labor costs of staff unable to work.

Question 2A – Calculating on a Unit Sales Basis

To calculate the value of your lost production or sales based on your unit sales, you need to use the quantities described below:

Units Sold or Produced per hour	times	Value of Sales per Unit	times	Number of Hours Shut Down	
			= cost per hour		*=total value of lost business*

- ***For example***, a business manufactures 1,000 electronic components every 8-hour day (or 125 units per hour) for an average wholesale price of $95. The power goes out for one hour, and because of this no components are manufactured for a total of two hours. The **cost per hour** of lost business is 125 x 95 = $11,875. Since no components were made for two hours, the **total value of lost business** is 11,875 x 2 = $23,750.

Now, please calculate the cost per hour of lost business for *your* organization:

____________ **times** ____________ = ____________

your units per hour | **your value per unit** | ***cost per hour of your lost business***

Question 2B – Calculating Cost of Staff Unable to Work

To calculate the labor costs of staff unable to work, you need to use the quantities described below:

Average Number of Employees	times	Average Hourly Wage	times	Number of Hours Shut Down	
			=cost per hour		*=total labor cost*

- ***For example***, a business has 10 hourly employees averaging $6.25 per hour. No one can work during the two hour outage. The **cost per hour of labor unable to work** is 10 x 6.25 = $62.50. Since no one can work for two hours, the **total labor cost of staff unable to work** is 62.50 x 2 =$125.

Now, please calculate the labor cost per hour for *your* organization:

____________ **times** ____________ = ____________

your number of employees | **average hourly wage** | ***cost per hour of staff unable to work***

Please continue on next page ⇨

OUTAGE SITUATIONS

The next set of questions concerns the costs you would incur with a particular kind of unexpected power outage, Situation 1, which will be described below. The costs you calculate here can be used to help with your total cost estimates for Situation 1, and then for the subsequent situations we will ask you about. Each outage situation is described in terms of its length, starting time, and day of the week.

SITUATION 1

First, we would like you to imagine what would happen if a power outage occurred *without warning* at 10:00 AM on an August weekday and lasted for ONE HOUR. Before the power returns, you don't know how long the outage will last.

2.1 Please check the sources of costs your organization would incur as a result of this 1 hour outage. (Check all that apply.)

- ☐1 Lost production, sales or revenues
- ☐2 Equipment damage
- ☐3 Material spoilage
- ☐4 Re-setting controls/equipment
- ☐5 Idle labor
- ☐6 Lost data files on computer
- ☐7 Loss of telephone system
- ☐8 Injury or accident
- ☐9 Other (please specify): ______________________________

2.2 Would production or sales stop or slow down as a result of this power outage?

- ☐ No ➡ *If no, please skip to Question 2.4*
- ☐ Yes ⬇

Please continue on next page ⇨

If production or sales *would* stop or slow down, please answer these questions:

2.2a For how many **hours** would production or sales stop or slow down during <u>and</u> after this 1 hour outage? ________ hours

2.2b Now we'd like you to estimate the approximate dollar value of the production or sales that would be lost, at least temporarily, during the power outage and any slow period after the power outage. To calculate this, first obtain the **cost per hour** you calculated on page 5 from Question 2A. Place that amount in the blank below:

_____cost per hour of lost business (from page 5)

2.2c Now put the number of hours you indicated in 2.2a above in the blank below:

_____ Hours production or sales would stop or slow down (from 2.2a above)

Now simply *multiply these two numbers together* to get the total value of lost production or sales your business would incur as a result of this 1 hour outage:

2.2d $__________________ total value of lost production or sales

2.3 Would you schedule additional shifts or overtime to make up some of the lost production or sales incurred at the time of the outage?

- ❑ No ➡ *If no, please skip to Question 2.4*
- ❑ Yes ⬇

Answer the questions below if the answer to Question 2.3 is "yes":

2.3a. What percent of this production or sales would be made up? (Circle one number.)

10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

2.3b. Estimate any costs (including wages, supplemental overtime pay and variable fringe benefits) that you would pay to make up for this 1 hour outage.

$__________________

2.3c. Estimate any additional costs ***beyond*** wages, supplemental overtime pay, and variable fringe benefits that you would incur because of this 1 hour outage.

$__________________

Please continue on next page ⇨

2.4 Based on your experiences with similar outages, what is the amount of money you would have to pay to repair any equipment damaged because of this 1 hour outage? (For example, equipment may need to be dismantled and solidified liquids removed because of the outage.) (Write 0 if none.)

$__________________

2.5 Based on your experiences with similar outages, what is the cost of any production materials or finished goods that would be damaged as a result of this 1 hour outage? (For example, the value of the liquids that solidified in the example above; or the value of spoiled food, etc.) (Write 0 if none.)

$__________________

2.6 Would you operate an emergency backup generator during this 1 hour outage? (please check one.)

___ Yes ___ No ___Don't have one

2.7 Again, based on your experience with similar outages, please estimate the cost of resuming operations. (For example, paying employees additional wages for cleanup; or hiring an outside consultant to assure restarting would be handled safely.) (Write 0 if none.)

$__________________

2.8 What would be the cost of labor for staff unable to work? Use these amounts:

_____ cost per hour from Question 2B on Page 5
_____ Number of hours that staff would be unable to work due to this 1 hour outage

Multiply these together to obtain this cost:

$__________________

2.9 Estimate any additional costs not included above that would be incurred as a result of this 1 hour outage. (For example, loss of customer goodwill.)

$__________________

Please continue on next page ⇨

2.10 Now we'd simply like you to add together the amounts you estimated for each of these types of costs to get the most likely total cost your business would incur due to this 1 hour outage. Please place those amounts in the blanks below:

_____ (from 2.2d)
_____ (from 2.3b)
_____ (from 2.3c)
_____ (from 2.4)
_____ (from 2.5)
_____ (from 2.7)
_____ (from 2.8)
_____ (from 2.9)

Now please simply add these amounts together:

$__________ Most Likely Total Cost for this 1 hour Outage

Now, you've just calculated the outage cost for a typical 1 hour outage. We understand that outage costs may vary from time to time, and that estimating these values may be difficult. So we'd also like you to give us your LOWEST estimate for the total costs associated with this 1 hour outage (this estimate should be lower than the most likely cost you calculated above):

$__________ Low Estimate of total outage cost for this 1 hour outage ("best case")

And finally, we'd like you to give us your HIGHEST estimate of the total costs associated with this 1 hour outage (this estimate should be higher than the most likely cost you calculated above):

$__________ High Estimate of total outage cost for this 1 hour outage ("worst case")

Please continue on next page ⇨

On the next 4 pages are 4 more outage situations that are different from the 1 hour outage situation you have been considering, although they do have similarities to that situation. You can use the 1 hour outage scenario as a guide in determining your cost estimates for each of the following different situations.

Please continue on next page ⇨

SITUATION 2

3.1 This outage is identical to Situation 1 *except* that it is a momentary outage lasting one or two seconds instead of one hour. As before, it would take place *without warning* on an August weekday at 10:00 AM. Remember, you don't know how long the outage will last until the power returns.

Considering **all** the costs and savings you might experience as a result of this outage, please write in the lowest total cost you would expect, the most likely total cost you would expect, and the highest total cost you would expect to experience.
(Write in zero if none.)

$__________	$__________	$__________
Low Estimate of Total Outage Cost (Best Case)	**Most Likely** Total Outage Cost (Typical Case)	**High Estimate** of Total Outage Cost (Worst Case)

Please continue on next page ⇨

SITUATION 3

3.2 This is an outage that lasts for <u>one hour</u>. This outage would take place *without warning* at <u>12:00 midnight on an August weekday</u>. Remember, you don't know how long the outage will last until the power returns.

Considering **all** the costs and savings you might experience as a result of this outage, please write in the <u>lowest</u> total cost you would expect, the <u>most likely</u> total cost you would expect, and the <u>highest</u> total cost you would expect to experience.
(Write in zero if none.)

$__________	$__________	$__________
Low Estimate	**Most Likely**	**High Estimate**
of Total Outage Cost	Total Outage Cost	of Total Outage Cost
(Best Case)	(Typical Case)	(Worst Case)

Please continue on next page ⇨

SITUATION 4

3.3 This is a situation in which the outage takes place on a weekend rather than a weekday. This outage takes place *without warning* at 10:00 AM on a Saturday morning in August and lasts one hour. Remember, you don't know how long the outage will last until the power returns.

Considering **all** the costs and savings you might experience as a result of this outage, please write in the lowest total cost you would expect, the most likely total cost you would expect, and the highest total cost you would expect to experience.
(Write in zero if none.)

$__________	$__________	$__________
Low Estimate of Total Outage Cost (Best Case)	**Most Likely** Total Outage Cost (Typical Case)	**High Estimate** of Total Outage Cost (Worst Case)

Please continue on next page ⇨

SITUATION 5

3.4 This is an outage that lasts <u>one-half hour</u>. The outage takes place *without warning* at <u>10:00 AM on a weekday in August</u>. Remember, you don't know how long the outage will last until the power returns.

Considering **all** the costs and savings you might experience as a result of this outage, please write in the <u>lowest</u> total cost you would expect, the <u>most likely</u> total cost you would expect, and the <u>highest</u> total cost you would expect to experience.
(Write in zero if none.)

$__________	$__________	$__________
Low Estimate of Total Outage Cost (Best Case)	**Most Likely** Total Outage Cost (Typical Case)	**High Estimate** of Total Outage Cost (Worst Case)

Please continue on next page ⇨

ACCEPTABLE LEVEL OF RELIABILITY

SRP works hard to prevent power outages, but eliminating all outages would be very costly, if not impossible. The next questions help us understand what you consider an acceptable level of electric service reliability from SRP.

4.1 If each of the following occurred, would you think you were getting an *acceptable* or *unacceptable* level of service reliability from Salt River Project?

a. An outage lasting **less than a minute** ... (Please check one box *on each line*.)

	Acceptable Level of Service	Unacceptable Level of Service	Don't know/ No opinion
Once weekly	❑	❑	❑
Once monthly	❑	❑	❑
Once quarterly	❑	❑	❑
Once semi-annually	❑	❑	❑
Once annually	❑	❑	❑

b. An outage lasting a **few minutes to an hour** ... (Check one box *on each line*.)

	Acceptable Level of Service	Unacceptable Level of Service	Don't know/ No opinion
Once weekly	❑	❑	❑
Once monthly	❑	❑	❑
Once quarterly	❑	❑	❑
Once semi-annually	❑	❑	❑
Once annually	❑	❑	❑

Please continue on next page ⇨

c. An outage lasting **one to four hours** ... (Check one box *on each line*.)

	Acceptable Level of Service	Unacceptable Level of Service	Don't know/ No opinion
Once weekly	❑	❑	❑
Once monthly	❑	❑	❑
Once quarterly	❑	❑	❑
Once semi-annually	❑	❑	❑
Once annually	❑	❑	❑

d. An outage lasting **more than four hours** ... (Check one box *on each line*.)

	Acceptable Level of Service	Unacceptable Level of Service	Don't know/ No opinion
Once weekly	❑	❑	❑
Once monthly	❑	❑	❑
Once quarterly	❑	❑	❑
Once semi-annually	❑	❑	❑
Once annually	❑	❑	❑

4.2 Please **rank** the following choices in terms of their attractiveness to you. (Write **one** number on each line: 1 = most preferred; 2 = next most preferred; 3 = least preferred. Please use each number just once.)

_____ Half as many outages as you receive currently with a 10% price increase.

_____ The number of outages you currently receive with the same price.

_____ Twice as many outages as you receive currently with a 10% price reduction.

Comments:

____

____

____

Please continue on next page ⇨

The electric utility industry in Arizona is undergoing change to allow for more competition. Soon, you may be able to choose which electricity company actually produces or generates the electricity for your business. Under deregulation, SRP would still be responsible for transmitting and distributing the electricity from whichever company that produces it directly to your business.

4.3 If you could choose your electric power provider, what is the likelihood that you would...?

a) Review rate and service information that is mailed to you by other electricity providers, to compare this to what SRP offers.

Definitely would				Definitely would not
1	2	3	4	5

b) Actually switch electric power companies from SRP to someone else.

Definitely would				Definitely would not
1	2	3	4	5

c) Agree to speak or meet with another electricity provider to discuss the possibility of switching your electric service away from SRP.

Definitely would				Definitely would not
1	2	3	4	5

d) Take the initiative to request rate and service information from other electricity providers, to compare this to what SRP offers.

Definitely would				Definitely would not
1	2	3	4	5

4.4 If another electric company offered you electric service that was **comparable** to SRP's, and at the **same price** as SRP, would you be likely to discontinue your service with SRP?

Yes, would discontinue with SRP 1
No, would not discontinue...................................2
Don't Know 3

Please continue on next page ⇨

4.5 If another electric company offered you electric service that was **comparable** to SRP's, but they offered you **lower rates**, at what percentage would you be likely to discontinue your service with SRP?

	Yes	No	Don't Know
a) 2% lower than SRP's	1	2	3
b) 5% lower than SRP's	1	2	3
c) 10% lower than SRP's	1	2	3
d) 15% lower than SRP's	1	2	3
e) 20% lower than SRP's	1	2	3
f) 30% lower than SRP's	1	2	3
g) 40% lower than SRP's	1	2	3

Please continue on next page ⇨

ABOUT YOUR ORGANIZATION

Some background information about your organization will help us understand how power outages affect your type of organization. All of your answers are **strictly confidential.** The information will be used only to report comparisons among major categories of organizations, such as "manufacturers." **We will never identify individuals or organizations with their responses.**

5.1 How many employees, including management and working owners, are employed by your organization at this location?

Number of full-time employees: ________ Number of part-time employees: _______
(30+ hours)

5.2 Approximately what percentage of your organization's annual operating budget is spent on energy costs at this location, including gas and electricity?

__________________%

Please continue on next page ⇨

5.3 Does your organization have emergency or backup electrical supply equipment?

- ❑ No ➡ *If no, please skip to Question 6.1*
- ❑ Yes ⬇

If you said you **do** have emergency and backup electrical supply equipment:

5.4 What type of system do you have?

- ❑ Battery System
- ❑ Engine-Driven System
- ❑ Other (please specify) ____________________

5.5 About what percentage of your power needs can your backup system supply?

____________________%

5.6 How long can your firm operate on this backup system?

____________________ hours

5.7 How much did you spend to install your backup system?

$____________________

5.8 Are your computer systems backed up by an *Uninterruptible Power Supply* ("UPS")? (Please check one.) ___ Yes ___No ___Don't have computer systems

5.9 Are your telephone systems backed up by an *Uninterruptible Power Supply* ("UPS")? (Please check one.) ___ Yes ___No ___Don't have telephone systems

Please continue on next page ⇨

6.1 If you have any additional comments, please write them below.

____

____

____

____

____

____

____

THANK YOU FOR YOUR HELP

Please return this questionnaire in the enclosed postage-paid envelope to:

Salt River Project Study
c/o Freeman, Sullivan & Co.
131 Steuart Street, Suite 500
San Francisco, CA 94105-9582

Please continue on next page ⇨

5.3 Survey Instrument 3: Agricultural Customers

I THE QUALITY OF PG&E SERVICE

The first few questions on the survey concern your perceptions of the quality of service provided by PG&E.

Q-1.1 Overall, how would you rate the quality of the service provided by PG&E? (circle number)

POOR					EXCELLENT	
1	2	3	4	5	6	7

Q-1.2 In your opinion, about what percent of the outages you experience (for the enterprise indicated in our letter) could have been prevented by PG&E? (make an 'X' anywhere on the line)

None — About Half — All

Q-1.3 For each of the two month periods listed below, please circle the time during the day when a four-hour power outage would be <u>most</u> costly to the enterprise indicated in our letter. (circle only one daily time slot for each two month period).

	6am-Noon	Noon-6pm	6pm-Midnight	Midnight-6am	All Times
JAN - FEB	Morning	Afternoon	Evening	Night	No Difference
MAR - APR	Morning	Afternoon	Evening	Night	No Difference
MAY - JUN	Morning	Afternoon	Evening	Night	No Difference
JUL - AUG	Morning	Afternoon	Evening	Night	No Difference
SEP - OCT	Morning	Afternoon	Evening	Night	No Difference
NOV - DEC	Morning	Afternoon	Evening	Night	No Difference

Q-1.4 If a four-hour outage occurred during the worst time of day for the months listed below, how costly would this outage be for the enterprise indicated in your letter? (Circle only one number for each two month period)

	NOT COSTLY						VERY COSTLY
JAN - FEB	1	2	3	4	5	6	7
MAR - APR	1	2	3	4	5	6	7
MAY - JUN	1	2	3	4	5	6	7
JUL - AUG	1	2	3	4	5	6	7
SEPT - OCT	1	2	3	4	5	6	7
NOV - DEC	1	2	3	4	5	6	7

Q-1.5 Thinking back over the last 10 years, about how much do you think is the most a single outage has cost for the indicated enterprise? (enter 0 if none)

$________________

Q-1.6 When was your most recent power outage for the indicated enterprise?

________ Year (continue)

________ Don't Know (Skip to 2.1)

________ Never (Skip to 2.1)

Q-1.7 About how many hours did it last (make an 'X' anywhere on the line)?

0 — 1 — 2 — 3 — 4 — 5 — 8 — 12 — Longer

Hours

Q-1.8 All things considered, about how much do you think this most recent outage for the identified enterprise cost your organization? (enter 0 if none)

$________________

Q-1.9 Did you attempt to call PG&E during this most recent outage?

___ YES (continue)

___ NO (Skip to 1.12)

Q-1.10 Were you able to speak with someone from PG&E during this most recent outage?

___ YES (continue)

___ NO (Skip to 1.12)

Q-1.11 Was the person (or persons) you spoke with courteous and responsive to your needs?

___ YES

___ NO

Q-1.12 Were you satisfied with PG&E's overall handling of this most recent outage?

___ YES

___ NO

Q-1.13 How could PG&E improve its service to you during outages? (Please be specific)

____

____

____

____

II HOW POWER OUTAGES AFFECT YOU

In this section please estimate the costs of an electric outage for the agricultural enterprise indicated in our letter. In answering the questions, assume the circumstances of the outage are like those described in the box below. The outage affects all of the electricity serving the enterprise described in the cover letter. (If you are not sure about this location call Chris Sullivan at Doane Marketing Research 1-800-~~752~~-6263).
753

POWER OUTAGE	
Conditions: Hot Day 2nd Week in July	Start Time: 3:00 pm
Warning: Outage begins and ends unexpectedly	End Time: 7:00 pm

Q-2.1 Please use the checklist below to indicate all costs you would incur as a result of the four-hour mid-July outage illustrated above for the indicated enterprise. (Check all items which apply)

PRODUCT LOSSES:

_____ PERMANENT CROP YIELD
_____ DAIRY MILK
_____ GREENHOUSE PRODUCT
_____ COLD STORAGE PRODUCT
_____ LIVESTOCK LOSSES
_____ OTHER PRODUCT LOSSES
_____ NO PRODUCT LOSSES

INDIRECT COSTS:

_____ EQUIPMENT REPAIR
_____ ADDITIONAL CROP CHEMICALS
_____ RE-PLANT EXPENSES
_____ REFUELING PROBLEMS (e.g. Tractors and Combines)
_____ ADDITIONAL ANIMAL HEALTH EXPENSES
_____ OTHER INDIRECT COSTS
_____ NO INDIRECT COSTS

OPERATING COSTS:

_____ ADDITIONAL IRRIGATION WATER
_____ RUNNING BACK-UP POWER
_____ ADDITIONAL LABOR
_____ INCREASE IN TIME-OF-USE RATES
_____ OTHER OPERATING COSTS
_____ NO OPERATING COSTS

Q-2.2 Under normal circumstances, about how many hours do you think it would take you to discover that this four-hour mid-July outage had occurred (make an 'X' anywhere on the line)?

|—————|—————|—————|—————|—————|—————|—————|—————|
0 1 2 3 4 5 8 12 Longer

Hours

Q-2.3 Would you take any precautionary measures during this **four-hour mid-July** outage to protect the indicated enterprise or to save money (e.g. shut off motors or operate generators)?

___ YES **(continue)**

___ NO **(Skip to 2.5)**

Q-2.4 Please describe the measures you would take in the space provided below.

____

____

____

Q-2.5 Given the precautions you would take, would any product be lost due to this **four-hour** outage **in mid-July** (this includes losses due to crop damage, stress, spoilage or livestock death)?

___ YES **(continue)**

___ NO **(Skip to 2.8)**

Q-2.6 About how much of the lost product from the indicated enterprise could be made up at a later date (make an 'X' anywhere on the line)?

None | About Half | All

|----|----|----|----|----|----|----|----|----|----|

Q-2.7 Given the precautions you would take, please estimate the approximate dollar value of enterprise production that would be lost due to this **four-hour mid-July outage** (please include only production losses that <u>cannot</u> be made up within a few weeks). (enter 0 if none)

$________________

Q-2.8 Given the precautions you would take, do you think it is likely that any damage to equipment for the indicated enterprise would result from this **four-hour mid-July** outage (e.g., damage to motors or electronic devices)?

___ YES **(continue)**

___ NO **(Skip to 2.10)**

Q-2.9 Please estimate the costs required to repair this damaged equipment.

$________________

Q-2.10 Do you have a back-up generator which can be used to provide standby power for this enterprise during this power outage?

___ YES (continue)

___ NO (Skip to 2.13)

Q-2.11 What is its rated capacity?

__________kW or __________hp

Q-2.12 About how much did you spend to purchase and install the system?

$________________

Q-2.13 Please estimate any additional costs you would experience for the indicated enterprise as a result of this **four-hour mid-July** outage. (enter 0 if none)

$__________ Additional Water

$__________ Re-planting Expenses

$__________ Labor to Recover From Outage

$__________ Additional Electricity

$__________ Additional Chemicals

$__________ Other

Q-2.14 Considering all of the costs you might experience as a result of this **four-hour outage in mid-July** for the indicated enterprise, please estimate costs for the most likely case, best case and worst cases you would experience (including product losses). (enter 0 if none)

1) MOST LIKELY CASE $__________

2) BEST CASE $__________

3) WORST CASE $__________

III. THE COSTS OF ELECTRIC OUTAGES

In this section please estimate the outage costs that you would experience as a result of each of the different types of outages presented. The outages have been selected to represent a range of possibilities you might experience.

Please limit your cost estimates to those that would be experienced by the enterprise indicated in our letter.

POWER OUTAGE	
Conditions: Hot Day 2nd Week in July	Start Time: 3:00 pm
Warning: Outage begins and ends unexpectedly	End Time: 4:00 pm

Q-3.1 Please use the checklist below to indicate all costs you would incur as a result of the one-hour outage illustrated above for the indicated enterprise. (Check all items which apply)

PRODUCT LOSSES:

_____ PERMANENT CROP YIELD
_____ DAIRY MILK
_____ GREENHOUSE PRODUCT
_____ COLD STORAGE PRODUCT
_____ LIVESTOCK LOSSES
_____ OTHER PRODUCT LOSSES
_____ NO PRODUCT LOSSES

INDIRECT COSTS:

_____ EQUIPMENT REPAIR
_____ ADDITIONAL CROP CHEMICALS
_____ RE-PLANT EXPENSES
_____ REFUELING PROBLEMS (e.g. Tractors and Combines)
_____ ADDITIONAL ANIMAL HEALTH EXPENSES
_____ OTHER INDIRECT COSTS
_____ NO INDIRECT COSTS

OPERATING COSTS:

_____ ADDITIONAL IRRIGATION WATER
_____ RUNNING BACK-UP POWER
_____ ADDITIONAL LABOR
_____ INCREASE IN TIME-OF-USE RATES
_____ OTHER OPERATING COSTS
_____ NO OPERATING COSTS

Q-3.2 Please estimate the total dollar cost of this one-hour outage for the indicated enterprise (including product losses).

1) MOST LIKELY CASE $_________
2) BEST CASE $_________
3) WORST CASE $_________

Q-3.3 Suppose PG&E announced on radio and television starting at 2:00 pm that this outage was going to occur. How likely are you or someone at your operation to hear or see the emergency broadcast notice from PG&E? (make an 'X' anywhere on the line)

VERY UNLIKELY VERY LIKELY

0 10 20 30 40 50 60 70 80 90 100

Percent Likely To Hear or See

Q-3.4 If you heard the advance warning on the radio or television, would you be able to do anything to reduce the effects of this outage on the indicated enterprise?

___ YES (continue)

___ NO (Skip to 3.7)

Q-3.5 Please describe the measures you would take in the space provided below.

____

____

____

Q-3.6 Given any precautions you might be able to take with one-hour advance notice, please estimate the total dollar cost of this outage for this enterprise assuming you heard the advance notice.

1) MOST LIKELY CASE $________

2) BEST CASE $________

3) WORST CASE $________

POWER OUTAGE

Conditions: Cold Night 2nd Week in February	Start Time: 1:00 am
Warning: Outage begins and ends unexpectedly	End Time: 5:00 am

Q-3.7 Please use the checklist below to indicate all costs that would be incurred as a result of the four-hour outage in mid-February illustrated above. (Check all items which apply)

PRODUCT LOSSES:

_____ PERMANENT CROP YIELD
_____ DAIRY MILK
_____ GREENHOUSE PRODUCT
_____ COLD STORAGE PRODUCT
_____ LIVESTOCK LOSSES
_____ OTHER PRODUCT LOSSES
_____ NO PRODUCT LOSSES

INDIRECT COSTS:

____ EQUIPMENT REPAIR
_____ ADDITIONAL CROP CHEMICALS
_____ RE-PLANT EXPENSES
_____ REFUELING PROBLEMS (e.g. Tractors and Combines)
_____ ADDITIONAL ANIMAL HEALTH EXPENSES
_____ OTHER INDIRECT COSTS
____ NO INDIRECT COSTS

OPERATING COSTS:

_____ ADDITIONAL IRRIGATION WATER
_____ RUNNING BACK-UP POWER
_____ ADDITIONAL LABOR
_____ INCREASE IN TIME-OF-USE RATES
_____ OTHER OPERATING COSTS
_____ NO OPERATING COSTS

Q-3.8 Please estimate the total dollar cost of this four-hour outage in mid-February for the indicated enterprise (including product losses).

1) MOST LIKELY CASE $__________

2) BEST CASE $__________

3) WORST CASE $__________

POWER OUTAGE

Conditions: Hot Day 2nd Week in July | Start Time: Noon

Warning: Outage begins and ends unexpectedly | End Time: 8:00 pm

Q-3.9 Please use the checklist below to indicate all costs that would be incurred for the indicated enterprise as a result of the **eight-hour mid-July** outage illustrated above. (Check all items which apply)

PRODUCT LOSSES:

_____ PERMANENT CROP YIELD
_____ DAIRY MILK
_____ GREENHOUSE PRODUCT
_____ COLD STORAGE PRODUCT
_____ LIVESTOCK LOSSES
_____ OTHER PRODUCT LOSSES
_____ NO PRODUCT LOSSES

INDIRECT COSTS:

_____ EQUIPMENT REPAIR
_____ ADDITIONAL CROP CHEMICALS
_____ RE-PLANT EXPENSES
_____ REFUELING PROBLEMS (e.g. Tractors and Combines)
_____ ADDITIONAL ANIMAL HEALTH EXPENSES
_____ OTHER INDIRECT COSTS
_____ NO INDIRECT COSTS

OPERATING COSTS:

_____ ADDITIONAL IRRIGATION WATER
_____ RUNNING BACK-UP POWER
_____ ADDITIONAL LABOR
_____ INCREASE IN TIME-OF-USE RATES
_____ OTHER OPERATING COSTS
_____ NO OPERATING COSTS

Q-3.10 Please estimate the total dollar cost of this **eight-hour mid-July** outage for the indicated enterprise (including product losses).

1) MOST LIKELY CASE $__________
2) BEST CASE $__________
3) WORST CASE $__________

VOLUNTARY CURTAILMENT -- NOT AN OUTAGE

Conditions: Hot Day 2nd Week in July

Start Time: 11:00 am

Warning: Radio and Television appeals starting at 10:00 am

End Time: 5:00 pm

Q-3.11 How likely are you or someone from your operation to hear or see the advance broadcast notice from PG&E (make an 'X' anywhere on the line)?

VERY UNLIKELY — VERY LIKELY

|—|—|—|—|—|—|—|—|—|—|

0 10 20 30 40 50 60 70 80 90 100

Percent Likely to Hear or See

Q-3.12 What proportion of your regular power consumption would you be willing to give up for the indicated enterprise, assuming that you heard the appeals (make an 'X' anywhere on the line)?

NONE — ALL

|—|—|—|—|—|—|—|—|—|—|

0 10 20 30 40 50 60 70 80 90 100

Percent Of Power You Would Give Up

Q-3.13 Please use the checklist below to indicate all costs that would be incurred for the indicated enterprise as a result of any voluntary curtailment you might make. (Check all items which apply)

PRODUCT LOSSES:

- ____ PERMANENT CROP YIELD
- ____ DAIRY MILK
- ____ GREENHOUSE PRODUCT
- ____ COLD STORAGE PRODUCT
- ____ LIVESTOCK LOSSES
- ____ OTHER PRODUCT LOSSES
- ____ NO PRODUCT LOSSES

INDIRECT COSTS:

- ____ EQUIPMENT REPAIR
- ____ ADDITIONAL CROP CHEMICALS
- ____ RE-PLANT EXPENSES
- ____ REFUELING PROBLEMS (e.g. Tractors and Combines)
- ____ ADDITIONAL ANIMAL HEALTH EXPENSES
- ____ OTHER INDIRECT COSTS
- ____ NO INDIRECT COSTS

OPERATING COSTS:

- ____ ADDITIONAL IRRIGATION WATER
- ____ RUNNING BACK-UP POWER
- ____ ADDITIONAL LABOR
- ____ INCREASE IN TIME OF USE RATES
- ____ OTHER OPERATING COSTS
- ____ NO OPERATING COSTS

Q-3.14 Assuming you gave up the portion of power you said you would be willing to curtail, please estimate the total dollar cost of this voluntary curtailment for the indicated enterprise (including product losses)

1) MOST LIKELY CASE $__________

2) BEST CASE $__________

3) WORST CASE $__________

IV ABOUT THE INDICATED ENTERPRISE

Q-4.1 Listed below are various types of electric pumps. Please indicate the number of each kind of pump serving the indicated enterprise.

	NUMBER OF PUMPS
WELL	______
CANAL	______
BOOSTER	______
RIVER	______
RECIRCULATING PUMPS (boiler water etc)	______
FUEL PUMPS	______
LIVESTOCK DRINKING WATER PUMPS	______
WASTEWATER PUMPS	______
OTHER	______
(please specify) ____________________	

Q-4.2 Listed below are various agricultural pumping uses. Please check those which apply to this enterprise.

_____ DRIP IRRIGATION
_____ SPRINKLER IRRIGATION
_____ SURFACE IRRIGATION
_____ VENTILATION
_____ MILK
_____ LIVESTOCK WATER SUPPLY
_____ NONE

_____ COOLING
_____ FROST CONTROL
_____ CLEANING/WASHING
_____ REFUELING
_____ WASTEWATER
_____ OTHER (specify)
____
____

V ABOUT YOUR WHOLE FARM OPERATION

Q-5.1 Listed below are various types of equipment that are used by different farms. Please indicate how important each of these types of equipment is to your entire farm and not just the indicated enterprise.

TYPE OF EQUIPMENT	DO NOT HAVE	NOT VERY IMPORTANT	IMPORTANT	VERY IMPORTANT
Animal climate control	1	2	3	4
Computer	1	2	3	4
Electronic control (timers)	1	2	3	4
Indoor lighting	1	2	3	4
Frost Protection fans	1	2	3	4
Outdoor lighting	1	2	3	4
Refrigeration/freezing	1	2	3	4
Ventilation	1	2	3	4
Telephones and Radios	1	2	3	4
Fuel Pumps	1	2	3	4
Milking Equipment	1	2	3	4
Shop Equipment	1	2	3	4

Q-5.2 What was the total (gross) income from sales of all farm products from your entire farm or ranch during the entire year of 1990? (Please do not include off-farm income, government payments or income from land rented out or not farmed by you) (Please check one line)

_______ $5,000,000 and over
_______ $2,500,000 - $4,999,999
_______ $1,000,000 - $2,499,000
_______ $500,000 - 999,000
_______ $250,000 - $499,999
_______ $100,000 - $249,000
_______ $50,000 - $99,000
_______ Under $50,000

Q-5.3 What was the number of permanent employees working on all types of agricultural production during 1990? (please exclude any seasonal laborers)

NUMBER OF PERMANENT WORKERS

FULL TIME (including yourself) __________

PART TIME (excluding seasonal workers) __________

Q-5.4 How much formal education have you completed? (Circle number)

1. NO FORMAL EDUCATION
2. SOME GRADE SCHOOL
3. COMPLETED GRADE SCHOOL
4. SOME HIGH SCHOOL
5. COMPLETED HIGH SCHOOL
6. TRADE SCHOOL
7. SOME COLLEGE
8. COMPLETED COLLEGE
9. SOME GRADUATE WORK
10. ADVANCED COLLEGE DEGREE

Q-5.5 Please indicate the number of the following livestock you have on your entire farm today (enter 0 if none).

	ON FARM TODAY
DAIRY ANIMALS	________
BEEF ANIMALS	________
HOGS AND PIGS	________
HORSES	________
POULTRY	________
SHEEP AND GOATS	________
OTHER LIVESTOCK (SPECIFY)	

____

____

Chech here if no livestock ____
(SKIP To Q.5.7)

Q-5.6 Please indicate the number of the following livestock sold during 1990 (enter 0 if none).

	SOLD IN 1990
BEEF CATTLE	________
BEEF FEEDER CALVES	________
MARKET HOGS	________
PIGS SOLD AS FEEDERS	________

Q-5.7 Please indicate the number of acres grown for each of the crops you raised on the your entire farm operation during 1990. This includes all acres you manage on a day-to-day basis.

Crop	Acres Grown 1990	Crop	Acres Grown 1990
Corn	________	Grapes	________
Sorghum	________	Tree Nuts	________
Wheat	________	Citrus Fruits	________
Barley	________	Other Fruits (specify)	
Oats & Rye	________	________	________
Soybeans	________	________	________
Cotton	________	________	________
Tobacco	________	Vegetables (specify)	
Rice	________	________	________
Alfalfa/Alfalfa Mixtures	________	________	________
Other Hays (not pasture)	________	________	________
Sugar Crops	________	Ornamental Nursery	________
Sunflowers	________	(specify if Sq. feet)	
Pasture and Range	________	Other Crops (specify)	
		________	________
		________	________
		________	________

Is there anything we may have overlooked? Please use this space for any additional comments you would like to make concerning Pacific Gas and Electric Company and your electric power service.

When you have completed this survey, please return it to Doane Marketing Research In the enclosed business reply en-velope.

5.4 Survey Instrument Example 4: Large Commercial Customers

Salt River Project

Large Industrial and Commercial Value of Service Survey

Associated Delivery Numbers

CASEID #.________________

Date of Interview.________________
Interviewer Name.________________

Interview Start Time:________________
Interview End Time.________________
(Use military time, e g ,8 30 a m = 0830; 5 p m = 1700)

Name of Respondent:________________________ Title:________________

Name of Respondent.________________________ Title:________________

Name of Respondent.________________________ Title.________________

Today, I would like to talk to you about the costs of power outages for.
(describe the part of the site served by the selected deliveries)

Company name:________________________

Service address:________________________

If delivery serves only part of site, describe location served:

OUTAGE SCENARIOS

Case #1: Unexpected outage on a hot Summer weekday at 11 a m lasting for 1 hour
Case #2: Unexpected outage on a hot Summer weekday at 11 a m lasting for 1/2 hour
Case #3: Unexpected outage on a hot Summer weekday at 11 a m lasting for four hours
Case #4: Unexpected momentary outage on a hot Summer weekday at 11 a m lasting 1-2 seconds
Case #5: On a hot Summer weekday the lights and equipment flicker due to a voltage sag at around 11 a m

What are the operating hours of this facility (or part of the facility)?
Use military time If open 24 hours, use 00 00 to 00 00

	Weekday		Saturday		Sunday	
	Open	Close	Open	Close	Open	Close
Shift 1						
Shift 2						
Shift 3						

PRODUCT AND PROCESS DESCRIPTION

1) What products do you make and/or what services do you provide at this facility?

2) What processes do you use to make these products and/or generate these services?

Salt River Project
Large Industrial and Commercial Value of Service Survey

Processes (please check all processes used at this facility)

☐ Assembly	☐ Filtering	☐ Mixing	☐ Shipping
☐ Carding	☐ Forming	☐ Molding	☐ Slashing
☐ Cutting	☐ Furnace	☐ Opening	☐ Software Programming
☐ Drawing	☐ Grinding	☐ Baking	☐ Spinning
☐ Drilling	☐ Heat Treating	☐ Packaging	☐ Stamping
☐ Drying	☐ Knitting	☐ Pumping	☐ Warping
☐ Dying	☐ Laboratory	☐ Refrigeration	☐ Waste Treatment
☐ Experiments	☐ Machining	☐ Sawing	☐ Weaving
☐ Extruding	☐ Medical	☐ Sewing	☐ Welding

Equipment (Please check all equipment used at this facility)

☐ A C Variable Motors	☐ Extruders	☐ Opening Lines	☐ Sanders
☐ Blenders	☐ Grinders	☐ Personal Computers	☐ Sanforizers
☐ Carding Machines	☐ Hvac Equipment	☐ PLC's	☐ Saws
☐ CNC Machines	☐ Knitting Machines	☐ Presses	☐ Stashing Machines
☐ Controlled Valves	☐ Looms	☐ Air Compressors	☐ Spinning Frames
☐ Crushers	☐ Mainframe Computers	☐ Process Controllers	☐ Telecommunications
☐ Drawing Machines	☐ Mini Computers	☐ Pumps	☐ Twisting Machines
☐ Dryers	☐ Mixers	☐ Reamers	☐ Warping Frames
☐ Dying Machines	☐ Molding Machines	☐ Robots/Automation	☐ Welders
☐ Electric Furnaces	☐ Network Controllers	☐ Roving Machines	☐ Winding Frames

Other Equipment
(list)

☐ ____________________
☐ ____________________
☐ ____________________
☐ ____________________
☐ ____________________

ACTUAL OUTAGE EVENTS

Please describe your three most recent voltage disturbances or power outages.

	Outage Date *Mo/Yr*	Type *E/M/VD*	Duration *Hrs/Mins/Secs*	Time *Military*	Weather Conditions *Clear/Stormy*	Description of Impacts
3 1)	______	______	______	______	______	__________
3 2)	______	______	______	______	______	__________
3.3)	______	______	______	______	______	__________

4) What normally happens to your facility's operations when a prolonged power outage (lasting more than five minutes) occurs? (Prompt for major equipment affected, worst effects on operations, etc)

____
____
____
____

5 1) Does an outage at this location have financial effects on other sites owned by your company?
1) Yes 2) No (if No skip to Ques 5 4)

5 2) What type or duration of an outage has financial effects on other sites owned by your company?
(Probe for interdependencies of the production network)

____
____
____
____

5.3) What are the specific financial effects?

5.4) Does an outage at this location have financial effects at customers' sites?
1) Yes 2) No

6.1) Are you familiar with the term,"voltage sag"?
1) Yes 2) No (give the definition of a voltage sag)

6 2) What are the short term effects on your facility's operation if a voltage sag caused by your power company occurs?
(Prompt for major equipment affected, worst effects on operations, etc)

6 3) What are the long term effects to your facility's operations if repeated voltage sags caused by your power company occur (1 to 2 per month) over a long period of time (5 - 10 yrs)?
(Prompt for major equipment affected, worst effects on operations, what steps would be taken, etc.)

7 1) Have you ever used power monitoring devices on any of your equipment to detect voltage sags?
1) Yes 2) No (if No skip to Ques 8 1)

7 2) On what equipment/process did you install the power monitoring device?

____

____

7 3) When did you install/purchase the monitoring equipment? __________yr

7 4) What was the reason behind installing it?

____

____

8 1) What do you think is the most frequent source of the voltage disturbances you have experienced?
1 Salt River Project
2 Internal electrical problems
3 Unknown

8 2) How did you determine the most frequent source of the voltage disturbances?

1) Conducted study 2) Personal judgment 3) Salt River Project informed you

I am now going to review a list of manufacturing equipment For each type of equipment please let me know: the number, whether any repairs or replacements had been made due to outages, whether the equipment is critical to the operation of the facility, if the equipment is connected to power conditioning equipment and when the equipment was installed

Table 1: Critical Equipment List

EQUIPMENT	Number	Has Power Conditioning? (Y/N)	Ever Repair/Replace Due to Outage? (Y/N)	Critical to Operations? (Y/N)
AC Variable Speed Motors				
CNC Machines				
Extruders				
Heat Treating Ovens/Dryers				
HVAC Equipment				
Machine Tools				
Main Frame Computers				
Network Controllers				
Personal Computers				
PLCs				
Process Controllers				
Robots/Automation				
Telecomm Equipment				
Work Stations/Mini Computers				
Other Equipment				

INTERVIEWER:
Go through the list of equipment, noting the number of each type and whether it has power conditioning equipment.
Then ask:
"Have you ever repaired or replaced any of these items due to a power outage?" Indicate Y/N next to each item
Then ask:
"Are any of these items not critical to your operations?" Indicate Y/N next to each item

9 1) Does your firm generate any of its own electricity?
1) Yes 2) No (if No Skip to Q10 1)

9 2) What percentage of your electrical demand is supplied by your generation equipment?
_________%

9 3) What is the rated capacity of your generation equipment?
________kW

10 1) Does your firm have some form of backup electrical power or power conditioning equipment?
1) Yes 2) No (if No Skip Table Two)
I am going to read a list of generation and conditioning equipment For each type of equipment, please tell me: the number you have, supply life, the date installed and the systems or processes the equipment supports

Table 2: Generation and Conditioning Equipment

Conditioning Equipment	Number	Supply Life	Year Installed	Equipment/Processes Supplied
UPS				
Standby Generators				
Harmonic Filters				
Isolation Transformers/Reactors				
Ferroresonant Transformers				
Automatic Transfer Switches				
Batteries				
Other Equipment				

10 2) What is the yearly maintenance cost? $____________________

10 3) Do you have any money presently budgeted to purchase back-up generators and/or power conditioning equipment?
1) Yes $__________ 2) No (Skip to 10 4)

What equipment have you budgeted for?

____

____

10 4) Was there a specific incident which influenced your decision to install (or budget for) the back-up generator and/or power conditioning equipment?

1) Yes Explain ____
2) No

Outage Cost Measurements

	CASE #1 Unexpected One Hour Outage at 11 a m. During Summer	CASE #2 Unexpected 1/2 Hour Outage at 11 a.m During Summer	CASE #3 Unexpected Four Hour Outage at 11 a m. During Summer	CASE #4 Unexpected Momentary Outage at 11 a m. Lasting 1-2 Sec Summer	CASE #5 Clear Day Unexpected Voltage Sag Around 11 a m Summer
C1) How long would activities stop or slow down as a result of this outage?	________ hrs.	________ hrs.	________ hrs.	________ hrs.	________ hrs.
(if zero skip to Ques C6)	________ min.	________ min.	________ min.	________ min.	________ min.
C2) By what percentage would activites stop or slow down?	________ %	________ %	________ %	________ %	________ %
C3) What is the value of output (cost plus profit) that would be lost (at least temporarily) while activities are stopped or slowed down due to the outages?	________ $	________ $	________ $	________ $	________ $
C4) What percent of this lost output is likely to be made up?	________ %	________ %	________ %	________ %	________ %

	CASE #1 Unexpected One Hour Outage at 11 a m During Summer	CASE #2 Unexpected 1/2 Hour Outage at 11 a m During Summer	CASE #3 Unexpected Four Hour Outage at 11 a m During Summer	CASE #4 Unexpected Momentary Outage at 11 a m Lasting 1-2 Sec Summer	CASE #5 Clear Day Unexpected Voltage Sag Around 11 a m Summer
C5) So I would estimate that the amount that your firm's revenue and/or budget would change in the time period during which the outage occurred as a result of the outage would be: IS THAT RIGHT?	________$	________$	________$	________$	________$
Extra Materials Cost					
C6) Damage/spoilage to raw or intermediate materials	________$	________$	________$	________$	________$
C7) Cost of disposing of hazardous materials	________$	________$	________$	________$	________$
C8) Damage to your firm's plant or equipment	________$	________$	________$	________$	________$

	CASE #1 Unexpected One Hour Outage at 11 a m During Summer	CASE #2 Unexpected 1/2 Hour Outage at 11 a m During Summer	CASE #3 Unexpected Four Hour Outage at 11 a m During Summer	CASE #4 Unexpected Momentary Outage at 11 a m Lasting 1-2 Sec Summer	CASE #5 Clear Day Unexpected Voltage Sag Around 11 a m. Summer
C9) Costs to run backup plant or equipment	______$	______$	______$	______$	______$
C10) Additional materials and other fuel costs to restart facilities	______$	______$	______$	______$	______$
Savings On Materials Cost					
C11) Savings from unused raw and intermediate materials (except fuel)	______$	______$	______$	______$	______$
C12) Savings on your firm's fuel (electrical) bill	______$	______$	______$	______$	______$
C13) Scrap value of damaged product or inputs	______$	______$	______$	______$	______$

	CASE #1 Unexpected One Hour Outage at 11 a.m During Summer	CASE #2 Unexpected 1/2 Hour Outage at 11 a.m During Summer	CASE #3 Unexpected Four Hour Outage at 11 a m. During Summer	CASE #4 Unexpected Momentary Outage at 11 a.m. Lasting 1-2 Sec Summer	CASE #5 Clear Day Unexpected Voltage Sag Around 11 a m Summer
Labor Costs					
C14) How would this lost output most likely be made up? *Check all that apply*					
a) Overtime	______	______	______	______	______
b) Extra Shifts	______	______	______	______	______
c) Work more intensely	______	______	______	______	______
d) Reschedule work	______	______	______	______	______
e) Other	______	______	______	______	______
C15) Labor costs to make-up lost output	______$	______$	______$	______$	______$
C16) Extra labor costs to restart activities	______$	______$	______$	______$	______$
C17) Savings from wages that were not paid	______$	______$	______$	______$	______$
C18) Other costs	______$	______$	______$	______$	______$
C19) Other savings	______$	______$	______$	______$	______$

	CASE #1	CASE #2	CASE #3	CASE #4	CASE #5
	Unexpected One Hour Outage at 11 a.m During Summer	Unexpected 1/2 Hour Outage at 11 a m. During Summer	Unexpected Four Hour Outage at 11 a m During Summer	Unexpected Momentary Outage at 11 a.m. Lasting 1-2 Sec. Summer	Clear Day Unexpected Voltage Sag Around 11 a m Summer
C20) Total Costs (to be used if respondent will not give you components costs)	________$	________$	________$	________$	________$
C21) Cost Differentials					
3PM / 11AM	________	________	________	________	________
Shift 2 / Shift 1	________	________	________	________	________
Shift 3/ Shift 1	________	________	________	________	________
Saturday/Shift 1	________	________	________	________	________
Sunday/Shift 1	________	________	________	________	________

I1) Now that we have discussed the direct costs associated with these outages
Would you experience any intangible costs such as loss of good will, potential liability, or loss of future customers?
1 Yes   2 No   (if Yes please explain)

____

____

12 1) Has your organization installed equipment that is more sensitive to voltage disturbances in the last five years

1) Yes   2) No   Please Explain: ______________________

12.2) Do you plan to upgrade, expand, or otherwise change this facility within the next 24 months?

1) Yes   2) No

→ 12.3) Are you explicitly considering the sensitivity of new equipment to voltage disturbances in the design of the facility?

1) Yes   2) No

→ 12 4) Are you considering?

1 Specifying ridethrough capability

2 Installing mitigation equipment

3 Other ______________________

Based on your observations of this facility, give a brief summary of the facility, any freak occurences with their power supply, and the critical factors that minimize and/or exacerbate outage costs

Proposal to Conduct a New Value of Service Estimation Study for Pacific Gas and Electric Company

Energy and Environmental Economics, Inc.

December 27, 2004

John Carruthers & Lise Jordon
Pacific Gas & Electric Company
San Francisco, CA

Dear John and Lise:

Energy & Environmental Economics, Inc. (E3) is pleased to provide the attached Proposal to conduct a new Value of Service (VOS) Estimation Study to aid in Pacific Gas and Electric Company's compliance with the CPUC decision D.04-10-034.

In this proposal, we have provided the following documentation for your review:

1. An overview of E3's recommended market-based approach for VOS estimation
2. A description and evaluation of VOS estimation methods
3. Response to comments on E3's market-based approach
4. A description of proposed tasks and deliverables
5. A proposed staff team, schedule, and not-to-exceed budget to complete tasks
6. Supporting qualifications, references, and refereed publications

If you have any questions or comments regarding this proposed offer, please contact me at (415) 391-5100 or at ck@ethree.com.

Sincerely,

C.K. Woo
Senior Partner
Energy & Environmental Economics, Inc.

PROPOSAL TO CONDUCT A NEW VALUE OF SERVICE ESTIMATION STUDY FOR PACIFIC GAS & ELECTRIC COMPANY

PREPARED FOR:

JOHN CARRUTHERS AND LISE JORDAN
PACIFIC GAS & ELECTRIC COMPANY
SAN FRANCISCO, CA

DECEMBER 27, 2004

SUBMITTED BY:

ENERGY AND ENVIRONMENTAL ECONOMICS, INC.
SAN FRANCISCO, CA

Energy and Environmental Economics, Inc.

1.0 Introduction and overview

On October 28, 2004, the California Public Utilities Commission (CPUC) issued Decision (D.) 04-10-034, Interim Opinion on Storm and Reliability Issues, finding that "[t]he record in this proceeding does not contain value of service information that sufficiently captures the significant changes that have occurred in the electric industry or the California economy in the last decade" (Finding of Fact #8, p.100). As a result, the CPUC stated: "PG&E should be directed to conduct a new value of service study prior to its next GRC" (Conclusions of Law #9, p.102); "... PG&E should file an advice letter that sets forth PG&E's proposed approach to conducting the value of service study and a proposed budget for Commission consideration" (Conclusions of Law #10, p.103); and "[a]t a minimum, the new VOS study should include a 'willingness to pay' element" (p.54).

For PG&E's evaluation, Energy and Environment Economics, Inc. (E3) is pleased to submit this proposal to conduct a new VOS estimation study to aid PG&E's compliance with D. 04-10-034. E3's recommended approach is "market-based," quantifying VOS estimates using PG&E's billing/outage data and publicly available market data (e.g., wage rate, employment, income, and weather).

E3's recommendation offers the following advantages:

- It uses billing/outage data that PG&E currently has.
- Its cost is moderate when compared to VOS surveys.
- It can be completed before PG&E's next GRC application.

- It can be updated in the future by PG&E's staff, without incurring substantial cost of data collection.
- It yields estimates of values for willingness-to-accept a decrease in reliability (WTA) and willingness-to-pay for an increase in reliability (WTP) that are consistent with the theory and practice of applied microeconomics.

To successfully complete this project, E3 has assembled a team of experts with extensive experience with VOS estimation:

- Dr. C.K. Woo (E3 Senior Partner) will be the project manager and principal investigator, overseeing and participating in all aspects of the project. Dr. Woo was responsible for PG&E's VOS survey and estimation in the 1980s and his work is widely cited by researchers and is quoted in D. 04-10-034 (p.50). Recognized by *Who's Who in America* and *Who's Who in Science and Engineering*, Dr. Woo is an associate editor of *Energy – The International Journal* and their guest editor of a forthcoming special issue on electricity deregulation to appear in 2005. He is also a member of the editorial board of *The Energy Journal* and has served as their guest editor for a 1988 special issue on electricity reliability.
- Professor Asher Tishler of Tel Aviv University, an E3 academic affiliate and a frequent collaborator with Dr. Woo, will serve as a technical advisor to this project. With more than 60 refereed articles and extensive experience in econometrics and market-based outage cost estimation, Professor Tishler's participation will ensure that the project produces theoretically correct and numerically accurate VOS estimates.

- Graduate Research Professor (*emeritus*) Ira Horowitz of University of Florida, an E3 academic affiliate and a frequent collaborator with Dr. Woo, will serve as a technical advisor to this project. He has authored several books and more than 100 refereed articles in applied microeconomics, statistics, decision science, regulation, and industrial organization. He was Editor-in-Chief of *Decision Science* and *Managerial and Decision Economics* and currently serves on the editorial boards of several journals. In addition to ensuring project quality and VOS estimation accuracy, Professor Horowitz's participation will ensure the final report's clarity of exposition on the complicated subject of VOS estimation.

Dr. Woo, Professor Tishler and Professor Howoritz will be assisted by Mr. Brian Horii (E3 Senior Partner), Mr. Arne Olson (E3 Senior Consultant), Ms. Carmen Baskette (E3 Senior Consultant), and Mr. Mike King (E3 Senior Consultant). Their resumes are attached to this proposal as Appendix A.

E3 proposes that PG&E authorize a not-to-exceed budget of US$250K for E3 services to estimate VOS for the following customer classes: (1) residential; (2) small commercial/industrial; (3) large commercial/industrial; and (4) agricultural. E3 will bill PG&E monthly on a time-and-material basis. E3 will complete the proposed work within six months from PG&E's authorization to proceed.

The remainder of the proposal proceeds as follows. Section 2 describes and evaluates alternative approaches to VOS estimation, leading to E3's recommended approach of market-based estimation. Section 3 lists the tasks and deliverables. Section 4 presents the research team. Section 5 proposes the budget and schedule. Appendix A contains the resumes of the research team members and E3's corporate qualifications. Appendix B lists the references cited in Section 2. Appendix C contains the hard copies of E3 papers on which E3's recommended approach is based.

2.0 VOS estimation methods

2.1 Description

There are three categories of methods commonly used to quantify VOS (Ajodhia, van Gemert and Hakvoort, 2002; Woo and Pupp, 1992; Cave, Herriges and Windle, 1990):

- Proxy methods that use secondary data to infer customer WTP for service reliability, including:
  (1) Average electricity rate that proxies the marginal value of electricity;
  (2) Costs of owning and operating backup generation that proxies the cost of mitigating an outage's effects;
  (3) Wage rate that proxies the value of lost leisure due to an outage; and
  (4) GDP per kWh that proxies the cost of foregone production.
- Contingent valuation methods (CVM) that use surveys to elicit customer responses on:
  (1) WTA, via a bill reduction, for an outage;
  (2) Direct costs (DC) due to an outage; and
  (3) WTP, via rental payment for a backup generator, to avoid an outage.

Both SCE and PG&E have used surveys to obtain their VOS estimates (SCE, 1999; PG&E, 2000), as have other utilities (Lawton et al, 2003; Lineweber and McNulty, 2001). The typical results are: (a) WTA estimates are close to DC estimates, which are 2-3 times WTP estimates; and (b) many individual WTP estimates are zero for short (1-hour) outages (e.g., up to 70% for residential and up to 50% for non-residential), see Lawton et al (2003), PG&E (2000), SCE (1999), Woo and Pupp (1992), Munasinghe, Woo and Chao (1988), and Hartman, Doane and Woo (1991).

- Market-based methods that estimate VOS based on:
  (1) Consumer surplus - the area under the demand curve, net of bill payment (Hausman, 1981; Sanghvi, 1983);
  (2) Customer valuation of the tradeoff between the price of electricity and reliability, based on participation in programs offering non-firm rate options for interruptible and curtailable services (Caves, Herriges and Windle, 1990; Hartman, Doane and Woo, 1991);
  (3) Customer valuation of the tradeoff between the benefit and cost of reliability, based on backup generation ownership (Matsukawa and Fujii, 1994); and
  (4) A firm's lost profit due to power outages based on detailed data on industrial firms (Grosfeld-Nir and Tishler, 1993; Tishler, 1993).

2.2 Evaluation

Table 1 evaluates the three method categories based on the criteria of:

- <u>Data requirements</u>: An approach with lower requirements is more desirable.
- <u>Data collection effort in terms of time and cost:</u> An approach with less time and cost is more desirable.

- Computation complexity: An approach that yields accurate VOS estimates without complicated computation is more desirable.
- Details in outage attributes and customer demographics: An approach that yields VOS estimates that vary with outage attributes (e.g., notice, duration, time-of-day) and customer characteristics (e.g., kW/kWh size and customer type: residential vs. non-residential) is more desirable than one that produces estimates invariant to known drivers of VOS.
- Verifiability - the extent that results match actual customer behavior: VOS estimates should reflect actual customer behavior and real-world decision making.

An immediate finding from Table 1 is that proxy methods can only provide a "back-of-the-envelope" estimate for VOS.

Table 1: Evaluation of VOS estimation methods. "+" = "desirable"; "+/-" = "not certain"; "-" = "undesirable"

Criteria	Proxy	Contingent valuation method (CVM) surveys	Market-based estimation
Data requirement	+ Minimal requirement	- Needs good survey data	+/- Data requirements vary, depending on estimation method
Data collection effort	+ Wage and GDP data are available from CA Dept. of Finance	- Survey data can be time consuming and costly to collect	+ A utility should have billing and outage data, but may not have good data on backup generation ownership, customer subscription to non-firm rate options, or detailed data on industrial firms
Computation complexity	+ Little to compute	+/- Depends on sophistication of analysis	+/- Depends on sophistication of analysis
Outage attributes	- No outage attribute details	+ Can obtain very detailed data via survey design	+/- Duration and season, and possibly time-of-day, but not notice
Customer characteristics	- Very little information	+ Can design a survey to get detailed data	+/- As much detail as in the billing/outage data and publicly available demographic data
Verifiability	- Cannot verify without doing additional research	- Little is known if survey data match actual behavior	+ Transaction data reflect actual behavior

More costly and time-consuming than proxy methods, CVM surveys can yield detailed VOS estimates that vary with outage attributes and customer characteristics. "However, the survey method is limited in that it elicits information on the outage costs associated with hypothetical power interruptions and, consequently, indicates customers' attitudes and intentions, without necessarily reflecting how customers will behave in the event of an actual outage. Research based upon actual customer behavior is needed in order to validate outage cost estimates derived from surveys" (Caves, Herriges and Windle, 1990, p.114).

Moreover, "[w]hen conducted according to the exacting standards of the profession, these studies can be very expensive because of the extensive pre-testing and survey work. In addition, while this technique appears easy, its application involves numerical challenges. For example, applications of the method are prone to strategic biases on the part of respondents or to structural problems in the design of the questionnaire (Mitchell and Carlson 1989). Question framing, mode of administration, payment formats, and interview interactions can all affect the results of contingent market valuation (Commings et al 1986)" (U.S. DOE, 1997, p. 26).

Finally, the papers in Hausman (1993) by prominent economists, including two Nobel Prize winners (Kenneth Arrow and Daniel McFadden), question CVM's ability to produce estimates that are free from various biases. Such biases include those described in McClelland, *et al.* (1990), Kahneman and Tversky (2000), and Horowitz and McConnell (2002):

- Hypothetical bias due to customers' view that they have not actually bought or sold outages. An example of this kind of customer response is: "I don't sell outages and I don't really know how much to charge."
- Protest bids of $0 due to customer refusal to submit WTP numbers. An example of a protest bid is: "I am already paying a lot, why should I pay more?"
- Strategic response due to customers concern over how their responses will be used. An example of a strategic response is: "Should I bid low, given that the utility may use my response to set rates?"
- Status quo bias due to customers' extreme risk aversion. An example of this bias in customer response is: "I like what I have now; why change?"

Such biases translate into the large disparity between WTA and WTP estimates for non-market goods in general (U.S. DOE, 1997; Kahneman and Tversky, 2000; Horowitz and McConnell, 2002) and for electricity outages in particular (Lawton *et al*, 2003; Woo and Pupp, 1992; Cave, Herriges and Windle, 1990; SCE, 1999). Recent research shows that market experience leads to WTA/WTP convergence (List, 2004), as predicted by microeconomic theory (e.g., Hausman, 1981). Unfortunately, an outage cost survey is a one-round elicitation, not affording respondents the opportunity to gain market experience from repeat trading as in an experimental economics setting.

In contrast, market-based estimation produces VOS estimates that match with observed customer behavior reflected by market data. A case in point is the inference of economic loss due to water service interruption based on (a) consumer surplus lost due to availability reduction (Woo, 1994); and (b) production cost increase due to availability reduction (Woo and Lo, 1993). Both (a) and (b) use *actual* market data reflecting *actual* customer behavior to estimate VOS, and both can apply to the estimation of VOS for electricity. This is because estimation problems are almost identical (i.e., quantifying the economic effect of supply interruption/availability) and the data requirements are very similar (i.e., billing and outage data, plus income and employment data from public sources).

Market-based estimation requires billing/outage data with sufficient variation to allow a precise estimation. Fortunately, PG&E's billing data reflect the significant price changes of the last few years. In addition, PG&E's data offer substantial geographic variation, tracking interruption-minutes per customer to the circuit level. Finally, although market-based estimation may not provide as much detail on outage attributes and customer characteristics as CVM surveys, such details may not be necessary for reliability planning, see Forte *et al* (1995).

2.3 Recommended approach

Based on the evaluation results in Table 1, E3 recommends market-based estimation of VOS. Described below, this recommendation is justified on the following grounds:

- It uses billing/outage data that PG&E currently has.
- Its cost is moderate when compared to VOS surveys.
- It can be completed before PG&E's next GRC application.
- It can be updated in the future by PG&E's staff, without incurring substantial cost of data collection.
- It yields both WTA and WTP estimates that are consistent with the theory and practice of applied microeconomics.

2.3.1 Residential VOS estimation based on Woo (1994) in Appendix C

Based on the theory of consumer behavior, a demand curve, like the one marked "Demand: low availability" in Figure 1, measures the marginal benefit of consumption under low supply availability (Woo, 1990; Katz and Rosen, 1991, Chapter 4). At rate $P/kWh, the quantity demanded is Q_L that equates marginal benefit of electricity consumption with marginal cost of obtaining that consumption. The gross benefit of consumption is area (A + B) and the bill is area B. Hence area A is the net benefit of consumption, also known as consumer surplus (Katz and Rosen, 1991, Chapter 4).

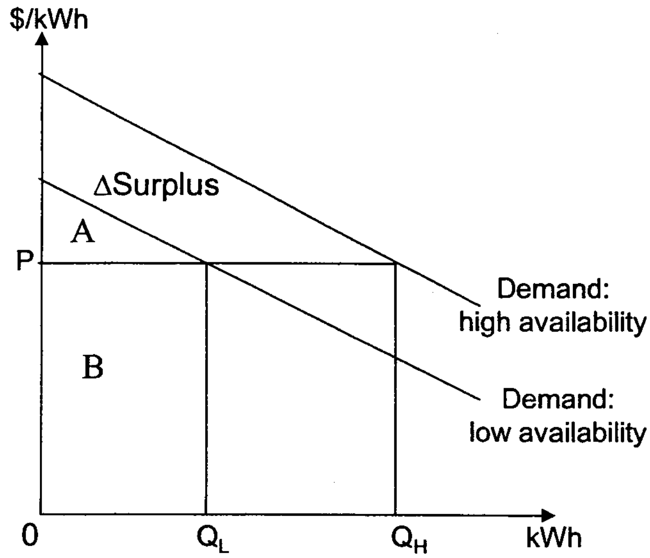


Figure 1: Residential demand for electricity by supply availability.

Suppose availability improves and shifts the demand curve to the right (Dias-Bandaranaike and Munasinghe, 1983; Woo, 1994). At rate $P/kWh, the quantity demanded is QH, yielding a net benefit that is ΔSurplus greater than area A. Thus, ΔSurplus measures the benefit of an availability improvement, the most that a rational consumer is willing to pay for the improvement. In short, ΔSurplus is a WTP estimate.

Implementing this market-based method entails first estimating the residential electricity demand, the major drivers of which are income, electricity rates, weather, and supply reliability (e.g., interruption-minutes per customer). The estimation uses the econometric techniques in Berndt (1991, Chapter 7) and Woo (1992). Once done, the estimated demand equation allows a VOS computation based on the WTP for a reliability change, as shown in Woo (1994). The sample will likely be regional data spanning several years. Regional differences in reliability and temporal change in rate levels provide the necessary reliability/rate variance to precisely estimate the demand equation.

2.3.2 *Non-residential VOS estimation based on Woo and Lo (1993) in Appendix C*

Successfully used to estimate the non-residential cost of water service interruption, this approach assumes that a cost-minimizing firm uses variable inputs like labor and electricity to produce an intermediate output (e.g., process heat), subject to electricity availability. The optimal inputs, when evaluated at the input prices, result in a variable cost function whose key drivers are the output level, input prices, and supply availability. Shown in Figure 2, this cost function declines with supply availability (S), consistent with the notion that reliability deterioration imposes costs on firms.

One can estimate the cost function using production econometrics, as shown in Berndt (1991) and Woo and Lo (1993). Once done, the estimated cost function allows a VOS computation based on the cost change due to a reliability change. Specifically, the firm's WTP for a supply availability change from S_L to S_H can be computed as (%change in average cost per 1% change in S) x Total production cost at S_L.

The sample will likely consist of regional data spanning several years. Regional differences in reliability and temporal change in rate levels provide the necessary reliability/rate variance to precisely estimate the cost equation.

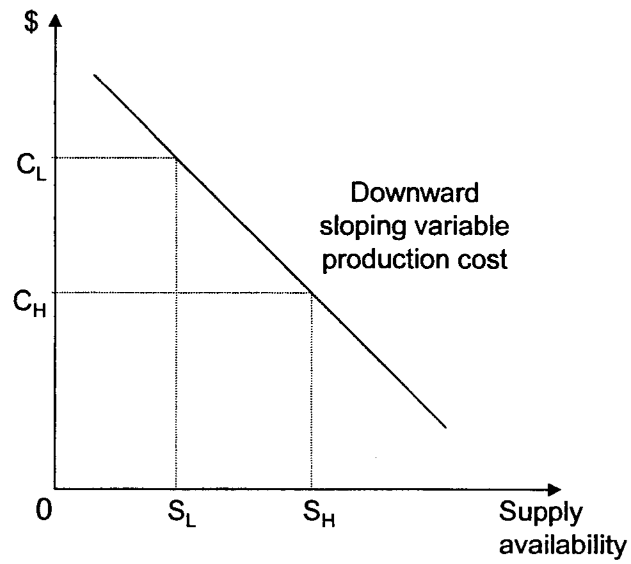


Figure 2: Variable production cost by supply availability.

2.4 Responses to comments on E3's market-based VOS estimation

E3 presented its recommended approach to (a) the CPUC's Office of Ratepayer Advocates (ORA); and (b) various stakeholders (e.g., the CPUC's Energy Division, TURN, Farm Bureau, the labor union, and large electricity users). A number of comments arose during the two presentations. Table 2 addresses these comments. Its first column describes the comments and its second column contains E3's responses. The overall conclusion from Table 2 is that these comments guide E3's choice of data sample, but without altering the validity or impeding the implementation of E3's recommended approach.

Table 2: Comments and E3 responses in connection to E3's VOS estimation

Comment	Response
There is insufficient variation in rates to permit an estimation of electricity demand.	Rate changes due to the California energy crisis provide the necessary price variation.
Low usage residential customers do not see rate changes.	If the demand equation is estimated using regional average rate data, there will be sufficient price variation.
The residential rate structure is an inverted block, implying that average rate level and consumption are positively correlated, leading to an "upward" sloping demand curve.	Correctly estimating electricity demand under a block rate structure is a well-known problem with a known solution (Berndt, 1991, Chapter 7). The problem is also common in water demand estimation and has the same solution (Woo, 1992).
Electricity demand moves with weather, income, and possibly other drivers like the 20/20 program.	Correctly estimating electricity demand requires specification tests of key drivers, an integral part of the estimation process (Berndt, 1991, Chapter 7; Woo, 1992).
Consumer surplus, as an area under the demand curve, does not capture the unexpected nature of an outage.	The welfare effect of a sharp price spike that induces voluntary consumption to zero may differ from a supply interruption that denies consumption at the posted rate. Hence, the supply interruption effect is modeled as the change in consumer welfare due to a change in supply reliability (Woo, 1994).
The effect of supply reliability on electricity demand is not detectable.	This is an empirical issue to be addressed in this project. In addition to common intuition, economic theory predicts that consumption and supply availability are positively correlated (Woo, 1994; Woo and Lo, 1993).
Backup generation cost understates the cost of mitigating an outage.	This comment questions the validity of using the backup generation cost to proxy outage cost. Since E3's method does not use backup generation cost, it is unaffected.
Market-based estimation cannot yield VOS estimates by customer class	PG&E's billing data are by customer class. Its detailed outage data show which customers are affected by the outages. Matching the class-specific billing/outage data with publicly available data on income, wage rate, and employment yields the suitable data files for estimating VOS by class.
Surveys are the only way to obtain outage cost estimates	Market-based estimation has been used in electricity outage cost studies, see Sanghvi, (1983), Woo and Pupp (1992), Caves, Herriges and Windle (1990, 1992), Grosfeld-Nir and Tishler (1993), Tishler (1993), Mat sukawa and Fujii (1994), and Ajodhia, van Gemert and Harkvoort (2002).

3.0 Task description and deliverables

3.1 Task 1: Project kickoff meeting

E3 will meet with PG&E staff to refine the scope of the project and discuss the data requirements. E3 will then produce a technical memo summarizing the key findings from the meeting.

3.2 Task 2: Data collection

Based on the first meeting's memo, E3 will request from PG&E the necessary billing/outage/weather data for empirical implementation. The request will specify the format and content of the desired data sample. E3 will collect additional data from public sources (e.g., California Department of Finance and U.S. Labor Bureau of Statistics) for the other drivers in its demand/cost estimation. E3 will then construct the Excel/SAS data samples by customer class, suitable for estimating VOS by customer class. E3 will deliver the samples, along with documentation on the definition, format, and use of each variable. The documentation will have sufficient detail to allow third-party review and verification and PG&E's future updates.

3.3 Task 3: Model specification

E3 will specify the demand/cost estimation in a technical report for PG&E's consideration. Fully documented, the report will explain in simple terms the steps for empirical implementation. This will allow PG&E to perform subsequent VOS updates without relying on outside consultants. It will have an appendix detailing the specification's theoretical foundation, supported by a comprehensive list of references.

3.4 Task 4: Estimation

E3 will first econometrically estimate the demand/cost equations required for quantifying VOS by customer class. It will then construct a spreadsheet model for simulating class-specific VOS using the data from Task 2 and assumptions on reliability changes. For PG&E's review and future use, E3 will deliver the SAS programs used in estimation and Excel programs in simulation. E3 will also fully document the results in a report submitted for PG&E's review.

3.5 Task 5: Final report

Based on the deliverables from Tasks 1 - 4, E3 will prepare a draft final report for review by PG&E. The report will have an overview section, concisely written for easy consumption by a non-technical audience. It will document the data, computation and key findings. It will discuss the market-based VOS estimates in connection to those in the outage cost literature (e.g., Lawton et al, 2003; Woo and Pupp, 1992; Cave, Herriges and Windle, 1990; PG&E, 2000; SCE, 1999). E3 will also present the key findings to PG&E and various stakeholders. After receiving comments from PG&E and various stakeholders, E3 will revise the draft report to produce a final report that will contain revisions in response to the comments.

4.0 Staffing

The combination of our team's academic and professional experience in VOS estimation, electricity economics, applied microeconomics, and econometrics, affords us the unique ability to provide a sound VOS estimation for PG&E that will fully and cost-effectively comply with the CPUC's decision. As described previously, our team includes both E3 partners and senior staff, as well as expert technical advisors with substantial national and international reputations. The highlights of each researcher are described below and resumes are provided in Appendix A.

- Dr. C.K. Woo, E3, Senior Partner. As the project manager, Dr. Woo will provide oversight and analytical expertise throughout all stages of the project. With over 20 years of electricity industry experience, Dr. Woo has published over 70 refereed articles on electricity deregulation, electricity procurement, value of electricity service reliability, electricity pricing, integrated resource planning, applied microeconomics, and applied finance. Dr. Woo was responsible for PG&E's VOS survey and estimation in the 1980s and his work is widely cited by researchers and is quoted in D. 04-10-034 (p.50). Dr. Woo's current research focuses in electricity procurement, risk management, avoided cost estimation, integrated resource planning, customer value of service reliability, deregulation, transmission pricing, and retail rate design. Recognized by *Who's Who in America* and *Who's Who in Science and Engineering*, Dr. Woo is an associate editor of *Energy – The International Journal* and their guest editor of a forthcoming special issue on electricity deregulation to appear in 2005. He is also a member of the editorial board of *The Energy Journal* and has served as their guest editor for a 1988 special issue on electricity reliability.
- Professor Asher Tishler of Tel Aviv University. Professor Tishler is an E3 academic affiliate and a frequent collaborator with Dr. Woo and will serve as a technical advisor to this project. With over 60 refereed articles and extensive experience in applied econometrics and market-based outage cost estimation, Professor Tishler's participation will ensure the project's quality in producing theoretically correct and numerically accurate VOS estimates. Complimenting his academic experience, Professor Tishler has

consulted to public and private electric industry organizations for over 25 years. Most recently, Professor Tishler worked extensively with Israel Electric Company to develop analytically rigorous VOS estimates. Professor Tishler will draw upon this vast and diverse experience in estimating VOS in his advisory role with E3 to ensure the highest quality results.

- Graduate Research Professor (*emeritus*) Ira Horowitz of University of Florida. Professor Horowitz is an E3 academic affiliate and a frequent collaborator with Dr. Woo, and he will serve as a technical advisor to this project. Professor Horowitz is a world-renowned expert in economic and financial theory and application. He has authored several books and over 100 refereed articles in applied microeconomics, statistics, decision science, regulation, and industrial organization. Most recently, Professor Horowitz's research has focused on electric utility pricing and procurement challenges. He was Editor-in-Chief of *Decision Science* and *Managerial and Decision Economics* and currently serves on the editorial boards of several journals such as *Quarterly Journal of Business and Economics*, *Multinational Finance Journal*, *Pacific Economic Review*, and *Omega*. Professor Horowitz's participation will ensure project quality and VOS estimation accuracy.

Dr. Woo, Professor Tishler and Professor Howoritz will be assisted by Mr. Brian Horii (E3 Senior Partner), Mr. Arne Olson (E3 Senior Consultant) Ms. Carmen Baskette (E3 Senior Consultant) and Mike King (E3 Senior Consultant). Their experience and qualifications are highlighted below:

- Mr. Brian Horii, Senior Partner, E3. His areas of expertise include marginal cost estimation, utility revenue allocation and rate design, resource planning, VOS estimation and integration of DSM and distributed generation (DG) into utility planning practices. Mr. Horii was a lead author on E3's work for PG&E that re-examined the customer energy management (CEM) paradigm and provided PG&E with a framework for evaluating EE programs under the changing electric generation market structure. Mr. Horii is the primary architect of numerous computer models currently being used by electric utilities across the United States and Canada. These models address such topics as: evaluation of bilateral trading decisions in an open access market; estimation of area- and time-specific marginal costs; and dynamic evaluation of the potential local-area benefits of targeted DSM and modular generation.
- Arne Olson, Senior Consultant, E3. Mr. Olson recently completed an economic analysis and model development for Lower Valley Energy to determine the value of their procurement options for their upcoming rate design and utility rate case. Mr. Olson's experience includes representing BC Hydro in the RTO West development process in the areas of congestion management, ancillary services, and transmission pricing. He has previously worked with British Columbia Transmission Corporation on transmission tariff redesign and with BC Hydro to develop a stepped rate design to facilitate retail access for large industrial customers. Mr. Olson is experienced in energy model design and developed models to estimate energy and demand savings resulting from California energy efficiency standards for central air conditioners.
- Carmen Baskette, Senior Consultant, E3. Ms. Baskette's primary practice areas at E3 include integrated resource planning, distributed energy resources economics,

electricity deregulation, and renewable energy markets. She has been working to develop an economic and engineering methodology for four California municipal utilities to evaluate renewable distributed generation as a resource in their planning process. Additionally, Ms. Baskette is investigating the effects of distributed energy resources on a real-world distribution system under San Francisco Distributed Energy Resources "Test-bed" project. Work completed for previous clients has included advising two major New York utilities throughout compliance with the New York State Public Service Commission distributed generation pilot program and contributing to a detailed cost-benefit analysis-based evaluation methodology for the Bonneville Power Administration to determine the cost-effectiveness of alternatives to new transmission construction.

- Michael King, Senior Consultant, E3. Mr. King has contributed to a variety of economic evaluations at E3, including avoided cost analyses, distributed generation benefit/cost analyses, and transmission ratemaking. In previous experience with PG&E Energy Services, Mr. King assisted the company's Power Quality division in estimating VOS for industrial customers with power sensitive manufacturing processes.

5.0 Budget and schedule

The proposed budget for the five project tasks will be completed with a not-to-exceed budget of $250,000. Table 3 shows the breakdown of hours for each researcher under each task. The entire project will be completed within six months of the contract award date.

Table 3: Proposed Not-to-Exceed Budget

		Task 1 Project Kickoff Meeting	Task 2 Data Collection	Task 3 Model Specification	Task 4 VOS Estimation	Task 5 Final Report
Researcher	**Hourly Rate**	**Hours by Task**				
CK Woo	$300	8	24	64	64	48
Ira Horowitz	$350	0	16	36	24	16
Asher Tishler	$350	0	16	40	32	16
Brian Horii	$250	8	24	44	36	28
Arne Olson	$200	4	28	40	64	28
Carmen Baskette	$175	4	28	32	48	32
Mike King	$175	4	28	32	48	32
	Hours by Task	28	164	288	316	200
	Task Cost Breakdown	$6,600	$39,800	$76,000	$77,400	$49,400
	Total Not-to-Exceed Budget					**$249,200**

6.0 Appendix A: Resumes and corporate qualifications

C.K. Woo

ck@ethree.com 415.391.5100 ext. 310

Dr. Woo specializes in public utility economics, applied microeconomics, and applied finance. With over 20 years of experience in the electricity industry, he has testified and prepared expert testimony for use in regulatory proceedings in California, British Columbia and Ontario. He has also filed declaration for and testified in arbitration in connection to contract dispute. Dr. Woo's current research focuses in electricity procurement, risk management, avoided cost estimation, integrated resource planning, customer value of service reliability, deregulation, transmission pricing, and retail rate design.

ENERGY & ENVIRONMENTAL ECONOMICS, INC. — San Francisco, CA

Senior Partner — 1993 – Present

Dr. Woo has published 70+ refereed articles on electricity deregulation, electricity procurement, electricity pricing, integrated resource planning, value of electricity service reliability, applied microeconomics, and applied finance. These articles appear in such scholarly journals as *Energy Policy, The Energy Journal, Energy-The International Journal, Electricity Journal, Resource and Energy Economics, Energy Economics, IEEE Transactions on Power Systems, Water Resources Research, Managerial and Decision Economics, OMEGA, Journal of Regulatory Economics, Journal of Public Economics, Quarterly Journal of Economics, Economics Letters, Journal of Business Finance and Accounting,* and *Pacific Basin Finance Journal*. Recognized by *Who's Who in America* and *Who's Who in Science and Engineering*, Dr. Woo is an associate editor of *Energy – The International Journal* and their guest editor of a forthcoming special issue on electricity deregulation to appear in 2005. He is also a member of the editorial board of *The Energy Journal* and has served as their guest editor for a special issue on electricity reliability.

CITY UNIVERSITY OF HONG KONG — Hong Kong, China

Associate Professor, Department of Economics and Finance — 1991 – 1993

Dr. Woo analyzed the economic impacts of supply shortage on consumers, resulting in a series of publications on water and electricity rationing. He also tested the specification errors of econometric models of stock returns. As a consultant, he performed marginal costing, demand-side-management evaluation and reliability planning which led to several publications on local integrated resource planning and T&D costing.

ANALYSIS GROUP, INC. — San Francisco, CA

Senior Associate — 1987 – 1991

Dr. Woo was responsible for applied microeconomics, outage cost estimation, reliability planning, and electricity pricing. He was the primary consultant to several utilities for outage cost estimation and reliability differentiation. His extensive publications in these two areas are widely cited by other researchers. He also performed economic analysis of mergers and acquisition with a primary focus on the anti-trust aspect of market power. The findings from this analysis were filed with both state and federal courts.

PACIFIC GAS AND ELECTRIC COMPANY — San Francisco, CA

Rate Economist — 1985 – 1987

Dr. Woo revamped PG&E's research on outage cost estimation whose findings appear in a special issue of *The Energy Journal* focusing on electricity reliability. He also participated in PG&E's preparation of the General Rate Cases.

SACRAMENTO MUNICIPAL UTILITIES DISTRICT Sacramento, CA

Econometrician 1984 – 1985

Dr. Woo was responsible for demand estimation and load forecasting. The results from his study guided SMUD's resource planning.

PACIFIC GAS AND ELECTRIC COMPANY San Francisco, CA

Rate Economist 1982 – 1984

Dr. Woo was responsible for time-of-use (TOU) demand analysis and TOU pricing mandated by the CPUC. This work resulted in a performance award from PG&E and several publications.

CALIFORNIA ENERGY COMISSION Sacramento, CA

Research Assistant 1978 – 1982

Mr. Woo was the primary author of the life cycle costing model used by the CEC to analyze solar energy and other DSM measures. He testified before the CPUC on the economics of solar financing.

Education

UNIVERSITY OF CALIFORNIA Davis, CA

Ph.D. in Economics

QUEENS UNIVERSITY Kingston, Ontario

M.A. in Economics

CONCORDIA UNIVERSITY Montreal, Quebec

B. Comm. in Economics

Languages

- Cantonese

Citizenship

United States Citizen

Refereed Papers

Special issues

1. *Woo, C.K., L.C.H. Chow and N. Lior, editors (2005) Special Issue on Electricity Deregulation, Energy-The International Journal, forthcoming.*

2. *Munasinghe, M., C.K. Woo and H.P. Chao, editors (1988) Special Electricity Reliability Issue, Energy Journal, 9.*

Electricity Procurement and Risk Management

1. *Woo, C.K., I. Horowitz, A. Olson, B. Horii and C. Baskette (2004) "Efficient Frontiers for Electricity Procurement by an LDC with Multiple Purchase Options," OMEGA, forthcoming.*

2. *Woo, C.K., D. Lloyd and W. Clayton (2004) "Did a Local Distribution Company Procure Prudently during the California Electricity Crisis?" Energy Policy, forthcoming.*

3. *Orans, R., C.K. Woo and W. Clayton (2004) "Benchmarking the Price Reasonableness of a Long-Term Electricity Contract," Energy Law Journal, 25:2, 357-383.*

4. *Woo, C.K., A. Olson and R. Orans (2004) "Benchmarking the Price Reasonableness of an Electricity Tolling Agreement," Electricity Journal, 17:5, 65-75.*

5. *Lloyd, D., C.K. Woo, M. Borden, R. Warrington and C. Baskette (2004) "Competitive Procurement and Internet-based Auction: Electricity Capacity Option," Electricity Journal, 17:4, 74-78.*

6. *Woo' C.K., I. Horowitz, B. Horii and R. Karimov (2004) "The Efficient Frontier for Spot and Forward Purchases: An Application to Electricity," Journal of the Operational Research Society, 55, 1130-1136.*

7. *Woo, C.K., R. Karimov and I. Horowitz (2004) "Managing Electricity Procurement Cost and Risk by a Local Distribution Company," Energy Policy, 32:5, 635-645.*

8. *Woo, C.K., D. Lloyd, M. Borden, R. Warrington and C. Baskette (2004) "A Robust Internet-Based Auction to Procure Electricity Forwards," Energy - The International Journal, 29, 1-11.*

9. *Woo, C.K., M. Borden, R. Warrington and W. Cheng (2003) "Avoiding Overpriced Risk Management: Exploring the Cyber Auction Alternative," Public Utilities Fortnightly, 141:2, 30-37.*

10. *Woo, C.K., I. Horowitz and K. Hoang (2001) "Cross Hedging and Forward-Contract Pricing of Electricity," Energy Economics, 23, 1-15.*

11. *Woo, C.K., I. Horowitz and K. Hoang (2001) "Cross Hedging and Value at Risk: Wholesale Electricity Forward Contracts," Advances in Investment Analysis and Portfolio Management, 8, 283-301.*

Electricity Deregulation

1. *Woo, C.K., M. King, A. Tishler and L.C.H. Chow (2004) "Costs of Electricity Deregulation," Energy-The International Journal, forthcoming.*

2. *Tishler, A. and C.K. Woo (2004) "Likely Failure of Electricity Deregulation: Explanation with Application to Israel," Energy-The International Journal, forthcoming.*

3. *Tishler, A., J. Newman, I. Spekterman and C.K. Woo (2004) "Cost-Benefit Analysis of Reforming Israel's Electricity Industry," Energy Policy, forthcoming.*

4. *Woo, C.K. (2004) "Book Review: Electricity Reform in China, India and Russia by Xu Yi-chong," Energy Studies Review, forthcoming.*

5. *Woo, C.K. (2004) "Book Review: Reforming the Power Sector in Africa edited by M.R. Bhagavan," Energy - The International Journal, 29, 1231-1232.*

6. *Woo, C.K., D. Lloyd, R. Karimov and A. Tishler (2003) "Stranded Cost Recovery in Electricity Market Reforms in the US," Energy - The International Journal, 28:1, 1-14.*

7. *Woo, C.K., D. Lloyd and A. Tishler (2003) "Electricity Market Reform Failures: UK, Norway, Alberta and California," Energy Policy, 31:11, 1103-1115.*

8. *Tishler, A., C.K. Woo and D. Lloyd (2002) "Reforming Israel's Electric Sector," Energy Policy, 30:4, 347-353.*

9. *Woo, C.K. (2001) "What Went Wrong in California's Electricity Market?" Energy - The International Journal, 26:8, 747-758.*

10. *Woo, C.K., D. Lloyd-Zannetti and I. Horowitz (1997) "Electricity Market Integration in the Pacific Northwest," Energy Journal, 18:3, 75-101.*

Electricity Pricing and Rate Design

1. *Horowitz, I. and C.K. Woo (2004) "Designing Pareto-Superior Demand-Response Rate Options," Energy - The International Journal, forthcoming.*

2. *Woo, C. K., B. Horii and I. Horowitz (2002) "The Hopkinson Tariff Alternative to TOU Rates in the Israel Electric Corporation," Managerial and Decision Economics, 23, 9-19.*

3. *Seeto, D. Q., C.K. Woo and I. Horowitz (2001) "Finessing the Unintended Outcomes of Price-Cap Adjustments: An Electric Utility Multi-Product Perspective," Energy Policy, 29:13, 1111-1118.*

4. *Hartway, R., S. Price and C.K. Woo (1999) "Smart Meters, Customer Choice and Profitable Time of Use Rate Option," Energy - The International Journal, 24, 895-903.*

5. *Woo, C. K., I. Horowitz and J. Martin (1998) "Reliability Differentiation of Electricity Transmission," Journal of Regulatory Economics, 13, 277-292.*

6. *Seeto, D.Q., C. K. Woo and I. Horowitz (1997) "Time-of-Use Rates vs. Hopkinson Tariffs Redux: An Analysis of the Choice of Rate Structures in a Regulated Electricity Distribution Company, " Energy Economics, 19, 169-185.*

7. *Woo, C.K., P. Chow and I. Horowitz (1996) "Optional Real-Time Pricing of Electricity for Industrial Firms," Pacific Economic Review, 1:1, 79-92.*

8. *Horowitz, I., D.Q. Seeto and C.K. Woo (1996) "Ramsey Pricing of Electricity under Unknown Bypass Costs," Energy Journal, 17:2, 59-77.*

9. *Woo, C.K., R. Orans, B. Horii and P. Chow (1995) "Pareto-Superior Time-of-Use Rate Option for Industrial Firms," Economics Letters, 49, 267-272.*

10. *Seeto, D.Q., S.D. He and C.K. Woo (1994) "Pricing Electric Harmonics," Energy - The International Journal, 20:7, 617-621.*

11. *Woo, C.K., B. Hobbs, R. Orans, R. Pupp and B. Horii (1994) "Emission Costs, Customer Bypass and Efficient Pricing of Electricity," Energy Journal, 15:3, 43-54.*

12. *Orans, R., C.K. Woo, R. Pupp and I. Horowitz (1994) "Demand Side Management and Electric Power Exchange," Resource and Energy Economics, 16, 243-254.*

13. *Woo, C.K. (1993) "Efficient Electricity Pricing with Self-Rationing: Reply," Journal of Regulatory Economics, 5:1, 101-102.*

14. *Woo, C.K. (1992) "Optimal Electricity Pricing and Capacity Rationing," Hong Kong Economic Papers, 22, 1-6.*

15. *Woo, C.K. (1991) "Capacity Rationing and Fixed Cost Collection," Energy Journal, 12:2, 153-164.*

16. *Woo, C.K. (1990) "Efficient Electricity Pricing with Self-Rationing," Journal of Regulatory Economics, 2:1, 69-81.*

17. *Woo, C.K. (1988) "Optimal Electricity Rates and Consumption Externality," Resources and Energy, 10, 277-292.*

18. *Woo, C.K. and D.Q. Seeto (1988) "Optimal Off-Peak Incremental Sales Rate in Electricity Pricing," Energy Journal, 9:1, 93-102.*

19. *Woo, C.K. (1988) "Inefficiency of Avoided Cost Pricing of Cogenerated Power," Energy Journal 9:1, 103-113.*

20. *Woo, C.K. and N. Toyama (1986) "Service Reliability and the Optimal Interruptible Rate Option in Residential Electricity Pricing," Energy Journal, 7:3, 123-136.*

21. *Woo, C.K. (1985), "An Application of the Expenditure Function in Electricity Pricing: Optimal Residential Time-of-Use Rate Option," Energy Journal, 6:2, 89-99.*

Integrated Resource Planning

1. *Heffner, G., C.K. Woo, B. Horii and D. Lloyd-Zannetti (1998) "Variations in Area- and Time-Specific Marginal Capacity Costs of Electricity Distribution," IEEE Transactions on Power Systems, PE-493-PWRS-012-1997, 13:2, 560-567.*

2. *Forte, V.J., R. Pupp, R. Putnam and C.K. Woo (1995) "Using Customer Outage Costs in Electricity Reliability Planning," Energy - The International Journal, 20:2, 81-87.*

3. *Pupp, R., C.K.Woo, R. Orans, B. Horii and G. Heffner (1995) "Load Research and Integrated Local T&D Planning," Energy - The International Journal, 20:2, 89-94.*

4. *Woo, C.K., D. Lloyd-Zannetti, R. Orans, B. Horii and G. Heffner (1995) "Marginal Capacity Costs of Electricity Distribution and Demand for Distributed Generation," Energy Journal, 16:2, 111-130.*

5. Woo, C.K., R. Orans, B. Horii, R. Pupp and G. Heffner (1994) "Area- and Time-Specific Marginal Capacity Costs of Electricity Distribution," Energy - The International Journal, 19:12, 1213-1218.

6. Orans, R., C.K. Woo and B. Horii (1994) "Targeting Demand Side Management for Electricity Transmission and Distribution Benefits," Managerial and Decision Economics, 15, 169-175.

7. Orans, R., C.K. Woo and R.L. Pupp (1994) "Demand Side Management and Electric Power Exchange," Energy - The International Journal, 19:1, 63-66.

8. Keane, D.M. and C.K. Woo (1992) "Using Customer Outage Costs to Plan Generation Reliability," Energy - The International Journal, 17:9, 823-827.

Value of Electricity Service Reliability

1. Woo, C.K. and R.L. Pupp (1992) "Costs of Service Disruptions to Electricity Consumers," Energy - The International Journal, 17:2, 109-126.

2. Woo, C.K., R.L. Pupp, R. Mango and T. Flaim (1991) "How Much Do Electricity Consumers Want to Pay for Reliability?" Energy Systems and Policy, 15, 145-159.

3. Hartman, R.S., M.J. Doane and C.K. Woo (1990) "Status Quo Bias in the Measurement of Value of Service," Resources and Energy, 12, 197-214.

4. Goett, A.A. D. McFadden and C.K. Woo (1988) "Estimating Residential Value of Service Reliability with Market Research Data," Special Electricity Reliability Issue, Energy Journal, 9, 105-120.

5. Woo, C.K. and K. Train (1988) "The Cost of Electric Power Interruption to Commercial Firms," Special Electricity Reliability Issue, Energy Journal, 9, 161-172.

6. Doane, M.J., R.S. Hartman and C.K. Woo, (1988) "Households' Perceived Value of Electric Power Service Reliability: An Analysis of Contingent Valuation Data," Special Electricity Reliability Issue, Energy Journal, 9, 135-149.

7. Doane, M.J., R.S. Hartman and C.K. Woo, (1988) "Household Preferences of Interruptible Rate Options and the Revealed Value of Service Reliability," Special Electricity Reliability Issue, Energy Journal, 9, 121-134.

8. Keane, D.M., L.S. MacDonald and C.K. Woo (1988) "Estimating Residential Partial Outage Costs with Market Research Data," Special Electricity Reliability Issue, Energy Journal, 9, 151-159.

Applied Microeconomics

1. Woo, C.K. and R.H.F. Kwok (1994) "Vanity, Superstition and Auction Price," Economics Letters, 44, 389-395.

2. Woo, C.K. (1994) "Managing Water Supply Shortage: Interruption vs. Pricing," Journal of Public Economics, 54, 145-160.

3. Woo, C.K. and K.W.K. Lo (1993) "Factor Supply Interruption, Welfare Loss and Shortage Management," Resource and Energy Economics, 15, 339-352.

4. *Woo, C.K. (1992) "Drought Management, Service Interruption and Water Pricing: Evidence from Hong Kong," Water Resources Research, 28:10, 2591-2595.*

5. *Hartman, R.S., M.J. Doane and C.K. Woo (1991) "Consumer Rationality and the Status Quo," Quarterly Journal of Economics, February, 141-162.*

6. *Woo, C.K., P. Hanser and N. Toyama (1986) "Estimating Hourly Electric Load with Generalized Least Squares Procedures," Energy Journal, 7:2, 153-170.*

7. *Woo, C.K. (1985) "Demand for Electricity of Small Nonresidential Customers under Time-of-Use Pricing," Energy Journal, 6:4, 115-127.*

8. *Woo, C.K. (1984) "A Note on Measuring Household Welfare Effects of Time-of-Use Pricing," Energy Journal, 5:3, 171-181.*

Applied Finance

1. *Wong, K.A., C.K. Woo and R.Y.K. Ho (1998) "Macroforecasting Accuracy and Gains from Stock Market Timing," Research in Finance, 16, 127-139.*

2. *Woo, C.K. and Y.L. Cheung (1996) "Specification Tests of A Market Model of Stock Returns," Advances in Quantitative Finance and Accounting, 4, 187-194.*

3. *Woo, C.K., A. Lai and Y.L. Cheung (1995) "Specification Tests of A Market Model of Asia-Pacific Stock Returns: Thailand and Hong Kong," Journal of Business Finance and Accounting, 22:3, 363-375.*

4. *Woo, C.K., Y.L. Cheung and R.Y.K. Ho (1994) "Endogeneity Bias in Beta Estimation: Thailand and Hong Kong," Pacific-Basin Finance Journal, 2, 453-461.*

5. *Ho, R.Y.K., Z. Fang and C.K. Woo (1992) "Intraday Arbitrage Opportunities and Price Behavior of Hang Seng Index Futures," The Review of Futures Markets, 11:3, 413-430.*

6. *Fang, Z. and C.K. Woo (1991) "Two Factor Model for Bond Selection," Economics Letters, 37, 417-421.*

Research Reports

1. *Woo, C.K. and M. King (2004) Costs of Electricity Deregulation and Implications for Israel, report submitted to Israel Electric Corporation.*

2. *Woo, C.K. (2004) Declaration of Dr. C.K. Woo in support of Micrel Inc.'s final offer: Micrel Inc. v. Chevron Energy Solutions, LP.*

3. *Woo, C.K. (2002) Rebuttal Testimony filed on the behalf of Southern California Water Company before the California Public Utilities Commission.*

4. *Woo. C.K. and D. Lloyd (2001) Stranded Cost Recovery in Electricity Market Reforms, report submitted to Israel Electric Corporation.*

5. *Woo. C.K. and D. Lloyd (2001) Assessment of the Peak Benefit Multiplier Effect: (a) Economic Theory and Statistical Specification; and (b) Theory, Estimation and Results, reports submitted to Pacific Gas and Electric Company.*

6. *Horii, B., C.K. Woo and D. Engel (2000) PY2001 Public Purpose Program Strategy and Filing Assistance: (a) A New Methodology for Cost-Effectiveness Evaluation; (b) Peak Benefit Evaluation; (c) Screening Methodology for Customer Energy Management Programs; and (d) Should California Ratepayers Fund Programs that Promote Consumer Purchases of Cost-Effective Energy Efficient Goods and Services? reports submitted to Pacific Gas and Electric Company.*

7. *Tishler, A., C.K. Woo and D. Lloyd (2000) Reforming Israel's Electric Sector: Choices for Change, position paper submitted to Israel Electric Corporation.*

8. *Woo, C.K. and P.D. Ferguson (1999) Comments on the Ontario Energy Board Staff's Draft Electric Distribution Rate Handbook, report submitted to Ontario Energy Board on the behalf of The Upper Canada Energy Alliance.*

9. *Woo, C.K. and K. Hoang (1999) Cross Hedging and Risk Premium, report submitted to Ontario Power Generation Inc.*

10. *Woo, C.K. and B. Horii (1999) Should Israel Electric Corporation (IEC) Replace Its Industrial Time of Use Energy Rates with A Hopkinson Tariff? report prepared for IEC.*

11. *Lloyd-Zannetti D. and C.K. Woo (1997) Wheeling Charges for Transmission Service, report prepared for Israel Electric Corporation.*

12. *Lloyd-Zannetti D. and C.K. Woo (1997) Capacity Shortage and Profitable Rate Options, report prepared for Israel Electric Corporation.*

13. *Lloyd-Zannetti, D., B. Horii, J. Martin, S. Price and C.K. Woo (1996) Profitability Primer: A Guide to Profitability Analysis in the Electric Power Industry, Report No. TR-106569, Electric Power Research Institute.*

14. *Woo, C.K. (1996) Electricity Market Integration in the Western Interconnection, prepared for British Columbia Power Exchange Corporation (Powerex).*

15. *Woo, C.K. (1996) Direct Testimony, Industrial Service Options Application, prepared for B.C. Hydro.*

16. *Woo, C.K. (1996) Rebuttal Testimony Presenting an Analysis of the Use of Class-based Value of Service for Marginal Generation Capacity Costs, filed with California Public Utilities Commission for Pacific Gas Electric Company's 1996 General Rate Case.*

17. *Woo, C.K. and R. Orans (1996) Transmission: Spot Price, Reliability Differentiation and Investment, report submitted to Ontario Hydro.*

18. *Orans, R., C.K. Woo and B. Horii (1995) Impact of Market Structure and Pricing Options on Customers' Bills, report submitted to B.C. Hydro.*

19. *Woo, C.K., L. Woo and R. Orans (1995) Rationing and Area-Specific Generation Costs, report submitted to Pacific Gas and Electric Company.*

20. *Woo, C.K., D. Lloyd-Zannetti and L. Woo (1994) Using Residual Emissions Adders in Electricity Ratemaking, report submitted to Pacific Gas and Electric Company.*

21. Orans, R., C.K. Woo and C. Greenwell (1994) Designing Profitable Rate Options Using Area- and Time-Specific Costs, Report No. TR-104375, Electric Power Research Institute.

22. Orans, R. and C.K. Woo (1992) Marginal Cost Disaggregation Study, report submitted to Wisconsin Electric Power Corporation.

23. Orans, R., C.K. Woo, J.N. Swisher, B. Wiersma and B. Horii (1992) Targeting DSM for Transmission and Distribution Benefits: A Case Study of PG&E's Delta District, Report No. TR-100487, Electric Power Research Institute.

24. Pupp, R. and C.K. Woo (1991) Integrating Customer Outage Costs in Electricity Reliability Planning, report submitted to Niagara Mohawk Power Corporation.

25. Woo, C.K., R.L. Pupp and D. Glyer (1991) Voluntary Interruptible Pricing Program (VIPP): An Integrated Approach to Electricity Reliability Pricing, report submitted to Niagara Mohawk Power Corporation. Also in Caves, D.W. and D. Glyer (1992), Designing an Integrated Menu of Electric Service Options, Electric Power Research Institute Report TR-100523, Appendix B.

26. Doane, M.J., G. McCelland, W. Schulze and C.K. Woo (1990) Industrial Outage Cost Survey, report submitted to Niagara Mohawk Power Corporation.

27. Doane, M.J., G. McCelland, W. Schulze and C.K. Woo (1990) Residential Outage Cost Survey, report submitted to Niagara Mohawk Power Corporation.

28. Doane, M.J. and C.K. Woo (1988) An Analysis of Customer Subscription to PG&E's Interruptible and Curtailable Rates, report submitted to Pacific Gas and Electric Company.

29. Woo, C.K. (1988) Recent Contributions to Customer Outage Cost Estimation, report submitted to Israel Models Limited.

30. Doane, M.J. R.S. Hartman, W. Schulze and C.K. Woo (1988) Recommended Approach for Collecting Data on Outage Cost and Value of Service Reliability, report submitted to Niagara Mohawk Power Corporation.

31. Woo, C.K. (1987) Review of Existing NMPC Procedures for Collecting Data on Outage Cost and Value of Service Reliability, report submitted to Niagara Mohawk Power Corporation.

32. Woo, C.K., (1987) Recent Contributions to the Theory and Measurement of Customer Value of Service Reliability, report submitted to Niagara Mohawk Power Corporation.

33. Woo, C.K. (1984) Residential Time of Use Program - First and Second Semi-Annual Reports, Pacific Gas and Electric Company Reports filed with the California Public Utilities Commission.

34. Woo, C.K. (1983) A-20 Small Commercial Time of Use Experiment, Pacific Gas and Electric Company Reports filed with the California Public Utilities Commission.

35. Woo, C.K. and R. Orans (1983) Transferability of Other Utilities' Time of Use Experiments to PG&E's Service Schedule D-7, Pacific Gas and Electric Company Report filed with the California Public Utilities Commission.

36. Woo, C.K. (1979) Economics of Solar Financing, Order Instituting Investigation 42 Testimony submitted to the California Public Utilities Commission for the California Energy Commission.

Conference Papers

1. *Woo, C K, Karimov, R I and Lloyd, D (2003) "Did a Local Distribution Company Procure Prudently during the California Electricity Crisis?' International Conference on Energy Market Reform: Issues and Problems, Hong Kong, August 25-26.*

2. *Seeto, D. and C.K. Woo (1995) "Time-of-Use Rates vs. Hopkinson Tariffs in Electricity Pricing," Rutgers University Advanced Workshop in Regulation and Public Utilities Economics, 8th Annual Western Conference, July 5-7, San Diego, California.*

3. *Seeto, D., S.D. He and C.K. Woo (1994) "Regulatory Perspectives of the Harmonics Problem: Pricing Electric Harmonics," 1994 IEEE Summer Power Engineering Society Meeting, July 24-29, San Francisco, California.*

4. *Seeto, D. and C.K. Woo (1994) "Practical Ramsey Pricing of Electricity and Customer Bypass under Regulation," Rutgers University Advanced Workshop in Regulation and Public Utilities Economics, 7th Annual Western Conference, July 6-8, San Diego, California.*

5. *Orans, R., C.K. Woo, B. Horii and R. Pupp (1994) "Estimation and Applications of Area- and Time-Specific Marginal Capacity Costs," Proceedings: 1994 Innovative Electricity Pricing, (February 9-11, Tampa, Florida) Electric Research Power Institute, Report TR-103629, 306-315.*

6. *Heffner, G., R. Orans, C.K. Woo, B. Horii and R. Pupp (1993) "Estimating Area Load and DSM Impact by Customer Class and End-Use," Western Load Research Association Conference, September 22-24, San Diego, California; and Electric Power Research Institute CEED Conference, October 27-29, St. Louis, Missouri.*

7. *Woo, C.K. (1992) "Drought Management: Service Interruption," International Conference on Economics and Government, September 1-4, Gold Coast, Australia.*

8. *Woo, C.K. (1991) "Local Electric Service Reliability as a Public Good," 14th International Association of Energy Economists (IAEE) Conference, East-West Center, Hawaii.*

9. *Keane, D.M. and C.K. Woo (1991) "Using Customer Outage Costs to Plan Generation Reliability," 14th International Association of Energy Economists (IAEE) Conference, East-West Center, Hawaii.*

10. *Woo, C.K. (1990) "Outage Costs as Design Criteria for Product Differentiation," New Service Opportunities for Electric Utilities: Creating Differentiated Products, Symposium sponsored by Electric Power Research Institute and University of California, Berkeley.*

11. *Woo, C.K. (1988) "Recent Contributions to Customer Outage Cost Estimation," Invited Lecture at Workshop on Energy Load Management, Israel Ministry of Energy and Infrastructure.*

12. *Woo, C.K., B.M. Gray and M.E. Carl (1987) "Residential Air Conditioning Load Model," 8th International Association of Energy Economists (IAEE) Conference, MIT.*

13. *Woo, C.K., (1987) "Fixed Cost Recovery under Competition in Electricity Pricing," 8th International Association of Energy Economists (IAEE) Conference, MIT.*

Ira Horowitz
Graduate Research Professor Emeritus

EDUCATIONAL BACKGROUND

B.A. Johns Hopkins University (1955)
Ph.D. Massachusetts Institute of Technology (1959)

PREVIOUS APPOINTMENTS

Massachusetts Institute of Technology
 Teaching Assistant (1957-59)
University of Kansas City
 Lecturer (1960)
Indiana University
 Assistant Professor (1960-63)
 Associate Professor (1963-66)
 Professor (1966-72)
Catholic University of Louvain (Center for Operations Research and Econometrics)
 Visiting Professor (1968-69)
University of Florida
 Professor (1972-79)
 Graduate Research Professor (1979-present)
Michigan State University
 Visiting Professor (1978-79)
Institut Europeen d' Administration des Affaires
 Visiting Professor (1984-85; Summer 1987; Summer 1997)
City Polytechnic of Hong Kong
 Visiting Professor (1992-94)
Chiba University of Commerce
 Visiting Scholar (Summer 1993; November 1998)
Chinese University of Hong Kong
 Ho Sin-Hang Visiting Professor of Decision Sciences and
 Managerial Economics (April/August 1995)
 Visiting Scholar (May 1996)
City University of Hong Kong
 Visiting Professor (1997-98; February/April 2002)
San Diego State University
 Adjunct Professor (Summer 2000; Summer 2002 - 2004)
Adelaide University
 Visiting Professor (February/August 2001
University of Kansas (Consortium of International Universities, Paderno Del Grappa)
 Visiting Professor (Fall 2001)

SCHOLARLY HONORS AND AWARDS:

Phi Beta Kappa: Johns Hopkins University (1954)
Graduate with Honors: Johns Hopkins University (1955)
Woodrow Wilson Fellow: Massachusetts Institute of Technology (1955-56)
M.I.T. Fellow: Massachusetts Institute of Technology (1956-57)

Beta Gamma Sigma: Indiana University (1964)
Ford Faculty Research Fellowship: Indiana University (1965-66)
Beta Gamma Sigma Distinguished Scholar (1977-78)
American Institute of Decision Sciences Fellow (1978)
American Institute of Decision Sciences Distinguished Service Award (1983)
Teknologie Doktor h. c., Linköping Institute of Technology (1989)
Blue Key Distinguished Faculty Award (1990)

OFFICES IN BUSINESS, CIVIC, AND PROFESSIONAL ASSOCIATIONS

Head, Quantitative Business Analysis, Indiana University (1965-67)
Chairman, Department of Management, University of Florida (1972-78)
Chairman, Decision and Information Sciences (1986-1990)
Mathematical Statistician, U.S. Bureau of the Census (Summer, 1956)
Assistant Analyst, Johns Hopkins Operations Research Office (Summer, 1957-58); Consultant 1958-59)
Associate Analyst, Midwest Research Institute (1959-60)
Senior Economist, Economic Policy Office, Antitrust Division, U.S. Department of Justice (1975-6)
Academic Affiliate, Energy and Environmental Economics (1994-Present)

Consultant to:

American Telephone & Telegraph Co., Cummins Engine, Falstaff Brewing Company, Indiana Bell, Irwin Management Company, Joseph Schlitz Brewing Company, Various Law Firms, Federal Trade Commission, U.S. Department of Justice, National Science Foundation.

Prepared Expert Testimony:

In Re Bill S. 3445, Senate Commerce Committee (1972)
In Re FCC Docket 20002, 1975 (prepared statement on natural monopoly)
Hearings before the House Select Committee on Professional Sports (1976)
Various Antitrust and Other Court Cases

Editorships:

EDITOR:
DECISION SCIENCES: 1978-1983
Managerial and Decision Economics: 1988-1993

EDITORIAL BOARD:
DECISION SCIENCES: 1975-1977
Journal of Economics and Business: 1975-1986
Academy of Management Journal: 1976-1982
Journal of Industrial Economics: 1977-1985
Quarterly Journal of Business and Economics: 1984-Present
Journal of Comparative Economics: 1988-1990
Managerial and Decision Economics: 1994-Present
Hong Kong Economic Papers: 1993-1996

Hong Kong Journal of Business Management: 1995-1997
Multinational Finance Journal: 1995-Present
Pacific Economic Review: 1996-Present
Omega: 1997-Present
Journal of Sports Economics: 2002-Present

PUBLICATIONS:

Articles and Notes

"Project Selection in New Technical Fields," (Co-author: A.H. Rubenstein). NEC Proceedings, XV: 1960.

"Regression Models for Company Expenditures on the Returns from Research and Development." IRE Transactions, EM-7, 1:March, 1960.

"Estimating Changes in the Research Budget," Journal of Industrial Engineering, XII, 2: March-April, 1961.

"Firm Size and Research Activity," Southern Economic Journal, XVIII, 5: January, 1962.

"Depreciation and User Cost in Decision-Making." Quarterly Review of Economics and Business, 2, 2: May, 1962.

"Effects of Changes in the Corporate Tax Rate on the Allocation of Research and Development Funds." Journal of Industrial Engineering, XVIII, 4: July-August, 1962.

"Some Variables Affecting Investment Fund Performance," (Co-author: Harold Higgins). Quarterly Review of Economics and Business,. 3, 1: Spring, 1963.

"Evaluation of the Results of Research and Development: Where We Stand," IEEE Transactions, EM-10, 2: June, 1963.

"Research Inclinations of a Cournot Oligopolist," Review of Economic Studies, XIX, 4: July-August, 1963.

"A Probability Model for Baseball Management," Journal of Industrial Engineering, XIV, 4: July-August, 1963.

"An Econometric Model of Supply and Demand in the Synthetic Rubber Industry," International Economic Review, 4, 3: September, 1963.

"Size, Growth, and Concentration of Investment Funds," Quarterly Review of Economics and Business, 3, 3: Autumn, 1963.

"Formulation of the Price-Cost Relationship in a Class of Plant Investment Decisions," Journal of Industrial Engineering, XIV, 6: November-December, 1963.

"The Varying (?) Quality of Investment Trust Management," Journal of the American Statistical Association, 58, 304: December, 1963.

"A Note on the Hart-Prais Measure of Changes of Business Concentration," Journal of the Royal Statistical Society, Series A, 127, Part 2: 1964.

"The Regional Distribution of Scientific Talent," Southern Economic Journal, XXXI, 3: January, 1965.

"Firms in a Declining Market: The Brewing Case," (Co-author: Ann R. Horowitz). Journal of Industrial Economics, XIV, 2: March, 1965.

"A Model for Mutual Fund Evaluation," Industrial Management Review, 6, 2: Spring, 1965.

"A Rating of Mutual Fund Managements Investment Ability," Industrial Management Review, 7, 1: Fall, 1965.

"Popularity vs. Performance: The Mutual Funds," Quarterly Review of Economics and Business, 6, 1: Spring, 1966.

"The Plant Investment Decision Revisited," Journal of Industrial Engineering, XVII, 8: August, 1966.

"The Reward-to-Variability Ratio and Mutual Fund Performance," Journal of Business, XXXIX, 4: October, 1966.

"Some Aspects of the Effects of the Regional Distribution of Scientific Talent on Regional Economic Activity," Management Science (A), 13, 3: November, 1966.

"A Note on Semiprobabilistic Grading," Management Science (B), 13, 8: April, 1967.

"Risk and the Business Decision," (Co-author: Dale D. McFarlane). Business Horizons, 10, 2: Summer, 1967.(Also reprinted in Greek).

"The Advance of the Theory of the Firm: One Step Forward, One Step Back," Quarterly Review of Economics and Business, 7, 2: Summer, 1967.

"Profiles of the Future: The Brewing Industry," (Co-author: Ann R. Horowitz) Business Horizons, 10, 3: Fall, 1967. (Also reprinted in English and Italian).

"The Relationship Between Interstate Variations in the Growth of R and D Activity and Economic Activity," IEEE Transactions, EM-14, 3: September, 1967.

"Markov Processes and the Declining Brewing Population," (Co-author: Ann R. Horowitz). Proceedings of the Business and Economics Section: A.S.A.. 1967.

"Entropy, Markov Processes and Competition in the Brewing Industry," (Co-author: Ann R. Horowitz). Journal of Industrial Economics, XVI, 3: July, 1968.

"Concentration, Competition, and Mergers in Brewing," (Co-author: Ann R. Horowitz). in Weston and Petzman eds. Public Policy Toward Mergers: Goodyear, 1969.

"The Price-Quoter Under Risk," Western Economic Journal, VII, 2: June, 1969.

"Nondogmatic Conjectures in a Cournot Market," Western Economic Journal, VIII, 1: March, 1970

"A Note on Advertising and Uncertainty," Journal of Industrial Economics, XVIII, 2: April, 1970.

"Structural Changes in the Brewing Industry," (Co-author: Ann R. Horowitz). Applied Economics, 2, 2: May, 1970.

"Employment Concentration in the Common Market: An Entropy Approach," Journal of the Royal Statistical Society, A, 133, Part 3: 1970.

"On the Similarity of Wages, Sales, and Investment Among the Industries of the E.E.C. Nations: A Statistical Note," Economia Internazionale, 24, 1: February, 1971.

"An International Comparison of the International Effects of Concentration on Industry Wages, Investment and Sales," Journal of Industrial Economics, XIX, 2: April, 1971.

"Numbers-Equivalents in U.S. Manufacturing Industries: 1954, 1958 and 1963," Southern Economic Journal, XXXVI, 4: April, 1971.

"On Numbers-Equivalents and the Concentration Ratio: An International Empirical Comparison," Quarterly Review of Economics and Business, I, 3: Fall, 1971.

"Statistical Contamination and the Selection of Management," (Co-author: E.W. Martin). AIEE Transactions, III, 3: September, 1971.

"An Empirical Note on Long-Run Market Structure," Southern Economic Journal, XXXVII, 3: January, 1972.

"Entropy and Information Theory -- A Tutorial," Proceedings of NE Aids: 1972.

"Risk Preferences, Uncertainty and the Multiplier," Public Finance, XVII, 3: 1972.

"The Diminishing Returns to Sample Information in the Beta-Binomial Process," Zeitschrift fur Nationalokomie, 32, 4: 1972.

"A Bayesian Interpretation of Concentration Data," Industrial Organization Review, 1, 3: 1973.

"Sports and CATV: The Beauty and the Bane of Major College Football," Co-author: Philip Hochberg). Law and Contemporary Problems, XXXVIII, 1: Winter-Spring, 1973.

"Sports Broadcasting," in Roger Noll ed. Government and the Sports Business. Brookings Institution, Washington, D.C.,: 1974.

"The Implications of Uncertainty for Firm and Industry Behavior," (Coauthor: Saul Pleeter). Metroeconomica, XXVI, Fascioli I-II-III: 1974.

"Risk and Economic Policy Decisions," (Coauthor: Christopher B. Barry) Public Finance, XXX, 2: 1975.

"The Real and Illusory Virtues of Entropy-Based Measures for Business and Economic Analysis," (Co-author: Ann R. Horowitz). Decision Sciences, 7, 1: January, 1976.

"Engineering Economy: An Economist's Perspective," AIEE Transactions, VIII, 4: December, 1976.

"Sports Telecasts: Rights and Regulations," Journal of Communication, 27, 3: Summer, 1977.

"Decision Theory and Antitrust: Quantitative Evaluation for Efficient Enforcement," Indiana Law Journal: Summer, 1977.

"Pay TV and Sports Siphoning," Industrial Organization Review, 5, 2 and 3: 1977.

"On Defining the Geographic Market in Section 7 Cases," in Proceedings: Bank Structure and Competition (Federal Reserve Bank of Chicago): 1977.

"A Bayesian View of Post-Acquisition Evidence and Antitrust," The Antitrust Bulletin, XXII, 4: Winter, 1977.

"Market Entrenchment and the Sports Broadcasting Act," American Behavioral Scientist, 22, 2: January-February, 1978.

"The Implications of Home Box Office for Sports Broadcasting," The Antitrust Bulletin, XXIII, 4: Winter, 1978.

"The Economic Foundations of Self-Regulation in the Profession," in R. Blair and S. Rubin eds., Regulating the Professions (D.C. Heath and Company, Indianapolis, Indiana): 1980.

"The Relevance of the Relevant Market in Section 7 Analysis of Conglomerate Mergers (Whatever Those Are)," in R.F. Lanzillotti and R. Blair eds., Conglomerate Mergers (Oelgeschlager, Bunn & Hain, Inc., Cambridge): 1981.

"Limit Pricing in a Cournot-Stackelberg Market," Zeitschrift fur Nationalokonomie, 41, 1-2: 1981.

"Market Definition in Antitrust Analysis: A Regression-Based Approach," Southern Economic Journal, 48, 1: July, 1981.

"The Perceived Potential Competitor: Antitrust Sinner or Saint," The Antitrust Bulletin, XXV, 2: Summer, 1981.

"Market Definition" segment in D. Whitehead et al. "Special Issue" of the Federal Reserve Bank of Atlanta's Monthly Bulletin: April, 1982.

"More on the Labor-Managed Firm Under Uncertainty," Journal of Comparative Economics, 6, 3: September, 1982.

"Market Definition, Market Power and Potential Competition," Quarterly Review of Economics and Business, 24, 2: Summer, 1984.

"Entry Inclinations Under Uncertainty," Journal of Economics and Business, 35, 1: January, 1983.

"Market Growth, Demand Uncertainty and Potential Entry," Quarterly Review of Economics and Business, 24, 2: Summer, 1984.

"On the Use and Non-Use of Entry Deterrents," Journal of Business and Economics, 36, 4: December, 1984.

"Decision Making in the Two-Act Antitrust Decision Problem," (Co-author: Samuel Dennis). Managerial and Decision Economics, 5, 4: December, 1984.

"On the Probability of Potential Entry in Potential Competition Cases," Managerial and Decision Economics, 6, 2: June, 1985.

"The Risk-Averse Price-Taking Firm: A Partial Systhesis," Quarterly Journal of Business and Economics, 24, 3: Summer, 1985.

"On Whether to Prosecute Suspected Price-Fixing Conspiracies: A Hypothesis-testing Approach," Review of Industrial Organization, 2, 3: 1985,

"On Two-Source Factor Purchasing," Decision Sciences, 17, 2: Spring, 1986.

"Market Structure Implications of Export-Price Uncertainty," Managerial and Decision Economics, 8, 2: June, 1987.

"Regression-Estimated Market Demand and Quasi-Cournot Behavior," International Journal of Industrial Organization, 5, 2: June, 1987.

"On the Price-Taking Labor-Managed Supplier of a Perishable Good of Uncertain Demand Quantity," Atlantic Economic Journal, XV, 2: July, 1987.

"Uncertainty and the Lot-Size Reorder-Point Model," (Co-author: Ann R. Horowitz). Decision Sciences, 18, 4: Fall, 1987.

"Estimation Uncertainty and Optimal Advertising Decisions," (Co-authors: A. Aykac, M. Corstjens, and D. Gautschi). Management Science, 35, 1: January, 1989.

"The Short-Run Policies of the Labor-Managed Uncertain-Export-Price Taker," Economic Analysis and Worker's Management, XXIII, 2: 1989.

"Decision Making and Estimation-Induced Uncertainty," Managerial and Decision Economics, 11, 5: December, 1990.

"On the Effects of Cournot Rivalry Between Entrepreneurial and Cooperative Firms," Journal of Comparative Economics, 15, 1: March, 1991.

"The 'News Vendor Problem' Revisited: The Entrepreneurial Firm Versus The Cooperative," Atlantic Economic Journal, XIX, 2: June, 1991.

"Membership Size in the Educable Cooperative Facing Uncertain Demand," Journal of Economics (Zeitschrift fur Nationalokonomie), 55, 1: February 1992.

"Parameter-Estimation Uncertainty, Risk Aversion, and "Sticky" Output Decisions," Southern Economic Journal, 58, 4: April, 1992.

"Experimentation and Optimal Output Decisions: The Cooperative Versus the Entrepreneurial Firm," (Co-Author: Patrick Thompson). Management Science, 39, 1: January, 1993.

"Quasi-Cournot Behavior in a Multimarket Setting," (Co-author: Christopher Zappe). Managerial and Decision Economics, 14, 1:January-February, 1993.

"On the Persistence of Business Alliances: The Case of Major League Baseball Trading Patterns," Review of Industrial Organization, 8, 4: August, 1993.

"The Reasonableness of Horizontal Restraints: *NCAA* (1984)," in Lawwrence J. White and John Kwoka eds., The Antitrust Revolution (HarperCollins: New York, 1993); Revised, (Oxford University Press: Oxford, 1998).

"Using Linear Programming to Determine Post-Facto Consistency in Performance Evaluations: An Example from Major League Baseball," (Co-authors: Christopher Zappe and William Webster). INTERFACES, 23, 6: November-December, 1993.

"Pythagoras, Tommy Lasorda and Me: On Evaluating Baseball Managers," Social Science Quarterly, 75, 1: March, 1994.

"Demand-Side Management and Electric Power Exchange," (Co-authors: Ren Orans, C.K. Woo and Roger Pupp). Resource and Energy Economics, 16, 3: August, 1994.

"On the Manager as Principal Clerk," Managerial and Decision Economics, 15, 5: September-October, 1994.

"Copy Watches, Tailored Clothes, and the Structure→Conduct→Performance Paradigm," Review of Industrial Organization, 9, 6: December, 1994.

"A Further Note on the Theory of Labor Supply with Wage Rate Uncertainty," Seoul Journal of Economics, 7, 4: Winter, 1994.

"The Sophisticated Decision Maker: All Work and No Pay?" (Co-author: Patrick Thompson) Omega, 23, 1: February, 1995.

"Betto-san and the White Rat: Evaluating Japanese Major League Baseball Managers Vis-à-Vis Their American Counterparts," International Review for the Sociology of Sport, 30, 2: March, 1995.

"Product Quality Under Two-Pronged Uncertainty," Japanese Economic Review, 46, 3: September, 1995.

"The Linear Programming Alternative to Policy Capturing for Eliciting Criteria Weights in the Performance Appraisal Process," (Co-author: Christopher Zappe) Omega, 23, 6: November-December, 1995.

"The Cooperative Firm's Pricing of Durable Goods Under Stock Uncertainty," Journal of International and Cooperative Economics, 4, 4: 1995.

"Private Enforcement of the Antitrust Laws Works Occasionally: *The Board of Regents of the Univ. of Okla. v. NCAA*, A Case in Point," (Co-author: D. Kent Meyers). Oklahoma Law Review, 48, 4: Winter, 1995.

"Markets, Submarkets, and the Pacific Rim Stock Exchanges," (Co-author: Terence Khoo) in Chang-Soo Kim, Thomas Liaw, and Thomas Chen eds., Emerging Markets In Asia (Center for Asian Studies: St. John's University, 1996).

"A Note on Exports under Multi-Market Exchange-Rate Uncertainty," Economia Internazionale, XLIX, 2: Maggio, 1996.

"Ramsey Pricing of Electricity under Unknown Bypass Costs," (Co-authors: Dewey Seeto and C.K. Woo). The Energy Journal, 17, 2: 1996.

"Insider Ownership and Financial Leverage: An Empirical Analysis," (Co-author: Joseph Kang) in Ng Kaw-Hwa and Kwok Branson eds., Financial Markets and Analysis (Addison Wesley; New York, 1996),

"The Evolving Sectoral Structure of Hong Kong," Journal of Asian Economics, 7, 1:1996

"The Sino-British Accord and the Changing Industrial Structure of Hong Kong," Advances in the Pacific Basin in Business Economics and Finance, 2: 1996.

"Real-Time Pricing of Electricity for Industrial Firms," (Co-authors: C.K. Woo and Peter Chow). Pacific Economic Review, 1, 1: June 1996.

"Time-of-Use Pricing vs Hopkinson Tariffs *Redux*," (Co-authors: Dewey Seeto and C.K. Woo). Energy Economics, 19, 3: June, 1997.

"The Increasing Competitive Balance in Major League Baseball," Review of Industrial Organization, 12, 3: June,1997.

"Electricity Market Integration in the Pacific Northwest," (Co-authors: C.K. Woo and Debbie Lloyd-Zanetti). Energy Journal, 18, 3: 1997.

"Reliability Differentiation of Electricity Transmission," (Co-authors: C.K. Woo and Jennifer Martin). Journal of Regulatory Economics, 13, 3: May, 1998.

"Thanks for the Memories: Baseball Veterans' End-of-Career Salaries," (Co-author Christopher Zappe). Managerial and Decision Economics, 19, 6: September, 1998.

"Analysis of Capacity Management of the Intensive Care Unit in a Hospital," (Co-authors: Seung-Chul Kim, Karl K. Young and Thomas A. Buckley). European Journal of Operational Research, 15, 1: May, 1999.

"Risky Assets and the Choice of Tax Base," (Co-author: Ann R. Horowitz) Public Finance Review, 27, 5: September, 1999.

"Quality Choice: Does *Which* Workers Own and Manage the Cooperative Firm Matter?" (Co-author: Ann R. Horowitz). Atlantic Economic Journal, 27, 4: December, 1999.

An Option-Pricing Look at the Introduction of Private Labels," Journal of the Operational Research Society, 51, 2: February, 2000.

"EOQ and Inflation Uncertainty," International Journal of Production Economics, 65, 3: April, 2000.

"The Impact of Competition on Performance Disparities in Organizational Systems: Baseball as a Case," Journal of Sports Economics, 1, 2: May, 2000

"Constrained Service Reliability under Stochastic Demand," Omega, 28, 3: June, 2000.

"Flexible Bed Allocation and Performance in the Intensive Care Unit," (Co-authors: Seung-Chul Kim, Karl A. Young, and Thomas A. Buckley). Journal of Operations Management, 18, 4: June, 2000.

"Cross Hedging and Forward-Contract Pricing of Electricity," (Co-authors: Chi-Keung Woo and Khoa Hoang). Energy Economics, 23, 1: January 2001.

"Kyou-sou in the Nippon Baseball Leagues," Pacific Economic Review, 6, 2: June, 2001.

"On Professor Kohn and Expected Utility: Correction and Clarification," International Economic Journal, 15, 2: Summer, 2001.

"Finessing the Unintended Outcomes of Price-Cap Adjustments: An Electric Utility Multi-Product Perspective," (Co-authors: Dewey Q. Seeto and Chi-Keung Woo). Energy Policy, 29, 13: 2001.

"Cross Hedging and Value at Risk: Wholesale Electricity Forward Contracts," (Co-authors: Chi-Keung Woo and Khoa Hoang). Advances in Investment Analysis and Portfolio Management 8, 2001.

"What Price Quality? An Investigation into the Prediction of Wine-Quality Ratings," (Co-Author: Larry Lockshin). Journal of Wine Research, 13, 1: April, 2002.

"Scheduling Hospital Services: The Efficacy of Elective-Surgery Quotas," (Co-author: Seung-Chul Kim). Omega, 30, 5: October, 2002.

"Preference-Neutral Attribute Weights in the Journal-Ranking Problem," Journal of the Operational Research Society, 54, 5: May, 2003.

"Managing Electricity Procurement Cost and Risk By a Local Distribution Company," (Co-Authors: Chi-Keung Woo and Rouslan I. Karimov). Energy Policy, 32, 5: March, 2004.

"Aggregating Expert Ratings Using Preference-Neutral Weights: The Case of the College Football Polls," INTERFACES, 34, 4: July-August, 2004.

"The Efficient Frontier for Spot and Forward Purchases: An Application to Electricity," (Co-Authors: Chi-Keung Woo, Brian Horii and Rouslan I. Karimov). Journal of the Operational Research Society, 55, 11: November, 2004.

"Efficient Frontiers for Electricity Procurement by an LDC With Multiple Purchase Options," (Co-Authors: Chi-Keung Woo, Arne Olsen, Brian Horii and Carmen Baskette). Omega (forthcoming).

"Designing Pareto-Superior Demand-Response Rate Options," (Co-Author: Chi-Keung Woo). Energy (forthcoming).

"New-Product Success in the Pharmaceutical Industry," (Co-Authors: Marcel Corstjens and Edouard Demeire). Economics of Innovation and New Technology (forthcoming).

Comments

"Comments on the Growth of Research and Development Expenditures," Operations Research, 8, 4: July-August, 1960.

"Some Comments on 'The Future of Industrial Research'," Journal of Business, XXV, 2: April, 1962.

"Some Comments on 'Brand Loyalty'," Econometrica, 31, 3: July, 1963.

"Reply: To Dr. Fleischer," Journal of Industrial Engineering, 1: January-February, 1965,

"Re: How to Rate Management of Investment Funds," Harvard Business Review, 43, 3: May-June, 1965.

"Discussion," Proceedings: Bank Structure and Competition (Federal Reserve Bank of Chicago): 1970.

"A Comment on Branded Competition and Concentration Measures," Southern Economic Journal, XLIII, 4: April, 1978.

"How to Think Straight," FORTUNE, 105, 8: April 1982.

"Reply," Southern Ecomomic Journal, XLVII, 2: October, 1982.

"Comment on the Misuse of Accounting Rates of Return to Infer Monopoly Profits," American Economic Review, 74, 3: June, 1984.

"Comment on 'Monopoly Supply'," Atlantic Economic Journal, XIX, 4: December, 1991.

"FM Letter: Insider Equity Ownership and the Debt/Equity Ratio," (Coauthor: Joseph C. Kang). Financial Management, 22, 4: December, 1993.

"Does IO Economics *Really* Make the Case for Investments in IT? Comment on West and Courtney," Decision Sciences, 5, 4:July/August, 1994.

"The Effects of Business Taxes on Output and Location of the Firm Under Uncertainty: Comment," Public Finance Review, 25, 2: March, 1997.

"Pythagoras's Petulant Persecutors," Managerial and Decision Economics, 18, 4: June, 1997.

"Will a Risk-averse Decision Maker ever *Really* Prefer an Unfair Gamble?" Decision Sciences, 29, 3: Summer, 1998.

Book Reviews

John Meyer and Robert Glauber, Investment Decisions, Economic Forecasting and Public Policy in Engineering Economist, 9, 4: Summer, 1964.

George H. Hildebrand and Ta-Chang Liu, Manufacturing Production Functions in the United States, 1957 in Econometrica, 34, 2: April, 1966.

Donald Mulvihill (ed.), A Guide to the Quantitative Age in Journal of Business, XXIX, 4: October, 1966.

Daniel Hamberg, Essays on Research and Development in American Economic Review, VLII, 1: March 1967.

Yuji Ijiri, Fundamentals of Accounting Measurement in American Economic Review, LVII, 1: March, 1968.

Hadley, Introduction to Probability and Statistical Decision Theory in Journal of Business, 41,2: April, 1968.

G. Weber, Management in Interfaces, 6, 1: November, 1975.

K. Cohen and J. Cyert, Theory of the Firm in Journal,of the American Statistical Association, 71, 356: June, 1976.

A. Jacquemin, Economie Industrielle Europeenne in Journal of Economic Literature, XV, 2: June, 1977.

H. Theil, Theory and Measurement of Consumer Demand in Interfaces 8, 3: May, 1978.

G. Schwodiauer (ed). Equilibrium and Disequilibrium in Economic Theory in Interfaces, 9, 5: November, 1979.

P. Schoemaker, Experiments on Decisions Under Risk, in Interfaces, 11, 6: December, 1981.

D. Kahneman, P. Slovic and A. Tversky (eds.) Judgment Under Uncertainty: Heuristics and Biases, in Interfaces, 14, 1: Jan.-Feb. 1984.

F.M. Fisher, J.J. McGowan, and J.E. Greenwood, Folded, Spindled and Mutilated, in Information Economics and Policy, 2: 1986.

S.I. Gass, Decision Making, Models and Algorithms, in Interfaces, 16, 5: Sept.-Oct., 1986.

M. Ben-Akiva and S.R. Lerman, Discrete Choice Analysis, in Interfaces 17, 1: Jan.-Feb., 1987.

K.J. Arrow and R. Herve, Social Choice and Multicriterion Decision-Making,in Interfaces, 17, 5: Sept.-Oct., 1987.

G. Scully, The Business of Major League Baseball, in Review of Industrial Organization, 5, 3: Fall, 1990.

K.T. Marshall and R. M. Oliver, Decision Making and Forecasting, in International Journal of Forecasting, 12, 3: Sept., 1996

Books

Small Business and Government Research and Development (Co-author: James A. Alcott). Small Business Administration: Washington, D.C., 1962.

An Introduction to Quantitative Business Analysis. McGraw-Hill, 1965. (Also Reprinted in Spanish); Revised Edition, Spring 1972.

Decision Making and the Theory of the Firm. Holt, Rinehart and Winston, 1970.

Quantitative Economic Policy and Planning. (Co-author: Nicholas Spulber), W.W. Norton, 1976.

Organization and Decision Theory (Editor). Kluwer Academic Publishers, 1990.

TEL AVIV UNIVERSITY
Asher Tishler, Ph.D.

December 2004

CURRICULUM VITAE

Home Address:	25 Hahadarim Street, Mazkeret Batia, Israel
Home Tel:	08-9349606
Office Tel:	03-6407224
Fax:	08-9349501
e-mail:	atishler@post.tau.ac.il

EDUCATION

1972 -	B.Soc.Sc. (with honors) Economics, Statistics, The Hebrew University, Jerusalem.
1976 -	Ph.D., Economics, University of Pennsylvania. Dissertation: "An Econometric Model of the Commercial Banking Sector in a Complete Flow of Funds Model of the United States". Supervisers: Professors A. Ando and L. Klein

ACADEMIC POSITIONS & EXPERIENCE

1975 - 1976	University of Pennsylvania, Economic Research Unit, Research Associate
1976 - 1978	Tel Aviv University, Faculty of Management and Department of Economics, Post Doctoral Fellow
1978 - 1984	Tel Aviv University, Faculty of Management, Lecturer
1980 - 1981	University of Pennsylvania, Visiting Lecturer
1981 - 1982	University of Southern California, Visiting Assistant Professor
1982 - 1983	University of Southern California, Visiting Associate Professor
1985 - 1992	Tel Aviv University, Israel, Faculty of Management, Senior Lecturer (tenured)
1985	University of Iowa, Visiting Associate Professor
1986 - 1988	Tel Aviv University, Faculty of Management, Chair, Management-Economics Department
1988 - 1990	University of Iowa, Visiting Professor
1991 - 1994	Israel Institute of Business Research, Director

1992 - 2001	Tel Aviv University, Faculty of Management, Associate Professor
1994 - 1998	Top Executive Program, Faculty of Management, Tel Aviv University, Academic Director
1998 - 1999	University of Iowa, Visiting Professor
1999 - 2003	Academic Director of the Executive MBA program and the Kellogg-Recanati International Executive MBA program, Faculty of Management, Tel Aviv University
2001-	Tel Aviv University, Israel, Faculty of Management, Professor

Reviewer:

The Review of Economics and Statistics, Journal of Econometrics, Econometrica, European Economic Review, European Journal of Operational Research, Economic Journal, Applied Mathematics and Computation, International Economic Review, Resources and Energy Economics, Journal of Applied Econometrics, The Energy Journal, Computers and Operations Research.

Teaching Areas:

Managerial Economics, Microeconomics, Econometrics, Energy Economics, Macroeconomics, Operations Research.

Economic Consulting:

The Budgeting Office in Israel and I.B.M., 1977-1980.
The Energy Office in Israel, 1978-1980, 1983-1988.
Bank Leumi in Israel, 1983-1984.
The Energy Office in Israel, 1983-1988.
The Israel Electric Utility, 1986-
Israel Defense Ministry, 1997-1998.
The Ministry of National infrastructures (Israel), 2004-
Consultant to several high-tech firms in Israel, U.S., Hong Kong

Publications

Asher Tishler
December 2004

Tishler, A. and I. Zang, "A Switching Regression Method Using Inequality Conditions", *Journal of Econometrics*, Vol. 11, 259-274, 1979.

Klein, L.R. and A. Tishler, "Long-Run Projections of the LINK World Trade Model", in *Modelling the International Transmission Mechanism*, J.A. Sawyer, ed., North-Holland, 1979.

Flanders, M.J. and A. Tishler, "On the Choice of Currency Basket and on the Measurement of Effective Exchange Rate Changes: The Case of Israel", in *Israel - A Developing Society*, A. Arian, ed., 1979.

Ginsburgh, V. A. Tishler and I. Zang, "Alternative Estimation Methods for Two-Regime Models: A Mathematical Programming Approach", *European Economic Review*, 13, 207-228, 1980.

Flanders, M.J. and A. Tishler, "On the Choice of a Currency Basket", in *Studies in the Israeli Economy*, Bruno and Z. Zusman, eds., 1980 (Hebrew).

Tishler, A. and I. Zang, "A Maximum Likelihood Method for Piecewise Regression Models with a Continuous Dependent Variable", *The Journal of the Royal Statistical Society*, Series C (Applied Statistics), 30, 116-124, 1981.

Tishler, A. and I. Zang, "A New Maximum Likelihood Algorithm for Piecewise Regression", *The Journal of the American Statistical Association*, 76, 980-987, 1981.

Flanders, M.J. and A. Tishler, "The Role of Elasticity Optimism in Choosing an Optimal Currency Basket with Applications", *Journal of International Economics*, 11, 395-406, 1981.

Sheshinski, E., A. Tishler and Y. Weiss, "Inflation, Costs of Adjustment and the Amplitude of Real Price Changes: An Empirical Analysis", in *Development in an Inflationary World*, M.J. Flanders and A. Razin, eds., Academic Press, 1981.

Tishler, A., "The Demand for Cars and the Price of Gasoline: The User Cost Approach," *The Review of Economics and Statistics*, LXIV, 184-190, 1982.

Levin, N., A. Tishler and J. Zahavi, "A Time Step Equilibrium Model for the Electricity Sector", in *Perspectives on Resource Policy Modeling: Energy and Minerals*, R. Amit and M. Avriel, eds., Ballinger, 1982.

Tishler, A. and I. Zang, "An Absolute Deviations Curve Fitting Algorithm for Nonlinear Models", *TIMS Studies in the Management Sciences*, Vol. 19, 1982, 81-103.

Levin, N., A. Tishler and J. Zahavi, "Time Step vs. Dynamic Optimization of Generation-Capacity-Expansion Programs of Power Systems", *Operations Research*, Vol. 31, 891-914, 1983.

Tishler, A., "The Demand for Cars and Gasoline: A Simultaneous Approach," *European Economic Review*, 10, 271-287, 1983.

Tishler, A., "The Industrial and Commercial Demand for Electricity Under Time-of-Use Pricing," *Journal of Econometrics*, 23, 369-384, 1983.

Kalaba, R., N. Rasakhoo and A. Tishler, "Non-Linear Least Squares Via Automatic Derivative Evaluation", *Applied Mathematics and Computation*, 12, 119-137, 1983.

Kalaba, R. N. Rasakhoo, A. Tishler and J.S. Wang, "A New Proof for Decell's Finite Algorithm for Generalized Inverses", *Applied Mathematics and Computation*, 12, 199-211, 1983.

Kalaba, R and A. Tishler, "A Generalized Newton Algorithm Using Higher Order Derivatives", *Journal of Optimization Theory and Applications*, 39, 1-17, 1983.

Kalaba, R. and A. Tishler, "A Computer Program to Minimize a Function with Many Variables Using Computer Evaluated Exact Higher Order Derivatives", *Applied Mathematics and Computation*, 13, 143-172, 1983.

Tishler, A and I. Zang, "A Min-Max Algorithm for Non-Linear Regression Models", *Applied Mathematics and Computation*, 13, 95-115, 1983.

Levin, N., A. Tishler and J. Zahavi, "Perturbation Analysis of Power Generation Expansion Programs Subject to Uncertainty in the Prices of Primary Energy Resources". Special issue in "Energy Models and Studies". *Studies in Management Science and System Series*, 367-385, 1983.

Kalaba, R, A. Tishler and J.S. Wang, "Decell's Finite Algorithm for Generalized Inverses and Tests to Determine the Rank of a Matrix", *Computers and Mathematics with Applications*, 9, 679-686, 1983.

Kalaba, R. and A. Tishler, "On the Use of Higher Order Derivatives in Optimization Using Lagrange's Expansion", *Nonlinear Analysis: Theory, Methods and Applications*, 7, 1149-1161, 1983.

Levin, N., A. Tishler and J. Zahavi, "A Model for Planning Investments in the Energy Sector in the Medium Range", in *Analytic Techniques for Energy Planning*, J. Bloom, B. Lev and F. Murphy, eds., North-Holland, 1983.

Kalaba, R., A. Tishler and J.S. Wang, "Rate of Convergence of the Generalized Newton Algorithm Using the Fixed Point Approach", *Journal of Optimization Theory and Applications*, 43, 543-555, 1984.

Kalaba, R. and A. Tishler, "On the Use of the Table Method in Constrained Optimization", *Journal of Optimization Theory and Applications*, 43, 157-165, 1984.

Kalaba, R. and A. Tishler, "Generalized Newton Algorithm to Minimize a Function with Many Variables Using Computer Evaluated Exact Higher Order Derivatives", *Journal of Optimization Theory and Applications*, 42, 383-395, 1984.

Tishler, A., "Israel's Balance of Payments and Foreign Exchange Requirements", in *Studies in the Israeli Economy*, Z. Zusman, ed., 1984 (Hebrew).

A. Tishler, "A Model of Industrial Demand for Electricity Under Time-of-Use Pricing and Three Labor Shifts", *Resources and Energy*, 6, 107-127, 1984.

Kalaba, R. and A. Tishler, "Automatic Derivative Evaluation in the Optimization of Nonlinear Models", *The Review of Economics and Statistics*, LXVI, 653-660, 1984.

Itskovits, Z. and A. Tishler, "The Effect of Assets and Disposable Income on Private Consumption in Israel: Should There be Substantial Reduction of Real Wages in 1984?" *The Economic Quarterly*, 121, 143-147, 1984 (Hebrew).

Tishler, A. and I. Zilcha, "A Model of Household's Demand for Durables and Energy", *The Scandinavian Journal of Economics*, 86, 411-422, 1984.

Levin, N., A. Tishler and J. Zahavi, "Capacity Expansion of Power Generation Systems with Uncertainty in the Prices of Primary Energy Resources", *Management Science*, Vol. 31, 175-187, 1985.

Levin, N., A. Tishler and J. Zahavi, "Evaluating Energy Options for the State of Israel - A Case Study", *The Energy Journal*, 7, 51-65, 1986.

Mariano, R.S., J.B. McDonald and A. Tishler, "On the Effects of Multicollinearity Upon the Properties of Structural Coefficient Estimators", in *Advances in Econometrics*, D.J. Slottje and G.F. Rhodes, eds., Vol. 5, 1986.

Datta, S., J.B. Nugent, A. Tishler and J.L. Wang, "Seasonality, Differential access and Interlinking of Labour and Credit", *The Journal of Development Studies*, 24, 1988, 379-393.

Tishler, A., "The Response of Large Firms to Different Schemes of Time-of-Use Pricing When the Production Function is Quadratic", *The Energy Journal*, 10, 1989, 69-90.

Fethke, G. and A. Tishler, "The Optimal Choice of Inputs Under Time-of-Use Pricing and Fixed-Proportions Technology", *Resources and Energy*, 11, 1989, 241-259.

Tishler, A., "Complementarity - Substitution Relationships in the Demand for Time-Differentiated Inputs Under Time-of-Use Pricing", *The Energy Journal*, 12, 1991, 137-148.

Ein-Dor, P., R. Giladi and A. Tishler, "Economic Analysis of Computer Hardware Performance: Some Theoretical and Methodological Observations", *Communication of the ACM*, 34, 1991, 113-117.

Tishler, A., "Optimal Production with Uncertain Interruptions in the Supply of Electricity: Estimation of Electricity Outage Costs", *European Economic Review*, 37, 1259-1274, 1993.

Grosfeld-Nir, A. and A. Tishler, "A Stochastic Model for the Measurement of Electricity Outage Costs", *The Energy Journal*, 14, 157-174, 1993.

Giladi, R., S. Lipovetsky and A. Tishler, "Evaluation and Approximation of Large Systems Using Multi-Dimensional Eigenvector Analysis: An Application to MIS", *Proceedings of the Second International Conference on Systems Science and Systems Engineering*, August, 1993, Beijing, China, 44-48.

Lipovetsky, S., A. Ragowsky and A. Tishler, "The Utility from Applications of Management Information System", *Proceedings of the Second International Conference on Systems Science and Systems Engineering*, August, 1993, Beijing, China, 627-631.

Tishler, A. and Y. Ye, "Minimal Adjustment Costs, Factor Demands, and Seasonal Time-of-Use Electricity Rates", *Resources and Energy Economics*, 15, 313-335, 1993.

Tishler, A., S. Lipovetsky and J. Newman, "An Application of a New Family of Flexible Cost Functions", *Proceedings of the Second International Conference on Systems Science and Systems Engineering*, August, 1993, Beijing, China, 198-202.

Lipovetsky, S. and A. Tishler, "Linear Methods in Multimode Data Analysis for Decision Making", *Computers & Operations Research*, 21, 169-183, 1994.

Aigner, D.J., J. Newman and A. Tishler, "The Response of Small and Medium-Size Business Customers to Time-of-Use (TOU) Electricity Rates in Israel", *Journal of Applied Econometrics*, 9, 283-304, 1994.

Spector, Y., A. Tishler and Y. Ye, "Minimal Adjustment Costs and the Optimal Choice of Inputs Under Time-of-Use Electricity Rates", *Management Science*, 41, 10, 1679-1692, 1995.

Tishler, A. and Z. Rotem, "Determinants of the International Competitiveness of the Israeli Defence Industry", *The Economic Quarterly*, 42, 468-496, 1995 (Hebrew).

Tishler, A. D. Dvir, A. Shenhar and S. Lipovetsky, "Identifying Critical Success Factors in Defense Development Projects: A Multivariate Analysis", *Technological Forecasting and Social Change*, 51, 151-172, 1996.

Aigner, D.J., M. Amit and A. Tishler, "The Response of Residential Customers to Time-of-Use Electricity Rates in Israel", in *Bayesian Analysis in Statistics and Econometrics*, Essays in Honor of Arnold Zellner, D.A. Berry, K.M. Chaloner and J.K. Geweke Eds., John Wiley & Sons, p. 409-421, 1996.

Tishler, A. and S. Lipovetsky, "Canonical Correlation Analyses for Three Data Sets: A Unified Framework with Application to Management", *Computers and Operations Research*, 23, 667-679, 1996.

Tishler, A. and S. Lipovetsky, "The Flexible CES-GBC Family of Cost Functions: Derivation and Application", *The Review of Economics and Statistics*, 638-646, 1997.

Lipovetsky, S., A. Tishler, D. Dvir and A. Shenhar, "The Relative Importance of Success Dimensions of Defense Projects", *R&D Management*, 27, 97-106, 1997.

Tishler, A., S. Lipovetsky and R. Giladi, "The Performance of Firms and the Attributes of Their Information Systems: A Multivariate Analysis", The Journal of Management Sciences & Regional Development, 1, 49-66, 1998.

Tishler, A., "The Bias in Price Elasticity Estimates Under Weak Separability between Electricity and Labor in Studies of Time-of-use Electricity Rates: An Application to Israel", *The Energy Journal*, 10, 217-236, 1998.

Dalal, O. and A. Tishler, "The Effect of Time-of-Use Electricity Pricing on the Demand of Electricity in the Business Sector in Israel", *Bank of Israel Review*, 71, 65-78, 1998.

Lipovetsky, S. and A. Tishler, "Interval Estimation of Priorities in the AHP", *The European Journal of Operational Research*, 14, 1998, 153-164.

Dvir, D., A. Hauptman, Y. Sharan, A. Shenhar, M. Sokolov and A. Tishler, "Commercialization of Military Technologies in Israel", *The Economic Review* (Hebrew), 2/98, 358-370, 1998.

Ahituv, N., S. Lipovetsky and A. Tishler, "The Relationship Between Firm's Information Systems Policy and Business Performance: A Multivariate Analysis", in *Measuring Information Technology Investment Payoff: Contemporary Approaches*, M.A. Mahmood and E.J. Szewizak eds., Idea Group Publishing, Hershey, PA., 62-82, 1998.

Hougi, S., A. Shenhar, D.Dvir, A. Tishler and Y. Sharan, "Understanding the Defense Conversion Dilemma", *Technological Forecasting and Social Change*, 59, 275-289, 1998.

Dvir, D., S. Lipovetsky, A Shenhar and A. Tishler, "In Search of Project Classification: A Non-Universal Approach to Project Success Factors", *Research Policy*, 27, 915-935, 1998.

Tishler, A. and S. Lipovetsky, "Modelling and Forecasting with Robust Canonical Analysis: Method and Application", *Computers and Operations Research*, 27, 217-232, 2000.

Dvir, D. and A. Tishler, "The Changing Role of the Defense Industry in Israel's Industrial and Technological Development", *Defense Analysis*, 16, 1, 33-52, 2000.

Tishler, A. and S. Lipovetsky, "A Globally Concave, Monotone and Flexible Cost Function: Derivation and Application", *Applied Stochastic Models in Business and Industry*, 16, 279-296, 2000.

Tishler, A., R. Ventura and J. Watters, "Cellular Telephones in the Israeli Market: The Demand, the Choice of Provider and Potential Revenues", *Applied Economics*, 33, 1479-1492, 2001.

Tishler, A., C.K. Woo and D. Lloyd, "Reforming Israel's Electricity Sector", *Energy Policy*, 30, 4, 347-353, 2002

Azulay, I., M. Lerner and A. Tishler, "Converting Military Technology through Corporate Entrepreneurship", *Research Policy*, Vol. 31, 3, 419-435, 2002.

Hougui, S.J., A. J. Shenhar, D. Dvir and A. Tishler, "Defense Conversion in Small Companies: Risk, Activities, and Success Assessment", *Journal of Technology Transfer*, Vol. 27, 3, 245-261, 2002.

Shenhar, A., A. Tishler, D. Dvir, S. Lipovetsky and T. Lechler, "Refining the Search for Project Success Factors: A Multivariate Approach", *R&D Management*, Vol. 32, 2, 111-126, 2002.

Lipovetsky, S., A. Tishler and M. Conklin, "Multivariate Least Squares and Its Relation to Other Multivariate Techniques", *Applied Stochastic Models in Business and Industry*, 18, 347-356, 2002.

Woo, C.K., D. Lloyd and A. Tishler, "Electricity Market Reform Failures: UK, Norway, Alberta and California", *Energy Policy*, 31, 1103-1115, 2003.

Woo, C.K., D. Lloyd, R. Karimov and A. Tishler, "Stranded Cost Recovery in Electricity Market Reforms in the US", *Energy*, 28, 1-14, 2003.

Dvir, D., S. Lipovetsky, A. Shenhar and A Tishler, "What is really important for project success? A refined, multivariate, comprehensive analysis", *International Journal of Managementand Decision Making*, vol. 4, 4, 382-404, 2003.

Tishler, A., J. Newman, I. Spekterman and C.K. Woo, "Cost-Benefit Analysis of Reforming Israel's Electricity Industry", forthcoming in *Energy Policy*.

Carmeli, A. and A. Tishler, "Resources, Capabilities, and the Performance of Industrial Firms: A Multivariate Analysis", *Managerial and Decision Economics, 25, 299-315,2004.*

Mantin, B. and A. Tishler, "The Structure of the Defense Industry and the Security needs of the Country: A Differentiated Products Model", *Defence and Peace Economics*, 15, 5, 397-419, 2004.

Carmeli, A. and A. Tishler, "The Relationships between Intangible Organizational Elements and Organizational Performance", *Strategic Management Journal, 25, 1257-1278, 2004.*

S. Golde and A. Tishler, "Security Needs, Arms Exports and the Structure of the Defense Industry: Determining the Security Level of Countries", *Journal of Conflict Resolution*, 48, 5, 672-698, 2004.

Woo, C.K, M. King, A. Tishler and L. Chow, "Costs of Electricity Deregulation with Application to Israel". Forthcoming in *Energy*, 2005.

Tishler, A. and C.K. Woo, "Likely Failure of Electricity Deregulation: Explanation with Application to Israel". Presented at the 20th Meeting of the Israeli Economic Association, 7/6/2004. Forthcoming in *Energy*, 2005.

Kagan, K., A. Tishler, A.Weiss, "On the Use of Terror Weapons vs. Modern Weapon Systems in an Arms Race between Developed and Less Developed Countries", forthcoming in *Defence and Peace Economics.*

Ben-Israel, I., O. Setter and A. Tishler, "R&D and the War on Terrorism: Generalizing the Israeli Experience", forthcoming in *Science and Technology Policies for the Anti Terrorism Era, NATO.*

Carmeli, A. and A. Tishler, "Perceived Organizational Reputation and Organizational Performance: An Empirical Investigation of Industrial Enterprises", forthcoming in *Corporate Reputation Review.*

Shefi, Y and A. Tishler, "The Effects of the World Defense Industry and US Military Aid to Israel on the Israeli Defense Industry: A Differentiated Products Model", forthcoming in *Defence and Peace Economics.*

Papers at Conferences (Unpublished Only)

Tishler, A. and I. Zilcha, "A Model of Demand for Durables and Energy: Certainty and Uncertainty". Presented at the 4th World Congress of the Econometric Society in Aix-en-Provence, France, August 1980.

Tishler, A. and S. Lipovetsky, "The Mixed CES-GBC Cost Function: An Application to the Demand for Electricity Under Time-of-Use (TOU) Rates", The 20th Annual Conference of the European Association for Research in Industrial Economics (EARIE), Tel Aviv 1993, Abstracts of papers, pp. 301-302.

Tishler, A. and S. Lipovetsky, "Global Concavity of a Variant of the Flexible CES-GBC Cost Function: Preliminary Results", Summer Meeting of the Econometric Society, Iowa City, June 1996.

Sharan, Y., A. Hauptman, M. Sokolov, D. Dvir, A. Tishlerand A. Shenhar, "Commercialization of Military Technologies in Israel", presented at the Portland International Conference on Management of Technology (PICMET), Portland, Oregon, July 28-29, 1997.

Shenhar, A., A. Tishler, S. Lipovetsky and D. Dvir, "Refining the Search for Project Success Factors", accepted for presentation in the Academy of Management (ACM) Conference, August 1997.

Shenhar, A., A. Tishler, Dov Dvir and G.S. Lynn, "The Joint Product-Project Classification: When is a Radical Innovation Really Radical?", the Sixth International Conference on MOT, Orlando, Florida, February, 1998.

Shenhar, A., D. Dvir and A. Tishler, "Project Management: The Next Competitive Weapon", INFORMS, Israel 1998 (June).

Azulay, I., M. Lerner and A. Tishler, "Converting Military Technology Through Intrapreneurship: Israeli Research Findings", INFORMS, Israel 1998 (June).

Zipori, Y., B. Ronen and A. Tishler, "Nervousness Analysis in MRP Systems", The 10th Annual Conference of the Israeli Association of Civil Engineers, June 1998.

Tishler, A., R. Ventura and J. Watters, "The Demand for Cellular Phones and their Use in Israel", The Israel Economic Association Meeting, May 1998.

Dvir, D. and A. Tishler, "The Role of the Israeli Defense Industry", presented in the Workshop on the Place of the Defense Industry in National Systems of Innovation, October 1998, Cornell University.

Tishler, A., C.K. Woo and D. Lloyd, "Reforming Israel's Electricity Sector", presented at the First Asian Energy Conference, May 2001, Baptist University, Hong Kong.

Blume, A. and A. Tishler, "Security Needs and the Performance of the Defense Industry", presented at the Fifth Annual Conference on Economics and Security, Middlesex University, London, June 2001.

Tishler, A., J. Newman, I. Spekterman and C.K. Woo, "Cost-Benefit Analysis of Reforming Israel's Electricity Industry", presented at the Second Asian Energy Conference: "Energy Market Reform: Issues and Problems", August 2003, Baptist University, Hong Kong.

Kagan, K., A. Weiss and A. Tishler, "On the Use of Terror Weapons vs. Modern Weapon Systems in an Arms Race between Developed and Less Developed Countries". The Second International Conference on Defence, Security and Economic Development, TEI of Larissa, Greece, 18 - 20 June, 2004.

Shefi, Y. and A. Tishler, "The Effects of the World Defense Industry and US Military Aid to Israel on the Israeli Defense Industry: A Differentiated Products Model". The Eight Annual Conference on Economics and Security, University of the West of England, Bristol, June 26-28, 2004.

Setter, O. and A. Tishler, "The Role of Integrative Technologies as a 'Force Exponent' on Military Capability". The Eight Annual Conference on Economics and Security, University of the West of England, Bristol, June 26-28, 2004.

Research Reports (unpublished)

A. Tishler
"The Commercial Banks Liquidity Position and the Money Supply Determination," Foerder Institute, Working Paper No. 61-76, 1976.

A. Tishler
"A Model of Asset Allocation in the Commercial Banks Sector of the United States," Foerder Institute of Economic Research, Working Paper No. 56-76, 1976.

Tishler
"A Model of Demand for Consumer Durables," Foerder Institute for Economics Research, Working Paper No. 12/79, 1979.

A. Tishler, J. Zahavi
"Investment Planning in the Energy Sector in Israel, the Medium Range - First Phase", The Israel Institute of Business Research at Tel Aviv University, Research Report No. 25/79, November 1979 (Hebrew).

N. Levin, A. Tishler, J. Zahavi
"Loss Function Approach for Capacity Expansion Under Uncertainty in the Prices of Primary Energy Resource", Faculty of Management, Tel Aviv University, 1980.

N. Levin, A. Tishler, J. Zahavi
"An Electrical Energy Equilibrium Model - The Static Case" , Research Report 29/80, The Israel Institute of Business Research, Faculty of Management, Tel Aviv University, 1980.

N. Levin, A. Tishler, J. Zahavi
"An Electrical Energy Equilibrium Model - The Dynamic Case", Research Report 30/80, The Israel Institute of Business Research, Faculty of Management, Tel Aviv University, 1980.

A. Tishler, J. Zahavi
"Investment Planning in the Energy Sector In Israel, the Medium Range - Second Phase", The Israel Institute of Business Research, Faculty of Management, Tel Aviv University, Research Report No. 28/80, 1980 (Hebrew).

E. Sheshinski, A. Tishler, Y. Weiss
"Inflation, Costs of Price Adjustment, and the Amplitude of Real Price Changes: An Empirical Analysis", Foerder Institute for Economic Research, Working Paper 49-80, 1980.

A. Tishler
"The Estimation of Price Elasticities Under Time of Day Pricing Using Duality," Department of Economics, University of Southern California, 1982.

N. Levin, A. Tishler, J. Zahavi
"A Time-Step Equilibrium Model for the Energy Sector", Modelling Research Group, Working Paper 8213, Department of Economics, University of Southern California, 1982.

A. Tishler
"The Industrial Demand for Electricity, Labor and Capital Under Time-of-Use Pricing When the Production Function is Quadratic", Faculty of Management, Tel Aviv University, Working Paper No. 767/83, 1983.

S. Datta, J. Nugent, A. Tishler
"Determination of the Contractual Mix Between Cash and Kind Wages for Developing Agrarian Economies", Department of Economics, MRG W/P 8313, University of Southern California, 1983.

S. Datta, J. Nugent, A. Tishler
"Interlinking of Credit and Labor Markets in Agrarian Economy", Department of Economics, MRG W/P 8314, University of Southern California, 1983.

N. Levin, A. Tishler, J. Zahavi
"Electricity Equilibrium Models with Stochastic Fuel Prices", Working Paper, Management and Policy Sciences Department, School of Business, USC, 1983.

D. Chazan, M. Landsberger, A. Tishler, et al.
"Econometric Model of the Israeli Economy", Technical Report 117, I.B.M. Scientific Center, Israel, February, 1984.

Z. Itskovits, A. Tishler
"Evaluating the Effects of Dieselization in Israel", Research Report to the Energy Office, Jerusalem, July 1985 (Hebrew).

A. Tishler, I. Visco
"Estimating the Effects of Assets and Disposable Income in the Absence of Assets' Data: The Case of Israel and Italy", Faculty of Management, Tel Aviv University, July 1985.

M. Givon, A. Tishler
"Thurstone's Law of Comparative Judgement with Unequal Variances", Faculty of Management, Tel Aviv University, Working Paper No. 867/85, 1985.

A. Tishler
"The Estimations of Input's Demand Functions Under Time-of-Use Pricing of Electricity with Incomplete Data and Quadratic Production Function", Faculty of Management, Tel Aviv University, Working Paper No. 872/85, 1985.

A. Tishler
"Remarks on the Effect of Demand Charges on the Firm's Demand for Electricity", Faculty of Management, Tel Aviv University, Working Paper No. 899/86, 1986.

A. Tishler, J. Sheinin
"A Parametric Macro-Model of the Israeli Economy: The Real Sector", Research Report to the Energy Office, Jerusalem, 1987 (Hebrew).

P. Ein-Dor, R. Giladi, A. Tishler
"Economic Analysis of Computer Hardware Performance: Some Theoretical and Methodological Observations", Faculty of Management, Tel Aviv University, Working Paper No. 54/90, 1990.

L. Muus, A. Tishler, C. Whiteman
"Adjustment Costs in the Demand for Electricity: Application of Kalman Filter", The University of Iowa, 1990.

A. Tishler, S. Lipovetsky
"Flexible Functions in Electricity Time-of-Use (TOU) Studies: A Review", Faculty of Management, Tel Aviv University, Working Paper No. 31/92, 1992.

A. Tishler
"Evaluation of the Perceived Quality of Universities and the Demand for Higher Education in Israel: Preliminary Results", Faculty of Management, Tel Aviv University, Working Paper No. 47/92, 1992.

D.J. Aigner, A. Tishler
"The Time-of-Use Experiments on Lower Voltage Customers in Israel", The Israel Institute of Business Research, 1992.

A. Tishler, S. Lipovetsky
"A Lot of Data with Little Theory: A Possible Solution Based on Canonical and Partial Canonical Correlations with an Application to Management Information Systems", Faculty of Management, Tel Aviv University, Working Paper No. 32/93, 1993.

A. Shenhar, A. Tishler, D. Dvir, S. Lipovetsky
"Refining the Search for Project Success Factors: A Multivariate Typological Approach", Israel Institute of Business Research, Working Paper 13/95, Faculty of Management, Tel Aviv University, 1995.

A. Tishler, J. Newman
"The Demand of Electricity by Large Industrial Customers in Israel: the Effect of Time-of-use Rates", Israel Institute of Business Research, Working Paper No. 14/95, Faculty of Management, Tel Aviv University, 1995 (Hebrew).

O. Dalal, A. Tishler
"The Effect of Time-of-Use Electricity Rates on the Demand of Electricity in Kibbutzim", Israel Institute of Business Research, Working Paper No. 15/95, Faculty of Management, Tel Aviv University, 1995 (Hebrew).

D. Dvir, A. Hauptman, Y. Sharan, A. Shenhar, M. Sokolov, A. Tishler
"The Use of Defense Technologies in the Civilian Markets", IIBR and ICTAF, 1996 (Hebrew).

D. Dvir, S. Lipovetsky, A. Shenhar, A. Tishler
"Common Managerial Factors Affecting Project Success: A Multivariate Analysis"", Israel Institute of Business Research, Working Paper No. 2/99, Faculty of Management, Tel Aviv University, 1999.

A. Blume, A. Tishler
"Security Needs and the Performance of the Defense Industry", Israel Institute of Business Research, Working Paper No. 1/2000, Faculty of Management, Tel Aviv University, 2000.

A. Tishler, C.K. Woo, D. Lloyd
"Reforming Israel's Electricity Sector: The Options for Change", Israel Institute of Business Research, Working Paper No. 1/2001, Faculty of Management, Tel Aviv University, 2001.

A. Carmeli, A. Tishler
"Recources, Capabilities, and the Performance of Industrial Firms: A Multivariate Analysis", Israel Institute of Business Research, Working Paper No. 5/2002, Faculty of Management, Tel Aviv University, 2002.

A. Tishler
"On the Choice of Optimal R&D Programs in Oligopoly Markets: The Optimal Choice of Expected Outcome and Risk" Israel Institute of Business Research, Working Paper No. 4/2002, Faculty of Management, Tel Aviv University, 2002.

A. Tishler, J. Newman, I. Spekterman
"An Assessment of Market Reforms in the Electricity Sector in Israel: A Cost-Benefit Analysis", the Israel Electric Corporation, 2003 (Hebrew).

A. Tishler, C.K. Woo
"Likely Failure of Electricity Deregulation: Explanation with Application to Israel", Israel Institute of Business Research, Working Paper No. 8/2004, Faculty of Management, Tel Aviv University, 2004.

A. Tishler, Y. Shefi
"The Effects of the World Defense Industry on the Optimal Structure of the Israeli Defense Industry", Israel Institute of Business Research, Working Paper No. 8/2004, Faculty of Management, Tel Aviv University, 2004 (Hebrew).

Brian K. Horii

brian@ethree.com 415.391.5100 ext. 311

Mr. Horii is the primary architect of numerous computer models currently being used by electric utilities across the United States and Canada. These models address such topics as: evaluation of bilateral trading decisions in an open access market; estimation of area- and time-specific marginal costs; and dynamic evaluation of the potential local-area benefits of targeted DSM and modular generation.

ENERGY & ENVIRONMENTAL ECONOMICS, INC. — San Francisco, CA

Senior Partner — 1993 – Present

Utility Costing and Planning. Designed standard and innovate electric utility rate options for utilities the United States, Canada, and the Middle East. Authored testimony for BC Hydro on Bulk Transmission Incremental Costs (1997). Principal author of B.C. Hydro's *System Incremental Cost Study 1994 Update (With Regional Results Appendix)*. Performed detailed market segmentation study for Ontario Hydro under both embedded and marginal costs. Areas of expertise include marginal cost based revenue allocation and rate design, estimation of area and time specific marginal costs; incorporation of customer outage costs into planning criteria, and dynamic Distribution Resource evaluation to evaluate the potential local-area benefits of targeted DSM and modular generation. While at PG&E, also served as an expert witness and was instrumental in the formulation of new marginal cost and revenue allocation methods that were adopted by the CPUC for PG&E, and extended in select instances to other California investor-owned utilities.

Competitive Issues. Provided auction bid values for California Fossil plants under deregulation. This analysis included issues such as emission credits and potential offset costs, site land value, and historical interactions between the plants and the communities. Simulated bilateral trading decisions in an open access market; analyzed market segments for micro generation options under unbundled rate scenarios; forecasted stranded asset risk and recovery for North American utilities; and created unbundled rate forecasts. Other work in the area includes: teaching courses on profitability analysis for EPRI; performing customer market segmentation studies for PG&E and Ontario Hydro; designing a comprehensive billing and information management system for a major ESP operating in California; and testifying before the British Columbia Public Utilities Commission on electric market restructuring.

Time Dependant Valuation of Building Energy Efficiency. E3's co-lead, along with Snuller Price, into the investigation of refining the California Title-24 building standards to reflect how the value of energy usage reductions can vary by season and time of day. The investigation included a review of extant utility and CEC marginal cost and pricing methods and forecast, and resulted in recommendations for the new evaluation framework that has received the support of the CEC Commissioners, and is currently in the public comment process.

Past and present clients include: B.C. Hydro, Centerior, Central and Southwest Services, Central Power and Light Company, Commonwealth Edison, Consolidated Edison, EPRI, Kansas City Power and Light, National Renewable Energy Laboratory, New York State Electric and Gas, Ontario Hydro, Orange and Rockland Utilities, PG&E, PG&E Energy Services, Public Service Indiana Energy, Public Service Oklahoma, Puget Sound Energy, Tennessee Valley Authority, and Wisconsin Electric Power Company.

PACIFIC GAS & ELECTRIC COMPANY — San Francisco, CA

Project Manager, Supervisor of Electric Rates — 1987 – 1993

- Managed and provided technical support to PG&E's investigation into the Distributed Utilities (DU) concept. The projects included an assessment of the potential for DU devices at PG&E, an analysis of the loading patterns on PG&E's 3000 feeders, and formulation of the modeling issues surrounding the integration of Generation, Transmission, and Distribution planning models.

- Served as PG&E's expert witness on revenue allocation and rate design in testimonies before the California Public Utilities Commission (CPUC). Was instrumental in getting PG&E's area-specific loads and costs adopted by the CPUC. and extending their application to cost effectiveness analyses of DSM programs. Additional analytical work included creating interactive negotiation analysis programs, and forecasting electric rates trends for short-term planning.

INDEPENDENT CONSULTING San Francsico, CA
Product Marketing Manager 1989 – 1993

- Helped developed methodology for evaluating the cost-effectiveness of decentralized generation systems for relieving local distribution constraints, and created a model for determining the least cost expansion of local transmission and distribution facilities integrated with area-specific DSM incentive programs. Co-authored The Delta Report for PG&E and EPRI which examined the targeting of DSM measures to defer the expansion of local distribution facilities.

Education

STANFORD UNIVERSITY Palo Alto, CA
M.S. in Civil Engieering and Environmental Planning

STANFORD UNIVERSITY Palo Alto, CA
B.S. in Civil Engineering

Citizenship

United States Citizen

Refereed Papers

1. *Woo, C. K., B. Horii and I. Horowitz (2002) "The Hopkinson Tariff Alternative to TOU Rates in the Israel Electric Corporation," Managerial and Decision Economics, 23:9-19.*

2. *Chow, R.F., Horii, B., Orans, R. et. al. (1995), Local Integrated Resource Planning of a Large Load Supply System, Canadian Electrical Association.*

3. *Woo, C.K., R. Orans, B. Horii and P. Chow (1995) "Pareto-Superior Time-of-Use Rate Option for Industrial Firms," Economics Letters, 49, 267-272.*

4. *Woo, C.K., B. Hobbs, Orans, R. Pupp and B. Horii (1994), "Emission Costs, Customer Bypass and Efficient Pricing of Electricity," Energy Journal, 15:3, 43-54.*

5. *Pupp, R., C.K.Woo, R. Orans, B. Horii, and G. Heffner (1995), "Load Research and Integrated Local T&D Planning," Energy - The International Journal, 20:2, 89-94.*

6. *Woo, C.K., R. Orans, B. Horii, R. Pupp and G. Heffner (1994), "Area- and Time-Specific Marginal Capacity Costs of Electricity Distribution," Energy - The International Journal, 19:12, 1213-1218.*

7. *Orans, R., C.K. Woo and B. Horii (1994), "Targeting Demand Side Management for Electricity Transmission and Distribution Benefits," Managerial and Decision Economics, 15, 169-175.*

Research Reports and Filed Testimony

1. *Horii, B., C.K. Woo and D. Engel (2000) PY2001 Public Purpose Program Strategy and Filing Assistance: (a) A New Methodology for Cost-Effectiveness Evaluation; (b) Peak Benefit Evaluation; (c) Screening Methodology for Customer Energy Management Programs; and (d) Should California Ratepayers Fund Programs that Promote Consumer Purchases of Cost-Effective Energy Efficient Goods and Services? Reports submitted to Pacific Gas and Electric Company.*

2. *Woo, C.K. and B. Horii (1999) Should Israel Electric Corporation (IEC) Replace Its Industrial Time of Use Energy Rates with A Hopkinson Tariff? Report prepared for IEC.*

3. *B. Horii, J. Martin, Khoa Hoang, (1996), Capacity Costing Spreadsheet: Application of Incremental Costs to Local Investment Plans, Report and software developed for the Electric Power Research Institute.*

4. *Lloyd-Zanetti, D., B. Horii, J. Martin, S. Price, and C.K. Woo (1996), Profitability Primer: A Guide to Profitability Analysis in the Electric Power Industry, Report No. TR-106569, Electric Power Research Institute.*

5. *Horii B., (1996) Customer Reclassification Study, Report Submitted to Ontario Hydro.*

6. *Horii, B., Orans, R., Woo, C.K., (1995) Area- and Time- Specific Marginal Cost and Targeted DSM Study, Report submitted to PSI Energy.*

7. *Horii, B., Orans, R., Woo, C.K., (1995) Local Integrated Resource Planning Study - White Rock, Report submitted to B.C. Hydro.*

8. *Horii, B., Orans, R., Woo, C.K., (1995) Area- and Time- Specific Marginal Cost Study, Report submitted to B.C. Hydro.*

9. *Orans, R., C.K. Woo and B. Horii (1995), Impact of Market Structure and Pricing Options on Customers' Bills, Report submitted to B.C. Hydro.*

10. *Horii, B., R. Orans (1995), System Incremental Cost Study 1994 Update (With Regional Results Appendix), Report submitted to B.C. Hydro.*

11. *Horii, B., Orans, R., Woo, C.K., (1994) Marginal Cost Disaggregation Study, Report submitted to PSI Energy.*

12. *Orans, R., C.K. Woo, J.N. Swisher, B. Wiersma and B. Horii (1992), Targeting DSM for Transmission and Distribution Benefits: A Case Study of PG&E's Delta District, Report No. TR-100487, Electric Power Research Institute.*

13. *Horii, B., (1991) Pacific Gas and Electric Company 1993 General Rate Case Application (eight exhibits within Phase I, and contributions to five exhibits within Phase II), A. 91-11-036, Submitted to the California Public Utilities Commission*

14. *Horii, B., (1991) Pacific Gas and Electric Company 1991 Electricity Cost Adjustment Clause Application (Revenue Allocation and Rate Design), Submitted to the California Public Utilities Commission*

Conference Papers

1. *Heffner, G., C.K. Woo, B. Horii and D. Lloyd-Zannetti (1998) "Variations in Area- and Time-Specific Marginal Capacity Costs of Electricity Distribution," IEEE Transactions on Power Systems, PE-493-PWRS-012-1997, 13:2, 560-567.*

2. *Horii, B., (1995), "Final Results for the NMPC Area Costing and Distributed Resource Study," Proceedings Distributed Resources 1995: EPRI's First Annual Distributed Resources Conference, Electric Research Power Institute, August 29-31, 1995, Kansas City, Missouri*

3. *Orans, R., C.K. Woo, B. Horii and R. Pupp, (1994), "Estimation and Applications of Area- and Time-Specific Marginal Capacity Costs," Proceedings: 1994 Innovative Electricity Pricing, (February 9-11, Tampa, Florida) Electric Research Power Institute, Report TR-103629, 306-315.*

4. *Heffner, G., R. Orans, C.K. Woo, B. Horii and R. Pupp (1993), "Estimating Area Load and DSM Impact by Customer Class and End-Use," Western Load Research Association Conference, September 22-24, San Diego, California; and Electric Power Research Institute CEED Conference, October 27-29, St. Louis, Missouri.*

Arne Olson

arne@ethree.com   415.391.5100 ext. 307

ENERGY & ENVIRONMENTAL ECONOMICS, INC. San Francisco, CA
Senior Consultant 2002 – Present

- Electricity Transmission: Represent BC Hydro in RTO West process in areas of congestion management, ancillary services, and transmission pricing. Currently assisting British Columbia Transmission Corporation with transmission tariff re-design.
- Electric Utility Rate Design: Worked with BC Hydro to develop a stepped rate design to facilitate retail access for large industrial customers.
- Energy Conservation: Developed model to estimate energy and demand savings from California energy efficiency standards for central air conditioners.

WASHINGTON OFFICE OF TRADE AND ECONOMIC DEVELOPMENT Olympia, WA
Senior Energy Policy Specialist 1996 – 2002

Develop and represent state policy interests, provide information and analysis to state agencies, legislators, the governor's office, the media, and others, in the following areas:

Electricity Transmission: Lead responsibility for developing and representing agency policy interests in a variety of regional forums, with a primary focus on pricing and congestion management issues.

RTO West, 2000-present: Regular participant in RTO West Congestion Management, Ancillary Services, and Transmission Planning work groups. Participate in numerous subgroups developing issues such as congestion zone definition, nature of long-term transmission rights, RTO role in transmission grid expansion, and others.

Western Market Interface Committee, 1999-present: Participant in Western Market Interface Committee and WMIC "Seams" task force.

Western Regional Transmission Association, 1996-present: Member, WRTA Board of Directors. Participated in WRTA Tariff, Access and Pricing Committee. Participated in sub-groups examining "seams" issues among multiple independent system operators in the West and developing a proposal for tradable firm transmission rights in the Western interconnection.

IndeGO, 1996-1998: Regular participant in pricing, congestion management and governance committees developing Northwest independent grid operator proposal (has since evolved into RTO West).

Comprehensive Review of the Northwest Energy System, and Comprehensive Review Transition Board, 1996-1997: Served as staff to four-state governor-appointed committee charged with developing vision for the future of the Bonneville Power Administration and the Northwest's electricity industry. Recommendations stemming from transmission work group included formation of a regional independent system operator and "FERC-equivalent" jurisdiction over BPA transmission.

Northwest Regional Transmission Association, 1996: Participated in NRTA Pricing Committee process to develop Northwest regional transmission tariff.

Wholesale Energy Markets: Monitor and analyze trends in electricity, natural gas and petroleum markets. Editor and principal author of Convergence: Natural Gas and Electricity in Washington, a survey of the Northwest's natural gas industry in the wake of the extreme price events of winter 2000-2001, and on the eve of a significant increase in demand due to gas-fired power plants. Authored legislative testimony on the ability of the Northwest's natural gas industry to meet the demand from new, gas-fired power plants.

Electricity Restructuring: Co-authored Washington Electricity System Study, legislatively-mandated study of Washington's electricity system in the context of ongoing trends and potential methods of electric industry restructuring. Authored legislative testimony on the impact of restructuring on retail electricity prices in Washington, electric industry restructuring and Washington's tax system, and the interactions between restructured electricity and natural gas markets.

Energy Data: Manage three-person energy data team that collects and maintains a repository of state energy data. Developed Washington's Energy Indicators, a series of policy benchmarks and key trends for Washington's energy system; second edition published in January 2001.

Energy Taxes: Lead responsibility for developing state energy policy in area of energy taxation. Co-authored Department of Revenue Study of Energy Taxation in 1999.

DECISION ANALYSIS COROPORATION OF VIRGINIA Vienna, VA
Associate 1993-1996

Joined firm as Research Associate and was promoted to Associate after six months.

Energy Modeling and Analysis: Developed energy demand forecasting models for Energy Information Administration's National Energy Modeling System. Results are published each year in EIA's Annual Energy Outlook.

Energy Research Program Evaluation: Developed system for evaluating the potential impact of Department of Energy conservation and renewable energy research programs.

Education

UNIVERSITY OF PENNSYLVANIA Philadelphia, PA

What goes here? Is this affiliated with the institut?

INSTITUT FRANCAIS DU PETROLE Paris, France
M.S. International Energy Management & Policy

Collaborative Master's program focusing on the international energy industry.

Relevant Coursework: Resource economics; petroleum economics; environmental economics; energy conservation and demand-side management; energy modeling and analysis; petroleum exploration, production, refining and distribution; finance; marketing.

Special Research Topics: Energy pricing in developing countries; the economics of wind electricity generation; energy planning in Nepal; petroleum taxation in the European Community.

UNIVERSITY OF WASHINGTON Seattle, WA
B.S. Mathematical Sciences, B.S Statistics

Citizenship

United States Citizen

Refereed Papers and Publications

1. *"Market Power Mitigation and Energy-Limited Resources," co-author.* The Electricity Journal, *March 2003.*
2. *"Stepped Rate Design Report," April 2003.*
3. *"Convergence: Natural Gas and Electricity in Washington", presented to the Puget Sound chapter of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Seattle, Washington, November 14, 2001*
4. *"Convergence: Natural Gas and Electricity in Washington", presented to the Western Interstate Energy Board, Seattle, Washington, October 30, 2001*
5. *"Transmission Planning Under Regional Transmission Organizations: Issues and Priorities for Environmentalists and Residential Electricity Consumers", presented at the annual membership meeting of the Northwest Energy Coalition, Seattle, Washington, October 5, 2001*
6. *"The Impact of the 2000-2001 Energy Crisis on Washington's Economy", presented to the Conference of Business Economists, Seattle, Washington, July 19, 2001*
7. *Convergence: Natural Gas and Electricity in Washington, editor and principal author. Washington Office of Trade and Economic Development, May 2001. http://www.energy.cted.wa.gov/Papers/Convergence.htm.*
8. *Questions and Answers Concerning Impact of Current Energy Situation on Washington State's Economy, contributing author. Washington Office of Trade and Economic Development and Washington Office of Financial Management, April 2001. http://www.energy.cted.wa.gov/Energy Q&A.pdf.*
9. *2001 Biennial Energy Report: Issues and Analyses for the Washington State Legislature, contributing author. Washington Office of Trade and Economic Development, February 2001. http://www.energy.cted.wa.gov/BR2001/default.htm.*
10. *CTED Comments on RTO West Stage I Filing, author. November 2000. http://www.energy.cted.wa.gov/letters/RT01_35_WA_OTED.pdf.*
11. *Study of Electricity Taxation, contributing author. Washington Department of Revenue, December 1999. http://www.energy.cted.wa.gov/papers/taxstudy.doc.*
12. *Washington Energy Indicators, author. Washington Department of Community, Trade and Economic Development, February, 1999. http://www.energy.cted.wa.gov/Indicators99/Contents.htm.*
13. *Washington State Electricity Study, contributing author. Washington Department of Community, Trade and Economic Development and Washington Utilities and Transportation Commission, January 1999. http://www.energy.cted.wa.gov/6560/finalapp.htm.*
14. *CTED Comments on FERC ISO Policy, author. July 1998. http://www.energy.cted.wa.gov/letters/FERC-ISO.html.*

15. *CTED Comments on the IndeGO Proposal for a Northwest Independent Grid Operator*, author. February 1998. http://www.energy.cted.wa.gov/LETTERS/980209.HTML.
16. *Our Energy Future: At a Crossroads. 1997 Biennial Energy Report*, contributing author. Washington Department of Community, Trade and Economic Development, January 1997. http://www.energy.cted.wa.gov/BIENREPO/CONTENTS.HTM.
17. *Washington State Energy Use Profile 1996*, contributing author. Washington State Energy Office, June, 1996. http://www.energy.cted.wa.gov/FILES/PRFL/BASE02.HTM.
18. *NEMS Transportation Sector Model: Freight Truck Stock Adjustment Model Update*, author. Decision Analysis Corporation of Virginia. Prepared for Energy Information Administration, November 1995.
19. *NEMS Transportation Sector Mass Transit Model: Proposed Model Structure, Results and Sensitivity Analysis*, author. Decision Analysis Corporation of Virginia. Prepared for Energy Information Administration, August 1995.
20. *NEMS Transportation Sector Model: Light Truck Use in Freight vs. Commercial Fleets*, author. Decision Analysis Corporation of Virginia. Prepared for Energy Information Administration, February 1995.
21. *Quality Metrics Navigation System: User's Guide*, author. Decision Analysis Corporation of Virginia. Prepared for Office of Energy Efficiency and Renewable Energy, Department of Energy, October 1994.
22. *Model Documentation Report: Transportation Sector Model of the National Energy Modeling System*, contributing author. Decision Analysis Corporation of Virginia. Prepared for Energy Information Administration, March 1994.

Carmen Baskette
carmen@ethree.com 415.391.5100 ext. 308

Ms. Baskette provides expertise on projects involving distributed generation resource planning and economic analysis of renewable generation technologies. She also supports several practice areas including, transmission planning, distribution rate design, and electricity market restructuring.

ENERGY & ENVIRONMENTAL ECONOMICS, INC.
San Francisco, CA

Senior Consultant — 2002 – Present

- Advising two major New York utilities throughout compliance with the New York State Public Service Commission distributed generation pilot program.
- Developing an economic and engineering methodology for four California municipal utilities to evaluate renewable distributed generation as a resource in their planning process.
- Investigating the effects of distributed energy resources on a real-world distribution system under San Francisco Distributed Energy Resources "Test-bed" project.
- Participating in a collaborative effort with the Energy Innovation Institute (E2I) to promote distributed generation market integration.
- Contributed to non-construction alternatives evaluation methodology for the Bonneville Power Administration. Methodology involved a detailed cost-benefit analysis used to evaluate overall cost-effectiveness of alternatives to building new transmission resources.

BUSINESS FOR SOCIAL RESPONSIBILITY
San Francisco, CA

Independent Contractor — 2001

- Provided business research and analysis for a range of client projects.
- Wrote and edited project deliverables for both multinational and U.S. clients.

FORD MOTOR COMPANY
Cologne, Germany

Global Corporate Strategy Intern — Summer 2000

- Member of international team established to develop Ford's worldwide corporate citizenship strategy.
- Assessed emerging issues in corporate citizenship while identifying internal and external stakeholder expectations for Ford of Europe.
- Conducted benchmark study of leading corporate citizens throughout Europe.
- Presented global findings to Ford CEO, Chairman, President's Strategy Council, and Ford of Europe Management.

ARCO ALASKA, INC.
Anchorage, AK

Financial Analyst Intern — Summer 1999

- Analyzed risk in $175 MM annual capital budget for Alaskan North Slope oil field.
- Developed interactive financial model for capital budget development process to mitigate effects of risk.
- Evaluated bias and uncertainty in oil price forecasting for long-range planning strategies.
- Investigated escalating drilling program costs relative to oil field development costs time.

MAXYMILLIAN TECHNOLOGIES, INC. Boston, MA
Business Development Associate 1996-1998

- Led cross-functional teams through the procurement process for $15M - $100M environmental remediation projects.
- Designed and implemented company marketing strategy.
- Served as public relations contact for clients and industry regulators.
- Co-authored "Maxymillian Technologies' Indirect Thermal Desorption System: "A Technology Overview."

Education

UNIVERSITY OF MICHIGAN Ann Arbor, MI
MBA, M.S. Natural Resource Policy

- Concentration in Corporate Strategy and Finance
- Corporate Environmental Management Program (CEMP)
- Masters Thesis: *An economic and policy analysis of opportunities for distributed power generation technologies within state deregulation models*
- Graduate Student Instructor for "Environmental Decision-Making in Business"
- Finance Chair for Net Impact National Conference and Executive Board Member
- Led MTrek backpacking trip for incoming business school students

WESLEYAN UNIVERSITY Middletown, CT
B.A. Geology, Environmental Science

- Recipient of Pew and Wesleyan Dana Grant funding for research at the American Geological Institute in Washington, DC

Citizenship

United States Citizen

Publications

1. *Woo, C.K., D. Lloyd, M. Borden, R. Warrington and C. Baskette (2004) "A Robust Internet-Based Auction to Procure Electricity Forwards," Energy - The International Journal, 29:1, 1-11.*

2. *D. Lloyd, Woo, C.K., M. Borden, R. Warrington and C. Baskette (2004) "Competitive Procurement and Internet-based Auction: Electricity Capacity Auction" The Electricity Journal, forthcoming.*

Michael King

mikeking@ethree.com 415.391.5100 ext. 302

Energy Industry Experience

ENERGY & ENVIRONMENTAL ECONOMICS, INC. San Francisco, CA
Senior Consultant 2003 – Present

Conduct analyses for energy industry clients. Project work includes:

- Avoided cost estimation for the California PUC for use in evaluating DSM programs
- Litigation support and damages estimate for a large industrial customer related to breach of contract by an unregulated Energy Services Provider
- Cost-benefit analysis of renewable distributed generation for municipal utilities in California

PG&E ENERGY SERVICES San Francisco, CA
Product Development Specialist, Analyst 1997-1999

- Developed pricing model for multi-million dollar projects and coordinated with CFO, Sales, and technical staff to evaluate profitability of proposed projects
- Managed all aspects of development of a mid-market power reliability product, including negotiating terms with supply partners, managing sub-contractors, developing marketing collateral, and providing Sales training
- Led projects to establish framework for product development. Produced development process guidelines and provided coaching to product development managers. Created a database and cost accounting format to track product development efforts and the success of new products
- Facilitated senior management evaluation of new product ideas by creating a standard financial pro forma for analysis and working with product managers on business case assumptions

BARAKAT & CHAMBERLIN, INC. Oakland, CA; Washington D.C.
Associate 1993-1997

Completed consulting assignments for Fortune 500 electric utilities and other clients. Project work centered on market research and economic and statistical analyses. Project work included:

- Ongoing market research for an entrant into the deregulating electricity market
- Design and evaluation of Demand-Side Management programs for major electric utilities
- A multi-client study evaluating energy conservation programs. Conducted research, built and maintained database, conducted analyses.
- Completed all work within budget and met or exceeded client expectations.

Telecommunications Experience

VIRGIN MOBILE USA San Francisco, CA
Product and Project Manager 2001 – 2003

- Managed a suite of applications designed to bring entertainment value to the mobile phone. Set product strategy, defined business requirements, managed business partners, and worked cross-functionally to create and launch new applications.

- Managed employees and external parties to successfully complete projects critical to launch of Virgin's wireless service. Projects include development of innovative packaging for launch and development of sales brochures and other customer-facing materials.

GEOWORKS Alameda, CA
Product Marketing Manager 2000 – 2001

Performed management functions for wireless data communication products and services.

- Headed cross-functional team to create a functional specification for a global message dispatching system
- Conducted annual business planning process for Professional Services organization and presented scenario analysis to Executive staff
- Created standardized pricing, thereby allowing quicker response to customer opportunities, and provided customized pricing with summary format that expedited Executive review
- Worked with Engineering to develop cost model that increased understanding of service costs

VODAFONE AIRTOUCH Walnut Creek, CA
Project Manager 1999-2000

- Led implementation of Product Development database thereby increasing ease of tracking and communicating product status throughout the organization. Trained product managers on database use
- Conducted ongoing financial reporting for all products and distributed to Marketing and other organizations to track company performance
- Provided business case analysis to product managers to evaluate product opportunities
- Benchmarked best practices and documented process for development of new products
- Conducted financial analysis for evaluation of national retail distribution channel resulting in improved guidance for contract negotiations
- Led project to improve reporting on performance of national retail stores

Education

UNIVERSITY OF TEXAS AT AUSTIN, LBJ School of Public Affairs Austin, TX
M.P.Aff.

- Awarded Lyndon Johnson Congressional Fellowship – awarded to one student annually on a competitive basis.
- Conducted research for the U.S. Senate Committee on Agriculture, Nutrition, and Forestry
- Teaching assistant for graduate level operations research and econometrics classes
- Associate editor, LBJ Journal

UNIVERSITY OF CALIFORNIA Irvine, CA
B.A. English, B.A., Social Ecology

- One year of study in Italy

Energy and Environmental Economics, Inc. Corporate Qualifications

Introduction

Energy and Environmental Economics, Inc. (E3) is a San Francisco-based economics and engineering consulting firm specializing in strategic planning for public and private electric utilities and their customers. Founded in 1993, E3 is built upon the partners' extensive experience in resource planning, avoided cost quantification, load research and estimation, distributed generation analysis, electricity pricing, rate design, procurement cost and risk management, and financial evaluation. E3 complements its comprehensive knowledge of the industry's business practices with state-of-the-art analysis techniques, as demonstrated by its software development and extensive publications in scholarly journals in the fields of engineering, economics, and finance.

E3 is a well-established firm with dozens of major public and private utility clients throughout the United States and Canada, including PG&E, and additional clients in Central and South America, Europe, Asia, Africa and the Middle East. Non-utility clients include Golden Gate National Park Association (GGNPA), City of San Francisco, National Renewable Energy Laboratory (NREL), EPRI, DOE, USAID, World Bank, Energy Foundation, the Utility Photovoltaic Group (UPVG), municipal utilities, and a host of commercial energy customers.

The following summarizes E3's key project experience in core areas of our analysis. Important findings from these projects appear in scholarly journals and research reports and have been formally filed in regulatory proceedings in several jurisdictions in the U.S. and Canada.
Over the past decade, E3 has led numerous local integrated resource planning (LIRP) studies that identify and evaluate cost-effective applications of distributed resources (DR) such as small scale distributed generation (DG) and demand-side management (DSM) technologies on T&D systems. The cost-effectiveness tests compare the area- and time-specific benefits (i.e., avoided costs) and the cost of DR implementation.

Resource Planning and Avoided Cost Estimation

In quantifying avoided costs, E3 suitably includes various adders to capture factors not embodied in the market price (or marginal cost) of energy. Such factors include environmental externality, T&D capacity and line loss, marginal cost of ancillary services, and the price effect of demand reduction on energy consumers.

E3 has also developed several planning software products to help utility planners compare the profitability and risk of alternative plans, and has formed a cooperative alliance with Electrotek Concepts, Inc. to further the development and application of T&D system planning tools. These analytical tools have been jointly developed, documented and tested by E3, EPRI, and numerous utilities:

- The Area Investment Model (AIM) evaluates the profitability and risk associated with alternative T&D plans under uncertain load growth.

- ➢ The Engineering Design and Costing Model (EDC) constructs, performs technical analyses, and determines least-cost expansion plans combining traditional T&D investments with distributed generation alternatives, including renewables.
- ➢ The Delta model dynamically integrates DR technologies and DSM into existing plans using local area and time specific marginal costing methodology.
- ➢ The Remote Power Systems Applications Model (RPAM) helps utility distribution planners and engineers compare the economics of remote renewable hybrid power systems with those of conventional line extensions.

Examples of E3 past and on-going assignments in resource planning and avoided cost estimation are given below:

- **California Energy Commission:** (1999-2003). E3 worked with the California Energy Commission on changing the economic basis for the California Title 24 Building Energy Standards. Current standards are based on constant source energy credits that do not vary by time and area. Therefore, under the current standard energy conservation is valued equally at all times of the day and night, and in all areas of California. The study investigated a shift to a dollar-based standard which accounts for the time and geographic differences in energy costs seen in California energy prices, natural gas and propane markets, as well as in the costs of electric utility distribution and transmission systems. The new standards will be in place in 2005.
- **PG&E:** (2001). E3 was retained by PG&E to quantify the peak benefit multiplier effect of a demand reduction attributable to energy-efficiency programs. The multiplier effect occurs because the price decline caused by a reduced demand applies to all MWh (therms) transacted in the market, thus benefiting not just program participants but **all** electricity (gas) consumers. E3 modeled the econometric relationship between market price and sales, the basis for computing the escalators defined by Administrative Law Judge's 10/25/2000 ruling on *Applications 99-09-049, 99-09-050, 99-09-057 and 99-09-058*: "[t]he escalators are determined by looking at the "load reduction value" or "consumer surplus" relative to the market price and taking a ratio. The escalators are multiplied by the market price – either during peak or off-peak – to arrive at system value." (p.13). E3 presented the findings of this research in a CALMAC meeting to the staff of PG&E, SCE, SDG&E, and the CPUC.
- **PG&E**: (2000). E3 was retained by PG&E to develop: (a) a new methodology for cost-effectiveness evaluation to reflect the deregulated market environment; (b) peak benefit evaluation to account for time-varying energy market prices and marginal T&D costs; and (c) screening methodology for customer energy management programs.
- **The Energy Foundation**: 2000. E3 worked with Pacific Energy Associates of Portland, Oregon to assemble a summary of common and best practices for costing methodology for electric distribution system planning. The final report was presented to the annual meeting of the National Association of Regulatory Utility Commissioners (NARUC) Committee on Energy and Resources and the Environment on November 12, 2000.
- **EPRI:** 1997-1998. E3 was a subcontractor for an EPRI project on Power Quality Planning. E3 developed insurance-based pricing mechanisms for premium power quality services that

incorporate an understanding of customer outage costs, targeted technological solutions, and financial incentives for the customer and utility.

- **TVA:** 1995-1996. E3 was the prime contractor in an EPRI-TVA project to study the feasibility of distributed generation resources, including renewables, as an alternative to transmission and distribution expansion plans for the Tennessee Valley Authority, Nashville Electric Service, and Memphis Light, Gas & Water.
- **Centerior:** 1996. E3 was retained by Centerior to perform an independent review of their proposed transmission expansion. The report showed that the cost of lower reliability imposed on customers from delaying the project far outweighed any benefits of targeted DR for the area. E3 has performed similar reviews for Commonwealth Edison and New York Service Electric and Gas.
- **EPRI**: 1992-1998. E3 has been EPRI's primary contractor for integrated resource planning. E3 developed many of the EPRI planning and marginal costing methodologies field tested in numerous case studies. These case studies demonstrate that strategically placing DR on a utility's grid can be much more cost-effective and profitable than a system-wide implementation.
- **EPRI:** 1996. E3 customized its integrated planning models for Niagara Mohawk to allow NIMO to evaluate the cost effectiveness of Photovoltaic Grid Connected applications across all of NIMO's service areas. At the time, NIMO was actively promoting PV applications, and E3's model allowed NIMO to prioritize PV installation according to the variations in local weather patterns and transmission and distribution avoided costs.
- **EPRI/PG&E:** 1994-1996. E3 prepared the 1996 report *Distributed Utility Penetration Study*, Report No. TR-106265, Electric Power Research Institute. This report addressed the question of whether distribution load-growth related investment expenditures can be reduced or deferred by clipping peak loads in distribution planning areas. The objective was to estimate the achievable savings from targeting DSM, direct load control programs, and distributed generation to these capacity constrained distribution planning areas.
- **EPRI/NREL/PG&E:** 1993. E3 was a major contributor to the1993 report *Distributed Utility Valuation Project*, EPRI Report No. TR-102807. The purpose of the report was to describe the Distributed Utility concept and discuss the relevant research on the subject.
- **Ontario Hydro (Canada):** 1995. Ontario Hydro hired E3 to extend the local integrated resource planning framework and models to investigate various alternatives for meeting expected load growth in the City of Toronto. The results of the study showed the applicability of the local integrated resource planning framework to larger generation facilities (100MW) and demonstrated its value to bulk system planning.

The following publications provide a reference for this body of work:

Heffner, G., C.K. Woo, B. Horii and D. Lloyd-Zannetti (1998) "Variations in Area- and Time-Specific Marginal Capacity Costs of Electricity Distribution," IEEE Transactions on Power Systems, PE-493-PWRS-012-1997, 13:2, 560-567.

Ball, G., D.L. Zannetti, B. Horii, D. Birch, R. Ricks, and H Lively (1997) "Integrated Local T&D Planning Using Customer Outage Costs," Special Issue on Distributed Resources, Energy Journal, 137-160.

Forte, V.J., R. Pupp, R. Putnam and C.K. Woo (1995) "Using Customer Outage Costs in Electricity Reliability Planning," Energy - The International Journal, 20:2, 81-87.

Woo, C.K., D. Lloyd-Zannetti, R. Orans, B. Horii and G. Heffner (1995) "Marginal Capacity Costs of Electricity Distribution and Demand for Distributed Generation," Energy Journal, 16:2, 111-130.

Woo, C.K., R. Orans, B. Horii, R. Pupp and G. Heffner (1994) "Area- and Time-Specific Marginal Capacity Costs of Electricity Distribution," Energy - The International Journal, 19:12, 1213-1218.

Orans, R., C.K. Woo and B. Horii (1994) "Targeting Demand Side Management for Electricity Transmission and Distribution Benefits," Managerial and Decision Economics, 15, 169-175.

Orans, R., C.K. Woo and R.L. Pupp (1994) "Demand Side Management and Electric Power Exchange," Energy - The International Journal, 19:1, 63-66.

Keane, D.M. and C.K. Woo (1992) "Using Customer Outage Costs to Plan Generation Reliability," Energy - The International Journal, 17:9, 823-827.

RENEWABLE AND DISTRIBUTED GENERATION RESOURCES

- **California Energy Commission, Public Interest Energy Research Program:** (2001 – Present). E3, in conjunction with Electrotek Concepts, is completing a project to develop a methodology to assess renewable distributed generation (DG) for four California municipal utilities. The approach involves a combined economic and engineering analysis to determine where renewable DG has the most value on the electric grid.
- **California Energy Commission:** (2003 – Present). E3 is working with M-Cubed and Electrotek Concepts to monitor distributed energy resources (DER) to evaluate the actual impact of these resources on the San Francisco distribution system. This project was designed to provide a fair assessment of operation of DER on a local distribution system.
- **EPRI:** (2004 – Present). E3 is working with EPRI to develop a technical update of the costs and benefits of distributed energy resources (DER) from both the utility and customer perspectives. The goal of this technical update is to provide an objective quantitative analysis of the current costs and benefits of DER, and thereby identify the factors that have the greatest impact on DER's cost-effectiveness.
- **Energy Innovation Institute (E2I):** (2003 – Present). E3 is providing analytical support in collaborative effort spearheaded by E2I to reduce the barriers to more widespread deployment of distributed energy resources (DER). The goal is to develop new regulatory and business models and assessing environmental impacts through a collaboration of utilities, DER vendors and service providers, and public agencies. E3 is also participating in the Southern California Edison (SCE)

pilot program for procuring distributed generation under this E2I public/private collaborative partnership.

- **Bonneville Power Administration:** (2001- 2004). E3 assisted BPA in developing an internal planning process to effectively evaluate non-construction alternatives to upcoming transmission projects. This project has included an assessment of the current BPA planning process, delivered spreadsheet tools to facilitate economic screening, and trained BPA staff to perform the analysis. For each screening study, the cost-effectiveness of a broad range of options including numerous Demand-side Management (DSM) measures, Demand Response program designs, and Distributed Generation (DG) technologies is evaluated.
- **PG&E**: (2000). E3 was retained by PG&E to develop: (a) a new methodology for cost-effectiveness evaluation to reflect the deregulated market environment; (b) peak benefit evaluation to account for time-varying energy market prices and marginal T&D costs; and (c) screening methodology for customer energy management programs.
- **PG&E:** (1999-Present). E3 was retained by PG&E to perform several major studies evaluating the technical requirements and economic viability of using distributed resources (DR) to mitigate the need for contentious transmission expansion projects.
- **Puget Sound Energy (PSE):** (1999-2002). E3 has assisted PSE with the development and implementation of an integrated gas and electric planning process that best satisfies customer expectations, system reliability needs, and corporate financial strategies. The new planning process incorporates a multi-tiered set of screens for potential capital and O&M projects to more efficiently direct scarce planning resources toward areas with high potential for cost-saving expansion alternatives. E3 is also helping PSE refine their local-area load forecasting methodology and implement a probabilistic risk-based approach to their capacity planning procedures.
- **Orange and Rockland Utilities (ORU):** (1998-Present). E3 is under contract with ORU to evaluate numerous T&D expansion plans and to provide due diligence analyses of DR-based alternatives. E3 helped ORU develop a multi-stage screening process that efficiently identifies areas with high economic and technical potential for DR solutions so that limited planning resources can be used most effectively.
- **Consolidated Edison Company of New York (CECONY):** (1999-Present). E3 is working with CECONY to evaluate and provide due diligence analysis of distributed generation and energy efficiency alternatives to T&D expansion plans in the Manhattan area. The analysis extends the DR and DSM screening process to incorporate service reliability considerations for electricity delivery planning.
- **Golden Gate National Parks Association (GGNPA)**: 1999-2001. E3 has worked closely with the GGNPA in cooperation with the National Park Service to clearly define technology alternatives for potential onsite sustainability demonstration projects and interpretive programs as well as potential funding sources for leveraging Fort Baker resources for both its upper management and for potential developers.
- **Oklahoma Municipal Power Authority (OMPA)**: 2000. E3, in collaboration with Gridwise Engineering and Endecon Engineering, recently completed a distributed generation engineering study for the OMPA on behalf of its over 30 member municipal utilities. The technology

assessment portion of the study addressed (1) conventional DG technologies (diesel and spark ignition engines, mini and micro turbines), (2) renewable and advanced generation (photovoltaics, solar thermal electric, wind, battery energy storage and fuel cells), and (3) implementation issues. DG results included generator efficiency and performance characteristics (heat rates, unforced outage rates, size ranges, start-up time, reject heat temperatures, fuel requirements, maintenance and overhaul schedules, emissions characteristics, and interconnection requirements), and costs (capital, installation, operation, and permitting). Renewable energy generation performance and costs were modeled for several sites within the OMPA service area. Several key pragmatic distributed generation implementation issues were reviewed, including evaluation of OMPA's current capacity purchase contract for use with DG, related rate and tariff issues, interconnection requirements and issues, along with methods for selecting sites for DG.

- **Utility Photovoltaic Group (UPVG):** 1998. E3 was retained by the UPVG to update a working computer database of grid-connected and representative off-grid PV systems in the United States. An E3 staff member developed the original database in 1994. The database contains extensive information on the statistics, costs, performance, motivations, applications, and operating experiences of the PV systems. A significant portion of the updated database concentrates on UPVG Team-Up and SMUD installations in California.
- **Hawaiian Electric Company (HECO)** (2001-Present). E3 has developed a financial pro-forma tool for distributed generation applications from a utility perspective. The analysis incorporates a comprehensive view of project economics including a utility perspective that includes avoided energy purchases, and deferral of T&D capital projects, as well as societal and DG owner perspectives. The tool is designed to facilitate decision-making and provide analysts the necessary information to explain power project development decisions.
- **Golden Gate National Parks Association (GGNPA)**: 1999-2001. E3 has worked closely with the GGNPA/NPS project team to develop an overall energy systems plan in light of the sustainability objectives and tight budget. Key strategic issues include developing sustainability standards for potential developers, evaluating opportunities for green power procurements in the context of federal procurement regulations, evaluation of overall energy management system alternatives, describing technology alternatives for potential onsite sustainability demonstration projects and interpretive programs, identifying potential funding sources for leveraging Fort Baker resources, and evaluating alternative business arrangements and operating strategies for upgrading, operating and maintaining the energy distribution and delivery systems.

Energy Technology Assessment

E3 and its staff have been estimating avoided costs for use in numerous specific and broad technology assessment projects for NREL, EPRI, DOE, the Utility Photovoltaic Group (UPVG), utilities, and state and government agencies, among others. E3's avoided cost methodology is the foundation for computing cost effectiveness of alternative to centralized supply options such as large generation units and T&D facilities. E3 has performed technology assessments of currently available renewable and conventional technologies that can be used in distributed applications. In addition to the projects listed here that explicitly focus on technology assessment, E3's numerous LIRP studies performed since the formation of the company have required the staff to continually monitor existing and new technology cost, operation, and dispatch characteristics.

- **Golden Gate National Parks Association (GGNPA)**: 1999-2001. E3 has worked closely with the GGNPA in cooperation with the National Park Service to clearly define technology alternatives for potential onsite sustainability demonstration projects and interpretive programs as well as potential funding sources for leveraging Fort Baker resources for both its upper management and for potential developers.
- **Oklahoma Municipal Power Authority (OMPA)**: 2000. E3, in collaboration with Gridwise Engineering and Endecon Engineering, recently completed a distributed generation engineering study for the OMPA on behalf of its over 30 member municipal utilities. The technology assessment portion of the study addressed (1) conventional DG technologies (diesel and spark ignition engines, mini and micro turbines), (2) renewable and advanced generation (photovoltaics, solar thermal electric, wind, battery energy storage and fuel cells), and (3) implementation issues. DG results included generator efficiency and performance characteristics (heat rates, unforced outage rates, size ranges, start-up time, reject heat temperatures, fuel requirements, maintenance and overhaul schedules, emissions characteristics, and interconnection requirements), and costs (capital, installation, operation, and permitting). Renewable energy generation performance and costs were modeled for several sites within the OMPA service area. Several key pragmatic distributed generation implementation issues were reviewed, including evaluation of OMPA's current capacity purchase contract for use with DG, related rate and tariff issues, interconnection requirements and issues, along with methods for selecting sites for DG.
- **Pacific Gas and Electric Company (PG&E):** 1997-1998. PG&E retained E3 to conduct evaluations of all emerging distributed generation technologies and assess their economic and technical viability in the California market during and after the competitive transition charge (CTC) transition period. E3 evaluated generation from the "customer-side" perspective, covering such issues as the impact of the rate form for utility stand-by charges, customer access to natural gas at wholesale or retail rates, and the rate structure's impact on customer incentives to bypass the T&D system.
- **Utility Photovoltaic Group (UPVG):** 1998. E3 was retained by the UPVG to update a working computer database of grid-connected and representative off-grid PV systems in the United States. An E3 staff member developed the original database in 1994. The database contains extensive information on the statistics, costs, performance, motivations, applications, and operating experiences of the PV systems. A significant portion of the updated database concentrates on UPVG Team-Up and SMUD installations in California.
- **PG&E System Testing:** 1996-1997. E3 consulted to PG&E's Research and Development Department on several advanced power conversion and storage technologies. The work included serving on technological review groups, developing extensive test plans, and supervising the testing of the technologies. These technologies included: PQ-2000, a 2 MW, 10-second uninterruptible power supply designed for customer and utility applications; PM-250, a battery storage system designed for load peak-shaving and for hybrid operation with photovoltaics; Wavedriver, a power converter technology designed for cross-application modularity, with potential uses for wind, PV,

fuel cell, and battery systems; ASC, a cryogenically cooled power converter technology designed to provide high power conversion in a small volume package.

- **EPRI:** 1997. This project focused on the research analysis and design of alternative energy technology options for office buildings. Reference publication: *Office Complex Guidebook: Innovative Electric Equipment and Solutions*, by J. Swisher, Electric Power Research Inst., EPRI TR-109450, December 1997.
- **EPRI:** 1996. In a related project, this study focused on the design of alternative energy technology options for schools and universities. Reference publication: *Educational Facilities Guidebook: Innovative Electric Solutions*, by J. Swisher, Electric Power Research Inst., EPRI TR-107123, December 1996.

MEASUREMENT AND EVALUATION

In the last 10 years, Energy and Environmental Economics, Inc. has performed demand estimation, as well as load research analysis to determine the impact of DSM and TOU rate structures. For example, in 1999 E3 performed detailed statistical load analysis on the load impact of a voluntary Time-Of-Use rate pilot for 650 customers in Laredo, Texas. The pilot involved the installation of 350 'Smart' meters that could receive dispatch signals from the utility, and could be programmed to control appliances based on energy price. The study measured the demand response to the program and customer bill savings, after controlling for weather, home size, time-of-day, and seasonal factors. The following publications provide a reference for this body of work.

Hartway, R., S. Price and C.K. Woo (1999) "Smart Meters, Customer Choice and Profitable Time of Use Rate Option," Energy - The International Journal, 24, 895-903.

Pupp, R., C.K.Woo, R. Orans, B. Horii and G. Heffner (1995) "Load Research and Integrated Local T&D Planning," Energy - The International Journal, 20:2, 89-94.

Orans, R., C.K. Woo, J.N. Swisher, B. Wiersma and B. Horii (1992) Targeting DSM for Transmission and Distribution Benefits: A Case Study of PG&E's Delta District, Report No. TR-100487, Electric Power Research Institute.

Heffner, G., R. Orans, C.K. Woo, B. Horii and R. Pupp (1993) "Estimating Area Load and DSM Impact by Customer Class and End-Use," Western Load Research Association Conference, September 22-24, San Diego, California; and Electric Power Research Institute CEED Conference, October 27-29, St. Louis, Missouri.

Woo, C.K., B.M. Gray and M.E. Carl (1987) "Residential Air Conditioning Load Model," 8th International Association of Energy Economists (IAEE) Conference, MIT.

Woo, C.K., P. Hanser and N. Toyama (1986) "Estimating Hourly Electric Load with Generalized Least Squares Procedures," Energy Journal, 7:2, 153-170.

Woo, C.K. (1985) "Demand for Electricity of Small Nonresidential Customers under Time-of-Use Pricing," Energy Journal, 6:4, 115-127.

Woo, C.K. (1984) "A Note on Measuring Household Welfare Effects of Time-of-Use Pricing," Energy Journal, 5:3, 171-181.

REGULATORY ANALYSIS AND REQUIREMENTS

E3 provides expert opinions on pricing, regulation, marginal costing, resource planning and asset evaluation for electric utilities. E3 professionals have testified before public utilities commissions in the U.S. and Canada on such matters as market restructuring, asset evaluation, rate design, wheeling, marginal costing, and resource planning. E3's recent engagements entail analyzing the potential effects of market restructuring on customer bills and utility stranded costs; the company is directly involved in the ongoing market restructuring analyses in California, Ontario and British Columbia in Canada, Israel, and Hong Kong.

<u>Regulatory Analysis and Requirements</u>

Ren Orans, C.K. Woo and Brian Horii lead E3's litigation and regulatory support practice. With over 60 years of combined experience in the electric industry, we are recognized experts in the specific regulatory issues and applied economic solutions of concern to our clients. We have testified in numerous regulatory proceedings in California, Texas, British Columbia, Ontario and Quebec and have maintained ongoing client relationships with utilities in North America, Hong Kong and Israel.

Retained by the counsel or senior management of our clients, we offer expert opinions on industry issues such as general rate case proceedings, market reform strategies, stranded cost recovery, transmission access and pricing, regional transmission organization development, resource planning, cost allocation and recovery, rate design, and performance-based-regulation. We form our opinions based on sound economic and financial reasoning, supported by well-documented empirical evidence. These opinions are articulated through confidential reports to our clients, testimony submitted to regulators, and articles in scholarly journals.

Since 1994 E3 has been advising a number of electric utilities in their general rate case filings. We actively participate in the development of regulatory strategy, preparation of direct testimony, review of submissions by intervenors, training of witnesses, cross-examination of intervening parties, preparation of rebuttal testimonies and closing arguments. Examples of E3's regulatory work are given below.

<u>Electricity Market Reform</u>

- **Southern California Water Company (SCWC).** SCWC retained E3 in 2001 to rebut the large disallowance of power purchase cost recommended by the Office of Ratepayers Advocate (ORA) of the CPUC and a large user served by SCWC's subsidiary, Bear Valley Electric Service. The rebuttal testimony affirms that SCWC was prudent in signing a $95/MWH fixed price 5-year contract in March 2001, at the height of the California energy crisis. The testimony resulted in a favorable settlement for SCWC.

- **Ontario Hydro**. In 1997, Ontario Hydro (OH) retained E3 to develop its regulatory and business strategies in view of the market reform initiative in the Ontario Government's 1997 White Paper. During 1997-1998, we worked with Ontario Power Generation (OPG), the successor of Ontario Hydro's generation business, on strategic issues related to transmission pricing and access, market power mitigation and congestion management. Our advice helped OPG to develop and present its positions in the Ontario Market Design Committee.
- **Upper Canada Energy Alliance**. The Ontario Energy Board (OEB) in 1999 proposed price cap regulation for the municipal utilities that are resellers owned by city governments. E3 was the chief witness for the Upper Canada Energy Alliance of 10 large municipal utilities, and successfully defended the Alliance's positions before the OEB.
- **British Columbia (BC) Hydro**. During 1994-96, E3 assisted BC Hydro in responding to the provincial government's electricity market structure review (EMSR). Industrial customers, potential market entrants, and a commissioner of the BC Utilities Commission (BCUC) were pushing for a UK-style market reform that would establish a power pool and divest BC Hydro's vast hydroelectric assets. E3 affirmed that consumers could reap the benefits of wholesale competition via a regulatory reform that did not require market restructuring. The BCUC adopted E3's proposal and rejected market reform.
- **Israel Electric Corporation (IEC)**. Since the mid-1990s, the Israeli Government has been pushing market reform with the goal of privatizing IEC, the nationally-owned electricity monopoly. E3 is IEC's principle advisor in regulatory strategy. E3 has analyzed the effects of market reform on IEC, electricity consumers and Israel's economy. E3's research to date has discouraged the Israeli Government from adopting a market reform.
- **Hawaiian Electric Company (HECO)**. Since 1997, E3 has been HECO's advisor on regulatory and business strategies. Our advice spans asset valuation, merger, divestiture, customer bypass, distributed resources, rate design, metering and billing, and response to marker reform initiatives.

The following publications provide a reference for this body of work:

Woo, C.K., D. Lloyd, R. Karimov and A. Tishler (2003) "Stranded Cost Recovery in Electricity Market Reforms in the US," Energy - The International Journal, 28:1, 1-14.

Woo, C.K., D. Lloyd and A. Tishler (2003) "Electricity Market Reform Failures: UK, Norway, Alberta and California," Energy Policy, 31:11, 1103-1115.

Tishler, A., C.K. Woo and D. Lloyd (2002) "Reforming Israel's Electric Sector," Energy Policy, 30:4, 347-353.

Woo, C.K. (2001) "What Went Wrong in California's Electricity Market?" Energy - The International Journal, 26:8, 747-758.

Woo, C.K., D. Lloyd-Zannetti and I. Horowitz (1997) "Electricity Market Integration in the Pacific Northwest," Energy Journal, 18:3, 75-101.

Rate Design Opinions

- **Pacific Gas and Electric Company (PG&E).** E3 advised PG&E in 1994 on the use of emission adders in marginal costing and rate design. Based on our advice, PG&E successfully argued before the California Public Utilities Commission (CPUC) that misguided application of emission cost adders could cause uneconomic bypass and defeat the purpose of environmental protection. The economic reasoning is summarized in *Woo, C.K., B. Hobbs, R. Orans, R. Pupp and B. Horii (1994) "Emission Costs, Customer Bypass and Efficient Pricing of Electricity," Energy Journal, 15:3, 43-54.*
- **Pacific Gas and Electric Company (PG&E).** E3 testified in 1996 before the CPUC on the misuse of customer-class specific outage costs in developing customer-class specific marginal cost. Our testimony convinced the CPUC to reject the misuse. The testimony was based on *Woo, C.K. (1988) "Optimal Electricity Rates and Consumption Externality," Resources and Energy, 10, 277-292.*
- **Ontario Hydro.** E3 advised Ontario Hydro (OH) during 1994-1996 on how to price its service options, including real time pricing, interruptible and curtailable services, off-peak incremental sales, and economic development rate. These options were designed to provide customer choices and access to wholesale market prices without changing the extant regulatory regime. By taking advantage of the divergence between the regulated tariffs and the wholesale prices, the options were always profitable to OH. E3 then helped OH to prepare submissions filed with the Ontario Energy Board.
- **British Columbia (BC) Hydro.** In 1996, E3 was the witness for BC Hydro on industrial service options before the BC Utilities Commission (BCUC). Such options include real time pricing, curtailable service, and time-of-use service. The BCUC adopted E3's proposal whose economic reasoning is based on (a) *Woo, C.K., P. Chow and I. Horowitz (1996) "Optional Real-Time Pricing of Electricity for Industrial Firms," Pacific Economic Review, 1:1, 79-92;* (b) *Woo, C.K., R. Orans, B. Horii and P. Chow (1995) "Pareto-Superior Time-of-Use Rate Option for Industrial Firms," Economics Letters, 49, 267-272;* and (c) *Woo, C.K. (1990) "Efficient Electricity Pricing with Self-Rationing," Journal of Regulatory Economics, 2:1, 69-81.*
- **Israel Electric Corporation (IEC).** The IEC retained E3 in 2000 to analyze the economic efficiency and revenue collection of its industrial time-of-use (TOU) tariff. Our research shows that IEC's industrial TOU rates should be replaced by a Hopkinson tariff with demand charges that apply to a large firm's subscribed demand for generation capacity and connected load for transmission and distribution capacities. The IEC adopted E3's recommendation, which is documented in *Woo, C. K., B. Horii and I. Horowitz (2002) "The Hopkinson Tariff Alternative to TOU Rates in the Israel Electric Corporation," Managerial and Decision Economics, 23:9-19.*

The following publications provide further reference for this body of work:

Seeto, D. Q., C.K. Woo and I. Horowitz (2001) "Finessing the Unintended Outcomes of Price-Cap Adjustments: An Electric Utility Multi-Product Perspective," Energy Policy, 29:13, 1111-1118.

Woo, C. K., I. Horowitz and J. Martin (1998) "Reliability Differentiation of Electricity Transmission," Journal of Regulatory Economics, 13:277-292.

Seeto, D.Q., C. K. Woo and I. Horowitz (1997) "Time-of-Use Rates vs. Hopkinson Tariffs Redux: An Analysis of the Choice of Rate Structures in a Regulated Electricity Distribution Company, " Energy Economics, 19, 169-185.

Horowitz, I., D.Q. Seeto and C.K. Woo (1996) "Ramsey Pricing of Electricity under Unknown Bypass Costs," Energy Journal, 17:2, 59-77.

Orans, R., C.K. Woo, R. Pupp and I. Horowitz (1994) "Demand Side Management and Electric Power Exchange," Resource and Energy Economics, 16, 243-254.

Woo, C.K. (1991) "Capacity Rationing and Fixed Cost Collection," Energy Journal, 12:2, 153-164.

<u>Stranded Cost Opinions</u>

- **Israel Electric Corporation (IEC).** Anticipating a market reform, IEC retained in 2001 E3 to analyze the stranded cost recovery mechanisms used in the US and assess the financial performance of an incumbent utility under alternative mechanisms. The key finding was that a California-style "head-room" mechanism can easily doom the once-financially healthy utilities, Pacific Gas and Electric Company and Southern California Edison, as explained in *Woo, C.K., D. Lloyd, R. Karimov and A. Tishler (2003) "Stranded Cost Recovery in Electricity Market Reforms in the US," Energy - The International Journal, 28:1, 1-14.*
- **Legislature of the State of Alaska**. In 1998, the State of Alaska commissioned investigations to determine if there was clear evidence that restructuring would be in the public interest. E3 simulated the impact on all market participants of restructuring the Alaska Railbelt utilities under alternate market structure, bidder behavior, new generation entrant, transmission access and expansion, and fuel cost scenarios. E3's analysis showed that there was high risk and no compelling advantage to restructuring the Alaska Railbelt utilities. The Alaska Commission shelved further restructuring efforts.
- Central Power and Light. In 1996, E3 testified on behalf of the Texas utility regarding the levels of potential stranded costs under alternate retail access implementations. The Texas Public Utilities Commission had originally been considering open access in 1998. E3's analysis allowed the Commission to see the value of phased approach to retail access, and provided alternate methods to provide the efficiencies of "market prices" to customers without the disruption of rapid market restructuring. Texas did not open the electricity retail market until 2002.

<u>Transmission planning and pricing</u>

- **BC Hydro and Hydro Quebec.** To obtain power-marketing authorization (PMA) from the Federal Energy Regulatory Commission (FERC) in the US, Canadian utilities must file a transmission rate design consistent with the pro-forma tariff in the FERC's Order 888. E3 testified on rate design issues on behalf of BC Hydro (1996-97) and Hydro Quebec (2001) in their respective transmission tariff filings. The provincial regulators adopted the proposed designs.
- **Consolidated Edison (CECONY) and Orange and Rockland (ORU).** E3 is the T&D planning consultant for ConEd and its subsidiary OR. E3 successfully convinced the New York Public Services Commission (NYPSC) to adopt the T&D plans of the two utilities, while satisfying the concerns raised by environmentalists and consumer groups. The NYPSC also endorses E3's integrated approach to T&D planning in a deregulated market environment.
- **Regional Transmission Organization (RTO) West.** E3 is currently a representative of BC Hydro in the RTO West's design committee on congestion management. BC Hydro is the first Canadian utility to participate directly in a US regulated wholesale market structure. E3 has successfully argued against proposals that would deny BC Hydro reasonable access to the grid owned by the filing utilities of the RTO West. E3's prior work in transmission pricing and access allows BC to continue to have its rights as a sovereign country over its bulk power system and simultaneously participate in a seamless market across the Pacific Northwest.
- **California Energy Commission** 2000-2001. E3 is conducting research as subcontractor to Onsite Energy Corporation to evaluate the opportunities for rate unbundling to enhance the ability of distributed energy resources (DER) and demand side management (DSM) to provide transmission ancillary and supplemental services and distribution level services to California's electric power system. The evaluation includes definition and pricing of services, and characterization of the engineering and institutional limitations of DER and DSM to provide these T&D services.
- **B.C. Hydro (Canada):** 1996-Present. E3 is B.C. Hydro's principal consultant for the design of the utility's wholesale transmission service tariff which incorporates a two-part structure and the terms of the pro-forma tariff of Federal Energy Regulatory Commission (FERC). E3's findings were filed with the BCUC as prepared testimony. As a result of the tariff filed, FERC granted B.C. Hydro the Power Marketing Authorization.
- **B.C. Hydro (Canada)**, 1995-present. In 1995, B.C. Hydro retained E3 to analyze the effect of industry restructuring and the deregulation of the generation business on the bills of electricity consumers in British Columbia. As a result of this study, the British Columbia Utilities Commission (BCUC) adopted a path of gradual change, beginning with wholesale competition.
- **Central and Southwest Services (CSWS):** 1996. E3 was a regulatory witness for CSWS in their 1996 stranded cost case. E3's testimony was based on their forecast of the impact of changing regulatory structures in the electric sector on current generation plant values and the likely mix and price of new generation sources.
- **World Bank:** 1997. E3 designed a course for the World Bank titled "Electric Utility Regulatory Reporting and Accounting: Theory and Practice for Regulators". The purpose of this course is to review and discuss methods for assessing and regulating electric utility performance, with a focus on reported information. The course has since been given to regulators in Argentina.

- **Central Southwest Corporation (CSW):** 1996. E3 was retained by CSW to analyze the amount of generation investments potentially stranded by retail access. E3 applied the asset valuation and lost net revenue approaches to quantify this amount, which ranges from $1 to $3 billion depending on assumptions made about (a) future market prices; (b) pace of deregulation; and (c) sales by existing plants. The findings were presented to the Public Utilities Commission of Texas (PUCT) as direct and rebuttal testimonies. As a result of E3's participation, the PUCT recognized the size and degree of uncertainty surrounding the estimates of stranded cost. The adopted mean estimate was US$2 billion, significantly larger than the PUCT staff's original estimate of US$0.8 billion.

The following publications provide a reference for this body of work:

Orans, R., A. Olson and C. Opatrny (2003) "Market Power Mitigation and Energy-Limited Resources," Electricity Journal, March, 20-31.

Woo, C. K., I. Horowitz and J. Martin (1998) "Reliability Differentiation of Electricity Transmission," Journal of Regulatory Economics, 13:277-292.

Chow, R.F., Horii, B., Orans, R. et. al. (1995), Local Integrated Resource Planning of a Large Load Supply System, Canadian Electrical Association.

ENERGY PROCUREMENT AND RISK MANAGEMENT

E3 is an industry leader in defining standards for evaluating the profitability and risk of energy transactions, including power purchases. E3 has taught courses on profitability analysis to scores of utilities on behalf of the Electric Power Research Institute. E3's publications and courses demonstrate how a utility may quantify the expected margin from sales to a particular customer or customer segment using detailed information on the incremental revenue from sales and area-specific costs of serving such sales. In addition, E3's analyses translate uncertain costs and revenues into estimates of risk and return for each transaction or investment. Some examples of our work in energy procurement and risk management are given below.

- **Pacific Bell:** 1997. E3 conducted an auction to procure power for Pacific Bell, one of the largest and most visible energy consumers in the California market.
- **Ontario Hydro (Canada):** 1996 – 2001. E3 assisted Ontario Hydro in evaluating the expected return of alternative pricing strategies in anticipation of wholesale deregulation. These strategies were developed using the Strategic Planning Model, E3's proprietary software that considers transmission constraints, capacity and load projections, and behavior of buyers and sellers.
- **Central and Southwest Services (CSWS):** 1997-2001. CSWS was one of the original clients who funded the development of E3's proprietary software Contract Evaluator. E3 has been retained by CSWS to provide consulting on innovative rate design, and gave a training course for CSWS staff in using the Contract Evaluator software for this purpose.
- **PG&E Enterprises and PG&E Energy Trading:** 1995-2000. Prior to the restructuring announcements for the California market, PG&E's affiliate hired E3 to develop a computer model

to evaluate the competitive risk facing each of PG&E's industrial customers. This work helped form PG&E's strategy toward third party power projects over the following 3 years.

- **Ontario Hydro (Canada):** 1997. E3 advised Ontario Hydro on the development of marketing organizations. E3 provided training courses to Ontario Hydro and Ontario Municipal Electric Utilities on North American energy market and impact of deregulation. E3 also presented courses on designing customer specific marketing programs and methods of evaluating products and services offered by power marketers.

The following publications provide a reference for this body of work:

Woo, C.K., M. Borden, R. Warrington and W. Cheng (2003) "Avoiding Overpriced Risk Management: Exploring the Cyber Auction Alternative" Public Utilities Fortnightly, 141:2, 30-37.

Woo, C.K., R. Karimov and I. Horowitz (2003) "Managing Electricity Procurement Cost and Risk by a Local Distribution Company," Energy Policy, forthcoming.

Woo, C.K., I. Horowitz and K. Hoang (2001) "Cross Hedging and Forward-Contract Pricing of Electricity," Energy Economics, 23: 1-15.

Woo, C.K., I. Horowitz and K. Hoang (2001) "Cross Hedging and Value at Risk: Wholesale Electricity Forward Contracts," Advances in Investment Analysis and Portfolio Management, 8, 283-301.

Business Strategy and Finance

E3's understanding of the market for electric services, its understanding of customer considerations in electricity purchasing decisions, and its understanding of the electricity products being offered by utilities and Energy Service Providers in California offers a unique resource in assessing, evaluating and improving the effectiveness of City power project developments. Recent clients include:

- **Hawaiian Electric Company (HECO)** (2001-2003). E3 has developed a financial pro-forma tool for distributed generation applications from a utility perspective. The analysis incorporates a comprehensive view of project economics including a utility perspective that includes avoided energy purchases, and deferral of T&D capital projects, as well as societal and DG owner perspectives. The tool is designed to facilitate decision-making and provide analysts the necessary information to explain power project development decisions.
- **City of San Francisco** (1999): E3 was a subcontractor to Grueneich Resource Advocates for work with the City to evaluate the market viability of a proposed San Francisco Airport power development. E3 reviewed the finance and forecast methodology employed, and provided analysis of important contract terms, forecasts, and methodology. The analysis included an assessment of the California market structure including the ISO and PX markets.
- **Golden Gate National Parks Association (GGNPA)**: 1999-2001. E3 has worked closely with the GGNPA/NPS project team to develop an overall energy systems plan in light of the sustainability objectives and tight budget. Key strategic issues include developing sustainability standards for potential developers, evaluating opportunities for green power procurements in the context of

federal procurement regulations, evaluation of overall energy management system alternatives, describing technology alternatives for potential onsite sustainability demonstration projects and interpretive programs, identifying potential funding sources for leveraging Fort Baker resources, and evaluating alternative business arrangements and operating strategies for upgrading, operating and maintaining the energy distribution and delivery systems.

- **Upper Canada Energy Alliance (UCEA):** 1997-Present. This group of 10 Municipal Electric Utilities has joined together into an organization constituting the 3rd largest electrical load in Ontario, Canada. E3 was retained to develop the strategy and manage the procurement of energy for this group, as well as to assist in the development of their jointly owned competitive retail services company.
- **Oklahoma Municipal Power Authority (OMPA)**: 2000. E3, in collaboration with Gridwise Engineering and Endecon Engineering, recently completed a distributed generation engineering study for the OMPA on behalf of its over 30 member municipal utilities. The study evaluated the potential for deploying DG in the OMPA service territories, and explored the development of green power programs for its members' retail customers, including the potential to develop renewable resources to provide power for such programs. The strategic business planning portion of the study addressed economic and technical performance of conventional and renewable DG technologies and potential retail green power product offerings that could be implemented by OMPA and its members, along with an implementation plan. Several key pragmatic distributed generation implementation issues were reviewed, including evaluation of OMPA's current capacity purchase contract for use with DG, related rate and tariff issues, interconnection requirements and issues, along with methods for selecting sites for DG.
- **Newmarket Hydro:** 1998-2001. E3 was retained by Newmarket, an Ontario Municipal Utility, to develop their corporate business strategy under deregulation, including development of new competitive business opportunities, acquisition of strategic wires assets, as well as extending to the regulated business.
- **Puget Sound Energy (PSE):** 1998-Present. E3 is currently advising Puget on positioning their organization to compete in a fast deregulating world by integrating their business and regulatory strategies and planning processes.
- **Hawaiian Electric Company (HECO):** 1997-1999. HECO retained E3 to develop a business plan for an unregulated subsidiary company concentrating on hybrid photovoltaic systems and related products for off-grid residential applications. The plan was ultimately approved and financed by the utility's holding company. E3 has also advised HECO's management on best business strategies for restructuring the company and management of its own generation assets and purchases from IPPs. E3 was also retained by HECO to analyze the profitability of its customers. The findings from this analysis are used to formulate HECO's strategies in response to deregulation and potential competition.
- **Pacific Gas and Electric Company (PG&E):** 1997-1998. PG&E retained E3 to evaluate the impact of market restructuring in California on the economic viability of renewable and conventional distributed generation technologies. In addition, E3 evaluated the role that these technologies could play as bypass options to transmission and distribution expansion and upgrade. E3's results were presented to the PG&E management committee, and E3 continues to work with PG&E's corporate planning department on related issues.

- **B.C. Hydro (Canada):** 1995-1997. In preparation for emerging competition, B.C. Hydro retained E3 to design rate options to better serve diverse customer needs. The findings were filed with the BCUC that adopted B.C. Hydro's proposals without modification.
- **Fannie Mae:** 1992-1993. The goal of this project was to investigate whether energy efficiency lending could become a profitable new business for Fannie Mae and support its core mission for promoting housing affordability. The argument being that reducing the monthly operating expenses of a household, by reducing its electricity bill through energy efficiency measures and appliances, would bring home ownership within the reach of more Americans. The project required an assessment of the potential market for energy efficiency loans and a survey of utilities across the country.

7.0 Appendix B: References

[1] Ajodhia, V., M. van Gemert and R. Hakvoort (2002) "Electricity outage cost valuation: a survey," Proceedings of 2002 CEPSI Fukuoka, Japan.

[2] Berndt, E.R. (1991) *The Practice of Econometrics: Classics and Contemporary*, Addison-Wesley, NY: New York.

[3] Caves, D.W., J.A. Herriges and R.J. Windle (1990) "Customer demand for service reliability in the electric power sector: a synthesis of the outage cost literature," *Bulletin of Economic Research* 42(2): 79-119.

[4] Caves, D.W., J.A. Herriges and R.J. Windle (1992) "The cost of electric power interruptions in the industrial sector: estimates from interruptible service programs," *Land Economics* 68(1): 49-61.

[5] Dias-Bandaranaike, R. and M. Munasinghe (1983) "Demand for electricity services and the quality of supply," *Energy Journal* 4(2): 49-72.

[6] Forte, V.J., R. Pupp, R. Putnam and C.K. Woo (1995) "Using customer outage costs in electricity reliability panning," *Energy - The International Journal* 20(2): 81-87.

[7] Grosfeld-Nir A. and A. Tishler (1993) "A stochastic model of the measurement of electricity outage costs," *Energy Journal* 14(2): 157-174.

[8] Hartman, R.S., M.J. Doane and C.K. Woo (1991) "Consumer rationality and the status quo," *Quarterly Journal of Economics* 106(1): 141-162.

[9] Hausman, J.A. (1981) "Exact customer surplus and deadweight loss," *American Economic Review* 71(4): 662-676.

[10] Hausman, J.A. (1993) *Contingent Valuation: A Critical Assessment*, North Holland, Amsterdam.

[11] Horowitz J.K. and K.E. McConnell (2002) "A review of WTA/WTP studies," *Journal of Environmental Economics and Management* 44: 426-447.

[12] Kahneman D. and A. Tversky (2000) *Choices, Values and Frames*, Cambridge, UK: Cambridge.

[13] Katz, M.L. and H.S. Rosen (1991) *Microeconomics*, Irwin, MA: Boston.

[14] Lawton L. *et al* (2003) *A Framework and Review of Customer Outage Costs: Integration and Analysis of Electric Utility Outage Cost Surveys*, Report LBNL-54365, Lawrence Berkeley National Laboratory, CA: Berkeley.

[15] Lineweber D. and S. McNulty (2001) *The Cost of Power Disturbances to Industrial and Digital Economy Companies*, Report to ERPI, Primen, WI: Madison.

[16] List, J.A. (2004) "Substituability, experience, and the value disparity: evidence from the marketplace," *Journal of Environmental Economics and Management* 47: 486-509.

[17] Matsukawa I. and Y. Fujii (1994) "Customer preference for reliable power supply: using data on actual choices of back-up equipment," *Review of Economics and Statistics* LXXVI (3): 434-446.

[18] McClelland G., W. Schulze, D. Waldman, J. Irwin and D. Schenk (1990) "Sources of error in contingent valuation," Report to the US EPA, Department of Economics, University of Colorado.

[19] Munasinghe, M., C.K. Woo and H.P. Chao (1988) *Special Electricity Reliability Issue*, *Energy Journal*, 9.

[20] PG&E (2000) *Value of Service (VOS) Studies: Presentation to ISO Grid Planning Standards Subcommittee*, Pacifica Gas & Electric Company, CA: San Francisco.

[21] Sanghvi A. (1983) "Household welfare loss due to electricity supply disruptions," *Energy Journal* 4 (Special Electricity Issue): 33-54.

[22] SCE (1999) *Customer Value of Service Reliability Study*, Southern California Edison Company, CA: Rosemead.

[23] Tishler, A. (1993) "Optimal production with uncertain interruption in the supply of electricity: estimation of electricity outage costs," *European Economic Review* 37: 1259-1274.

[24] U.S. DOE (1997) *Natural Resource Valuation: A Primer on Concepts and Techniques*, Department of Energy, Washington D.C.

[25] Woo, C.K. (1994) "Managing water supply shortage: interruption vs. pricing," *Journal of Public Economics* 54: 145-160.

[26] Woo, C.K. (1992) "Drought management, service Interruption and water pricing: evidence from Hong Kong," *Water Resources Research* 28(10): 2591-2595.

[27] Woo, C.K. and K.W.K. Lo (1993) "Factor supply interruption, welfare loss and shortage management," *Resource and Energy Economics* 15: 339-352.

[28] Woo, C.K. and R.L. Pupp (1992) "Costs of service disruptions to electricity consumers," *Energy* 17(2): 109-126.

[29] Woo, C.K. (1990) "Efficient electricity pricing with self-rationing," *Journal of Regulatory Economics* 2(1): 69-81.

8.0 Appendix C: Hard copies of key E3 papers cited in Section 2

Energy Vol. 17, No. 2, pp. 109-126, 1992
Printed in Great Britain.

0360-5442/92 $5.00 + 0.00

COSTS OF SERVICE DISRUPTIONS TO ELECTRICITY CONSUMERS†

CHI-KEUNG WOO§ and ROGER L. PUPP‖,‡

§ Department of Economics and Finance, City Polytechnic of Hong Kong, 83 Tat Chee Avenue, Kowloon, Hong Kong

‖ Analysis Group, Inc., 100 Bush Street, Suite 900, San Francisco, CA 94104, USA

(Received 30 July 1991)

Abstract - After reviewing 16 recent studies, we (i) identify the general approaches used to estimate customer outage costs, (ii) ascertain the relative merits of each approach, and (iii) determine the extent to which existing studies can provide accurate and meaningful estimates. We present cost estimates on a common denominator, explain variations in the results, and suggest areas for future research.

1. INTRODUCTION

Electricity, unlike other forms of energy such as gas, oil or coal, cannot be economically stored, but rather must be provided on demand. Consequently, a major concern of all electric utilities is the level of reliability at which they can supply energy. Reliability is defined as the ability to deliver uninterrupted service on demand, to whatever degree required.¶ Common engineering service reliability criteria are one-day-in-ten-years loss-of-load-probability, expected unserved energy, and reserve margins. A discussion of each is presented in Refs. 1-4. An electric utility traditionally chooses a particular level of service reliability by using probabilistic and deterministic standards and judgements based on experience. For instance, a utility may design their generating system to maintain adequate generation reserve margin to provide an acceptable level of service reliability. Similarly, the design of a transmission and distribution (T&D) network may rely on redundancy to satisfy reliability standards determined by historical practice.[5-7] Customer preferences for service reliability are typically not considered in these types of planning decisions. As a result, the cost and level of service reliability supplied by a utility may differ from what customers want and for what they are willing to pay. If so, the reliability level provided is not economically efficient for either the utility or the customer.

Most electric utilities have also traditionally ignored customer reliability preferences in product development. For example, a retail customer class is typically offered a standard service whose price does not necessarily closely correspond with customer value of service reliability.[8] As a result, customers who are willing to pay for premium uninterruptible service or are willing to accept a bill discount for interruptible service have not been given the opportunity to choose between these two. This is in sharp contrast to the

---

† This paper is a highly condensed version of several reports sponsored by Niagara Mohawk Power Corporation (NMPC) during 1987-1990. The paper also benefits from the research partially funded during 1985-1988 by Pacific Gas and Electric Company (PG&E) and Economic Models of Israel (EML). However, the paper does not reflect the views of CPHK, AG, NMPC, PG&E and EML. Many individuals have contributed to our past research on the subject. In particular, we thank A. Adriance, D. Aigner, R. Billinton, H.P. Chao, M. Doane, T. Flaim, R. Hartman, D. Keane, R. Mango, G. McClelland, M. Munasinghe, B. Neenan, W. Schulze, D. Spulber, and G. Wacker. Without implications, all errors are ours. After completing the paper, we became aware of a recently published survey by D.W. Caves, J.A. Herriges and R.J. Windle (Ref. 21). There are substantial differences between their paper and ours. The two papers are complementary and should be read together to obtain a complete view of the subject.

‡ Author to whom all correspondence should be addressed.

¶ Reliability is distinct from service quality in that the latter refers to the provision of electricity within acceptable frequency and voltage ranges.

airlines and long-distance telecommunications industries, which offer a full spectrum of differentiated services from which customers can select options that best match their needs.†

Due to both customer dissatisfaction with utility electricity service and the financial risks of major plant additions, some electric utilities have recently begun to explore alternative methods to plan and price electricity supply. The result of this exploration is an increasing popularity of economic reliability planning and efficient pricing principles. To wit, (i) a reliability improvement should be undertaken if its benefits exceed its costs,[2-6,8,9,13,17] and (ii) the cost of an improvement should be reflected in the rate design.[2,8,9,11,13,18] Customer outage costs are an essential input for implementing these two important principles. We provide three notable examples. The first is from generation planning and marginal cost pricing. The benefit of new generation capacity is a decrease in expected customer outage costs. The reliability improvement obtained with additional capacity is economically efficient if the benefits of increased reliability exceed the costs of installing new capacity. Setting efficient electricity rates requires the change in expected customer outage costs and the capacity costs to be included in the rate design. Under a flat rate design, for example, the efficient price is the sum of the expected marginal fuel cost and the expected marginal outage cost. Under the economic reliability planning principle, the expected marginal outage cost at the long run equilibrium equals the marginal capacity cost.[2,8,13]

Our second example is the design of interruptible and curtailable (I/C) service. Offering I/C service at reduced rates to customers who have relatively low outage costs helps to both defer capacity expansion and decrease emergency power pool purchases.[9-11,13,15] Our final example is a T&D planning project. Repairing an aging transmission line after each failure may be more cost-effective than replacing the line. Another option may be to install switches to isolate faults so that distribution related outages are reduced. The costs of the switches must be balanced against the benefits to determine whether the reliability improvement is economically efficient. Benefits comprise reduced outage costs and corresponding lower maintenance costs.[5,7]

While the principles of economic planning and efficient pricing are well established, a utility may be unable to apply the principles because customer outage costs in each of the utility's service regions are generally unavailable. By reviewing some recent contributions to the estimation of customer outage costs, we (i) identify the general approaches used, (ii) ascertain the relative merits of each approach, and (iii) determine the extent to which existing studies can provide accurate and meaningful estimates which are transferable across utilities. If the existing estimates of different utilities varied little, a utility that has no information on their customers' outage costs may substitute the outage costs of another utility. Conversely, highly diverse estimates may indicate either a lack of consensus among experts regarding the magnitude of outage costs or a recognition that outage costs vary highly with customer characteristics. If the latter is true, utilities would need to collect outage costs estimates for their customers rather than substituting estimates from another utility.

With these objectives in mind, the remainder of the paper is organized as follows. Because a variety of measures have been used in the literature, we define in Sec. 2 the concept of customer outage costs to eliminate any ambiguities that may arise in the subsequent discussion. In Sec. 3, we identify and evaluate the approaches commonly employed to estimate customer outage costs. In Sec. 4, we present the empirical results in 16 recent studies, a majority of which are based on outage cost survey data.‡ We conclude in Sec. 5 by recapitulating the major findings and suggesting some areas for future research.

2. DEFINITIONS

The value of service reliability represents the maximum amount a customer is willing to pay for the particular level and type of service provided. As such, it reflects the usefulness and/or necessity of electric service to the customer. Although electricity is familiar to most users, the market for its reliability is not well developed. For example, since 1977, Pacific Gas and Electric Company has been offering interruptible and curtailable service options to approximately 1,000 large customers with monthly demand over 1,000 kW. However, less than 10% of these customers subscribed to any of these options.[22] It is difficult to judge consumers' willingness to pay (WTP) for different reliability levels, because there exists a limited amount of data on customer reliability/price choices. Accordingly, the amount customers are willing to pay for service reliability is often approximated by its opportunity costs which equals the value of unsupplied electricity. Thus, customer value of service reliability becomes synonymous with customer outage costs.

† Various form of reliability differentiation have been proposed in the literature including, (i) priority service in Refs. 9-10, (ii) simple interruptible service in Ref. 11, (iii) demand subscription service in Ref. 12, (iv) self-rationing in Ref. 13, and (v) proportional rationing in Refs. 14-15. However, their implementation is relatively limited as noted in Ref. 16.

‡ For surveys of earlier works, see Refs. 19 and 20. A review of North American studies prior to 1988 is provided in Ref. 21.

Customer outage costs can be collected either *ex post* (i.e. after the fact) or *ex ante* (i.e. before the fact).[23,24] *Ex post* measures represent the economic costs incurred by households or firms when a service disruption occurs with certainty. *Ex ante* measures equal the maximum amount a customer is willing to accept (pay) for an increase (decrease) in the likelihood that an outage will occur in the future. An *ex ante* value of reliability does not depend on the actual realization of an outage. It is sometimes inferred from household purchases of a backup generator or household participation in a load management program.

Outage costs are commensurate with a customer's dependence on electricity during an outage. Outage costs vary significantly depending on the particular attributes of the outage. Attributes known to influence costs include: timing (season and time-of-day), advance notice, frequency, duration and severity. With the exception of severity, the meaning of the remaining attributes is self-evident. Severity is the extent of service disruption characterized by the following: (i) Full Outage - A complete or total loss of service, typically resulting from a distribution-related cause (e.g. storms, car-pole accidents, or vandalism), or transmission failure, rotating blackouts or enforcement of an interruptible service contract as described in Ref. 6; and (ii) Partial Outage - A curtailment of service due to a utility's public appeal for voluntary load reduction, or participating in a load management program targeted to a particular end-use such as air conditioning or water heating.[25]

3. APPROACHES

Description

Using the preceding concepts and definitions, we describe three techniques commonly employed to estimate outage costs. These procedures are the (i) proxy, (ii) market-based and (iii) contingent valuation methods.

Proxy methods use secondary data to measure customer willingness to pay for service reliability. The following are examples of proxies: (i) Average electricity tariff[26,27] - This method is based on the assumption that customers purchase electricity if consumption benefits are greater than costs. As a result, the average electricity tariff measures what customers are willing to pay for the last kWh purchased. (ii) Cost of maintaining backup power[28] - This approach assumes that electricity users act rationally and insure themselves against the damages caused by power failures when it is economic for them to do so. For instance, a firm's acquisition of a backup generator will reflect the marginal value of unsupplied electricity. Outage costs are derived by assuming that a competitive risk-neutral firm maximizes expected profit. At the margin, they equate the expected marginal costs of self-generating a kWh of the unsupplied utility electricity to the expected avoided outage costs due to this self-generated kWh. (iii) Value of foregone leisure/wage rate[7] - This method views the principal cost of a power failure as a loss of leisure. (iv) Value of foregone production (GNP per kWh consumed) - The gross national product (GNP) measures the value of goods and services produced by an economy. Because electricity is an essential input to all economic activities, it is argued that the GNP would be greatly reduced in the absence of electricity. Thus, the ratio of GNP to total electricity consumption may be used as an approximation of the aggregate effect of an outage on an economy.

In contrast to proxy techniques, market-based methods use data from observed customer behavior to infer outage costs. These approaches include (i) consumer surplus methods used in Refs. 29-32 and (ii) analysis of customer choice of I/C rate options as in Ref. 22. The consumer surplus approach estimates outage costs by equating them to the compensating variation. The compensating variation equals the area under customers' compensated demand curves.[33-34] Early applications of this method relied on readily available monthly or yearly aggregate demand function data which were used to approximate either daily or hourly electricity consumption by customers.[29] Hourly and daily consumption was then used to estimate outage costs. In more recent work, outage cost estimates were obtained from consumer surplus losses calculated from a system of time-of-use demand equations.[31]

Also, the market-based approach uses data that utilities have collected from recently introduced I/C rate options for their large commercial and industrial users. These options, and others similar to them, offer a customer a price discount in return for a lower reliability of service.† In this approach, it is assumed that customers rationally choose an option which maximizes their expected net benefit of electricity consumption. Each option has both a particular rate discount and level of reliability. An econometric analysis of customer choices will provide a market determined value of service reliability. The data may be used to infer the monetary compensation required for each customer such that they are indifferent between the discount/reliability choice they actually made and alternative choices they could have made. These compensation differentials among the options measure customer WTP for alternative reliability levels. The

† For example, Pacific Gas and Electric Company rate E-20 for large light and power customers offers discounts for both the demand charge and the energy rate. Participation may result in service curtailment with varying degree of notice.[22]

procedures used to obtain such estimates are outlined in Refs. 25 and 35-38.

The contingent valuation method (CVM) is a third technique which may be used to collect outage costs. In the CVM approach, individuals are asked to reveal in a survey or experimental setting how much they value a hypothetical good which is not priced in the market. For instance, people have been asked "How much would you be willing to pay to clean-up this river?" A thorough description and assessment of this approach is contained in Ref. 39. CVM surveys have been widely used to estimate outage costs differentiated by outage attributes and customer characteristics. Empirical examples of the approach can be found in Ref. 35. Three contingent valuation techniques are discussed below.

The first technique is based on customer surveys of direct costs.[40-42] Customers are asked to identify the actions they would normally take to adjust to an outage. Next, they are asked to provide an estimate of the out-of-pocket and/or inconvenience costs of each action. The total outage cost is estimated as the sum of the individual costs. In the residential sector, the individual actions may include the use of candles for lighting; dining out or visiting friends; buying ice to preserve food; staying at a hotel or motel; or the use of a home generator, etc.† In the commercial and industrial sectors, specific costs comprise lost sales or production, spoilage, equipment repair and the expenses of making-up lost sales and production.

The second CVM technique asks customers in a survey to state the maximum amount of money they would be willing to pay (or accept) for an increment (or a decrement) in service reliability. The amount of money individuals are willing to pay (WTP) should approximately equal the amount of money that they are willing to accept (WTA) for a marginal change in service reliability. Willig[33] presents the theory from which this implication is drawn. It is possible that the WTP and the WTA may not by identical due to income effects. If these effects are negligible as assumed in this theory, the difference between WTP and WTA is slight. However, this hypothesis is contradicted by the empirical evidence presented in Refs. 37-38.

The last CVM technique we discuss is the analysis of customer preference data. In a survey, individuals are given a set of hypothetical mutually exclusive service alternatives. Each alternative depicts a different combination of service reliability and price. Individuals are then asked to rank the options by their order of preference or to choose the option that best meets their needs. Marginal rates of substitution and monetary values of willingness to pay can be inferred from these rankings.[25,37,38,40,43]

Evaluation

Here we evaluate the pros and cons of the three approaches. We summarize our findings in Table 1 which provides a synopsis of the relative merits of each method using the following criteria: (i) Data requirement Amount of data necessary for outage cost estimation, (ii) Computational cost Amount of research effort and time required for data analysis, (iii) Verifiability Extent to which the outage cost estimates are supported by observed customer behavior, and (iv) Outage attributes and customer demographics Extent to which the estimates reflect outage cost variations by these determining factors. In Table 1, the symbol + indicates that an approach scores well under a particular criterion while the symbol - indicates the opposite.

Table 1. Relative merits of outage cost estimation techniques.

Criterion	Proxy	Market-Based	Contingent Valuation
Data Requirement	+	-	+/-
Computation Cost	+	-	+/-
Verifiability	-	+/-	?
Outage Attributes	-	-	+
Customer Demographics	-	+	+

The major advantage of the proxy methods is that they are straightforward to apply and require minimal data. Thus, computational costs are relatively inexpensive. However, theoretical deficiencies and/or lack of detail may result in inaccurate outage cost estimates. This limits the usefulness of proxy outage cost estimates in a utility's planning and pricing activities, so that proxy methods score poorly under the remaining three categories. We argue why this is so by providing examples. First, the average electricity tariff proxy fails to quantify the total cost of a complete service disruption, because it only measures the value of the

† In most cases the resulting estimates should be interpreted as an upper bound of customers' willingness to pay. This is because certain actions during the outage provide an associated consumption benefit. For example, dining out in a fine restaurant during an outage has a consumption benefit due to the enjoyment consumers obtain by having someone else cook for them.

marginal kWh lost. If the marginal cost of backup power exceeds the marginal outage cost, a rational firm would not invest in backup power. This implies that the marginal cost of backup power overestimates the marginal outage cost.

Second, the wage proxy inaccurately measures outage costs because labor-leisure tradeoff theory assumes workers can vary their hours of work to equate their wage with the marginal value of their leisure time. This tradeoff may be infeasible due to the traditional 40-hour work week, union restriction on hours worked, or insufficient employment alternatives. It also effectively ignores the cost to nonwage earning family members. Another weakness of this approach is that it is valid only for electricity-dependent leisure activities.

Our third example is the GNP/kWh consumed proxy approach in which the underlying production technology for GNP is assumed to be a fixed coefficient. This assumption is not supported by empirical evidence presented in Ref. 44. Outage costs estimates from any of the three proxy methods can not be verified. In addition, none of these approaches is able to sufficiently estimate differences in outage costs due to outage attributes and customer demographics. In summary, we conclude that the proxy method has three deficiencies and only two advantages. On balance, the disadvantages may result in inaccurate outage cost estimates. This seriously limits their usefulness in a utility's planning and pricing activities.

Next, we discuss the advantages and disadvantages of using each of the two market-based methods (customer choice and consumer surplus) in estimating outage costs. The customer choice approach can generate valid, defensible and verifiable outage cost estimates, because it uses data on actual customer subscriptions to reliability differentiated rates. If data on customer demographics is also available, the effect of these variables on outage costs can be econometrically estimated if computational cost is not of high concern. On the other hand, sufficient data is generally not available to adequately estimate outage costs and the effect of outage attributes on outage costs, so it scores poorly on the data requirement and outage attribute criteria.† Thus, we conclude in Table 1 that this market-based method does not score well under the data requirement, computational cost and outage attribute criteria, but it scores well for the verifiability and demographic criteria.

The market-based consumer surplus approach suffers from a number of theoretical deficiencies making it difficult to verify outage cost estimates. First, considerable care must be taken to ensure that the correct demand curve is identified by which we mean that it corresponds to the period of the loss. In addition, using this approach to estimate outage costs for a momentary outage as in Ref. 31 is generally infeasible, because it requires the estimation of a demand equation for a time period less than a minute.‡

Second, Munasinghe[7] notes that the consumer surplus measure may be inappropriate because an unexpected service disruption is not the same as a reduction of planned consumption caused by a price increase. He argues that actual outage costs may be significantly larger due to the unplanned nature of the outage.¶ Finally, the consumer surplus approach requires an estimate of the price increase that would reduce the quantity demanded to zero. While this price increase is well defined for a linear demand equation,[32] most empirical demand equations are nonlinear. A finite price increase that would completely choke-off such demand may not exist. For example, the required price increase for the popular double-log demand equation is infinite, implying that the resulting consumer surplus loss due to the outage is also infinite.[34]

This approach performs poorly in evaluating the role of frequency and notice attributes on outage costs, because time-of-use data is collected for the purpose of determining how consumption varies with price. On the other hand, the effects of customer demographics and outage attributes such as duration and time-of-day on outage costs may be determined (if sufficient data on hourly loads and prices are available), but it requires extensive computational analysis.[45,46]

The last outage cost estimation approach we discuss is contingent valuation surveys. Depending on a utility's planning and pricing needs, the amount and detail of information collected on a survey can be

---

† For example, PG&E's interruptible rate option offers a large rate discount with little difference in actual service reliability.[22] Thus, the data available from this rate option experiment would not be rich enough to predict what customers would choose when confronted with a menu of truly competing service options.

‡ On the other hand, momentary outage costs can be estimated using the CVM approach. The authors of Ref. 40 estimated residential outage costs ranging from \$0.18 to \$1.88 (1989\$) per interruption.

¶ Ongoing research sponsored by NMPC and the Electric Power Research Institute (EPRI) attempts to address this issue using the hourly demand model.[46] Preliminary findings in this report support the hypothesis that actual outage costs due to an unexpected outage are higher than reductions in consumption due to price increases.

adjusted. A utility needing only a moderate amount of information may limit the length of a survey to a few pages and a couple of outage scenarios. Also, to limit computational costs, simple statistical techniques such as crude sample averages may be used to estimate outage costs from survey results. On the other hand, the utility may need much more detail. If so, the survey may contain a great number of demographic questions and collect much information on how outage attributes (such as duration, notice, etc.) affect outage costs. In addition, this more carefully designed survey may also be accompanied by a more thorough statistical analysis of the survey responses.[47-48] For example, survey data often contain up to 60% of zero cost responses, creating an estimation difficulty known as truncation bias. Statistical methods to correct for this bias are presented in Refs. 49-51, but it requires extra computational cost. For these reasons, Table 1 indicates that contingent valuation methods perform well under outage attributes and customer demographics criteria, but not as well under data requirement and computation cost criteria.

Verifiability of outage cost estimates obtained using CVM remains unknown, in particular because the results of CVM applications always show large disparities between reported WTP and WTA responses. In theory, there should be no empirical difference between these responses. However, typical reported WTP values ranges from one-fourth to one-third of reported WTA values. To date, researchers have been unable to definitively explain the persistence of this disparity. Various conjectures include both strategic response bias on the part of the respondent and cognitive dissonance. Coursey et al[52] designed a laboratory experiment to investigate if either of these conjectures can explain this disparity. In this experiment, individuals are given a drop of bitter tasting liquid, and asked both what they would be WTP and WTA to avoid and suffer the experience, respectively. A Vickrey auction mechanism is used to elicit the hypothesized values in the form of individual bids. The authors conclude the following: First, the observed divergences between WTP and WTA may be due to hypothetical bias resulting mainly from the lack of a market-like environment. This finding is consistent with results obtained from the analysis of survey data on customer subscription to hypothetical rate options. Choice sets that include unrealistic reliability levels such as a 1 five-second outage every 5 years vs 30 two-day outages every year tend to yield outage cost estimates that are unrealistically high.[45] More plausible estimates have been obtained when respondents have been confronted with a set of realistic service options as in Keane et al.[25]

Second, hypothetical bias is likely to yield outage costs responses above prices respondents would pay if the service were actually available in a market-like setting, because respondents are not required to purchase the product at the value they assign it. Third, WTP measures of value may correspond more closely to the true value than do WTA measures. Finally, extreme risk aversion in the form of a strong preference for the status-quo may also account for the disparity between WTA and WTP.† As shown in Refs. 37-38, this bias has important implications in estimating the value of service reliability, especially for those utilities interested in offering reliability-differentiated rates. The bias suggests that customers attach a strong premium to the current service level and are unwilling to select a non-firm service option unless the price discounts are sufficiently large to overcome the psychological barrier to participation. However, it is important to note that Cummings et al[39] document eight studies in which both CVM and actual market data were used to value the same commodity and each gave similar results. While outage cost estimates in the CVM approach are not directly verifiable at this time, this study indicates that these results are very reasonable.

4. SUMMARY OF PRIOR RESULTS

This section summarizes 16 recent studies on customer outage cost estimation. We choose these studies to (i) review the state-of-art approaches, (ii) demonstrate the differences in approaches and results by including some contributions not reviewed in prior survey articles,[19-21] and (iii) address the specific features of both the residential and nonresidential customer classes.‡ Due to dissimilar measurement concepts, and outage attributes and customer demographics in the databases used in various studies, the outage cost estimates are diverse. In our summary, we attempt to reconcile differences among estimates.

Residential Sector

Table 2 lists the features and the empirical results of eight residential studies; 3 and 5 studies use *ex*

† See Ref. 53 for a discussion on the kinked value function which implies extreme risk aversion due to status-quo bias.

‡ We have not discussed Refs. 37-38 in our review because the primary emphasis of these two papers is on investigating consumer rationality. Also, the numerical results in these papers are identical to those in Refs. 36 and 40. We have also excluded Ref. 54 because the authors use an input-output table to analyze the aggregate outage cost for the Egyptian economy. Because their study focuses on the macroeconomic impact of a capacity shortage rather than microeconomic effects, it is beyond the scope of our paper.

Table 2. Estimates of the value of service reliability and outage costs in the residential sector in 1989 U.S. $.

Study/Country	Method/ Cost Type	Season/ Time-of-Day	Frequency	Duration (Hours)	Notice (Hours)	Dollars Per Interruption	Dollars Per Hour Unserved	Dollars Per kWh Unserved
Doane, Hartman, and Woo (1988)/ California, USA	Customer Survey/ Ex Ante	Not Studied				Bill Increase /k		
			2	1	0	45.02/g	11.25/h	16.11/i
						Bill Decrease /l		
			5	2	0	12.82	6.41	9.18
			5	4	0	45.02	6.43	4.61
			15	2	0	12.82	6.41	9.18
			15	4	0	18.18	4.04	5.79
Keane, MacDonald, and Woo (1988)/ California, USA	Customer Survey/ Ex Ante	Summer/ Afternoon				Bill Decrease /m		
			1	4	0	18.43	4.61	1.84
Doane et al. (1990)/ New York, U.S.A.	Customer Survey/ Ex Post					Willingness-to-Pay /n		
		Summer/ 8 a.m.	Not Studied	1	0	4.43	4.43	5.40
				4	0	6.4	1.6	1.89
				8	0	9.99	1.25	1.50
		Summer/ 2 p.m.	Not Studied	1	0	3.55	3.55	4.38
				4	0	4.88	1.22	1.46
				8	0	7.33	0.92	0.97
				1	1	3.55	3.55	4.38
				4	1	4.88	1.22	1.46
				1	4	3.55	3.55	4.38
				4	4	4.88	1.22	1.46
		Summer/ 6 p.m.	Not Studied	1	0	3.67	3.67	3.72
				4	0	5.36	1.34	1.28
		Winter/ 8 a.m.	Not Studied	1	0	6.71	6.71	7.14
				4	0	8.96	2.24	2.30
				8	0	13.38	1.67	1.73
		Winter/ 2 p.m.	Not Studied	1	0	6.11	6.11	6.57
				4	0	8.05	2.01	2.07
				8	0	12.08	1.51	1.38
		Winter/ 6 p.m.	Not Studied	1	0	7.30	7.30	6.08
				4	0	9.75	2.44	2.01
				1	1	7.13	7.13	5.94
				1	4	6.80	6.80	5.60
				4	1	9.50	2.38	1.98
				4	4	8.71	2.18	1.80

Notes:

a/ Based on the costs of the actions taken to mitigate the affect of an outage. Actions examined include the purchase and use of candles, an emergency lantern, and/or an emergency stove; purchase or rental of a small or large backup generator.

b/ N.A. = Not Available

c/ Based on the costs of the actions taken to mitigate the affect of an outage. Actions examined include using candles, flashlights, a propane gas stove or grill, a kerosene heater or wood stove, and/or a battery-operated radio; going out to eat, shop, visit friends; staying home and doing activities which do not require electricity; using a home generator.

d/ A partial outage resulting from a customer's voluntary response to the utility's public appeal 4 – 6 hours before a capacity shortage.

e/ The amount a customer is willing to pay for the service of a backup generator.

f/ Amount of annual bill increase that a customer is willing to pay to move from the current reliability level of two one-hour winter outage per year to a lower reliability level.

g/ The change in the annual bill divided by a change in frequency relative to the current reliability level.

h/ The change in the annual bill divided by a change in hours unserved relative to the current reliability level.

i/ The change in the annual bill divided by a change in kWh unserved relative to the current reliability level.

j/ Amount of annual bill decrease that a customer is willing to accept to move from the current reliability level of two one-hour winter outages per year to a lower reliability level.

k/ Amount of annual bill increase that a customer is willing to pay to move from the current reliability level of three 2-hour outages per year to a higher reliability level.

l/ The amount of annual bill decrease that a customer is willing to accept to move from the current reliability of three 2-hour outages per year to a lower reliability level.

m/ Amount of annual bill decrease that a customer is willing to accept to tolerate the loss of air-conditioning due to voluntary participation in a program.

n/ What is the most you would be willing to pay as a lump sum increase in your annual electricity bill to prevent this outage from occurring?

Table 2. Estimates of the value of service reliability and outage costs in the residential sector in 1989 U.S. $.

Study/Country	Method/ Cost Type	Season/ Time-of-Day	Frequency	Duration (Hours)	Notice (Hours)	Dollars Per Interruption	Dollars Per Hour Unserved	Dollars Per kWh Unserved
Munasinghe (1980)/ Cascavel, Brazil	Proxy-Wage Rate/ Ex Post	Not Studied/ Evening	Not Studied	1	0	3.06	3.06	1.73–2.86
Sanghvi (1983)/ Wisconsin, USA	Consumer Surplus/ Ex Post	Summer/ 12 noon	Not Studied	1	0	0.37	0.37	0.17
				2	0	0.75	0.37	0.18
				4	0	1.64	0.41	0.21
				12	0	19.27	1.60	0.77
		Summer/ 8 a.m.	Not Studied	1	0	0.37	0.37	0.23
				2	0	0.77	0.38	0.24
				4	0	1.84	0.46	0.28
				8	0	5.45	0.68	0.40
		Summer/ 4 p.m.	Not Studied	1	0	0.78	0.78	0.31
				2	0	2.05	1.03	0.32
				4	0	4.54	1.14	0.38
				8	0	7.27	0.90	0.37
Wacker, Wojczynski, and Billinton (1983)/ Canada	Customer Survey/ Ex Post					Direct Costs /a		
		Winter/ Evening	Monthly	1	0	1.46	1.46	N.A. /b
			Monthly	4	0	14.68	3.67	N.A.
			Weekly	4	0	22.72	5.68	N.A.
						Willingness-to-Pay		
			Monthly	4	0	6.55	1.64	N.A.
			Weekly	4	0	9.97	2.49	N.A.
			Daily	1	0	9.96	9.96	N.A.
						Willingness-to-Accept		
			Monthly	4	0	13.62	3.40	N.A.
Doane, Hartman, and Woo (1988)/ California, U.S.A.	Customer Survey/ Ex Post					Direct Costs /c		
		Winter/ Evening	Not Studied	1	0	12.15	12.15	16.19
				4	0	22.5	5.63	6.06
		Winter/ Morning	Not Studied	4	0	13.65	3.41	4.33
				12	0	45.82	3.82	4.97
		Summer/ Afternoon	Not Studied	1	0	4.14	4.14	5.51
				4	0	15.36	3.84	4.80
				12	0	42.97	3.58	4.29
				1	1	3.15	3.15	4.20
				5 /d	0	2.88	0.58	N.A.
		Any-Time	Not Studied	Momentary		1.88	N.A.	N.A.
						Willingness-to-Pay /e		
		Winter/ Evening	Not Studied	1	0	3.33	3.33	4.44
				4	0	5.40	1.35	1.48
		Winter/ Morning	Not Studied	4	0	3.38	0.85	1.07
				12	0	10.21	0.85	1.04
		Summer/ Afternoon	Not Studied	1	0	1.85	1.85	2.46
				4	0	4.07	1.02	1.28
				12	0	9.83	0.82	0.96
				1	1	1.11	1.11	1.47
		Any-Time	Not Studied	Momentary		0.18	N.A.	N.A.
Goett, McFadden, and Woo (1988)/ California, USA	Customer Survey/ Ex Ante					Bill Increase /f		
		Winter/ Morning	1	1	0	21.36 /g	21.36 /h	27.14 /i
						Bill Decrease /j		
			1	4	0	94.42	47.21	59.86
			2	4	0	N.A.	19.30	24.50
			4	1	0	21.36	21.36	27.14
			4	4	0	79.28	5.68	7.20

ante and *ex post* costs, respectively.† *Ex post* costs are approximated by using a wage rate proxy, consumer surplus and CVM. Munasinghe[55] uses a wage rate proxy and verifies its accuracy by comparing outage cost estimates obtained from it with the outage costs estimates acquired from a personal interview with 27 households. Sanghvi[31] adopts a consumer surplus approach in which a system of 24 hourly electricity demand equations is estimated using data from a time-of-use experiment. The area under the demand curve approximates the consumer surplus of electricity service. Doane et al,[40] Doane et al[47] and Wacker et al[56] estimate outage costs with household contingent valuation survey responses on both direct costs and WTP.

These authors employ different statistical techniques to estimates outage costs. Wacker et al[56] use descriptive statistics to summarize the survey results. A limited dependent variable regression model based on Heckman[51] is used by Doane et al[47] to quantify the effects of outage attributes and customer demographics on outage costs. These authors also correct for bias introduced by protest bids. A protest bid is a zero WTP answer from a respondent who is unwilling to pay for a reliability improvement for non-economic reasons. These reasons include the following: (i) "The utility should provide reliable service." (ii) "Even if I pay, the utility cannot eliminate outages anyway." In addition, these authors remove observations with a studentized residual over 3.5 from their analysis. Such observations are called outliers; they tend to be observations with huge reported outage costs. The outlier classification technique is explained in Belsley et al.[57]

Goett et al,[43] Keane et al[25] and Doane et al[36] use *ex ante* data obtained from contingent valuation surveys. Outage costs are inferred by analyzing the choices made by households among alternative reliability options each characterized by both a different bill discount and outage attributes such as expected frequency and duration.

Outage costs expressed as dollars per interruption are available for all studies in Table 2. In addition, outage costs for all non-momentary outages are stated in dollars per hour unserved. It would be ideal if all cost estimates could be normalized to dollars per kWh unserved to facilitate comparisons among results. However, less than half of the studies provide these normalized cost estimates, presumably due to the lack of data on energy unserved during an outage.

Obtaining dollar per kWh unserved by normalization of the cost per interruption is an important issue in presenting and using outage cost estimates. For instance, these estimates are used for system reliability planning. A unbiased estimate of dollar per kWh unserved equals the population estimate of the cost per interruption divided by the population estimate of the expected unserved energy per interruption.[58] To the extent that the cost per interruption is relatively stable for small changes in reliability, the economic benefit of a reliability improvement equals the product of the dollar per kWh unserved and the change in the population estimate of expected unserved energy.[3-5,7] Estimates of dollar per kWh unserved presented in Table 2 and later in Tables 3 and 4 are computed as above.‡

The per interruption cost estimates in Table 2 ranges from $0.18 to $94. After normalizing the per interruption costs by dividing by the duration of the outage, variations in the dollars per hour unserved estimates remain substantial. They range from $0.37 to $47 per hour unserved. Furthermore, normalizing dollars per interruption by kWh unserved indicates that cost differences cannot be adequately explained by energy unserved. For example, based on a survey of households' direct costs, Doane et al[40] finds the cost of a 4-hour outage is approximately $4 to $6 per kWh unserved, three to four times higher than WTP estimates obtained in the same survey. The *ex post* direct cost estimate for a 4-hour summer afternoon outage is approximately $4.8 per kWh unserved, three times the *ex ante* cost estimate of $1.84 per kWh unserved reported in Keane et al[25] for a partial load curtailment. Moreover, these estimates are substantially larger than the full outage cost estimate of $0.37 per kWh unserved in Sanghvi[31] for a summer afternoon outage of the

---

† The estimates for countries outside the U.S. are first converted to U.S.$ using exchange rates published in the Statistical Abstract of the U.S. (1986). All estimates are then adjusted for inflation using the annual Consumer Price Index (CPI) available from the Monthly Labor Review (November 1990) published by the U.S. Bureau of Labor Statistics.

‡ For reliability pricing purposes, the cost per interruption is not meaningful since reliability differentiation requires information on the distribution of the individual per unit outage cost $y_i = c_i/e_i$; where c_i = estimate of cost per interruption for Customer i; and e_i = estimate of expected unserved energy per interruption for Customer i. Suppose the rate discount for a simple interruptible service is d ($/kwh). Customer i who is assumed to be risk neutral will select the interruptible service if his/her expected per unit cost of electricity consumption $[(1 - p)(z - d) + p(c_i - z - d)] < z$; where p = probability of service interruption; z = energy rate for firm service; and (z - d) = energy rate for interruptible service. If c_j is the per unit cost of the "marginal customer" who is indifferent between the two services, the participation rate in the interruptible service program is $F(c \leq c_j)$ where F(c) is the cumulative distribution function of $c > 0$.[11] For a similar discussion on this point, see Ref. 21.

same duration. Below we discuss the factors that cause this diversity of results.

The consumer surplus approach adopted by Sanghvi[31] results in the lowest *ex post* cost estimates of $0.18 to $0.77 per kWh unserved which likely underestimate the *ex post* cost of an outage.† The *ex post* cost estimates derived from the WTP survey responses are the next lowest. Wacker et al[56] report that the average rate increase acceptable to a Canadian household to avoid a monthly 4-hour winter evening outage is approximately $6.6 per interruption, corroborating the WTP estimate of $5.4 in Doane et al.[40] The corresponding dollars per hour unserved estimates are between $1.36 to $1.64, which are approximately 50% of the Brazilian wage rate proxy in Ref. 7. It was found in Doane et al[40] that the *ex post* cost estimates derived from direct costs are $12 to $15 per interruption for a 4-hour morning outage. These estimates, however, are almost three times higher than the WTP estimates from the same surveys and two times those in Doane et al.[48] This difference is expected since the contingent valuation literature suggests that the compensation measurement of value typically exceeds the WTP value.[59]

Finally, *ex ante* measures of the value of service in Table 2 are generally higher than the *ex post* cost estimates. The estimates in Goett et al[43] are the highest. For example, the cost for a 1-hour winter morning outage is close to $21 per hour unserved. The authors of three studies[36,47,48] show that this outcome can be partially explained by status-quo bias. The *ex ante* value of a partial load curtailment is reported in Keane et al[25] to be $4.5 per hour unserved. After normalizing it by expected unserved energy, the estimate is $1.84 per kWh unserved.

Winter outages impose higher costs on households than summer outages. Early evening outages are most costly followed by afternoon and morning outages. While an increase in outage frequency or duration raises the cost per interruption, the effect on the cost per hour unserved is unclear.‡ Advance warning may reduce costs substantially, up to 40%. For example, the summer afternoon 1-hour direct cost estimate in Doane et al[36] reduces from $5.51 to $4.29 per interruption when advance notice is provided. Also, advance notice decreases the WTP estimate from $1.85 to $1.11 per interruption. On the other hand, Doane et al[47] find little effect of advance notice on outage costs.

Momentary outages impose some small costs on households ranging from $0.18 to $1.88 per interruption. As expected, the *ex ante* costs per hour unserved for total service disruption are generally higher than for partial load curtailment. Few residential studies have attempted to relate outage costs to customer demographics. However, a positive relationship between household income and outage costs is reported in Munasinghe.[55] Doane et al[40] and Doane et al,[47] using contingent valuation data, find that customer demographics account for substantial cost variations. For example, large users with electric appliances for space and water heating and cooking tend to have higher outage costs than small users who do not own these appliances. And, young urban dwellers who own electronic equipment as personal computers, VCR's and security alarm systems value service reliability more than other households not having these types of appliances. Not surprisingly, households in which either a home business is operated, or a family member has health problems, or there is a large family all have higher outage costs.

The results presented in Table 2 agree reasonably well with those presented in Table 2 of Ref. 19 and in Table 2 of Ref. 20.¶ After adjusting for inflation, the similarity becomes more apparent. Most of the *ex post* full outage cost estimates in Table 2 and in Refs. 19 and 20 range from $1 to $6 per kWh unserved. The exceptions are the winter evening 1-hour direct cost estimate of $16.2 per kWh unserved in Doane et al[40] and the (inflation adjusted) 2-minute WTP estimate of $12 per kWh in Table 2 of Ref. 19. The similarity among the WTP estimates is even more striking, clustering around $1 to $2 per kWh unserved for outages lasting more than one hour. Based on this comparison, we conclude an upper bound estimate for total service disruption would be $6 per kWh unserved. This estimate is higher than the estimate of $1.36 to $2.0 per kWh unserved (in 1989 prices) recommended in page 190 of Ref. 19.

Industrial Sector

Table 3 presents industrial outage cost estimates for six studies conducted in Israel, Canada and the United States. Two studies use *ex ante* data and four use *ex post* data. *Ex ante* costs in Bental et al[28] are

---

† The theoretical premise of this approach is that the effect of an unexpected outage is the same as an instantaneous price increase that would completely "choke-off" demand. However, this price increase can only reduce planned consumption to zero but not necessarily the actual demand at the time of an unexpected outage.

‡ In Refs. 31 and 56, for example, the authors indicate that the cost per hour unserved increases with frequency or duration. However, this finding was not supported by Refs. 36, 40, 43 and 48.

¶ Because a majority of the residential studies cited in Fig. 2 of Ref. 21 are the same as those in our paper, we decided not to compare their summary with ours.

approximated by using the cost of owning and operating a backup generator. Also, these authors estimate the marginal cost of unserved energy by dividing the annual cost of owning and operating a 1 kw capacity backup generator by the expected yearly unserved energy. *Ex ante* outage costs in Gilmer et al[32] equal the loss in expected producer surplus caused by a change in service reliability. These authors show that the producer surplus lost due to an outage is the area under a linear electricity demand curve representing a firm's planned consumption at its expected unit cost of electricity. The total *ex ante* costs consist of the expected loss of profit and the cost of adjustment to the change in service reliability.

The four studies using *ex post* costs obtain them from contingent valuation surveys in which direct outage costs are reported. These studies primarily focus on the costs associated with full outages. The statistical techniques used to estimate direct outage costs vary among the studies. Descriptive statistics are used to examine the effects of causal factors on outage costs in Subramaniam et al.[60] Ordinary least squares regression is used by Fisher[61] to relate direct costs to customer characteristics and outage attributes. Woo et al[41] recognize that a sample truncation bias is caused by a large number of zero direct cost responses. They correct for this bias by using a two-step regression model to explain outage cost variations.

Doane et al[48] discovered that the distribution of the direct costs are log-normal with a few observations having very large values. As a result, they use a semi-log cost regression on a data sample that excludes outliers.† In addition to direct costs, Doane et al[48] measure industrial outage costs using data on WTP and WTA responses. However, they discovered that many firms exhibit strategic bias. Strategic bias occurs when WTP values are very small and close to zero while the WTA values are very large. The authors believe that this occurs because firms tend to relate WTP values to the best time an outage may occur such as when their plant is closed. On the other hand, firms associate WTA values to the worst time for an outage to occur such as when they are operating at full capacity. Due to this bias, the authors use direct costs in their outage cost analysis, because these costs are less likely to suffer from strategic bias.

The estimates of industrial outage costs are diverse, ranging from $324 to $1,334,055 per interruption. Even after adjusting for differences in outage duration, large variations still exist in cost per hour unserved estimates. For example, Subramanian et al[60] estimate outage costs ranging from $2,492 to $4,155 per hour unserved for a winter morning outage lasting one hour or more for firms without backup systems. Furthermore, large differences remain after adjusting outage costs by kWh unserved, so neither duration nor kWh unserved can adequately explain the differences in outage cost estimates among studies. For example, industrial *ex post* cost estimates in Fisher[61] range from approximately $8.3 to $26.7 per kWh unserved depending on the products produced and technology employed.

Bental et al[28] estimate *ex ante* outage cost by using backup generators as a proxy. They obtain lower estimates than Gilmer et al[32] who also use *ex ante* costs. The estimates range from $0.31 to $1.68 per kWh unserved depending on the expected number of unserved hours. This result is surprising because an industrial firm would install a backup generator only if it had a high value of service reliability. Thus, the cost of owning and operating a backup generator should reflect the high end of the range of industrial firms' *ex ante* outage costs.

Gilmer et al[28] report *ex ante* costs for an unspecified number of apparel manufacturing firms in the Tennessee Valley Authority service territory. Per interruption outage costs are over $1 million. After normalizing these costs by the amount of expected unserved energy, the per-unit outage costs are approximately $1.66 to $2.05 per kWh unserved. The highest outage cost estimates are those reported in the three contingent valuation studies. These estimates range from approximately $1,200 to $57,000 per interruption or $1,300 to $23,000 per hour unserved for outages lasting one hour or more. Fisher[61] presents normalized cost estimates ranging from $8.3 to $26.7 per kWh unserved. These estimates are substantially higher than the estimates of $1.7 to $7.3 per kWh unserved in Doane et al.[48]

The effects of outage attributes on industrial firms' outage costs are quite different from those for households. An increase in outage duration raises the industrial costs per interruption but at a decreasing rate. Perhaps after the first hour of an outage, additional costs become less significant (e.g. workers are sent home to reduce idle labor costs). Weekday outages occurring in the morning or the mid-afternoon are the most costly while weekend evening outages are the least costly. Seasonality does not appear to affect outage costs significantly. Estimates in Woo et al[41] indicate that outage costs per interruption decline when outages become more frequent. For a given number of unserved hours, industrial firms prefer fewer longer outages to a larger number of shorter outages. For example, the cost estimate for one 4-hour outage in Woo et al[41] is approximately 60% of the total costs of four 1-hour outages. Advance warning reduces outage costs sometimes

---

† An observation is classified as an outlier if its studentized residual is greater than 2.0 so that the likelihood of misclassification is less than 5%. This procedure is presented in Ref. 57.

Table 3. Estimates of the value of service reliability and outage costs in the industrial sector in 1989 U.S. $.

Study/Country	Method/ Cost Type	Season/ Time-of-Day	Frequency	Duration (Hours)	Notice (Hours)	Dollars Per Interruption	Dollars Per Hour Unserved	Dollars Per kWh Unserved
Bental and Ravid (1982)/Israel and USA	Proxy-Cost of Backup Generation/ Ex Ante	Not Studied	Not Studied	70 /a	0	N.A. /b	N.A.	0.31
				10 /c	0	N.A.	N.A.	1.68
Gilmer and Mack (1987)/ Tennessee, USA	Producer Surplus/ Ex Ante	Not Studied	0.1/year	4	0	1,334,056 /d	333,514	1.66 /e
			0.5/year	4	0	1,277,785	319,446	2.05
Subramaniam, Billington, Wacker (1985)/Canada	Cost Survey/ Ex Post	Winter/ Morning				Customers Without Standby System		
			Not Studied	1/60	0	324.3	19,468	N.A.
				1/3	0	2,061	6,182	N.A.
				1	0	4,155	4,155	N.A.
				4	0	9,965	2,492	N.A.
				8	0	25,097	3,137	N.A.
						Customers With Battery Standby System		
			Not Studied	1/60	0	5,259	315,571	N.A.
				1/3	0	11,436	34,307	N.A.
				1	0	17,904	17,904	N.A.
				4	0	38,727	9,682	N.A.
				8	0	57,189	7,148	N.A.
						Customers With Engine Standby System		
			Not Studied	1/60	0	10,874	652,468	N.A.
				1/3	0	14,015	42,045	N.A.
				1	0	22,821	22,821	N.A.
				4	0	39,060	9,764	N.A.
				8	0	56,752	7,094	N.A.
Fisher (1986)/ Massachusetts, USA	Cost Survey/ Ex Post	Summer/ Afternoon				Machinery		
			Not Studied	1/2	0	5,773	11,545	23.89
				1	0	11,380	11,380	22.74
				2	0	15,392	7,695	16.15
				4	0	20,503	5,126	18.83
						Electronic & Electrical Machinery		
			Not Studied	1/2	0	647	1,295	11.88
				1	0	1,375	1,375	9.12
				2	0	2,665	1,332	8.54
				4	0	4,814	1,203	8.33
						Measuring Analysis & Control Instruments		
			Not Studied	1/2	0	5,078	10,155	26.65
				1	0	9,478	9,478	19.11
				2	0	26,953	13,476	25.56
				4	0	37,460	9,364	17.96
						Other Manufacturing		
			Not Studied	1/2	0	9,077	18,155	19.40
				1	0	13,371	13,371	15.78
				2	0	22,565	11,282	15.20
				4	0	37,460	9,364	13.47
Woo and Gray (1987)/ California, USA	Cost Survey/ Ex Post	Summer/ Afternoon	1	1	1	14,450	14,450	57.91
			1	4	1	47,345	11,837	N.A.
			4	1	1	6,578	6,578	N.A.
			4	4	1	21,549	5,388	N.A.
			8	1	1	4,664	4,664	N.A.
			8	4	1	15,278	3,819	N.A.

Table 3. Estimates of the value of service reliability and outage costs in the industrial sector in 1988 U.S. $.

Study/Country	Method/ Cost Type	Season/ Time-of-Day	Frequency	Duration (Hours)	Notice (Hours)	Dollars Per Interruption	Dollars Per Hour Unserved	Dollars Per kWh Unserved
Doane et al. (1988)/ New York, U.S.A. f/	Cost Survey/ Ex Post	Summer/ 8 a.m.	Not Studied	8	0	49,392	6,174	4.41
		Summer/ 2 p.m.	Not Studied	1	0	10,480	10,480	7.29
				8	4	27,267	3,408	2.87
				8	24	17,255	2,157	1.89
		Winter/ 8 a.m.	Not Studied	8	0	62,064	7,758	5.57
		Winter/ 2 p.m.	Not Studied	4	0	20,064	5,016	3.79
				4	1	19,098	4,775	3.81
		Winter/ 8 p.m.	Not Studied	1	0	7,831	7,831	6.49

Notes:
a/ Estimated annual outage duration in Israel in 1980.
b/ N.A. = Not Available
c/ Estimated annual outage duration in the USA for 1980.
d/ Total costs per year for an unspecified number of small apparel manufacturing firms divided by the expected number of outages per year.
e/ Total costs per year divided by the expected unserved energy per year.
f/ Includes all large users with monthly billing demand over 1,000 kW.

Table 4 overleaf

Table 4. Estimates of the value of service reliability and outage costs in the commercial sector in 1989 U.S. $.

Study/Country	Method/ Cost Type	Season/ Time-of-Day	Frequency	Duration (Hours)	Notice (Hours)	Dollars Per Interruption	Dollars Per Hour Unserved	Dollars Per kWh Unserved
Billington, Wacker Subramaniam (1986)/ Canada	Cost Survey/ Ex Post	Winter/ Morning				Customers Without Standby System		
			Not Studied	1/60	0	79.1	4,714	N.A. /a
				1/3	0	334.5	1,002	N.A.
				1	0	828.3	828	N.A.
				4	0	3,036	759	N.A.
				8	0	8,161	1,020	N.A.
						Customers With Battery Standby System		
			Not Studied	1/60	0	16.95	1,050	N.A.
				1/3	0	218.1	654.3	N.A.
				1	0	696	696	N.A.
				4	0	2,941	736	N.A.
				8	0	8,030	1,003	N.A.
						Customers With Engine Standby System		
			Not Studied	1/60	0	2.3	122	N.A.
				1/3	0	853	2,559	N.A.
				1	0	2,189	2,189	N.A.
				4	0	5,862	1,466	N.A.
				8	0	14,309	1,789	N.A.
Fisher (1986)/ Massachusetts, USA	Cost Survey/ Ex Post	Summer/ Afternoon				Wholesale		
			Not Studied	1/2	0	2,112	4,225	6.95
				1	0	6,212	6,210	14.19
				2	0	12,578	6,290	16.30
				4	0	25,515	6,379	19.55
						Retail		
			Not Studied	1/2	0	293	585	15.35
				1	0	777	777	16.80
				2	0	1,216	608	13.11
				4	0	2,420	606	10.23
					0			
						Finance, Insurance & Real Estate		
			Not Studied	1/2	0	6,547	13,096	26.65
				1	0	9,299	9,299	15.92
				2	0	15,499	7,750	16.94
				4	0	27,815	6,954	20.13
						Services		
			Not Studied	1/2	0	9,077	18,155	8.69
				1	0	13,371	13,371	8.69
				2	0	22,565	11,282	9.20
				4	0	37,460	9,364	8.84
Woo and Train (1988)/ California, USA	Cost Survey/ Ex Post	Summer/ Afternoon	1	1	1	4,332	4,332	8.25
			1	4	1	14,118	3,529	N.A.
			4	1	1	2,885	2,885	N.A.
			4	4	1	9,400	2,349	N.A.
			8	1	1	2,495	2,495	N.A.
			8	4	1	8,130	2,032	N.A.

Note:
a/ N.A. = Not Available

substantially as discovered by Doane et al.[48] The cost for an 8-hour outage with 24-hour notice is $17,255 per interruption which equals 63% of the cost of an 8-hour outage with a 4-hour notice.

The more electricity-intensive the production process, the higher the cost per interruption. For instance, Doane et al[48] find that an outage is most damaging to firms with high load factors and greater dependence on such end uses as process heat and electronics. Prior outage experience tends to reduce outage costs as discovered by Fisher[61] and Subramaniam et al.[60] They indicate that large customers with backup systems tend to have higher costs per interruption. However, this finding is not supported by Woo et al[41] and Doane et al.[48,†]

The industrial outage cost estimates reported in Table 3 are generally higher than those reported in Table 3 of Ref. 19 and in Table 3 of Ref. 20. With the exception of the estimate of $58 in Woo et al,[41] the range for most of the cost estimates in Table 3 is $0.24 to $27 per kWh unserved for outages lasting one hour or more. However, Woo et al[41] admit that their estimate is too high partially due to the underestimation of the average industrial unserved energy. In summary, we note that the majority of the estimates in our Table 3 and Table 3 in both Refs. 19 and 20 are less than $10 per kWh unserved.

<u>Commercial Sector</u>

Table 4 presents the empirical results of three contingent valuation surveys in which commercial firms were asked to provide estimates of their *ex post* direct costs incurred as a result of a full outage. Commercial outage costs are extremely diverse as is true for both residential and industrial outage costs. Below we consider some of the factors accounting for the divergence of results. Again, part of the differences in results are due to the various statistical techniques used by the authors. On the other hand, the diverse results cannot be completely attributed to differences in type of cost data collected, because all three studies estimate commercial firms' *ex post* outage costs with direct cost survey response data. On the other hand, we do know that part of the diverse results are due to the attributes of the outages presented in the surveys.

The effects of outage attributes on commercial outage costs resemble those for industrial companies. An increase in duration raises costs per interruption, but at a decreasing rate. Weekday outages occurring during normal business hours are the most damaging, followed by early evening and late evening outages. Summer outages impose slightly higher costs than winter outages. Costs per interruption decline when outages become more frequent. Advance warning does not reduce outage costs significantly. Commercial firms, like industrial firms, prefer fewer but longer outages to more but shorter outages. For example, Woo et al[42] report that the cost of one 4-hour outage is approximately $2,000 less than the sum of the costs of four 1-hour outages.

Large commercial firms employing many workers have a higher cost per interruption than smaller firms with few employees. Financial service companies and food outlets value service reliability more than retail companies and wholesale stores. Firms with no prior outage experience are more likely to report zero cost than firms with outage histories. However, when these inexperienced firms report some outage costs, their estimates are higher than those of the experienced firms. Billinton et al[62] and Fisher[61] suggest that large users with backup systems tend to have higher costs per interruption. This finding is not supported by Woo et al.[42]

The commercial outage cost estimates in Table 4 generally agree with the estimates reported in Table 4 of Ref. 19. They range from $2.3 to $27 per kWh unserved.[‡] It should be noted that most of the estimates are quite large because commercial firms tend to have relatively small usage. Thus, even though the costs per interruption are small, the normalized values are fairly large such as over $10 per kWh unserved.

---

† While backup system ownership indicates a high *ex ante* value of service reliability, the *ex post* costs for firms with backup systems should be lower than firms without backup systems. For example, if the backup systems were sufficiently large, most of the negative effects of an outage on production could have been eliminated.

‡ The exceptions are the estimates for outages less than one hour and those reported by Ref. 63 in Table 2 of Ref. 19.

5. CONCLUSION

In this paper, we have reviewed the general approaches used to estimate customer outage costs and have summarized the empirical results in 16 recent studies. The following findings emerge from our review: (i) The value of service reliability represents the maximum amount a customer is willing to pay for the particular level and type of service provided. As such, it reflects the usefulness and/or necessity of service to the customer. (ii) Unlike other industries (e.g. airlines and telecommunications), the market for reliability in the provision of electricity service is not well established. As a result, there is a limited price history with respect to reliability from which to judge customers' willingness to pay. (iii) Absent a market for reliability, the amount customers are willing to pay for service reliability is often approximated by the opportunity cost of unsupplied electricity. Thus, customer value of service reliability becomes synonymous with customer outage costs. (iv) Outage costs can be evaluated either *ex post* (i.e. after the fact) or *ex ante* (i.e. before the fact). *Ex post* measures refer to the unavoidable costs a household or firm incur as the result of a power outage that occurs with certainty. *Ex ante* outage cost valuations represent the maximum amount a customer is willing to pay for a change in the likelihood of an outage. (v) Major factors known to affect customer outage costs are customer demographics and such outage attributes as frequency, duration, timing, advance warning and severity. Thus, a valid approach should generate outage cost estimates that are sensitive to such causal factors. (vi) A variety of approaches have been used to estimate outage costs. These approaches include simple proxies, market-based methods and contingent valuation surveys. The methods differ in terms of their data requirement, their theoretical rigor, and their ability to develop costs estimates distinguished by season, time-of-day, duration, and advance notice. (vii) An evaluation of the three common approaches indicates that absent good market data on customer choice of service reliability, one may use CVM to quantify outage costs. This recommendation is based on CVM's relative merits in data requirement, computational costs, verifiability of results and sensitivity to important causal factors such as outage attributes and customer demographics. However, the results based on CVM should be verified when suitable data on customer choice of I/C rate options become widely available. (viii) As shown in Tables 2-4, the empirical estimates of outage costs are diverse. This diversity can be explained by differences in the methods used, outage attributes considered, and customer characteristics. Therefore, considerable care must be taken when using outage cost estimates for the purpose of reliability planning and pricing.

Based on the above findings, we conclude that the recent research on estimating customer outage costs have made significant advances, especially in the areas of collecting and analyzing survey data. However, there is a number of important questions that remain unanswered. (i) What causes WTP and WTA values to differ substantially? Is it status-quo bias? (ii) How and when can survey results be validated by market data? (iii) Should we estimate costs for deterioration in other service attributes such as voltage? (iv) Should partial outage costs deserve more attention because they are important inputs to generation reliability planning? (v) Can outage cost data be used in an integrated framework for efficient pricing of and planning for reliability differentiated services? Ongoing and future research will hopefully provide answers to these questions which would result in a more efficient use of limited resources used in the production and distribution of electricity service.[†]

REFERENCES

1. M.L. Telson, Bell Journal of Economics 6, 679 (1975).
2. H.P. Chao, *Bell Journal of Economics* 14, 179 (1983).
3. G.C. Hall, M.T. Healy and W.B. Poland, "PG&E's New Methodology for Value-Based Generation Reliability Planning," Pacific Gas and Electric Company's Presentation to System Planning Committee, Edison Electric Institute, Minneapolis (1986).
4. W.B. Poland, *Electricity Reliability - Special Issue, Energy Journal* 9, 19 (1988).
5. W. Stephenson and W.C. Walters "Measurement of Residential Outage Cost for Reliability Planning," Pacific Gas and Electric Company's Presentation to Fourteenth Inter-Ram Conference for the Electric Power Industry, Toronto (1987).
6. H. Khatib, *Economics of Reliability in Electrical Power Systems*, Technicopy Limited (1978).
7. M. Munasinghe, *The Economics of Power System Reliability and Planning*, Johns Hopkins (1979).
8. C.K. Woo, *Resources and Energy* 10, 277 (1988).

[†] For example, Niagara Mohawk Power Corporation (NMPC) continues to investigate the effect of status-quo bias on customer participation in an I/C rate program. The Electric Power Research Institute and NMPC have jointly funded a study on the development of the integrated approach to reliability pricing using outage cost survey data and a demand model structure identified using real time pricing data. Initial results indicate that outage cost survey data can be used to parameterize the hourly electricity demand model for predicting customer response to alternative pricing schemes (e.g., priority service, proportional rationing and real time pricing). The response predictions are then used for evaluating the relative economic efficiency of the pricing schemes.

9. H.P. Chao and R. Wilson, *American Economic Review* 77, 899 (1987).
10. R. Wilson, *Econometrica* 57, 1 (1989).
11. C.K. Woo and N. Toyama, *Energy Journal* 7, 123 (1986).
12. H.P. Chao, S.S. Oren, S.A. Smith and R.B. Wilson, *Energy Economics* **October**, 199 (1986).
13. C.K. Woo, *Journal of Regulatory Economics* 2, 69 (1990).
14. D.F. Spulber, "Optimal Rationing and Contingent Contracts," Working Paper, Kellog School of Management, Northwestern University (1990).
15. C.K. Woo, *Energy Journal* 12, 152 (1991).
16. Ebasco, Innovative Rate Design Survey, Report EM-5705, Electric Power Research Institute (1986).
17. M. Munasinghe and M. Gellerson, *Bell Journal of Economics* 10, 353 (1979).
18. R.E. Bohn, M.C. Caramanis and Fred Schweppe, *Rand Journal of Economics* 15, 360 (1984).
19. A.P. Sanghvi, *Energy Economics* **July**, 180 (1982).
20. R. Andersson and L. Taylor, *Energy Economics* **July**, 139 (1986).
21. D.W. Caves, J.A. Herriges and R.J. Windle, *Bulletin of Economic Research* 42, 79 (1990).
22. M.J. Doane and C.K. Woo, An Econometric Analysis of Customer Subscription toCurtailable/Interruptible Rate Options, Report submitted to Pacific Gas and Electric Company (1988).
23. L.J. Helms, *International Economic Review* 26, 603 (1985).
24. R.S. Hartman and C.K. Woo, "The Value of Service Reliability, Alternative Welfare Measurement," Working Paper #167, Economics Department, Boston University (1988).
25. D. Keane, L. MacDonald and C.K. Woo, *Electricity Reliability - Special Issue. Energy Journal* 9, 151 (1988).
26. M. Webb, *Applied Economics* 9, 19 (1977).
27. H.J. Sheppard, "The Economic Cost of A Hypothetical Electric Power Shortage," B.C. Hydro, August (1967).
28. B. Bental and S.A.Ravid, *Bell Journal of Economics* 13, 249 (1982).
29. W.B. Shew, *Energy Systems and Policy* 2, 85 (1977).
30. G.S. Tolley, C.W. Upton and H.V. Stevens, Electric Energy Availability and Regional Growth, Ballinger Publishing Company, Cambridge, Massachusetts (1977).
31. A.P. Sanghvi, *Energy Journal* 4, 33 (1983).
32. R.W. Gilmer and R.S. Mack, *Energy Journal* 7, 89 (1986).
33. R.D. Willig, *American Economic Review* 66, 589 (1976).
34. J.A. Hausman, *American Economic Review* 71, 662 (1981).
35. M. Munasinghe, C.K. Woo and H.P. Chao (Editors), Electricity Reliability - Special Issue. Energy Journal 9 (1988).
36. M.J. Doane, R.S. Hartman and C.K. Woo. *Electricity Reliability - Special Issue. Energy Journal* 9, 121 (1988).
37. R.S. Hartman, M.J. Doane and C.K. Woo, *Resources and Energy* 12, 197 (1990).
38. R.S. Hartman, M.J. Doane and C.K. Woo, *Quarterly Journal of Economics* **February**, 141 (1990).
39. R.G. Cummings, D.S. Brookshire and W.D. Schulze, Valuing Environmental Goods: An Assessment of the Contingent Valuation Method, Rowan & Allanheld, New Jersey (1986).
40. M.J. Doane, R.S. Hartman and C.K. Woo, *Electricity Reliability - Special Issue. Energy Journal* 9, 135 (1988).
41. C.K. Woo and B.M. Gray, "An Econometric Analysis of Industrial Firms' Power Outage Costs in Northern California," Working Paper, Pacific Gas and Electric Company (1987).
42. C.K. Woo and K. Train, *Electricity Reliability - Special Issue. Energy Journal* 9, 161 (1988).
43. A.A. Goett, D. McFadden and C.K. Woo, *Electricity Reliability - Special Issue. Energy Journal* 9, 105 (1988).
44. E.R. Berndt and D.O. Wood, *American Economic Review* 69, 342 (1979).
45. C.K. Woo, *Energy Journal* 6, 115 (1985).
46. D. Caves and B. Neenan, "Real-Time Pricing, Will It Work?" Selected for Competitive Papers Session, 1990 Southeastern Regional Public Utilities Conference, Public Utilities Reports, Inc. (1990).
47. M.J. Doane, G. McClelland, W. Schulze and C.K. Woo, Residential Outage Cost Survey, Research Report submitted to Niagara Mohawk Power Corporation (1990)
48. M.J. Doane, G. McClelland, W. Schulze and C.K. Woo, Industrial Outage Cost Survey, Research Report submitted to Niagara Mohawk Power Corporation (1990).
49. J.P. Tobin, *Econometrica* 26, 24 (1858).
50. G.S. Maddala, Limited and Qualitative Dependent Variables in Econometrics, Cambridge (1983).
51. J. Heckman, *Econometrica* 47, 153 (1979).
52. D.L. Coursey, J.J. Hovis and W.D. Schulze, *Quarterly Journal of Economics* 102, 679 (1987).
53. D. Kahneman and A. Tversky, *Econometrica* 47, 263 (1979).
54. M. Bernstein and Y. Hegazy, *Electricity Reliability - Special Issue. Energy Journal* 9, 173 (1988).
55. M. Munasinghe, *Journal of Consumer Research* 6, 361 (1980).

56. G. Wacker, E. Wojczynski and R. Billinton, "Interruption Cost Methodology and Results - A Canadian Residential Survey," Power System Research Group, University of Saskatchewan, Saskatchewan, Canada (1983).
57. D.A. Belsley, E. Kuh and R.E. Welsch, Regression Diagnostics, John Wiley (1980).
58. W.G. Cochran, Sampling Techniques, John Wiley (1977).
59. J.L. Knetsch and J.A. Sinden, *Quarterly Journal of Economics* **99**, 507 (1984).
60. R.K. Subramaniam, R. Billinton and G. Wacker, "Factors Affecting the Development of an Industrial Customer Damage Function," Presented at IEEE/PS Summer Meeting, Vancouver (1985).
61. M.D. Fisher, "The Cost of Electrical Supply Interruptions," The Value of Service Reliability to Consumers, Report EA-4494, Electric Power Research Institute (1986).
62. R. Billinton, G. Wacker and R.K. Subramaniam, *IEEE Transactions on Power Systems, PWRS-1* **4**, 28 (1986).
63. A.D. Patton and C.R. Heising Cost of Electrical Interruptions in Commercial Buildings, IEEE Power System Subcommittee Report (1975).

CONSUMER RATIONALITY AND THE STATUS QUO*

RAYMOND S. HARTMAN
MICHAEL J. DOANE
CHI-KEUNG WOO

Received microeconomic theory presumes rational consumers maximize utility over all commodity bundles. Recent analysis, however, suggests that a consumer's status quo may limit economic rationality, "bias" consumer decisions, and induce serious errors in survey-based valuations of public and private goods. Using regression and choice-theoretic frameworks, we investigate the existence of status quo effects in the consumer valuation of a particular unpriced product—the reliability of residential electrical service. Such valuations have become important in electric utility resource planning and rate making. We find substantial status quo effects, which must be addressed in welfare comparisons regarding electric service reliability.

INTRODUCTION AND OVERVIEW

While the received theory presumes that consumers maximize utility over *all* possible commodity bundles, recent empirical analysis suggests that a consumer's status quo may be important in limiting economic rationality. This analysis suggests, for example, that consumers attach "undue" importance to their current commodity bundle, demonstrating "apparently irrational" reluctance to switch to alternative bundles. Likewise, as consumers evaluate alternatives, they are found to asymmetrically value the losses and gains derived from changing their status quo.

The work of Kahneman and Tversky [1979][1] formalizes the importance of this status quo effect. Using the standard expected utility maximization paradigm, they demonstrate a variety of consumer decisions that appear inconsistent if the importance of the status quo is ignored. For example, they observe and postulate a "certainty effect;" that is, people "overweight" certain outcomes relative to probable outcomes. They also observe and postulate a "reflection effect;" that is, individuals evaluate marginal gains and losses asymmetrically. Based on these and other observations, they formulate "Prospect Theory" to describe decision making under

*The empirical work reported in this paper was funded by the Pacific Gas and Electric Company (PG&E). The views expressed are those of the authors and do not necessarily represent the opinions of PG&E. The authors gratefully acknowledge the comments of William Schulze and the research assistance of Renee Rushnawitz.

1. And others, as summarized in Machina [1987].

The Quarterly Journal of Economics, February 1991

uncertainty. Their theory exploits a "value" function, rather than a utility function. This value function is centered at the status quo (the "reference point"); it is defined over deviations from the status quo; it is kinked at the status quo, being concave for gains and convex for losses; and it is steeper for losses than for gains. As a result, the value function exhibits risk-averting behavior in choices involving sure gains and risk-seeking behavior in choices involving sure losses.[2]

Contingent valuation studies used to value public goods have confirmed the presence of a status quo effect. The effect has appeared in the form of asymmetric valuations of losses and gains from the status quo. While traditional theory suggests that individuals will reveal nearly equal willingness-to-pay (*WTP*) and willingness-to-accept (*WTA*) measures of value [Willig, 1976], experimental and survey results have produced quite disparate *WTA* and *WTP* measures [Bishop and Heberlein, 1979; Brookshire and Coursey, 1987; Cummings, Brookshire, and Schulze, 1986; Knetsch and Sinden, 1984; Rowe, d'Arge, and Brookshire, 1980]. In many cases, the *WTA* measures of value have exceeded *WTP* measures by an order of magnitude of three-to-one, suggesting that individuals underperceive the value of the public good or overperceive the value of the financial loss required to pay for it.

An interesting experimental extension of these survey results is found in the work of Coursey, Hovis, and Schulze [1987]. They note that in many contingent valuation surveys for public goods, *WTA* and *WTP* measures are elicited from respondents for hypothetical, potentially unfamiliar commodities. The authors conjecture that the observed three-to-one disparity between *WTA* and *WTP* measures may therefore not reflect preferences. Rather, they hypothesize that it may be due to the essential novelty and one-time nature of the choices presented to survey respondents.

To test this hypothesis, the authors develop a *repeated* bidding experiment that allows for the respondents to learn about an unfamiliar good. They find that *initial WTA* valuations are orders of magnitude (three-to-one) greater than *WTP* measures, corroborating other experiments. However, in the series of *repeated* bidding experiments, the respondents' *WTA* measures are found to decline and converge to their *WTP* measures. Such results suggest

2. The possibility of differential risk-seeking and risk-averting behavior at different levels of wealth had been recognized previously by Friedman and Savage [1948].

that *WTA* and *WTP* measures may be approximately equal when valuing *familiar* goods and services.[3]

If such status quo effects occur, they have important implications for policy makers. For example, when contingent valuation methods are used to value public goods, the survey research must explicitly recognize the potential disparity that may arise between *WTA* and *WTP* measures. Likewise, when predictions of the market acceptance of new products or programs are required, policy makers must explicitly account for the inertia that may be engendered by a status quo effect.

The purpose of this paper is to empirically investigate the existence of a status quo effect in consumer valuations of a particular unpriced product, the reliability of residential electricity service. The notion of valuing electrical service reliability and pricing the product accordingly has recently assumed importance in utility resource planning, capacity expansion, and rate making.[4]

We base our analysis on the results of a contingent valuation survey of residential customers in the Pacific Gas and Electric Company (PG&E) service territory. In the survey each customer was asked to provide *WTA* and *WTP* measures of value for service reliability, where reliability was described by the presence or absence of service disruptions (i.e., power outages) with varying attributes (e.g., season, time-of-day, duration, and the extent of advance notice). The *WTP* measure represents the dollar amount customers would be willing to pay to avoid an additional service disruption; the *WTA* measure represents the dollar amount they would be willing to accept to incur an additional disruption. In addition to these standard contingent valuation questions, each customer was presented with a menu of six alternative rate options designed to reflect varying levels of service reliability. One option characterized the reliability experience and current service contract of the customer, i.e., his/her status quo. The other five contracts offered options with varying bill discounts and altered levels of service reliability. From this menu the customer was asked to identify his/her preferred option.

Using these data, we investigate the presence of a status quo effect in two ways. First, we estimate and compare respondents' *WTA* and *WTP* measures for several levels of service reliability.

3. Brookshire and Coursey [1987] corroborate these results.
4. See Chao and Wilson [1987]; Doane, Hartman, and Woo [1988a, 1988b]; Munasinghe [1979]; Munasinghe and Gellerson [1979].

Second, we examine and analyze respondents choices among the reliability levels offered by the six alternative rate options, one of which is the status quo. Using a choice-theoretic framework, we quantify the determinants of these choices and calculate the compensating variations required to make customers indifferent between particular options. These analytic methods and the data are discussed in Section I. The estimated models are presented in Section II.

Section III discusses our conclusions. To summarize them, we consistently find a substantial status quo effect. The *WTA* and *WTP* estimates for our sample customers differ by an order of magnitude of four to one, larger than would be expected from any reasonable income effects. These results corroborate the growing contingent valuation literature on consumer "irrationality" and the importance of the status quo [Brookshire and Coursey, 1987; Coursey, Hovis, and Schulze, 1987; Machina, 1987; Kahneman and Tversky, 1979; Samuelson and Zeckhauser, 1986). More importantly, the status quo effect is substantiated by the analysis of customer choice among reliability-differentiated service contracts. In fact, the status quo effect implied by the choice-theoretic model is even more severe. In particular, the compensation required for reliability changes is considerably higher than the *WTA* and *WTP* measures obtained from the contingent valuation analysis.

I. The Analysis

A. Analytic Framework

Figure I presents a standard indifference curve reflecting consumer trade-offs between service reliability (measured as decreased outage hours) and all other goods and services (measured as income, net of electricity expenditures). We assume that the income effect of our marginal reliability changes is small.[5] A customer is assumed to have an initial service contract (a_1-characterized by monthly bill and number of outage hours) reflecting his/her status quo. The actual service contracts are more complicated, as described later. Along I_1, the willingness to accept (WTA_1) a marginal decrease in reliability (by one outage hour) is approximately equal to the willingness to pay (WTP_1) for a marginal increase in reliability (by one outage hour). The slope of I_1 at a_1 is d, reflecting the relative price (or value) of reliability. If b_1 and c_1 represent alternative service contracts (alternative reliability levels and alternative monthly bills), only slight changes in the price of reliability (slope d) will be required to stimulate the customer to switch from the status quo to an alternative reliability regime (b_1 or c_1).

5. For our sample, electricity expenditure represents a small portion of a household's annual budget, approximately 1.3 percent ($400/$30,000).

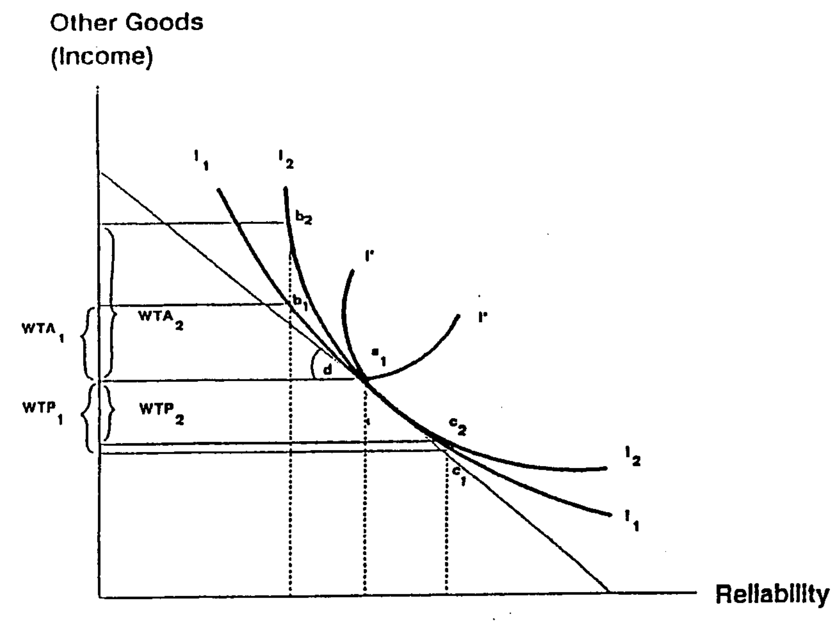


FIGURE I
Trade-offs Between Service Reliability and All Other Goods

However, if, in the spirit of Kahneman and Tversky, the indifference curve is kinked at the status quo, I_2 obtains. In that case, the willingness to accept a one-unit decrease in reliability along I_2 (WTA_2) is substantially larger than the willingness to pay for a unit of increased reliability (WTP_2). At the same time the change in the price (value) of reliability (slope d) required to induce the customer to switch from reliability regime a_1 to either b_2 or c_2 is now much greater or much less (respectively) than along I_1.

The hypothesized kink in utility at a_1 would explain the puzzling disparity frequently observed between *WTA* and *WTP* valuations. Using a variety of analytic methods, our empirical work examines whether such a kink does indeed exist. If preferences are indeed kinked at the status quo, we should expect that *all of our methods* would consistently identify that kink.

B. Analytic Methods

A standard contingent valuation survey was used to obtain *WTA* and *WTP* measures of the value of service reliability. The survey questionnaire was mailed to a stratified random sample of 2,200 residential customers in the Pacific Gas and Electric Company (PG&E) service area. Table I presents the sample means of customer and demographic characteristics for the approximately 1,500 survey responses. The survey was stratified by geographical location to allow adequate urban-rural and climate zone variation. A high response rate (approximately 70 percent), a subsequent nonrespondent telephone survey, and a comparison of the customer demographic data with other PG&E surveys indicated that the survey data are representative. See Doane, Hartman, and Woo [1988a, 1988b].

The survey characterized the status quo (a_1) and the socioeconomic attributes of the respondents. The customers were asked to state the dollar amount they would be willing to pay (*WTP*) to avoid a service outage as well as the amount by which they must be compensated to be willing to accept (*WTA*) the outage. *WTA* and *WTP* measures were obtained for the nine outage scenarios described in Table II. Table II also summarizes the mean, median, and truncation at zero for the *WTA* and *WTP* responses. The mean is computed for customer-reported responses below the 99.5 percentile, in order to remove atypical highly influential customer responses that seem to be outliers (e.g., households that reported identical cost estimates for each of the different scenarios while not completing the rest of the survey). Our treatment of these outliers is discussed further below.

To ensure reliable *WTA* estimates, respondents were asked to identify the actions normally taken to mitigate the effect of an outage and to consider the cost of such actions when estimating their *WTA*. To facilitate this process, a list of mitigating factors was provided and included such actions as the use of candles for light, eating out, the use of a backup generator, etc. We assume that consumers would be willing to accept an amount covering these costs.

To estimate *WTP*, each respondent was asked to state the amount he or she would be willing to pay for backup generator service. This backup service was described as one that would handle all of his/her electrical needs during the outage.

TABLE I
SAMPLE MEAN OF CUSTOMER CHARACTERISTICS

Variable	N^a	Mean	Standard deviation
Income	1,281	$33,793	$14,141
Household size (persons)	1,494	2.71	1.01
Average age (years)	1,488	41.7	11.7
Number of household members 65 years or older	1,488	0.37	0.48
Average monthly electricity sales in winter (kwh)	1,501	511	262
Average monthly electricity sales in summer (kwh)	1,501	495	266
Rural	1,460	0.03	0.12
Bay area	1,501	0.71	0.32
Large city	1,460	0.32	0.33
Electric appliance owsnership:			
Space heater	1,435	0.19	0.28
Water heater	1,470	0.17	0.26
Central air conditioner	1,509	0.23	0.30
Window air conditioner	1,432	0.15	0.25
Range	1,474	0.64	0.34
Security alarm	1,427	0.11	0.22
Personal computer	1,433	0.16	0.26
Video cassette recorder	1,430	0.55	0.35
Home business	1,451	0.10	0.21
Health problem	1,449	0.07	0.18
Number of household members generally at home during the day	1,445	1.29	0.81
Number of outages experienced during last twelve months	1,408	2.89	3.02

a. N = Number of observations.

As discussed in Schulze, d'Arge, and Brookshire [1981] and in Freeman [1982], our *WTA* and *WTP* measures may be subjected to strategic response bias. However, previous work has found such biases to be small (see Mitchell and Carson [1981], Rowe, d'Arge, and Brookshire [1980], Scherr and Babb [1975], and Smith, [1979]).

Once the *WTA* and *WTP* estimates were obtained, the custom-

TABLE II

WTA AND WTP MEASURES OF VALUE: CONTINGENT VALUATION SURVEY RESULTS

Scenario	Season	Time of-day	Duration	Notice	Willingness to accept (WTA) Mean	Median	% 0	Tobit	Willingness to pay (WTP) Mean	Median	% 0	Tobit
1	Winter	Evening	1 hour	none	10.75	5.00	24	10.96	2.95	1.00	43	3.13
2	Winter	Evening	4 hours	none	19.91	10.00	14	19.57	4.78	2.00	33	4.76
3	Winter	Morning	4 hours	none	12.08	3.00	37	9.22	2.99	0.14	45	3.01
4	Winter	Morning	12 hours	none	40.55	20.00	9	33.15	9.04	5.00	30	8.99
5	Summer	Afternoon	1 hour	none	3.66	0.00	61	3.63	1.64	0.00	63	1.51
6	Summer	Afternoon	4 hours	none	13.59	5.00	36	11.78	3.60	0.00	49	3.30
7	Summer	Afternoon	12 hours	none	38.03	20.00	9	37.56	8.70	5.00	32	8.52
8	Any	Any	Momentary[a]	none	1.66	0.00	69	1.44	0.16	0.00	69	0.15
9	Summer	Afternoon	1 hour	yes	2.79	0.00	64	3.01	0.98	0.00	68	1.01

a. Less than five seconds.

ers were stratified into two groups on the basis of their current service reliability. One group had experienced, on average, approximately three outages of two-hours' duration per year, while the second group had experienced approximately fifteen outages of four-hours' duration per year. The group with three outages accounted for approximately 90 percent of the sample.

The customers in each group were then presented with a menu of six rate options designed to reflect alternative reliability levels *as well as* their existing service reliability (i.e., status quo). The reliability contracts for the two groups of customers are presented in Table III. For each group the options were configured around the status quo reliability to represent realistic service alternatives. Each customer was asked to rank the options in order of desirability.

This part of the questionnaire was also carefully designed to avoid strategic response bias. In particular, respondents were reminded that the reliability provided by PG&E helps to determine the cost of electrical service. They were told that while PG&E cannot prevent all causes of power outages, it could spend more

TABLE III

SERVICE RELIABILITY RATE OPTIONS

Option	Frequency (outages/yr)	Average duration	Change in current bill	Percent of sample choosing[a]
A. For Households with Existing Reliability Characterized by Approximately Three Outages per Year				
1	3	2 hrs	*Status quo*	60.2 percent
2	2	1 hrs	+ 5 percent	13.6 percent
3	5	2 hrs	− 5 percent	12.0 percent
4	5	4 hrs	−10 percent	4.9 percent
5	15	2 hrs	−20 percent	3.6 percent
6	15	4 hrs	−30 percent	5.7 percent
B. For Households with Existing Reliability Characterized by Approximately Fifteen Outages per Year				
1	15	4 hrs	*Status quo*	58.3 percent
2	20	4 hrs	−10 percent	15.1 percent
3	15	2 hrs	+10 percent	12.7 percent
4	5	4 hrs	+20 percent	4.7 percent
5	5	2 hrs	+25 percent	3.4 percent
6	3	2 hrs	+30 percent	5.8 percent

a. Percent of sample choosing the specific rate option as most preferred.

money to improve service, which could increase rates, or it could reduce reliability and possibly reduce rates. Therefore, information on their reliability preferences for different levels of service would be used to help plan future service. The rate options presented in Table III were listed in different orders to different respondents.

We analyze these data in two ways. First, we examine the *WTA* and *WTP* estimates for each outage scenario, focusing on sample means and distributions. We find that the average *WTA* is substantially higher than the *WTP* for each scenario, supporting the hypothesized kink at the status quo (a_1 in Figure I).

Because we also find that a substantial number of survey responses for *WTP* and *WTA* are truncated at zero (see Table II), we also perform a two-stage Tobit analysis to eliminate any truncation bias that might affect these estimates. According to the Tobit model, if the V_i (individual i's value of service reliability) are truncated in the sample at zero, then for any random individual i,

$$(1)\qquad E(V_i) = \text{prob}(V_i > 0)*E(V_i|V_i > 0) + \text{prob}(V_i = 0)*0 = \text{prob}(V_i > 0)*E(V_i|V_i > 0).$$

In the first stage of our Tobit correction, we analyze the probability that an individual's valué of service reliability is positive (prob($V_i > 0$)) using a binary probit specification. In the second stage we utilize the estimated probit as the truncation-bias correction term (in the form of inverse mills ratios) in regressions ($E(V_i|V_i > 0)$) relating *WTP* and *WTA* measures to customer's demographic characteristics, his/her current reliability regime, and all attributes of the service. Because this method is fairly standard, we do not develop it here.[6]

6. For details see Doane, Hartman, and Woo [1988b]. See also Heckman [1979], Tobin [1958], and Cameron and James [1987], who have recently exploited a similar framework in analyzing truncated data generated by a "closed-end" contingent valuation of consumer willingness to pay for a recreational fishing day.

We expected that the truncation at zero would produce skewed distributions for all *WTA* and *WTP* responses, and the distributions for some outage scenarios are quite skewed. For example, 69 percent of the respondents had $WTA = 0$ for a momentary outage (Scenario 8), while the mean *WTA* for the scenario was \$1.66. Thus, respondents with positive *WTA* for this scenario had *WTA* measures several times the mean.

Because we carefully designed the survey instrument to reflect real valuations and because we have excluded large positive outliers, we believe that the remaining skewness is accurate. In order to assess the effect of our exclusion of the large positive outliers, we tested a second Tobit formulation for the imposed truncation from above. The resulting double truncation correction did not change the *WTA* and *WTP* regressions. These results are available from the authors upon request.

Notice that the potential effect of these outliers is limited to the Tobit regression results reported in Table II.

The "Tobit-corrected" *WTP* and *WTA* valuations corroborate the patterns found in the sample means. All *WTP* and *WTA* valuations are summarized in Table II.

As a second, more explicit test of the presence of a status quo effect, we use a probabilistic-choice model to quantify the customer preferences depicted in Figure I. We estimate the choice model using the data on customer selection of the rate options presented in Table III. Each rate option in the table offers a distinct level of service reliability characterized by the number of outages expected annually and their expected duration (denoted as Frequency (F) and Duration (D)). The associated electric bill for each rate option is denoted by Cost (C), which is measured in Table III *relative* to the status quo bill. Customers therefore have the opportunity to purchase lower reliability at reduced electricity prices (a lower bill) or greater reliability at higher prices (an increased bill). The resulting changes in the electric bill (i.e., changes in income, net of electricity charges) are assumed to summarize demand for other goods and services.

Our choice-theoretic framework follows standard lines. An individual selects his/her most preferred rate option j to maximize random utility. Representative utility is assumed to be determined by the service reliability offered with each contract, in addition to all other goods and services (measured by changes in the electric bill). In order to focus on the shape of I_2 *around* the status quo a_1 in Figure I, we "frame" representative customer utility of alternative rate option j (with attributes F_j, D_j, C_j) *relative* to the status quo (the customer's existing level of service reliability: F_0, D_0, and C_0) as

$$(2)\qquad \overline{U}_j = \overline{U}(F_j, D_j, (C_j/C_0), Z) + d_0 * ALT_0.$$

Thus, the cost effect is measured relative to the status quo monthly bill (C_0). We also include ALT_0 as an alternative-specific (or mode-specific) dummy variable denoting the status quo service option ($ALT_0 = 1$ when the alternative contract reflects the customer's current reliability regime; 0 otherwise). This mode-specific dummy allows us to test the hypothesis that there exists a status quo (SQ) effect using a simple t-test (H_0: $SQ = 0$ if $d_0 = 0$). The vector Z summarizes customer attributes.

Using (2), representative utility derived at the status quo is

$$(3a)\qquad \overline{U}_{i0} = \overline{U}_{i0}(F_0, D_0, (C_0/C_0), Z_i) + d_0 * ALT_0,$$

while the utility for any alternative reliability contract j is

$$(3b)\qquad \overline{U}_{ij} = \overline{U}_{ij}(F_j, D_j, (C_j/C_0), Z_i).$$

Because we have no strong priors on the shape of utility, we tested a full second-order approximation in F, D, C/C_0, and Z using a logit framework. As indicated by the reported estimates in Table V, we found that we could not reject the following simplified specification of utility for reliability option $j = 0, \ldots, J$:

$$(4) \quad \overline{U}_{ij} = d_1{*}F_j + d_2{*}D_j + d_3{*}(C_j/C_0) + d_4{*}(C_j/C_0){*}Z_i + d_0{*}ALT_0.$$

Using our estimates of (4), we derive the compensating variation required for changes in reliability from the status quo as follows. We seek the compensation necessary to make a customer indifferent between the status quo $\{F_0,D_0,C_0\}$ and the alternative reliability offered by rate option j $\{F_j,D_j,C_j\}$; in other words, the compensation required for $\overline{U}_{ij} = \overline{U}_{i0}$.[7] We derive that compensation as follows:

$$d_1{*}F_j + d_2{*}D_j + d_3{*}(C_j/C_0) + d_4{*}(C_j/C_0){*}Z_i$$
$$= d_1{*}F_0 + d_2{*}D_0 + d_3{*}(C_0/C_0) + d_4{*}(C_0/C_0){*}Z_i + d_0{*}ALT_0.$$

Hence,

$$(5) \quad \frac{C_j - C_0}{C_0} = (-1){*}\frac{d_1{*}(F_j - F_0) + d_2{*}(D_j - D_0) - d_0{*}ALT_0}{d_3 + d_4{*}Z_i},$$

where $(C_j - C_0)/C_0$ is the proportional change in the customer's bill required to compensate him for altered service reliability $(F_j - F_0)$ and $(D_j - D_0)$. The total compensation required is therefore

$$(6) \quad TC = (C_j - C_0)$$
$$= (-C_0){*}\{d_1{*}(F_j - F_0) + d_2{*}(D_j - D_0)$$
$$- d_0{*}ALT_0\}/\{d_3 + d_4{*}Z_i\}.$$

Returning to Figure I, TC measures the compensating variation required to maintain a customer's initial level of utility for reliability changes from the status quo a_1, to alternative regimes reflecting decreased reliability b_2, or increased reliability c_2. For increased reliability the implied compensation will be negative, reflecting a willingness to pay. It should be noticed that given the interactive terms (d_4), compensation measures will be heterogeneous in the population.

7. This development is equivalent to the derivation of compensating variation for quality changes in Small and Rosen [1981].

II. Empirical Results

Table II indicates that the reported *WTA* measures are uniformly three to four times larger than the *WTP* measures for all outage scenarios.[8] While the sample truncation evident in the table argues for the two-stage Tobit correction, the "corrected" Tobit measures[9] are quite similar to the sample means for all outage scenarios except 3 and 4. For all scenarios the Tobit results corroborate the three-to-four time differential between *WTA* and *WTP* measures. Both sets of results confirm the kink in household preferences in a_1 in Figure I.

Before turning to estimates of our choice model, it is interesting to note in Table III the percentage of survey respondents in each group that selected the alternative options as their most preferred choice. While there was little difference in the demographic characteristics between the two groups of households, we find that *both* groups express a strong preference for their *quite different* status quos. Approximately 60 percent of the respondents in *each* group prefer the status quo. Approximately 85 percent of the respondents in *each* group prefer the set of reliability regimes around the status quo, again in spite of the fact that the reliability levels for these sets of regimes are quite different. The average characteristics of the two respondent groups are presented in Table IV. The groups are quite similar, except for fairly minor differences in income, monthly electricity consumption (due to greater electric space heating and cooling), and rural location. As discussed below, none of these differences had a statistically significant effect upon the choice of reliability contract.

Turning to our choice model estimates, Table V reflects the preferences for the status quo. The mode-specific status quo variable (ALT_0) is consistently the most statistically significant determinant of reliability contract choice, indicating that residential customers do attach a substantial premium to their existing service level, ceteris paribus, and that they have a strong aversion toward alternative reliability options, no matter how desirable they may be based upon attributes (F and D) and cost (C). Alternative specific dummy variables for the other options proved insignificant.

8. Some of this difference may reflect a rational distinction. For example, customers may believe that backup service for which they are willing to pay may not be a perfect substitute for regular service.
9. The full set of Tobit regressions for *WTP* and *WTA* are described fully in Doane, Hartman, and Woo [1988b].

TABLE IV
SAMPLE MEAN OF CUSTOMER CHARACTERISTICS FOR THE TWO GROUPS OF RESPONDENTS

Variable	Respondents experiencing approximately three outages N^a	three outages Mean	fifteen outages N^a	fifteen outages Mean
Income	1,121	$33,301	134	$41,165
Household size (persons)	1,300	2.71	156	2.80
Average age (years)	1,299	41.7	153	39.6
Number of household members 65 years or older	1,299	0.37	153	0.27
Average monthly electricity sales in winter (kwh)	1,306	489	156	715
Average monthly electricity sales in summer (kwh)	1,306	474	156	692
Rural	1,271	0.03	157	0.09
Bay area	1,306	0.72	156	0.61
Large city	1,271	0.33	157	0.23
Electric appliance ownership:				
Space heater	1,249	0.18	152	0.29
Water heater	1,276	0.15	157	0.33
Central air conditioner	1,311	0.22	159	0.33
Window air conditioner	1,248	0.14	152	0.21
Range	1,279	0.63	157	0.76
Security alarm	1,244	0.11	151	0.19
Personal computer	1,248	0.16	152	0.17
Video cassette recorder	1,247	0.54	151	0.68
Home business	1,265	0.10	151	0.15
Health problem	1,266	0.07	149	0.09
Number of household members generally at home during the day	1,262	1.28	153	1.29
Number of outages experienced during last twelve months	1,255	2.17	133	10.9

a. N = Number of observations.

This predisposition for the status quo may result from familiarity and satisfaction with the current level of service; a belief that the utility will not be able to provide the actual level of service offered by the new rate options, habit, or inertia.

TABLE V
CONDITIONAL LOGIT ESTIMATION FOR SERVICE RELIABILITY CHOICE

	Model 1	Model 2
Observations	853	853
Log-likelihood	−1,118.3	−1,104.4
Log-l(slopes = 0)	−1,528.4	−1,528.4
Chi-squared	820.1	845.9
FREQUENCY	−0.47306	−0.3292
	(−5.36)	(−3.49)
DURATION	−1.19874	−0.8290
	(−5.97)	(−3.96)
COST	−25.92580	−22.4183
	(−5.97)	(−4.39)
ALT_0	1.90240	1.7161
	(23.48)	(19.96)
COST*AVGOUT		6.2552
		(4.73)

Note. t-statistics for H_0: $d = 0$ are in parentheses.
FREQUENCY = Number of outages per year.
DURATION = Duration of outage in hours.
COST = Bill discount of alternative reliability contracts relative to the status quo (equal to the monthl electricity bill of the alternative contract divided by the status quo monthly electricity bill: C_i/C_0).
ALT_0 = Alternative-specific dummy variable denoting the customer's status quo service reliability. ALT_0 = 1 when the alternative reliability contract is the status quo; zero otherwise.
AVGOUT = Dummy variable equal to one if the household indicated its current reliability level was bes characterized by three outages per year; zero otherwise (i.e., household indicated its current reliability level wa best characterized by fifteen outages per year).

Based on the chi-squared tests, both models have considerabl explanatory power. The coefficients of FREQUENCY, DURATION, and COST are highly significant and have the correct sign In both models the effect of DURATION is larger than that o FREQUENCY, implying that a single two-hour outage requires a greater compensation than two individual one-hour outages, al else constant.

Model 2 introduces the term COST*AVGOUT into Model 1 ir order to indicate whether the households' prior reliability experience affects required compensation. AVGOUT is a dummy variabl set equal to one when a household's current reliability level wa best characterized by three outages over the past year (the system average); zero otherwise (i.e., the household indicated its current reliability level was best characterized by fifteen outages over the past year). Model 2 indicates that households experiencing a larger number of outages require *lower* compensation, ceteris paribus. In both models, we were unable to reject the hypothesis that all other second-order terms were zero.

Using the parameter estimates from choice Model 2, Table VIA reports the compensating variation required for a move from a status quo of three outages of two hours each per year (Option 1) to the alternative reliability options presented in Table IIIA. Because our estimates are conditional upon the size of a household's status quo monthly electricity bill (C_0), we present compensation estimates (TC) for five monthly bill quantiles (10 percent, 25 percent, 50 percent, 75 percent, 90 percent) where the 50 percent quantile is defined as the median household.

The compensation estimates in Table VIA are derived using equation (6); they include the mode-specific status quo effect. The compensation estimates in Table VIB *net out* the mode-specific status quo variable by setting $d_0 = 0$ in equation (6). A comparison of these two sets of estimates is informative. *Netting out* the

TABLE VI
IMPLIED COMPENSATION FOR ALTERED RELIABILITY LEVELS: STATUS QUO DEFINED: AS THREE OUTAGES OF TWO-HOURS' DURATION

A. Including Mode-Specific "Status quo" Effect, $ Month

From base to option	Attributes		TC by monthly bill quantile				
	Freq	Dur	10 percent	25 percent	50 percent (Median)	75 percent	90 percent
2	2	1	0.37	0.83	1.60	2.24	3.13
3	5	2	1.57	3.54	6.81	9.56	13.36
4	5	4	2.68	6.02	11.57	16.24	22.69
5	15	2	3.76	8.46	16.25	22.82	31.89
6	15	4	4.86	10.94	21.01	29.50	41.22

B. Netting out the Mode-Specific "Status quo" Effect, $ Month

From base to option	Attributes		TC by monthly bill quantile				
	Freq	Dur	10 percent	25 percent	50 percent (Median)	75 percent	90 percent
2	2	1	−0.76	−1.73	−3.32	−4.66	−6.52
3	5	2	0.44	0.98	1.89	2.65	3.71
4	5	4	1.53	3.46	6.64	9.33	13.04
5	15	2	2.62	5.90	11.34	15.91	22.24
6	15	4	3.72	8.38	16.09	22.59	31.57

Notes. Base option attributes: Freq = 3; Dur = 2.
Freq = number of outages per year.
Dur = average duration of outage in hours.
Average monthly electricity bill quantiles: 10 percent = $11.15; 25 percent = $25.08; 50 percent = $48.16; 75 percent = $67.61; 90 percent = $94.48.
All values are in 1986 dollars.
Negative compensation estimates imply willingness to pay.

mode-specific "status quo" effect, the median household (50 percent quantile) in Table VIB would be *willing to pay* $3.32/month[10] to move from its current reliability level (three outages of two-hour duration, annually) to an *increased* reliability level (two outages of one hour, annually); this same household would require compensation of $1.89 or $16.09/month to move from its current reliability level to the *diminished* reliability of Options 3 (five outages of two hours, annually) or 6 (fifteen outages of four hours, annually) respectively.

When we include the mode-specific status quo effect (Table VIA), however, this same median household *would require a compensation* of $1.60/month to move to the *improved* reliability level offered in Option 2, *precisely* because the disutility of leaving the status quo outweighs the perceived benefit of the improved service reliability. Similarly, this same household would require compensation of $6.81 or $21.01/month to move to the diminished reliability levels of Option 3 or Option 6, respectively. For all scenarios in Table VI the compensation required for rate switching from the status quo is consistently found to be much higher than those levels required if there were no mode-specific status quo inertia. In fact, the customers must be compensated for switching reliability regimes *even when the alternative regime entails more reliable service.*[11] This suggests that the kink in utility at a_1 in Figure I is even more serious than that suggested by the disparity between *WTA* and *WTP*. Because customers must *be compensated for small increases* in reliability from the status quo, utility I' rather than I_2 is a better representation of preferences for reliability increases immediately to the right of a_1.

Furthermore, the required compensation for reliability *decreases* to the left of a_1, as suggested by the choice analysis, are higher than those suggested by the self-stated *WTA*. Evidence supporting this contention is provided in Table VII for a scenario of diminished reliability: a single one-hour outage. The sample mean *WTA* for the one-hour outage is $7.29, while the compensation implied by the choice model (including the mode-specific status quo effect) is $52.78. These estimates suggest that I' may also be a

10. We interpret a negative compensation as a willingness to pay.
11. Parenthetically, Table VI also indicates a wide dispersion of implied compensation, a result corroborated in the Tobit analysis. For example, households in the 90 percent monthly bill quantile require compensation approximately ten times larger than those households in the 10 percent quantile. This suggests considerable customer heterogeneity.

TABLE VII
A COMPARISON OF SELF-STATED *WTA* AND REQUIRED COMPENSATION (TC) FOR IDENTICAL DECREASES IN RELIABILITY ($/OUTAGE)

	Self-stated cost (*WTA*)	Total compensation including mode-specific effect
One-hour outage	7.29	52.78

Notes. The one-hour outage *WTA* represents the average costs of scenarios 1 and 5 in Table II.
The total compensation (equation (6)) is calculated for the median household using Model 1 in Table III. The calculation assumes that the household's status quo reliability of three outages of one-hour duration per year was reduced to four outages of one-hour duration per year.
All values are in 1986 dollars.

better representation of consumer utility for reliability decreases to the left of a_1 in Figure I. Clearly, I' is more kinked at a_1 than I_2.

Table VIII analogously reports the estimated compensating variations required for a move from the status quo of fifteen outages of four-hours' duration to the alternative reliability regimes identified in Table IIIB. The same pattern of compensating variations found in Table VI occurs, indicating an analogous kink in utility for this quite different status quo. For example, in Table VIIIB, we find that absent the mode-specific status quo effect, the median customer must be compensated $3.54 per month for a decrease in reliability from fifteen to twenty outages per year (Option 2). When we include the mode-specific effect, the necessary compensation rises to $7.22 per month. Absent the mode-specific status quo effect, the median customer is willing to pay $3.56 per month for the *increased* reliability reflected in Option 3 (i.e., a 50 percent reduction in the average duration of each outage). However, when the mode-specific status quo effect is taken into account, this customer *must be compensated* $0.12 per month for the improved reliability, in order to overcome the status quo inertia. All customers within all bill quantiles are willing to pay for the improved reliability embodied in Options 4 through 6. However, they are willing to pay considerably less when the mode-specific status quo effect is taken into account.

III. SUMMARY AND CONCLUSIONS

Several conclusions are evident. First, our results corroborate the large disparity between *WTA* and *WTP* measures found in the literature, suggesting the hypothesized kink (along I_2) in utility at

TABLE VIII
IMPLIED COMPENSATION FOR ALTERED RELIABILITY LEVELS: STATUS QUO DEFINED AS FIFTEEN OUTAGES OF FOUR-HOURS' DURATION

A. Including Mode-Specific "Status quo" Effect, $ Month

From base to option	Attributes: Freq	Attributes: Dur	TC by monthly bill quantile: 10 percent	25 percent	50 percent (median)	75 percent	90 percen
2	20	4	1.67	3.76	7.22	10.14	14.17
3	15	2	0.03	0.06	0.12	0.17	0.24
4	5	4	−0.78	−1.76	−3.39	−4.76	−6.65
5	5	2	−1.61	−3.62	−6.95	−9.76	−13.63
6	3	2	−1.94	−4.36	−8.37	−11.74	−16.41

B. Netting out the Mode-Specific "Status quo" Effect, $ Month

From base to option	Attributes: Freq	Attributes: Dur	TC by monthly bill quantile: 10 percent	25 percent	50 percent (median)	75 percent	90 percen
2	20	4	0.82	1.84	3.54	4.97	6.94
3	15	2	−0.82	−1.85	−3.56	−5.00	−6.99
4	5	4	−1.64	−3.68	−7.07	−9.93	−13.88
5	5	2	−2.46	−5.54	−10.64	−14.93	−20.87
6	3	2	−2.79	−6.28	−12.05	−16.92	−23.64

Notes. Base option attributes: Freq = 15; Dur = 4.
Freq = number of outages per year.
Dur = average duration of outage in hours.
Average monthly electricity bill quantiles: 10 percent = $11.15; 25 percent = $25.08; 50 percent = $48.16; 75 percent = $67.61; 90 percent = $94.48.
All values are in 1986 dollars.
Negative compensation estimates imply willingness to pay.

the status quo. Our *WTA* measures are consistently three to four times our *WTP* measures.

Second, our analysis of the choice of reliability regime further corroborates the importance of the status quo and the hypothesized kink. Compensation levels required for reliability decreases are found to be considerably higher than was suggested by the *WTA* estimates. More importantly, customers do not seem to be willing to pay for marginal reliability increases; rather, they require *compensation* for reliability increases that involve movements from the status quo. As a result, the kink in utility implied by the choice model is substantially more severe (along I'). The fact that two fairly similar groups of households exhibit strong "kinked" preferences for quite different status quos is particularly compelling.

These results are not surprising, given other empirical literature. For example, Hausman [1979] and Hartman and Doane [1986] find consumers "irrationally" reluctant to move from the status quo. In particular, they use choice-theoretic models to analyze consumer trade-offs between capital and operating costs when deciding on the purchase of energy-efficient appliances and structures. In both cases, they find that the "implied" discount rates revealed by the consumers' choices were well above market rates of interest. This finding is consistent with the status quo effect found here.

Third, our analysis sheds some limited light on the hypothesis that more rational valuations obtain with respondent learning. The results in Table V suggest that customer experience with outages does lower the compensation required for diminished reliability, supporting the Coursey, Hovis, and Schulze [1987] experiments. If more rational valuations can be obtained through learning, it may be appropriate to ask electricity customers to select their reliability contract every year.

Finally, the usefulness of our empirical results for utility planning merits comment. The value of service reliability is used increasingly to judge the need for capacity expansion and to more efficiently price electricity services. In the process, better information about consumers' willingness to pay for reliability has been required as utilities have attempted to design reliability-differentiated services for heterogeneous customer groups.[12] We find that the *WTA*, *WTP*, and compensating variations vary significantly in the residential population. Detailed information on these heterogeneous valuations is a necessary first step for utilities interested in designing new products and services or considering adding capacity to improve the existing service quality. Furthermore, the presence of the "status quo" effect has important implications. If a utility is interested in quantifying consumers' willingness to switch to alternative service options, simple *WTP* estimates of the value of service reliability may be insufficient. In fact, such estimates may seriously *overestimate* consumers' willingness to accept alternative

12. For example, the California Public Utilities Commission explicitly recognizes the need for unbundling traditional energy services in Decision 86-012-010, December, 1986. In this decision the state utilities are allowed to negotiate rates with large natural gas users that reflect a separate rate element for their desired priority of service.

reliability-differentiated service options because of the status quo effect.[13]

School of Law, University of California at Berkeley,
and The Law and Economics Consulting Group, Berkeley
Analysis Group, Inc., San Francisco
Analysis Group, Inc., San Francisco

References

Bishop, R. C., and T. A. Heberlein, "Measuring Values of Extra-Market Goods: Are Indirect Measures Biased?" *American Journal of Agricultural Economics*, VII (1979), 916–30.
Brookshire, D. S., and D. L. Coursey, "Measuring the Value of a Public Good: An Empirical Comparison of Elicitation Procedures," *American Economic Review*, LXXVII (1987), 554–66.
Cameron, T. A., and M. D. James, "Efficient Estimation Methods for 'Closed-Ended' Contingent Valuation Surveys," *Review of Economics and Statistics*, LXIX (1987), 269–76.
Chao, H. P., and R. Wilson, "Priority Service: Pricing, Investment and Market Organization," *American Economic Review*, LXXVII (1987), 899–916.
Coursey, D. L., J. L. Hovis, and W. D. Schulze, "The Disparity Between Willingness to Accept and Willingness to Pay Measures of Value," *Quarterly Journal of Economics*, CII (1987), 679–90.
Cummings, R. G., D. S. Brookshire, and W. D. Schulze, eds., *Valuing Environmental Goods: An Assessment of the Contingent Valuation Method* (Totowa, NJ: Rowman and Allanheld, 1986).
Doane, M. J., R. S. Hartman, and C. K. Woo, "Household Preference for Interruptible Rate Options and the Revealed Value of Service Reliability," *Energy Journal—Special Issue*, IX (1988a), 121–34.
——, ——, and ——, "An Econometric Analysis of Perceived Value of Service Reliability," *Energy Journal—Special Issue*, IX (1988b), 135–50.
Freeman, A. M. III, *Air and Water Pollution Control: A Benefit-Cost Assessment* (New York: John Wiley & Sons, 1982).
Friedman, M., and L. Savage, "The Utility Analysis of Choices Involving Risk," *Journal of Political Economy*, LVI (1948), 279–304.
Hartman, R. S., and M. J. Doane, "Household Discount Rates Revisited," *The Energy Journal*, VII (1986), 139–48.
Hausman, J. A., "Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables," *Bell Journal of Economics*, X (1979), 33–54.
Heckman, J., "Sample Selection Bias as a Specification Error," *Econometrica*, XLVII (1979), 153–61.
Kahneman, D., and A. Tversky, "Prospect Theory: An Analysis of Decision Under Risk," *Econometrica*, XLVII (1979), 263–91.
Knetsch, J. L., and J. A. Sinden, "Willingness to Pay and Compensation Demanded: Experimental Evidence of an Unexpected Disparity in Measures of Value," *Quarterly Journal of Economics*, XCIX (1984), 507–21.
Machina, M., "Choice Under Uncertainty: Problems Solved and Unsolved," *Economic Perspectives*, I (1987), 121–54.
Mitchell, R. C., and R. T. Carson, *An Experiment in Determining Willingness to Pay*

13. This phenomenon is not new. The need to offer low "introductory" prices for new products to overcome status quo inertia is a recognized business strategy. Ignoring status quo inertia can be serious. The greatest marketing error in recent decades—the substitution of "new" for "old" Coca Cola—stemmed from a failure to recognize status quo bias. See "Saying No to New Coke," *Newsweek*, June 24, 1985, pp. 32–33.

for National Water Quality Improvements, draft report prepared for the U. S. Environmental Protection Agency (Washington, DC: Resources for the Future, Inc., 1981).

Munasinghe, M., *The Economics of Power System Reliability* (Baltimore, MD: Johns Hopkins University Press, 1979).

——, and M. Gellerson, "Economic Criteria for Optimizing Power System Reliability Levels," *Bell Journal of Economics*, X (1979), 353–65.

Rowe, R. D., R. C. d'Arge, and D. S. Brookshire, "An Experiment on the Economic Value of Visibility," *Journal of Environmental Economics and Management*, VII (1980), 1–19.

Samuelson, W., and R. Zeckhauser, "Status Quo Bias in Individual Decision Making," Harvard University Working Paper, 1986.

Scherr, B. A., and E. M. Babb, "Pricing Public Goods: An Experiment with Two Proposed Pricing Systems," *Public Choice*, XXIII (1975), 35–48.

Schulze, W. D., R. C. d'Arge, and D. S. Brookshire, "Valuing Environmental Commodities: Some Recent Experiments," *Land Economics*, LVII (1981), 151–72.

Small, K. A., and H. S. Rosen, "Applied Welfare Economics with Discrete Choice Models," *Econometrica*, XLIX (1981), 105–30.

Smith, V. L., "Incentive Compatible Experimental Processes for the Provision of Public Goods," in V. L. Smith, ed., *Research in Experimental Economics*, Volume 1 (Greenwich, CT: JAI Press, 1979).

Tobin, R. P., "Estimation of Relationships for Limited Dependent Variables," *Econometrica*, XXVI (1958), 24–86.

Willig, R. D., "Consumers' Surplus Without Apology," *American Economic Review*, LXVI (1976), 589–97.

Reprinted from

JOURNAL OF PUBLIC ECONOMICS

Journal of Public Economics 54 (1994) 145–160. North-Holland

Managing water supply shortage
Interruption vs. pricing

Chi-Keung Woo*

Department of Economics and Finance, City Polytechnic of Hong Kong, 83 Tat Chee Avenue, Kowloon, Hong Kong

Received March 1992, final version received July 1992

ELSEVIER

Journal of Public Economics 54 (1994) 145–160. North-Holland

Managing water supply shortage

Interruption vs. pricing

Chi-Keung Woo*

Department of Economics and Finance, City Polytechnic of Hong Kong, 83 Tat Chee Avenue, Kowloon, Hong Kong

Received March 1992, final version received July 1992

Supply shortage is a common problem faced by a consumer. Solutions for allocating the limited supply include rationing, queuing, interruption and pricing. While previous research has examined the welfare losses generated by each solution, there is little evidence on their relative magnitudes within a *common* framework. The objective of this paper is to specify a model of consumer behaviour under service interruption to estimate the exact welfare loss of service interruption. The *same* model is used to estimate the loss of a price increase intended to resolve a supply shortage. Using water consumption data collected for Hong Kong, we find that relative to pricing, service interruption is inefficient for water shortage management.

1. Introduction

Supply shortage is a common problem faced by a consumer. Solutions for allocating the limited supply include rationing, queuing, interruption and pricing. Quantity rationing refers to placing a limit on the total amount of consumption. An example is the fixed number of work hours (and therefore leisure hours) per week observed by a worker in the labour market [see Deaton and Muellbauer (1981) and Kapteyn et al. (1990)]. Queuing allocates supply by imposing waiting costs on a consumer during times of price control. An example is the U.S. gasoline crisis in the 1970s [see Frech and Lee (1987) and Deacon and Sonstelie (1989)].

Interruption is a complete disruption of supply. Good examples are public utility services. During the period of interruption, consumption of a service is zero; otherwise, a consumer may purchase an *unlimited* amount at the prevailing price. This differentiates service interruption from quantity rationing. For instance, random electric power outages occur because of rotating blackouts implemented by an electric utility to resolve a capacity shortage.

Correspondence to: Chi-Keung Woo, Energy and Environmental Economics, 353 Sacramento St., Suite 1540, San Francisco, CA 94111, USA.

*This research is funded by CPHK Small Scale Research Grant no. 903107. I thank S. Chan and D. Ng for their research assistance. Comments from two referees helped to improve this paper substantially. Without implications, all errors are mine

SSDI 0047-2727(93)01380-S

Such power outages impose large economic costs on consumers as reported by Munasinghe et al. (1988) and Woo and Pupp (1992). Because most of the outage cost estimates are based on contingent valuation survey data, they have been criticized as implausible.[1] Hartman et al. (1990, 1991) argue that the large estimates are partially due to the status quo bias in consumer decision-making, as documented by Kahneman et al. (1991). However, cost estimates based on survey data remain controversial since they cannot be readily verified in a well-established market environment with many consumers and repeat transactions.

Another example is that a water utility may use service interruption to reduce consumption during periods of severe drought. In contrast to electricity, there is no empirical evidence on the economic costs of water service interruption, even though Riley and Scherer (1979) and Krzysztofowicz (1986) show that the information is essential to optimal water pricing and planning. To wit, Moncur (1987) estimates the effect of rationing on residential water consumption. Hamilton et al. (1989) compute the benefit of diverting irrigation water for hydro power production. Sengupta and Khalili (1986) estimate the shadow value of irrigation water shortage using quadratic programming. Whittington et al. (1990) apply the contingent valuation method to estimate the willingness to pay for the access to water service in a less developed country. Though related, these studies do not estimate the welfare loss of water service interruption.

Responsive pricing, first proposed by Vickrey (1971), is an efficient solution to resolve a shortage of utility services. In the case of electricity, Bohn et al. (1984) recommend the use of spot pricing to continuously equate demand and supply. Since the implementation of spot pricing may be costly, an alternative is forward contracts that prescribe the allocation of the limited supply during a shortage [see Chao and Wilson (1987), Wilson (1989), Spulber (1990) and Woo (1990)]. Under certain conditions, forward contracts can be as efficient as spot pricing. Both spot pricing and forward contracts welfare dominate random service interruption. In view of this finding, they have been implemented by some electric utilities in California (e.g. Pacific Gas and Electric Company and Southern California Edison) and in New York (e.g. Niagara Mohawk Power Corporation).

Parallel to the electricity pricing literature, there is general consensus supporting the use of prices to efficiently allocate scarce water resources.[2] However, pricing continues to play little role in water shortage management [see DWR (1987), Schuster (1987) and Schwartz (1988)]. Growing demand

[1]See Caves et al. (1990). For details on the use of contingent valuation surveys, see Cummings et al. (1986), Brookshire and Coursey (1987) and Mitchell and Carson (1989).

[2]See, for example, Howe and Linaweaver (1967), Riley and Scherer (1979), Mercer and Morgan (1985), Martin and Thomas (1986), Moncur (1987), Moncur and Pollock (1988) and Morris (1990).

for water is met by new supplies and conservation programs (e.g. public education, improved irrigation practice, leak detection and low flow shower heads). If a severe shortage develops, a water utility implements such programs as quantity rationing or service interruption to reduce water consumption.

The objectives of this paper are several. First, we specify in section 2 a model of consumer behaviour under service interruption which can be implemented using market data. Our approach differs from Deaton and Muellbauer (1981) and Kapteyn et al. (1990) who model the effect of a quantity constraint on consumer behaviour. Our model is also different from Frech and Lee (1987) and Deacon and Sonstelie (1989) who use the value of waiting time to analyse the welfare loss of rationing-by-queuing. Our model yields a rigorous measure of welfare loss of service interruption. The measure is exact in the sense of Hausman (1981). We parameterize the welfare loss resulting from service interruption or price increase using the *same* representation of consumer behaviour. Second, we demonstrate the fruitfulness of our approach by implementing it in section 4 using water consumption data of Hong Kong described in section 3. Since our estimates of welfare loss are based on actual market data, they are free from the common criticisms often levied on the use of survey data. Third, we compare the welfare loss of water service interruption with that of a price increase which yields the same amount of consumption reduction. This comparison shows that service interruption is very inefficient relative to pricing for water shortage management.

2. The model

Let $S>0$ be the time interval during which the supply of service is available at a price equal to P. S is known in advance. Let $I \geqq S$ be the entire time period in which a consumer selects his or her consumption bundle. The duration of service interruption is $(I-S) \geqq 0$. The indirect utility function of a consumer with income Y is

$$V(P, Y, S) = \max_{\{q_i\}} U\left(\int_0^S W(q_i)\,\mathrm{d}i;\ Y - P\int_0^S q_i\,\mathrm{d}i\right), \tag{1}$$

where $U(\cdot)$ is the direct utility function. In eq. (1), $W(q_i)$ is a sub-utility function which is increasing and concave in service consumption, q_i. We assume that $U(\cdot)$ is increasing and concave in $W(q_i)$ and the numeraire $(Y-P\int_0^S q_i\,\mathrm{d}i)$; see Koenker (1979).

If $V(P, Y, S)$ is twice differentiable in S, eq. (1) implies

$$\partial V/\partial S \geqq 0 \quad \text{and} \quad \partial^2 V/\partial S^2 \leqq 0. \tag{2}$$

Thus, the marginal utility of S is positive and diminishing. We make additional assumptions regarding the effect of S on $\partial V/\partial P$ and $\partial V/\partial Y$:

Assumption 1. $\partial^2 V/\partial P \partial S \leqq 0$, implying that an increase in P reduces the marginal utility of S.

Assumption 2. $\partial^2 V/\partial Y \partial S \geqq 0$, implying that an increase in S increases the marginal utility of income.

Invoking Roy's Identity yields

$$-(\partial V/\partial P)/(\partial V/\partial Y) = \int_0^S q_i(P, Y, S)\, \mathrm{d}i$$

$$= Q(P, Y, S), \tag{3}$$

the *observed* total consumption. If the service is a normal good, then consistency with consumer maximization requires $Q(P, Y, S)$ to be decreasing in P and increasing in Y. We further assume:

Assumption 3. $$\partial Q/\partial S = [-\underset{(+)}{(\partial V/\partial Y)}\underset{(-)}{(\partial^2 V \partial S \partial P)}$$

$$+\underset{(-)}{(\partial V/\partial P)}\underset{(+)}{(\partial^2 V/\partial Y \partial S)}]/\underset{(+)}{(\partial V/\partial Y)^2} \geqq 0. \tag{4}$$

This assumption is imposed to recognize that total use increases with supply availability as measured by S.

We shall use eqs. (2)–(4) and Assumptions 1–3 to specify an empirical version of $V(P, Y, S)$ that is consistent with consumer maximization.

Using $V(P, Y, S)$, we define the exact welfare loss of service interruption when the supply duration is reduced from S_0 to S_1. Extending Hausman (1981), this loss is the Hicksian compensating variation (CV_S) for service interruption implicitly measured by

$$V(P, Y + CV_S, S_1) = V(P, Y, S_0). \tag{5}$$

CV_S in eq. (5) is perfectly general. If $S_0 = I$ and $S_1 < I$, then CV_S represents the exact welfare measure of service interruption with duration $(S_0 - S_1)$. If $I > S_0 > S_1$, CV_S measures the incremental welfare loss of an increase in the interruption duration. For CV_S to be able to rank alternative supply regimes meaningfully, the following conditions hold:

C.1. $CV_S(P, Y, S_0, S_0) = 0.$

C.2. $CV_S(P, Y, S_0, S_1) > 0.$

C.3. $CV_S(P, Y, S_0, S_1) > CV_S(P, Y, S_0, S_1')$ if and only if $S_1 < S_1'$.

To compare the welfare loss of service interruption with that of a price increase, we use the concept of virtual price [see Tobin and Houthakker (1951)]. Let VP be the virtual price so that $Q(VP, Y, S_0) = Q(P, Y, S_1)$. In other words, VP is the 'imagined' price that rationalizes the observed consumption $Q(P, Y, S_1)$. Assumption 3 (i.e. $\partial Q/\partial S \geqq 0$) and the fact that $Q(P, Y, S)$ is decreasing in P imply $VP \geqq P$ whenever $S_0 \geqq S_1$. We can now define the exact welfare measure for a price increase that has the same effect on consumption as $(S_0 - S_1)$. This measure is CV_P implicitly measured by

$$V(VP, Y + CV_P, S_0) = V(P, Y, S_0). \tag{6}$$

If $CV_P < CV_S$, the pricing strategy is said to be more efficient than the interruption strategy.

For empirical implementation, we consider two functional forms for $Q(P, Y, S)$ which in turn determine the parametric specifications of $V(P, Y, S)$, CV_S and CV_P. They are the double-log and linear specifications.

Several reasons support our interest in the double-log and linear forms. First, these forms have been used extensively in prior studies on price responsiveness of water demand [see, for example, Agthe and Billings (1980), Agthe et al. (1986) and Deller et al. (1986)]. Thus, our estimates of price and income elasticities can be readily compared with previous findings. Second, Hausman (1981) shows that these empirically popular and easy-to-implement functional forms are consistent with utility maximization and they can be used to derive exact welfare loss measurements. Third, the linear form is unrestrictive in that it allows the elasticity estimates to vary with quantity demanded. Finally, the indirect utility function for a demand function with higher order terms (e.g. quadratic or translog) is complicated; and as a result, welfare loss calculations become difficult to implement.[3]

Under the double-log specification,

$$Q(P, Y, S) = AP^{\alpha} Y^{\beta} S^{(1-\phi)}.$$

$Q(P, Y, S)$ is well behaved if $A > 0$, $\alpha < 0$ and $\beta > 0$. Assumption 3 requires $(1-\phi) \geqq 0$. Corresponding to the double-log consumption function is the following indirect utility function:

$$V(P, Y, S) = -ASP^{1+\alpha}/(1+\alpha) + Y^{1-\beta} S^{\phi}/(1-\beta).$$

[3]Of course, these reasons do not preclude using a flexible form to approximate $V(P, Y, S)$. However, the monthly water expenditure is a very small fraction (almost zero) of the monthly income, thus posting a difficulty in the estimation process to ensure that the coefficient estimates satisfy the regularity conditions (e.g. positive expenditure share for all observations in the sample) for a valid second-order approximation. For a discussion on the global properties of various flexible forms, see Barnett and Lee (1985).

If $\alpha=-1$ (or $\beta=1$), we replace the price (or income) term in $V(P,Y,S)$ by $\ln P$ (or $\ln Y$). From eq. (2), $\partial V/\partial S \geqq 0$ requires $\phi \geqq 0$ and $\partial^2 V/\partial S^2 \leqq 0$ requires $\phi \leqq 1$. Thus $1 \geqq \phi \geqq 0$. $V(P,Y,S)$ satisfies Assumptions 1 and 2.

Using eq. (5) we find

$$CV_S(P,Y,S_0,S_1)=\{[(1-\beta)(S_1-S_0)/(1+\alpha)S_1 \underset{(-)}{Y^\beta}]PQ(P,Y,S_1) + \underset{(+)}{(S_0/S_1)^\phi} Y^{1-\beta}\}^{1/(1-\beta)}-Y. \tag{7}$$

Eq. (7) suggests that the double-log model yields a welfare loss measurement that depends on P, Y, S_0 and S_1. Condition C.1 is met as $CV=0$ when $S_0=S_1$. Since the terms in curly brackets on the right-hand side of eq. (7) have opposite signs, we need to verify conditions C.2 and C.3 empirically.

For the pricing strategy, we use eq. (6) and Hausman (1981) to find

$$CV_P(P,VP,Y,S_0)=\{[(1-\beta)/(1+\alpha)][VPQ(VP,Y,S_0) - PQ(P,Y,S_0)]+Y^{1-\beta}\}^{1/(1-\beta)}-Y. \tag{8}$$

A comparison between eqs. (7) and (8) reveals that $CV_S(\cdot)$ and $CV_P(\cdot)$ are very different. This difference allows us to compare the relative efficiency of the two strategies intended for consumption reduction.

Under the linear specification,

$$Q(P,Y,S)=A+\alpha P+\beta Y+(1-\phi)S.$$

For $Q(P,Y,S)$ to be well behaved, $\alpha<0$ and $\beta>0$. Assumption 3 requires $(1-\phi)\geqq 0$. The corresponding indirect utility function is

$$V(P,Y,S)=e^{-\beta P}[Y+1/\beta(A+\alpha/\beta+\alpha P+(1-\phi)S)].$$

$V(P,Y,S)$ satisfies eq. (2) and Assumptions 1 and 2. Using eq. (5), we find

$$CV_S(P,Y,S_0,S_1)=(1-\phi)(S_0-S_1)/\beta. \tag{9}$$

Eq. (9) indicates that $CV_S(\cdot)$, based on a linear demand function, is proportional to (S_0-S_1) but is independent of P and Y. Moreover, CV_S meets conditions C.1–C.3.

We use eq. (6) and Hausman (1981) to find

$$CV_P(P,VP,Y,S_0)=(1/\beta)\{e^{\beta(VP-P)}[Q(P,Y,S_0)+\alpha/\beta] - [Q(P,Y,S_0)+\alpha/\beta]\}. \tag{10}$$

Table 1

Hong Kong water service interruption history for the period 1973–1990.

Event number	Starting date	Ending date	Duration (days)	Daily unserved hours	Time-of-day
1	25 September 1974	8 October 1974	14	8	10.00 p.m.–6.00 a.m.
	9 October 1974	17 October 1974	9	14	11.00 a.m.–4.00 p.m. and 9.00 p.m.–6:00 a.m.
2	1 June 1977	4 July 1977	34	8	10.00 p.m.–6.00 a.m.
	5 July 1977	18 April 1978	288	14	11.00 a.m.–4.00 p.m. and 9.00 p.m.–6.00 a.m.
3	8 October 1981	25 October 1981	18	8	10.00 p.m.–6.00 a.m.
	26 October 1981	4 May 1982	191	14	11.00 a.m.–4.00 p.m. and 9.00 p.m.–6.00 a.m.
	5 May 1982	28 May 1982	24	8	10.00 p.m.–6.00 a.m.

Source: Hong Kong Monthly Digest of Statistics, various years.

Similar to the case of the double-log, $CV_S(\cdot)$ is very different from $CV_P(\cdot)$. Calculating welfare losses using eqs. (7)–(10) requires estimating $Q(P, Y, S)$ using actual market data to be described below.

3. Data

Precise estimation of $Q(P, Y, S)$ requires data with sufficient variations in (Q, P, Y, S).[4] Such data are available for per capita water use in Hong Kong. Table 1 describes the water service interruption history for the period 1973–1990. Because of severe drought, the Hong Kong Water Supplies Department (HKWSD) used service interruption three times to reduce demand. The number of days with service interruption ranged from 23 to 322. Each interruption event consisted of two stages. The first stage involved eight unserved hours per day. When the supply shortage worsened, the HKWSD implemented the second stage by increasing the number of unserved hours to 14 per day.

These interruptions were implemented after turning off the supply to public swimming pools, soccer fields, parks and fountains. The interruptions were highly publicized prior to their implementation, and consumers were well informed so as to take actions to mitigate the interruption effects (e.g.

[4]For the case of electricity, disaggregated data on (Q, P, Y) are readily available from the billing records of an electric utility. Although generation outages are rare, the supply duration per month by customer location can be constructed from the utility's records of power outages due to distribution network failures [see Hartman et al. (1990, 1991)].

purchase of water buckets). Consumption reduction was accomplished by complete service disruption with a duration ranging from eight to fourteen hours per day. During the unserved hours, water service to all residential and commercial buildings were shut off by manually closing the valves in the streets in Hong Kong. However, service continued for clinics and hospitals, fire and police stations, power plants, large hotels and industrial firms. In contrast, water rationing in Hawaii described by Moncur (1987) is a quantity constraint which a user can violate by paying a fine.[5]

Table 2 describes the monthly data for estimating $Q(P,Y,S)$.[6] We use the aggregate data because of the lack of information on consumption by rate class (residential, commercial and others). Moreover, accurate and precise estimation of $Q(P,Y,S)$ requires subtracting from Hong Kong's total use the aggregate consumption of the water users unaffected by the interruptions. However, such detailed information is unavailable from the HKWSD. For empirical implementation, we assume that the 'correctly' measured but unobserved consumption is proportional to the observed consumption, resulting in a possible measurement error to be captured by the random disturbance term of the demand equation; see eq. (11) below.

For the last year (1980) that the HKWSD published the annual sales by rate class, residential use contributed 36.2 percent of total water consumption in Hong Kong. Historic rate schedules indicate that residential use was billed under inverted block rates while non-residential use was subject to a flat $\$/m^3$ charge. Thus, the average price of water use may be endogenous, an issue to be resolved in the estimation process.[7]

4. Results

Without any prior knowledge about the specific form for $Q(P,Y,S)$, we begin our analysis by estimating a Box–Cox monthly consumption function:

$$Q_t(\lambda) = \text{Intercept} + \alpha P_t(\lambda) + \beta Y_t(\lambda) + (1-\phi)S_t(\lambda) + \sum_j a_j W_{jt} + \sum_k b_k D_{kt} + cN_t(\lambda) + u_t, \tag{11}$$

[5]Thus, this is not really a case of quantity rationing. Instead, one may view it as a multi-block rate schedule with a large marginal price for consumption above the quantity constraint. See Hausman (1985) for the econometrics of non-linear budget sets.

[6]We choose April 1973–March 1984 to be our sample period for several reasons. First, there was no service interruption after 1982 because of increasing imports from China. The share of Hong Kong's aggregate consumption met by Chinese imports in 1984 was approximately 0.4 and rose to 0.6 in 1990. Second, the billing frequency was changed in April 1984 from once a month to once every three months. This change in billing policy may complicate a customer's understanding of the water bill. Finally, there was substantial economic growth in the mid-1980s which may cause a structural change in the per capita use of water. Further details on data construction are available in the appendix.

[7]For a thorough discussion on this issue, see Agthe et al. (1986) and Deller et al. (1986).

Table 2

Descriptive statistics of monthly data for estimating per capita water use in Hong Kong sample period: April 1973–March 1984 (132 observations) prices and income in constant HK$ (Consumer price index for April 1973 = 1.0).

Variable	Definition	Minimum	Maximum	Mean	SD
Q_t	Monthly per capita water use (cubic meter or m^3)	5.374	10.366	7.726	1.043
P_t	Monthly average rate ($\$/m^3$)	0.308	0.478	0.377	0.034
Y_t	Monthly per capita income ($)	661.921	1,336.39	1,007.64	215.310
S_t	Monthly supply hours	280.000	744.000	673.330	140.740
W_{1t}	(Rainfall − evaporation): actual − normal (mm/month)	−323.300	613.500	32.555	161.308
W_{2t}	Average temperature: actual − normal (°C)	−3.200	3.000	0.053	1.015
D_{1t}	= 1, if first quarter; = 0, otherwise	0.000	1.000	0.250	0.435
D_{2t}	= 1, if second quarter; = 0, otherwise	0.000	1.000	0.250	0.435
D_{3t}	= 1, if third quarter; = 0, otherwise	0.000	1.000	0.250	0.435
N_t	Number of calendar days per month	28.000	31.00	30.440	0.813
Z_{1t}	Monthly last residential block rate ($\$/m^3$)	0.517	1.657	1.072	0.313
Z_{2t}	Monthly first residential block rate ($\$/m^3$)	0.000	0.152	0.050	0.067
Z_{3t}	Average of block rates ($\$/m^3$)	0.258	0.677	0.504	0.113
Z_{4t}	$Z_{1t} * Z_{6t}$ less bill for Z_{6t} at actual rates	4.704	26.908	15.793	6.594
Z_{5t}	Number of blocks (residential)	2.000	5.000	3.364	1.499
Z_{6t}	Sum of block quantities (residential) (m^3)	9.100	22.700	17.791	5.104
Z_{7t}	Monthly commercial water rate ($\$/m^3$)	0.523	0.880	0.654	0.069

where $X_t(\lambda) = (X_t^{\lambda} - 1)/\lambda$, a Box–Cox function with parameter λ for $X_t = Q_t, P_t, Y_t, N_t$; and W_{jt}, D_{kt} and N_t are conditioning variables defined in table 2 to control for their respective effects on Q_t.[8] Since the data are monthly series, we postulate that u_t is an AR(1) error so that $u_t = \rho u_{t-1} + e_t$ with $|\rho| < 1$ and e_t being white noise with zero mean and finite variance. We shall refer to this model as the Box–Cox/AR(1) model.

Treating the Box–Cox/AR(1) model as the unrestricted model, we apply the likelihood ratio test to determine whether the data will reject the following restricted models: (1) double-log/AR(1): $\lambda = 0$; (2) linear/AR(1): $\lambda = 1$; (3) Box–Cox/white noise: $\rho = 0$; (4) double-log/white noise: $\lambda = 0$ and $\rho = 0$; and (5) linear/white noise: $\lambda = 1$ and $\rho = 0$.

[8]We have omitted the residential infra-marginal price as one of the regressors because of the lack of disaggregated data. The effect of this omission should be small, in view of the convincing argument put forth by Berndt (1990, ch. 7). Because the time-of-day binary variables are highly correlated with S_t (see table 1), they are not included in the regression analysis.

Agthe et al. (1986) and Deller et al. (1986) argue that the average price, P_t, may be correlated with the error term, u_t. We perform the Hausman test by running an expanded regression for each model. This expanded regression includes an additional regressor, the price instrument constructed using a linear regression model.[9]

Table 3 reports the likelihood ratio test results which indicate that the data do not reject the double-log/AR(1) and linear/AR(1) models at the 1 percent level. The Hausman test results show that the data do not reject the null hypothesis of P_t and u_t being uncorrelated. Hence, the double-log/AR(1) and linear/AR(1) models are plausible specifications for explaining the per capita use of water in Hong Kong.

Table 4 presents the estimates for the double-log/AR(1) and linear/AR(1) models. Both models yield a good fit with adjusted R^2's over 0.9. While there is autocorrelation, the Durbin–Watson statistics show that the transformed residuals are serially uncorrelated. All coefficient estimates have the expected signs. Except for the rainfall variable and the intercept under the linear/AR(1) specification, all coefficient estimates are statistically significant at the 1 percent level.[10]

The own-price and income elasticities based on the double-log/AR(1) specifications are respectively equal to -0.4684 and 0.2354, similar to those in Agthe et al. (1986), Martin and Thomas (1986), Deller et al. (1986) and Moncur (1987). The estimate for $(1-\phi)$ is 0.1642 with a standard error of 0.0301, indicating that the double-log/AR(1) specification is consistent with consumer maximization.[11] The findings based on the linear/AR(1) specification are similar and are not repeated.

We apply eqs. (7)–(10) to compute the welfare losses for the following changes in supply hours: (1) from 24 to 20 hours per day; (2) from 24 to 16 hours per day; and (3) from 24 to 10 hours per day. Associated with these changes are the following daily unserved hours: 4, 8 and 14. Since eqs. (7), (9) and (10) are non-linear, we use sample enumeration to compute the per capita welfare loss ($/month).[12]

Table 5 indicates that consumption reduction through service interruption

[9]The dependent variable is P_t and the independent variables include an intercept, Y_t, S_t, W_{1t}, W_{2t}, D_{1t}, D_{2t}, D_{3t}, $Z_{1t}, \ldots, Z_{7t}$. See table 2 for the variable definitions.

[10]Because of limited land, residential irrigation of lawns and gardens is almost non-existent in Hong Kong. As a result, an increase in rainfall does not have a significant effect on water consumption.

[11]Since $(1-\phi)$ is the elasticity of consumption with respect to supply hours, we can use it to predict the impact of service interruption on water consumption. For example, a policy of 8 unserved hours per day would result in approximately 6.65 percent $(=0.1642 \times \ln(16/24))$ reduction in monthly use. The same reduction can be achieved by increasing the average rate by 13.68 percent (=6.65 percent/0.4684); see Moncur (1987) for a similar calculation.

[12]We first compute the welfare loss for each month and then take the average of the monthly results.

Table 3

Specification tests for monthly water demand model in Hong Kong. Sample period: April 1973–March 1984.

Model	λ	ρ	Durbin–Watson statistic	Log-likelihood	Likelihood ratio statistic[a]	Degrees of freedom	Hausman test statistic[b]
Box–Cox/AR(1)	0.58	0.800	2.0268	−24.88	N.A.	N.A.	0.3354
Double log/AR(1)	0.00	0.790	1.9840	−26.08	2.40	1	0.2043
Linear/AR(1)	1.00	0.803	2.0497	−25.48	1.20	1	0.4464
Box–Cox/white noise	0.91	0.000	0.8623	−66.29	82.82	1	0.5284
Double-log/white noise	0.00	0.000	0.7995	−69.11	88.46	2	0.7310
Linear/white noise	1.00	0.000	0.8677	−66.32	82.88	2	0.4907

[a]Likelihood ratio statistic = −2 [log-likelihood(restricted) − log-likelihood(unrestricted)] which is distributed as χ^2 with d.f. equal to the number of restrictions; $\chi^2=6.635$ with 1 d.f. at 1 percent level; $\chi^2=9.210$ with 2 d.f. at 1 percent level; and N.A. = not applicable.

[b]Hausman test statistic = standard normal variate (z) and $z=2.576$ at 1 percent level.

Table 4

Monthly per capita water consumption (Q_t) model sample period: April 1974–March 1984 (132 observations).

Variable with expected sign in [ ]	Double-log/AR(1)	Linear/AR(1)
Intercept [?]	−5.2209[a]	−0.7730
	(0.5020)	(1.1993)
P_t: monthly average rate (\$/m^3) [−]	−0.4684[a,b]	−9.0284[a]
	(0.1134)	(2.2946)
Y_t: monthly per capita income (\$) [+]	0.2354[a,b]	0.0019[a]
	(0.0624)	(0.0005)
S_t: monthly supply hours [+]	0.1642[a,b]	0.0026[a]
	(0.0301)	(0.0005)
W_{1t}: (rainfall − evaporation): actual − normal (mm/month) [−]	−0.000038	−0.0002
	(0.000018)	(0.0001)
W_{2t}: average temperature: actual − normal (°C) [+]	0.0094[a]	0.0742[a]
	(0.0032)	(0.0243)
D_{1t}: = 1, if first quarter; = 0, otherwise [?]	−0.0456[a]	−0.3135[a]
	(0.0121)	(0.0942)
D_{2t}: = 1, if second quarter; = 0, otherwise [?]	0.0502[a]	0.3366[a]
	(0.0145)	(0.1111)
D_{3t}: = 1, if third quarter; = 0, otherwise [?]	0.0498[a]	0.3632[a]
	(0.0114)	(0.0867)
N_t: number of calendar days per month [+]	1.2010[a,b]	0.2700[a]
	(0.0958)	(0.0252)
ρ	0.7897[a]	0.8025[a]
	(0.0534)	(0.0519)
Adjusted R^2	0.9143	0.9150
Log-likelihood	−26.0761	−25.4755
Durbin–Watson statistic	1.9840	2.0497
Standard error of regression	0.0384	0.2923

Note: Standard errors in parentheses.
[a]Significant at 1 percent level.
[b]Coefficient estimate for log (variable).

creates large welfare losses.[13] For example, the per capita CV_S estimate under the double/AR(1) specification ranges from \$221 to \$1,607 per month. The per capita CV_S estimate is increasing in interruption duration at an increasing rate. The per capita CV_S estimate under the linear/AR(1) specification is proportional to the monthly interruption duration and is smaller than the one under the double-log/AR(1) specification.

Three factors account for the large CV_S estimates. First, service interruption is assumed to occur daily, implying a large number of unserved hours per month. Even though the estimated per capita welfare loss per hour unserved appears to be reasonable (\$1.36 to \$3.8/hour), the estimated total loss is large. Second, service interruption only allows consumption during the

[13]Numerical results indicate that both conditions C.2 and C.3 are satisfied for all 132 monthly observations.

Table 5

Average monthly per capita welfare loss within-sample simulation (132 observations). Number of calendar days per month = 30.44; see table 2.

Variable	Double-log/AR(1)			Linear/AR(1)		
Total unserved hours per month	121.76[a]	243.52[b]	426.15[c]	121.76	243.52	426.15
Total unserved water (m^3/month)	0.2293	0.5008	1.0411	0.3127	0.6254	1.0945
CV_S: welfare loss (interruption) (\$/month)	221.12	559.13	1,607.78	166.03	332.06	581.11
CV_S per unserved hour (\$/hour)	1.816	2.296	3.773	1.364	1.364	1.364
VP: virtual price (\$/m^3)	0.4012	0.4307	0.4929	0.4117	0.4464	0.4984
CV_P: welfare loss (pricing) (\$/month)	0.1783	0.3759	0.7232	0.2686	0.5265	0.8929

[a]4 unserved hours per day.
[b]8 unserved hours per day.
[c]14 unserved hours per day.

supply hours, thus severely limiting a consumer's choice set. In contrast, a quantity constraint allows the consumer to allocate the total monthly consumption among the hours of the month; see eq. (1). Finally, our parametric specification of $Q(P, Y, S)$ may be restrictive in the determination of CV_S. For instance, the linear specification implies $CV_S(P, Y, S_0, S_1) = (1-\phi)(S_0 - S_1)/\beta$ and $Q(P, Y + CV_S, S_1) = Q(P, Y, S_0)$. Thus, maintaining the utility level at $V(P, Y, S_0)$ requires an income increase that will keep consumption unchanged. Since $Q(P, Y, S)$ is income inelastic, the resulting CV_S is large.

The per capita CV_P estimate is less than \$1 per month, indicating that the service interruption strategy is highly inefficient relative to pricing in reducing water consumption. The CV_S estimate exceeds the CV_P estimate by more than 500 times. This finding of service interruption being inefficient is insensitive to the choice of functional form.

5. Conclusion

In this paper we have specified a model of consumer behaviour under service interruption and implemented it using water consumption data. From this model we have developed the exact welfare loss of water service interruption designed to reduce consumption during times of severe drought. Using the same model, we have also computed the welfare loss due to a price increase that yields the same amount of consumption reduction. Since our welfare loss estimates are based on actual market data, they are free from the common criticisms related to the results developed from contingent valuation survey data. The major finding is that the welfare loss of water service interruption greatly exceeds that of a price increase, indicating that service interruption is very inefficient for water shortage management.

Appendix: Data description and sources

Variable	Description
Q_t	Monthly per capita water use (m^3) = (monthly water consumption/monthly population). Monthly population is estimated by linear interpolation using mid-year estimates. *Source: Hong Kong Monthly Digest of Statistics*, various years.
P_t	Monthly average rate ($\$/m^3$) = (Water Department's fiscal year revenue/Fiscal year water consumption), deflated by monthly CPI (April 1973 = 1.00). *Source: Hong Kong Annual Report* and *Hong Kong Monthly Digest of Statistics*, various years
Y_t	Monthly per capita income (\$) = (Quarterly GDP/3)/monthly population *Source: Quarterly GDP: Gross Domestic Product Quarterly Estimates and Revised Annual Estimates*, Census and Statistics Department, Hong Kong, August 1991.
S_t	Monthly supply hours = monthly total hours − monthly total unserved hours *Source:* Table 1.
W_{1t}	(Rainfall − evaporation): actual–normal (mm/month) = (monthly total rainfall − 30-year average of monthly rainfall) − (monthly total evaporation − 30-year average of monthly evaporation). *Source: Hong Kong Monthly Digest of Statistics* and *Hong Kong Annual Report*, various years.
W_{2t}	Average temperature: actual–normal (°C) = (monthly total temperature − 30-year average of monthly temperature). *Source: Hong Kong Monthly Digest of Statistics* and *Hong Kong Annual Report*, various years.

References

Agthe, D.E. and R.B. Billings, 1980, Dynamic models of residential water demand, Water Resources Research 16, no. 3, 476–480.

Agthe, D.E. et al., 1986, A simultaneous equation demand model for block rates, Water Resources Research 22, no. 1, 1–4.

Barnett, W.A. and Y.W. Lee, 1985, The global properties of the minflex Laurent, generalized Leontief, and translog flexible functional forms, Econometrica 53, no. 6, 1421–1437.

Berndt, E.R., 1990, The practice of econometrics: Classic and contemporary (Addison Wesley, New York).

Bohn, R.E. et al. 1984, Optimal pricing in electricity network over space and time, Rand Journal of Economics 15, no. 3, 360–373.

Brookshire, D.S. and D.L. Coursey, 1987, Measuring the value of a public good: An empirical comparison of elicitation procedures, American Economic Review 77, no. 4, 554–566.

Caves, D.W., J.A. Herriges and R.J. Windle, 1990, Consumer demand for service reliability in electric power industry: A synthesis of the outage cost literature, Bulletin of Economic Research 42, no. 2, 79–119.

Chao, H.P. and R. Wilson, 1987, Priority service: Pricing, investment and market organization, American Economic Review 77, no. 5, 899–916.

Cummings, R.G. et al., eds., 1986, Valuing environmental goods: A state of art assessment of the contingent method (Rowman and Allanheld, Totowa).

Deacon, R.T. and J. Sonstelie, 1989, The welfare costs of rationing by waiting, Economic Inquiry, Apr., 179–196.

Deaton, A. and J. Muellbauer, 1981, Functional forms for labour supply and commodity demands with and without quantity restrictions, Econometrica 49, no. 6, 1521–1532.

Deller, S.C., D.L. Chicoine and G. Ramamurthy, 1986, Instrumental variables approach to rural water service demand, Southern Economic Journal 53, 33–46.

DWR, 1987, California water: Looking to the future, Publication no. 160-87, California Department of Water Resources.

Frech, H.E. and W.C. Lee, 1987, The welfare cost of rationing-by-queuing across markets: Theory and estimates from the U.S. gasoline crises, Quarterly Journal of Economics, Feb., 97–108.

Hamilton, J.R., N.K. Whittlesey and P. Halverson, 1989, Interruptible water markets in the Pacific Northwest, America Journal of Agricultural Economics 71, no. 1, 63–75.

Hartman, R.S., M.J. Doane and C.K. Woo, 1990, Status-quo bias in the measurement of value of service, Resources and Energy 12, 197–214.

Hartman, R.S., M.J. Doane and C.K. Woo, 1991, Consumer rationality and the status-quo, Quarterly Journal of Economics, Feb., 141–162.

Hausman, J.A., 1981, Exact consumer's surplus and deadweight loss, American Economic Review 71, no. 4, 662–676.

Hausman, J.A., 1985, The econometrics of nonlinear budget sets, Econometrica 53, no. 6, 1255–1282.

Howe, C.W. and F.P. Linaweaver, 1967, The impact of price on residential water demand and relation to system design and price structure, Water Resources Research 3, no. 1, 13–32.

Kahneman, D., J.L. Knetsch and R.H. Thaler, 1991, The endowment effect, loss aversion and status quo bias, Journal of Economic Perspectives 5, no. 1, 193–206.

Kapteyn, A., P. Kooreman and A. Van Soest, 1990, Quantity rationing and concavity in a flexible household labour supply model, Review of Economics and Statistics 72, 55–62.

Koenker, R., 1979, Optimal peak load pricing with time-additive consumer preferences, Journal of Econometrics 9, 175–192.

Krzysztofowicz, R., 1986, Expected utility, benefit and loss criteria for seasonal water supply planning, Water Resources Research 22, no. 3, 303–312.

Martin, W.E. and J.F. Thomas, 1986, Policy relevance in studies of urban residential water demand, Water Resources Research 22, no. 13, 1735–1741.

Mercer, L.J. and D.W. Morgan, 1985, Conservation using a rate of return decision rule: Some examples from California municipal utilities departments, Water Resources Research 21, no. 7, 927–933.

Mitchell, R.C. and R.T. Carson, 1989, Using surveys to value public goods: The contingent valuation method (Resources for the Future, Washington, DC).

Moncur, J.E.T., 1987, Urban water pricing and drought management, Water Resources Research 23, no. 3, 393–398.

Moncur, J.E.T. and R.L. Pollock, 1988, Scarcity rents for water: A valuation and pricing model, Land Economics 64, no. 1, 62–72.

Morris, J.R., 1990, Pricing for conservation, Contemporary Policy Issues 8, no. 4, 79–91.

Munasinghe, M., C.K. Woo and H.P. Chao, eds., 1988, Special electricity reliability issue, Energy Journal 9.

Riley, J.G. and C.R. Scherer, 1979, Optimal water pricing and storage with cyclical supply and demand, Water Resources Research 15, no. 2, 233–239.

Schuster, D.R., 1987, Water supply needs and management in south San Francisco Bay SWP Service Area, State Water Contractors, Sacramento.

Schwartz, J., 1988, The real price of water, American Demographics, Sept., 29–32.

Sengupta, J.K. and M. Khalili, 1986, Efficiency in water allocation under stochastic demand, Applied Economics 18, no. 1, 37–48.

Spulber, D.F., 1990, Optimal rationing and contingent contracts, Working paper (Kellogg School of Management, Northwestern University).

Tobin, J. and H.S. Houthakker, 1951, The effect of rationing on demand elasticities, Review of Economic Studies 18, 140–153.

Vickrey, W., 1971, Responsive pricing for utility services, Bell Journal of Economics 2, no. 1, 337–346.

Whittington, D. et al., 1990, Estimating the willingness to pay for water services in developing countries: A case study of the use of contingent valuation surveys in Southern Haiti, Economic Development and Cultural Change 38, no. 2, 293–311.

Wilson, R., 1989, Efficient and competitive rationing, Econometrica 57, no. 1, 1–40.

Woo, C.K., 1990, Efficient electricity pricing with self-rationing, Journal of Regulatory Economics 2, no. 1, 69–81.

Woo, C.K. and R.L. Pupp, 1992, Costs of service disruptions to electricity consumers, Energy – The International Journal 17, no. 2, 109–126.

Resource and Energy Economics 15 (1993) 339–352. North-Holland

Factor supply interruption, welfare loss and shortage management

Chi-Keung Woo and Kenneth W.K. Lo*

Department of Economics and Finance, City Polytechnic of Hong Kong (CPHK), 83 Tat Chee Avenue, Hong Kong

Factor supply shortage is a common problem faced by a firm. Solutions for allocating the limited supply include rationing, interruption and pricing. While previous research has examined the welfare losses generated by each solution, there is little evidence on their relative magnitudes within a *common* framework. The objective of this paper is to specify a model of firm behaviour under service interruption to estimate the welfare loss of service interruption. The *same* model is used to estimate the loss due to a price increase intended to resolve a supply shortage. Using water consumption data collected for Hong Kong, we find that relative to pricing, service interruption is inefficient for water shortage management.

Key words: Factor supply shortage; Service interruption; Welfare loss; Shortage management
JEL classification: D6; H3; Q3

1. Introduction

Factor supply shortage is a common problem faced by a firm. Good examples are public utility services. Solutions for allocating the limited supply include rationing, interruption and pricing.[1] Quantity rationing refers to placing a limit on the total amount of consumption.[2] For example, a six-year drought results in quantity rationing in central California whereby the consumption of a firm is limited to a fraction of its historic usage level. During the severe winter of 1989, industrial users of natural gas in California were also required to curtail their usage so that the gas utility, Southern California Gas, can continue to serve its residential customers.

Interruption is a complete disruption of supply. During the period of

Correspondence to: C.K. Woo, Department of Economics and Finance, City Polytechnic of Hong Kong (CPHK), 83 Tat Chee Avenue, Hong Kong. Telephone: (852) 788-8812; Fax: (852) 788-8806.

*We thank Ira Horowitz, Asher Tishler and a referee for their helpful comments and the Hong Kong Water Supplies Department (HKWSD) for supplying the water consumption data. The views expressed here do not reflect the position of the HKWSD. All errors are ours.

[1]Queuing is another mechanism that allocates supply by imposing waiting costs on a consumer during times of price control. An example is the US gasoline crisis in the 1970s, see Frech and Lee (1987) and Deacon and Sonstelie (1989).

[2]An example of rationing for the case of a consumer is the fixed number of work hours (and therefore leisure hours) per week observed by a worker in the labour market, see Deaton and Muellbauer (1981) and Kapteyn et al. (1988).

interruption, consumption of a service is zero; otherwise, a firm may purchase an *unlimited* amount at the prevailing price. This differentiates service interruption from quantity rationing. For instance, random electric power outages occur because of rotating blackouts implemented by an electric utility to resolve a capacity shortage. Such power outages impose large economic costs on firms as reported by Woo and Pupp (1992) and Munasinghe et al. (1988). Because most of the outage cost estimates are based on contingent valuation survey data, they have been criticized to be unreliable.[3] As noted by Woo et al. (1991), cost estimates based on survey data remain to be controversial for they cannot be readily verified in a well established market environment with many consumers and repeat transactions.

There are recent attempts to use market data to quantify the costs of an outage to a firm. For instance, Coate and Panzar (1989) propose a variable profit function for estimating a firm's outage costs. However, Coate and Panzar (1989) do not provide the empirical evidence to demonstrate the usefulness of their proposal. An alternative is to use a dynamic cost function estimated using highly disaggregate (hourly) data. Woo and Glyer (1990) show that outage costs can be measured by the production cost increase due to the price increases that could have rationalized the observed consumption of a firm under service interruption. Finally, Tishler (1992) computes the costs of an outage to a firm using a variable profit function whose parameters are inferred from electricity demand elasticities under time-of-use pricing. Tishler (1992) notes that the elasticity estimates used do not capture the effect of an outage on demand and that the reported results may be biased.

Another example is that a water utility may use service interruption to reduce consumption during periods of severe drought. In contrast to electricity, there is no empirical evidence on the economic costs of water service interruption, even though Riley and Scherer (1979) and Krzysztofowicz (1986) show that this information is essential to optimal water pricing and planning. To wit, Moncur (1987) estimates the effect of rationing on residential water consumption. Hamilton et al. (1989) compute the benefit of diverting irrigation water for hydro power production. Sengupta and Khalili (1986) estimate the shadow value of irrigation water shortage using quadratic programming. Whittington et al. (1990) apply the contingent valuation method to estimate the willingness to pay for the access to water service in a less developed country. Though related, these studies do not estimate the welfare loss of water service interruption.

[3]See Caves et al. (1990). For details on the use of contingent valuation surveys, see Cummings et al. (1986), Brookshire and Coursey (1987) and Mitchell and Carson (1989). In the case of consumers, Hartman et al. (1990, 1991) argue that the large estimates are partially due to the status-quo bias in consumer decision making as documented by Kahneman et al. (1991).

First proposed by Vickrey (1971), responsive pricing is an efficient solution to resolve a shortage of utility services. In the case of electricity, Bohn et al. (1984) recommend the use of spot pricing to continuously equate demand and supply. Since the implementation of spot pricing may be costly, an alternative is forward contracts that prescribe the allocation of the limited supply during a shortage, see Chao and Wilson (1987), Wilson (1989), Spulber (1992) and Woo (1990). Under certain conditions, forward contracts can be as efficient as spot pricing. Both spot pricing and forward contracts welfare dominate random service interruption. In view of this finding, they have been implemented by some electric utilities in California (e.g., Pacific Gas and Electric Company and Southern California Edison) and in New York (e.g., Niagara Mohawk Power Corporation).

Parallel to the electricity pricing literature, there is general consensus supporting the use of prices to efficiently allocate scarce water resources.[4] However, pricing continues to play little role in water shortage management, see Schwartz (1988), DWR (1987) and Schuster (1987). Growing demand for water is met by new supplies and conservation programs (e.g., public education, improved irrigation practice, leak detection and low flow shower heads). If a severe shortage develops, a water utility resorts to such non-market programs as quantity rationing or service interruption to reduce water consumption.

The objectives of this paper are several. First, we specify in section 2 a model of firm behaviour under service interruption which can be implemented using market data.[5] Our model yields a rigorous measure of the welfare loss of service interruption. The measure is based on the increase in production costs due to a change in supply condition. More importantly, the data requirement for implementing our model is minimal, thus making the approach particularly useful for developing countries (e.g., China and Eastern Europe) where detailed data collection is economically infeasible. We then parameterize the production cost increase due to service interruption or pricing using the *same* representation of firm behaviour. Second, we demonstrate the fruitfulness of our approach by implementing it in section 4 using the monthly non-residential (industrial and commercial) water consumption data for Hong Kong described in section 3. Since our estimates of interruption costs are based on actual market data, they are free from the common criticisms often levied on the use of survey data. Third, we compare the welfare loss of water service interruption to that of a price increase which

[4]See e.g., Howe and Linaweaver (1967), Riley and Scherer (1979), Mercer and Morgan (1985), Moncur (1987), Moncur and Pollock (1988), Martin and Thomas (1986) and Morris (1990).

[5]Our approach differs from Deaton and Muellbauer (1981) and Kapteyn et al. (1988) who model the effect of a quantity constraint on consumer behaviour. Our model is also different from Frech and Lee (1987) and Deacon and Sonstelie (1989) who use value of waiting time to analyze the welfare loss of rationing-by-queuing.

yields the same amount of consumption reduction. This comparison shows that service interruption is inefficient relative to pricing for water shortage management.

2. Model

Let $h>0$ be the daily supply hours during which the supply of an input service (water) is available at its market price P_1. The value of h is known in advance. The technology of a firm producing final output y is the daily production function $f(z, k)$, where z is an intermediate output and k represents the other inputs (e.g., capital). Thus, the technology is weakly separable, an assumption imposed to minimize the data requirement for empirical implementation. The daily production of z requires two inputs: x_1 (water) and x_2 (labour), which can be purchased at market prices P_1 and P_2. We assume labour service is not subject to interruption.

The optimization problem facing the firm is:

$$\underset{x_1,x_2}{\text{Minimize}}\, A = P_1 x_1 + P_2 x_2$$

$$\text{Subject to: } g(x_1,x_2) = z \text{ (technology constraint); and}$$

$$\phi h - x_1 \geq 0 \text{ (capacity constraint).}$$

In the above problem, $g(\cdot)$ is the production function for z. We assume $g(\cdot)$ being concave and increasing in inputs with $g_i = \partial g/\partial x_i > 0$; $g_{12} = \partial^2 g/\partial x_1 \partial x_2 > 0$; and $g_{ii} = \partial^2 g/\partial x_i^2 < 0$ for $i=1$, 2. The constant scalar ϕ is the maximum hourly intake rate of the firm. In other words, ϕh is the daily maximum water intake dictated by the size of the pipe connected to the firm and the firm's storage facility installed. Our formulation of the firm's optimization problem have the following implications. First, an increase in h reduces A only when the capacity constraint is binding (i.e., $\phi h = x_1$). If $\phi h > x_1$, $A(\cdot)$ does not vary with h. Second, water service interruption seldom causes a complete disruption of the firm's production because water is storable. This is in sharp contrast to the case of electricity whereby service interruption often reduces the firm's output to zero.

To formulate the empirical model and to interpret the later findings, we state the following proposition whose proof is given in the Appendix.

Proposition. The daily cost function $A(P_1, P_2, h, \phi, z)$ is non-increasing and convex in h so that $\partial A/\partial h \leq 0$ and $\partial^2 A/\partial h^2 \geq 0$.

Thus, the marginal benefit $(-\partial A/\partial h)$ of daily supply hours is non-negative and it obeys the law of diminishing returns because $-\partial^2 A/\partial h^2 \leq 0$.

If $g(\cdot)$ is homogeneous of degree one in inputs, Diewert (1974, 1976) shows that $A(\cdot)$ can be written as $B(P_1, P_2, h, \phi)z$ so that $B(\cdot)$ is the unit cost function.[6] $B(\cdot)$ is estimable if disaggregate daily data are available. The disaggregate approach is useful for testing whether the constraint $\phi h \geq x_1$ is binding. When the constraint is binding so that $\phi h = x_1^*$, the optimal daily water demand is insensitive to a change in the water price. Thus, H_0: $\partial x_1^*/\partial P_1 = 0$ is the hypothesis to be tested.

In practice, however, we often do not have detailed daily data. What we usually observe are monthly data so that $X_i = \sum x_i$ is the monthly input use. Using monthly data to estimate the unit cost function requires two modifications to our formulation. The first modification reflects our inability to determine whether the constraint $\phi h \geq x_1$ is binding on any given day. This inability arises from not observing z, the daily production level of the intermediate output. Since it is possible for some days when $\phi h > x_1$, we should allow for $\partial x_1^*/\partial P_1 < 0$ in our empirical model. The second modification reflects the varying number of days in a calender month. We introduce S, the fraction of time when supply is available, to measure the extent of supply availability.[7]

The *estimable* unit cost function is $c(P_1, P_2, S) = [(P_1X_1 + P_2X_2)/Z] = \sum A(\cdot)/Z = \sum B(\cdot)/D$, where X_i and Z are the monthly sums of x_i and z, and D is the number of calender days in a month.[8] We assume that $c(P_1, P_2, S)$ is twice differentiable in S even though $\partial c/\partial S$ may not be continuous at the point of full capacity. Because $A(\cdot)$ is non-decreasing and convex in h, $c(P_1, P_2, S)$ is non-decreasing and convex in S.[9] In other words, the marginal benefit of supply availability $(-\partial c/\partial S)$ is non-negative and it is diminishing because $-\partial^2 c/\partial S^2 \leq 0$.

Using $c(\cdot)$, we define the welfare loss of service interruption when S is reduced from S_0 to S_1. Similar to Aigner and Hirschberg (1985), the percentage increase in $c(\cdot)$ is

$$\Delta \ln c_S = \ln c(P_1, P_2, S_1) - \ln c(P_1, P_2, S_0). \tag{1}$$

$\Delta \ln c_S$ is perfectly general. If $S_0 = 1$ and $S_1 < 1$, then $\Delta \ln c_S$ represents the percentage cost increase caused by a daily interruption duration of $[24(1 - S_1)]$ hours. If $1 > S_0 > S_1$, $\Delta \ln c_S$ measures the incremental welfare loss due to an increase in the daily interruption duration equal to $[24(S_0 - S_1)]$ hours.

To compare the welfare loss of service interruption with that of a price

[6] As will be seen below, the assumption of constant returns to scale eliminates the need for collecting information about z.

[7] S = (the total number of supply hours)/(the total number of hours in a month).

[8] $c(P_1, P_2, S)$ does not contain the unobservable variable ϕ. Its exclusion does not affect the final results under the assumption that ϕ is a constant scalar.

[9] Because $S = \sum h/24D$ and $(\partial c/\partial S)(\partial S/\partial h) = \partial A/\partial h$, $\partial c/\partial S = (\partial A/\partial h)24D \leq 0$; and $\partial^2 c/\partial S^2 = (\partial^2 A/\partial h^2)24D \geq 0$.

increase, we use the concept of virtual price, see Tobin and Houthakker (1951). Let VP_1 be the virtual price so that $X_1(VP_1, P_2, S_0) = X_1(P_1, P_2, S_1)$. In other words, VP is the 'imagined' price that rationalizes the observed consumption $X_1(P_1, P_2, S_1)$. Because cost minimization implies $\partial X_1/\partial S \geq 0$ and $\partial X_1/\partial P_1 \leq 0$, $VP_1 \geq P_1$ whenever $S_0 \geq S_1$. We can now define the welfare loss due to a pricing strategy that has the same effect on consumption as $(S_0 - S_1)$. This measure is

$$\Delta \ln c_P = \ln c(VP_1, P_2, S_0) - \ln c(P_1, P_2, S_0). \tag{2}$$

If $\Delta \ln c_P < \Delta \ln c_S$, the pricing strategy is said to be more efficient than the interruption strategy.

Estimating $c(P_1, P_2, S)$ requires a parametric specification, usually a second order local approximation. Barnett and Lee (1985) describes the various flexible forms and their global properties. We propose to use the translog specification as our second order local approximation of $\ln c(\cdot)$:

$$\begin{aligned} \ln c = {} & \alpha_1 \ln P_1 + \alpha_2 \ln P_2 + \tfrac{1}{2}\beta_{11}(\ln P_1)^2 + \beta_{12} \ln P_1 \ln P_2 \\ & + \tfrac{1}{2}\beta_{22}(\ln P_2)^2 + \beta_{1S} \ln P_1 \ \ln S + \beta_{2S} \ln P_2 \ln S, \end{aligned} \tag{3}$$

with the following linear restrictions: $\alpha_1 + \alpha_2 = 1$, $\beta_{11} + \beta_{12} = \beta_{12} + \beta_{22} = \beta_{1S} + \beta_{2S} = 0$, see Berndt (1990, ch. 9). The translog is flexible and unrestrictive in that it does not place any prior restriction on the elasticity estimates.

Several reasons support our interest in using the translog specification. First, the specification has been used successfully in prior studies on price responsiveness of non-residential water demand, see e.g., Babin et al. (1982) and Grebenstein and Field (1979). Second, $\Delta \ln c_S$ and $\Delta \ln c_P$ can be easily calculated using the estimated version of eq. (3) because the translog unit cost function is a superlative index number for evaluating welfare changes, see Diewert (1976). Finally, invoking Shephard's Lemma yields the water cost share equation

$$W_1 = P_1 X_1/(P_1 X_1 + P_2 X_2) = \alpha_1 + \beta_{11} \ln (P_1/P_2) + \beta_{1S} \ln S, \tag{4}$$

which is linear in parameters and is therefore easy to implement.

Using the parameter estimates for $\ln c$, we can compute various price elasticities $e_{ij} = \partial \ln X_i/\partial \ln P_j$ and interruption elasticities $e_{iS} = \partial \ln X_i/\partial \ln S$. To wit,

$$e_{ii} = (\beta_{ii} + W_i^2 - W_i)/W_i.$$

Since X_i is homogeneous of degree zero in prices, $e_{ij} = -e_{ii}$ for $i \neq j$ in our two-input case. Direct computation yields

Table 1
Hong Kong water service interruption history for the period 1973–1990.

Event number	Starting date	Ending date	Duration (days)	Daily unserved hours	Time-of-day
1	Sept./25/74	Oct./08/74	14	8	10:00 p.m. – 6:00 a.m.
	Oct./09/74	Oct./17/74	9	14	11:00 a.m. – 4:00 p.m. &9:00 p.m. – 6:00 a.m.
2	June/01/77	July/04/77	34	8	10:00 p.m. – 6:00 a.m.
	July/05/77	April/18/78	288	14	11:00 a.m. – 4:00 p.m. &9:00 p.m. – 6:00 a.m.
3	Oct./08/81	Oct./25/81	18	8	10:00 p.m. – 6:00 a.m.
	Oct./26/81	May/04/82	191	14	11:00 a.m. – 4:00 p.m. &9:00 p.m. – 6:00 a.m.
	May/05/82	May/28/82	24	8	10:00 p.m. – 6:00 a.m.

Source: *Hong Kong Monthly Digest of Statistics*, various years.

$$e_{1S}=\beta_{1S}[W_1 \ln(P_1/P_2)+1]/W_1;$$

and

$$e_{2S}=\beta_{1S}[W_2 \ln(P_1/P_2)-1]/W_2.$$

We measure the percentage change in water consumption using

$$\Delta \ln X_1 = (\% \text{ change in } X_1 \text{ per } 1\% \text{ change in } S)\ \% \text{ change in } S$$
$$= e_{1S}(\ln S_1 - \ln S_0).$$

In other words, $\Delta \ln X_1$ is the water demand elasticity with respect to supply duration times the percentage change in supply duration. We compute VP_1 by calculating the percentage increase in P_1 that results in $\Delta \ln X_1$. This proportional price increase is

$$\ln VP_1 - \ln P_1 = \% \text{ change in } X_1/\text{own-price elasticity of } X_1$$
$$= \Delta \ln X_1/e_{11},$$

where $\Delta \ln X_1$ and e_{11} are evaluated at (P_1, P_2, S_0). Thus, $(\ln VP_1 - \ln P_1)$ is the percentage change in the water price that would yield the same percentage change in water consumption as the interruption policy.

3. Data

Precise estimation of eq. (4) requires data with sufficient variations in (X_1, X_2, P_1, P_2, S). Such data are available for non-residential water use in Hong Kong.[10] Table 1 describes the water service interruption history for the

[10]Non-residential use accounts for approximately 60% of the total water consumption in Hong Kong.

Table 2
Descriptive statistics of monthly data for estimating the translog water cost share equation. Sample period: April 1981–June 1990 (111 observations).

Variable	Description and source	Mean	S.D.
W_1	Water cost share $= P_1X_1/(P_1X_1+P_2X_2)$	0.0067464	0.0012249
P_1	Water price ($\$/m^3$) [a]	1.9677	0.4558
X_1	Monthly non-residential water use (m^3) [b]	24,985,593	6,378,090
P_2	Monthly salary (\$) = Monthly total payroll for the private sector/(Monthly total employment − government employment) [c]	5,034	1,889
X_2	Monthly total employment (persons) = Total labour force × participation rate × (1 − unemployment rate) [c]	1,472,040	123,584
$\ln(P_1/P_2)$	Log(water price/monthly salary)	−7.8125	0.1722
S	Fraction of time with supply = Monthly supply hours/Monthly total hours [d]	0.9627	0.1379
$\ln S$	Log(Fraction of time with supply)	−0.05427	0.2038

[a] Source: *Hong Kong Government Gazette*, various years.
[b] Source: Hong Kong Water Supply Department.
[c] Source: *Hong Kong Monthly Digest of Statistics*.
[d] Source: Table 1.

period 1973–1990. Because of severe drought, the Hong Kong Water Supplies Department (HKWSD) used service interruption three times to reduce demand. The number of days with service interruption ranged from 23 to 322. Each interruption event consisted of two stages. The first stage involved eight unserved hours per day. When the supply shortage worsened, the HKWSD implemented the second stage by increasing the number of unserved hours to fourteen per day.

These interruptions were implemented after turning off the supply to public swimming pools, soccer fields, parks and fountains. The interruptions were highly publicized prior to their implementation; and consumers were well informed so as to take actions to mitigate the interruption effects (e.g., purchase of water buckets). Consumption reduction was accomplished by complete service disruption with a duration ranging from eight to fourteen hours per day. During the unserved hours, water service to all buildings were shut off by manually closing the valves in the streets in Hong Kong. However, service continued for clinics and hospitals, fire and police stations, power plants, large hotels and industrial firms. In contrast, water rationing in Hawaii described by Moncur (1987) is a quantity constraint which a user can violate by paying a fine.[11]

Table 2 describes the monthly data for estimating W_1. The sample size is

[11]Thus, this is not really a case of quantity rationing. Instead, one may view it as a multi-block rate schedule with a large marginal price for consumption above the quantity constraint. See Hausman (1985) for the econometrics of nonlinear budget sets.

Table 3

Translog water cost share (W_1) equation. Sample period: April 1981–June 1990 (111 observations). Standard error in parentheses.

Coefficient	Value
α_1	0.04489 *
	(0.0028)
β_{11}	0.004839 *
	(0.000351)
β_{1S}	0.001494 *
	(0.00051)
ρ	0.9288 *
	(0.0352)
Adjusted R^2	0.8692
Log-likelihood	700.14
Durbin–Watson statistic	2.2243
Standard error of regression	0.00044

* Significant at 1%.

111 months, covering the period of April 81–June 90. The choice of sample period is dictated by data availability.[12] As shown in table 2, W_1 is small, less than 1% of total costs, the sum of water and labour expenses. This finding is consistent with Renzetti (1988) who reports water cost shares of similar magnitude.

4. Results

To estimate the parameters of the unit translog cost function, we first affix an additive error u_t on the right hand side of eq. (4). Since the data are monthly series, we assume u_t to be an AR(1) error so that $u_t = \rho u_{t-1} + v_t$ with $|\rho| < 1$ and v_t being white noise with zero mean and finite variance. The resulting model is estimated using the maximum likelihood (ML) method in White (1988).

Table 3 reports the ML estimates of (α_1, β_{11}, β_{1S}, ρ). The fit is good with an adjusted R^2 over 0.85. All coefficient estimates are significant at the one percent level. While there is autocorrelation, the Durbin–Watson statistic indicates the transformed residuals are serially uncorrelated.

Table 4 presents the elasticity estimates under alternative supply scenarios: (1) $S = 24/24$ or no interruption; (2) $S = 20/24$ or 4 unserved hours per day; (3) $S = 16/24$ or 8 unserved hours per day; and (4) $S = 12/24$ or 12 unserved hours per day. Because the formulae for computing the elasticities are nonlinear, we use sample enumeration to compute the average responsiveness

[12]The HKWSD can only provide monthly consumption data for April 81 – March 91. Moreover, the salary information in *Hong Kong Monthly Digest of Statistics* is only available for April 81 – June 90.

Table 4

Elasticity estimates for water (X_1) and labour (X_2) demand in Hong Kong.

Elasticity estimate	Fraction of time with supply (number of violations) [a]			
	24/24 (1)	20/24 (2)	16/24 (4)	12/24 (13)
e_{11}	−0.3055	−0.2777	−0.2452	−0.2126
e_{22}	−0.0023	−0.0020	−0.0017	−0.0014
e_{1S}	0.2005	0.2091	0.2193	0.2294
e_{2S}	−0.0132	−0.0132	−0.0131	−0.0131

[a] All cost shares are found to be positive. Thus, the violations are observations for which $c(\cdot)$ is not concave in prices. The average elasticity estimates reported here excludes these observations.

of demand with respect to prices and supply duration.[13] We do not report cross price elasticities as they are the negative of the own price elasticities, see section 2. Table 4 also reports the number of observations that fail to satisfy the regularity conditions governing $c(\cdot)$ (i.e., positive cost share and concavity in prices for all observations in the sample).

The translog appears to be a valid second order local approximation for $\ln c(\cdot)$ when $S \geq (16/24)$ because the number of violations is only 4 or less. When S ($=$ 12/24) deviates substantially from the sample mean of 0.96, the number of violations increases to 13. This finding is expected for two reasons. First, the translog is only a local approximation around the sample mean. Second, demand responsiveness to water price changes declines with supply duration as predicted by the proposition stated in section 2.

The own-price elasticity (e_{11}) estimates range from -0.21 to -0.30, indicating that water demand is price inelastic. This finding is consistent with Renzetti (1988), Babin et al. (1982) and Grebenstein and Field (1979). The size of price responsiveness is decreasing in S. In other words, if the interruption duration is lengthened, a firm becomes less price sensitive, thus corroborating the theoretical prediction made by Tobin and Houthakker (1951, p. 145). However, e_{1S} estimates show that water demand is less responsive to changes in S when S is close to unity (i.e., perfect supply availability). Equivalently said, if the interruption duration is short, eliminating the interruption has little effect on a firm's water demand.

The own-price elasticity estimates for labour demand range from -0.001 to -0.002, indicating that labour demand are insensitive to changes in wage rate. This is expected since labour accounts for over 99% of the variable costs. Similarly, labour demand does not vary significantly with supply duration in view of the small estimate of -0.013 for labour demand's elasticity with respect to supply duration.

[13] We first compute the elasticity value for each month and then take the average of the monthly results.

Table 5

Total economic costs of water service interruption to Hong Kong firms. Benchmark for comparison: $S_0 = (24/24) = 1$.

Variable and definition	Fraction of time with supply (S_1)		
	20/24	16/24	12/24
$\Delta \ln X_1$: % reduction in water demand due to interruption	3.66	8.10	13.54
ΔX_1: reduction in water demand due to interruption (m^3/month)	935,774	2,011,291	3,234,243
$\Delta \ln c_S$: % increase in unit costs due to interruption	0.2125	0.4722	0.8043
Total welfare loss due to interruption (HK$million/month)	16.36	35.87	58.23
Loss per unit unserved ($/$m^3$) due to interruption = Total loss/ΔX_1	17.48	17.83	18.0
($\ln VP_1 - \ln P_1$): required % change in price to achieve identical demand reduction	14.02	29.51	44.48
$\Delta \ln c_P$: % increase in unit costs due to pricing	0.1001	0.2275	0.3676
Total cost increase due to pricing (HK$million/month)	8.62	19.06	28.02
Loss per unit unserved ($/$m^3$) due to pricing = Total loss/ΔX_1	9.21	9.48	8.66

Using the translog unit cost function, we apply eqs. (1) and (3) to simulate the welfare loss of service interruption.[14] Table 5 presents the results for $S_0 = 1$ and $S_1 = 20/24$, 16/24, 12/24. The demand reduction ranges from 3.6% to 13.6% of total demand. The welfare loss due to interruption range from 0.2% to 0.8% of the total costs, or HK$16 to HK$58 million per month.[15] The welfare loss is increasing in interruption duration at an increasing rate, thus satisfying $\partial c/\partial S \leq 0$ and $\partial^2 c/\partial S^2 \geq 0$, the theoretical prediction established in section 2. The estimate for loss per m^3 unserved is $18 and does not vary with S_1, indicating that the total loss is proportional to the demand reduction. The price increase required to achieve the same consumption reduction is between 14% to 45%. The cost increase due to a pricing strategy ranges from 0.10% to 0.36%, or HK$8.6 to HK$28 million per month. Thus, the welfare loss due to pricing is half the loss due to interruption. This shows that pricing is more efficient than interruption in resolving a water supply shortage.

5. Conclusion

This paper specifies a model of firm behaviour under service interruption

[14]This simulation involves observations that satisfy the following criteria: (1) the observation does not violate the concavity condition; and (2) $S_0 = 1$ for that observation. The first criterion is imposed to avoid the problem of $VP_1 < P_1$. The second criterion allows us to compute the total cost increase as the product of $\Delta \ln c_S$ and the observed total cost $(P_1X_1 + P_2X_2)$ at $S_0 = 1$. Eight observations are excluded under the second criterion.

[15]Exchange rate: HK$7.8 = US$1.0.

and implements it using water consumption data. From this model, we develop the welfare loss of water service interruption designed to reduce consumption during times of severe drought. Using the same model, we have also computed the welfare loss due to a price increase that yields the same amount of consumption reduction. Using the monthly non-residential water use data, we estimate the two types of welfare loss. Since our loss estimates are based on actual market data, they are free from the common criticisms related to the results developed from contingent valuation survey data. We find the welfare loss due to interruption being twice the loss due to pricing. These findings lead us to conclude that relative to pricing, service interruption is inefficient for water shortage management.

Appendix

Proof of proposition 1

We first prove $\partial A/\partial h \leq 0$. The Lagrangian for the cost minimization problem with multipliers λ and θ is

$$L = P_1 x_1 + P_2 x_2 + \lambda(z - g(x_1, x_2)) + \theta(x_1 - \phi h). \tag{A.1}$$

Let $x_1^* > 0$ and $x_2^* > 0$ be an interior solution to the programming problem. If $x_1^* = \phi h$, then the Kuhn–Tucker conditions for an interior solution imply $\partial A/\partial h = -\phi\theta = \phi(P_1 - \lambda g_1) < 0$. When $x_1^* < \phi h$, $\partial A/\partial h = -\phi\theta = 0$. Thus, $\partial A/\partial h \leq 0$. □

We now prove $\partial^2 A/\partial h^2 \geq 0$. When $x_1^* < \phi h$ and therefore $\theta = 0$, we have the trivial case of $\partial^2 A/\partial h^2 = 0$. Suppose $x_1^* = \phi h$. We rewrite eq. (A.1) as

$$L = P_1 \phi h + P_2 x_2 + \lambda(z - g(\phi h, x_2)). \tag{A.2}$$

The first order conditions for an interior solution are: $P_2 - \lambda g_2 = 0$, and $z - g(\phi h,\ x_2) = 0$. Totally differentiating these conditions and setting $dP_1 = dP_2 = dz = 0$, we find $\partial x_2^*/\partial h = (-\phi g_1/g_2) < 0$, and $\partial\lambda/\partial h = (\phi/g_2)(-\lambda g_{12} + g_1 g_{22}/g_2) < 0$. Since $\partial A/\partial h = \phi(P_1 - \lambda g_1)$ at $x_1^* = \phi h$, $\partial^2 A/\partial h^2 = -\phi(\phi\lambda g_{11} + \lambda g_{12}\partial x_2^*/\partial h + g_1 \partial\lambda/\partial h) > 0$. Thus, $\partial^2 A/\partial h^2 \geq 0$. □

References

Aigner, D.J. and J.G. Hirschberg, 1985, Commercial/industrial customer response to time-of-use electricity prices: Some experimental results, Rand Journal of Economics 16 (3), 341–355.

Babin, F., C. Willis and P. Allen, 1982, Estimation of substitution possibilities between water and other production inputs, American Journal of Agricultural Economics 64 (1), 148–151.

Barnett, W.A. and Y.W. Lee, 1985, The global properties of the Minflex Laurent, Generalized Leontief, and Translog flexible functional forms, Econometrica 53 (6), 1421–1437.

Berndt, E.R., 1990, The practice of econometrics: Classic and contemporary, Addison Wesley, Reading, MA.

Bohn, R.E., et al., 1984, Optimal pricing in electricity network over space and time, Rand Journal of Economics 15 (3), 360–373.
Brookshire, D.S. and D.L. Coursey, 1987, Measuring the value of a public good: An empirical comparison of elicitation procedures, American Economic Review 77 (4), 554–566.
Caves, D.W., J.A. Herriges and R.J. Windle, 1990, Consumer demand for service reliability in electric power industry: A synthesis of the outage cost literature, Bulletin of Economic Research 42 (2), 79–119.
Chao, H.P. and R. Wilson, 1987, Priority service: Pricing, investment and market organization, American Economic Review 77 (5), 899–916.
Coate, S. and J.C. Panzar, 1989, Public utility pricing and capacity choice under risk: A rational expectation approach, Journal of Regulatory Economics 1 (3), 305–317.
Cummings, R.G., et al., eds., 1986, Valuing environmental goods: A state of art assessment of the contingent method, Rowman and Allanheld.
Deacon, R.T. and J. Sonstelie, 1989, The welfare costs of rationing by waiting, Economic Inquiry, April, 179–196.
Deaton, A. and J. Muellbauer, 1981, Functional forms for labour supply and commodity demands with and without quantity restrictions, Econometrica 49 (6), 1521–1532.
Diewert, E.W., 1974, Applications of duality theory, in: M.D. Intrilligator and D.A. Kendricks, eds., Frontier of quantitative economics, Vol. II, North-Holland, Amsterdam, 106–171.
Diewert, E.W., 1976, Exact and superlative index numbers, Journal of Econometrics 4, 115–145.
DWR, 1987, California water: Looking to the future, Publication No. 160-87, California Department of Water Resources.
Frech, H.E. and W.C. Lee, 1987, The welfare cost of rationing-by-queuing across markets: Theory and estimates from the U.S. gasoline crises, Quarterly Journal of Economics, February, 97–108.
Grebenstein, C. and B. Field, 1979, Substituting for water in U.S. manufacturing, Water Resources Research 15 (2), 228–232.
Hamilton, J.R., N.K. Whittlesey and P. Halverson, 1989, Interruptible water markets in the Pacific Northwest, America Journal of Agricultural Economics 71 (1), 63–75.
Hartman, R.S., M.J. Doane and C.K. Woo, 1990, Status-quo bias in the measurement of value of service, Resources and Energy 12, 197–214.
Hartman, R.S., M.J. Doane and C.K. Woo, 1991, Consumer rationality and the status-quo, Quarterly Journal of Economics, February, 141–162.
Hausman, J.A., 1985, The econometrics of nonlinear budget sets, Econometrica 53 (6), 1255–1282.
Howe, C.W. and F.P. Linaweaver, 1967, The impact of price on residential water demand and relation to system design and price structure, Water Resources Research 3 (1), 13–32.
Kahneman, D., J.L. Knetsch and R.H. Thaler, 1991, The endowment effect, loss aversion and status-quo bias, Journal of Economic Perspectives 5 (1), 193–206.
Kapteyn, A., P. Kooreman and A. Van Soest, 1988, Quantity rationing and concavity in a flexible household labour supply model, Review of Economics and Statistics, 55–62.
Krzysztofowicz, R., 1986, Expected utility, benefit and loss criteria for seasonal water supply planning, Water Resources Research 22 (3), 303–312.
Martin, W.E., and J.F. Thomas, 1986, Policy relevance in studies of urban residential water demand, Water Resources Research 22 (13), 1735–1741.
Mercer, L.J. and D.W. Morgan, 1985, Conservation using a rate of return decision rule: Some example from California municipal utilities departments, Water Resources Research 21 (7), 927–933.
Mitchell, R.C. and R.T. Carson, 1989, Using surveys to value public goods: The contingent valuation method, Resources for the Future, Washington, DC.
Moncur, J.E.T., 1987, Urban water pricing and drought management, Water Resources Research 23 (3), 393–398.
Moncur, J.E.T. and R.L. Pollock, 1988, Scarcity rents for water: A valuation and pricing model, Land Economics 64 (1), 62–72.
Morris, J.R., 1990, Pricing for conservation, Contemporary Policy Issues 8 (4), 79–91.
Munasinghe, M., C.K. Woo and H.P. Chao, eds., 1988, Special electricity reliability issue, Energy Journal, 9.

Renzetti, S., 1988, An econometric study of industrial water demands in British Columbia, Canada, Water Resources Research 24 (10), 1569–1573.
Riley, J.G. and C.R. Scherer, 1979, Optimal water pricing and storage with cyclical supply and demand, Water Resources Research 15 (2), 233–239.
Sengupta, J.K. and M. Khalili, 1986, Efficiency in water allocation under stochastic demand, Applied Economics 18 (1), 37–48.
Schuster, D.R., 1987, Water supply needs and management in South San Francisco Bay SWP service area, State Water Contractors, Sacramento, CA.
Schwartz, J., 1988, The real price of water, American Demographics, September, 29–32.
Spulber, D.F., 1992, Optimal rationing and contingent contracts, International Economic Review 33 (4), 747–772.
Tishler, A., 1992, Optimal production with uncertain interruptions in the supply of electricity: Estimation of electricity outage costs, European Economic Review, forthcoming.
Tobin, J. and H.S. Houthakker, 1951, The effect of rationing on demand elasticities, Review of Economic Studies 18, 140–153.
Vickrey, W., 1971, Responsive pricing for utility services, Bell Journal of Economics 2 (1), 337–346.
White, K.J., 1988, SHAZAM: A comprehensive computer program for regression models (Version 6), Computational Statistics and Data Analysis, August, 102–104.
Whittington, D., et al., 1990, Estimating the willingness to pay for water services in developing countries: A case study of the use of contingent valuation surveys in Southern Haiti, Economic Development and Cultural Change 38 (2), 293–311.
Wilson, R., 1989, Efficient and competitive rationing, Econometrica 57 (1), 1–40.
Woo, C.K., 1990, Efficient electricity pricing with self-rationing, Journal of Regulatory Economics 2 (1), 69–81.
Woo, C.K. and D. Glyer, 1990, Voluntary interruptible pricing program: An integrated approach to electricity reliability pricing, Research Report submitted to Niagara Mohawk Power Corporation, Analysis Group, Inc., San Francisco, CA.
Woo, C.K. and R.L. Pupp, 1992, Costs of service disruptions to electricity consumers, Energy – The International Journal 17 (2), 109–126.
Woo, C.K., et al., 1991, How much do electricity customers want to pay for reliability? New evidence on an old controversy? Energy Systems and Policy 15, 145–159.