Evaluation of the 2005

Energy-Smart Pricing Plan^SM

Final Report

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E EXECUTIVE SUMMARY

This report presents results from an impact evaluation of the Community Energy Cooperative's Energy-Smart Pricing Plan ^{SM} (ESPP) residential real-time pricing (RTP) program for 2005. This analysis is a direct continuation of the impact evaluation of ESPP conducted by Summit Blue Consulting in 2003 and 2004.[1]

This effort is particularly timely given the passage of the U.S. Energy Policy Act of 2005.[2] Sections 1252(e) and (f) of the U.S. Energy Policy Act of 2005 (EPACT) state that it is the policy of the United States to encourage "time-based pricing and other forms of demand response." In addition, EPACT contains, under its amendments to the Public Utility Regulatory Policies Act (PURPA), provisions that **each *State regulatory authority*** shall conduct an investigation and issue a decision whether or not it is appropriate for electric utilities to provide and install time-based meters and communications devices for each of their customers which enable such customers to participate in time-based pricing rate schedules and other demand response programs (Section 115(i) of PURPA). This is to be undertaken within 18 months of the passage of EPACT. This legislation along with increasing pressures on energy costs has resulted in many regulatory jurisdictions taking an interest in time-based pricing such as the Community Energy Cooperative's day-ahead RTP Energy-Smart Pricing Plan. This impact assessment of the ESPP will be an important part of what should be a growing body of literature on time-based rates across all sectors.

This evaluation focuses on several key research questions including:

- Will residential customers respond to hourly market-based electricity prices?
- What is the magnitude of the effect, i.e., to what degree is electricity consumption affected by prices?
- How have the customers' responses changed over time (2003 to 2005), particularly given the fact that summer 2005 was considerably hotter than either 2003 or 2004 with correspondingly higher prices?

The hot 2005 summer temperatures coupled with the natural gas disruptions caused by the multiple hurricanes make this report of particular significance. These acted together to result in hourly electricity prices which were appreciably higher than in the previous summers. As a result, assessing how participants respond to the higher prices and repeated high price notifications was an important research effort.

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[1] The reports can be found at http://www.energycooperative.org/how-it-works.php.

[2] Public Law 109-58, August 8, 2005.

The continuing findings of the Community Energy Cooperative's ESPP program, as detailed in this evaluation, are important, given the national need to develop estimates of price responsive load in mass markets. These results will augment the few studies that have been conducted examining these mass market customers.

ES.1 Background on Real-Time Pricing Plans

The Community Energy Cooperative, in association with ComEd, has developed the first significant effort to introduce hourly market-based electricity pricing to residential customers. The goal is to allow both participating customers and the market as a whole to capture the benefits of having retail prices of electricity reflect the costs of providing that power to customers.

This project addresses some of the central issues associated with providing residential customers electric price signals that reflect the changing costs of providing electricity. While the hourly costs of electricity in wholesale markets can vary dramatically, retail pricing, particularly for residential and small commercial customers, has largely remained subject to regulated tariffs. These tariffs typically have provided customers with fixed rates, i.e., they pay the same price for electricity regardless of when and how much is used. This fixed rate does not reflect the true cost to the economy of consuming electricity at a given point in time, and therefore it distorts key market decisions.

Prices provide the market signals that are used to allocate resources. The question that needs to be addressed by those administering, regulating, designing, and participating in electricity markets is:

> ***How can we expect to have efficient electricity markets without having price signals that accurately price what is scarce, i.e., on-peak electricity use?***[3]

As long as consumers have flat rates, there is little incentive to manage what is scarce. With real-time pricing, residential customers still receive a monthly bill that represents an average of electricity costs across that month. However, these customers are now afforded an opportunity to manage their bills and reduce their energy costs by shifting some of their energy use from high price periods to lower price periods.

A rationally priced retail electric market can support business cases for innovation. Technology companies such as Microsoft, Carrier, Honeywell, and others are developing equipment that will allow customers to manage demand while increasing overall comfort and benefits from energy services. The business cases for the development of these technologies depend, in part, on both business and residential customers seeing cost savings result from managing peak demand. Appropriate pricing reflecting what is costly and scarce will allow customers to be passive and still save money. The technology companies will have the business case needed to innovate, develop, and market new energy management technologies to customers. They will drive changes in energy-using equipment and energy management technologies that will help customers shift and conserve energy during periods of scarcity and high prices.

The results of the Community Energy Cooperative's ESPP program, detailed in this evaluation, are important in demonstrating what a sustained RTP program might accomplish in the residential customer segments. ESPP is one of the few studies to address the future of innovative residential pricing programs.

[3] And similarly, accurately price what is abundant, i.e., off-peak electricity use.

ES.2 Community Energy Cooperative's Energy-Smart Pricing Plan[SM] (ESPP)

The Community Energy Cooperative's (Cooperative) Energy-Smart Pricing Plan was started in January 2003. It provides customers with electricity prices that accurately reflect the hourly market price of electricity, and gives them the opportunity to make informed decisions about electricity use based on these prices. Details on the characteristics of ESPP can be found at the Community Energy Cooperative website: http://www.energycooperative.org/how-it-works.php.

This past year (i.e., 2005) represents the third year of operation for this pricing plan. ESPP had 750 participants in 2003 and this number grew to almost 1,500 customers in 2005. Features of ESPP include:

- Day-ahead prices. Prices for the next day are posted on the website or available by phone after 5 p.m.
- High price day-ahead notification. When the day-ahead price of electricity is over ten cents/kWh, ESPP customers are notified by telephone or e-mail. The purpose of this notification is to provide a mechanism for participants to become aware of relatively expensive prices and to adjust their consumption accordingly without relying upon expensive technology, i.e., metering and monitoring systems.
- Price protection cap. The Cooperative includes a price limit hedge at $0.50 per kWh, meaning that no customer participating in ESPP will see a net hourly price greater than $0.50 per kWh.
- Energy management and price response information. The Cooperative provides energy education and individual usage information.

ES.3 Estimation of 2005 Program Impacts

The previous evaluations of ESPP have shown that residential customers do respond to hourly prices. In this third year, the purpose of the evaluation was to determine if customers continue this trend and how this changes under different market conditions (e.g., the extreme summer weather and higher prices during 2005). In addition, the impact evaluation addressed the following key issues:

- What is participants' price elasticity, and how do they respond to high price notifications?
- Are there any differences in price response between participants who started in 2003, 2004, and new participants in 2005 given the different conditions in each year?
- How does the response to price vary by house types (single family and multifamily) and air conditioning technology (central, window, and none) and other customer characteristics?
- Have differences in the responses of participants in the Central Air Conditioner Cycling Option occurred, particularly when they have been controlled for very long periods of time, both in terms of the number of hours per day and the number of consecutive days?
- Does this program have an effect on energy consumption (in addition to the above demand impacts)? Does hourly energy pricing contribute to conservation?

In order to address these issues, several econometric models were estimated that combined monthly and hourly electricity consumption with the hourly electricity prices, census data, survey responses, and weather data. The results from each model are presented below.

ES.3.1 Energy Impacts Model

A regression-based model was developed to estimate the electricity consumption of each participant. The results show that ESPP participants consumed 35.2 kWh less per month during the summer months under ESPP relative to what their usage was estimated to be had they not received hourly electricity prices. This represents a savings of 3 to 4% of summer (June through August) electricity usage. During the winter months,[4] there was no statistically significant difference in monthly energy use between ESPP participants and individuals not facing hourly electricity prices. Therefore, ESPP results in a net decrease in **monthly** energy consumption.

ES.3.2 Hourly Price Response

The analysis developed several models to determine participants' response to hourly electricity prices. The first model was identical to the models that were used in the past two analyses to allow for comparison of results over time. The price elasticity estimated with this model is -4.7% (t-value of -16.6). This compares favorably to the elasticity estimate found in the evaluation of ESPP 2003 (-4.2% with a t-value of 12.6), i.e., a bit higher and a bit more significant.

The second model looked more specifically at individual customers' responses in order to understand the factors that influence a given customer's price response. Average results (weighted by the variance of each individual result) are presented below.

Exhibit ES-1. Aggregate Results (weighted by individual variance)

Period	Elasticity	T-Value
Daytime (before 4 PM)	-1.5%	-60.42
Late Afternoon/Evening (4 PM or later)	-2.6%	-106.42
Response on High Price Alert Days		
Daytime (before 4 PM)	-2.0% (.5% increment)	-5.77
Late Afternoon/ Evening (4 PM or later)	-4.8%(-2.2% increment)	-26.61

This shows that customers reduce consumption in response to higher electricity prices. This response varies from an elasticity of 1.5% during the day to 4.8% during high-priced late afternoon/evening hours.

One of the key aspects of ESPP is the personal notification (via phone or e-mail) to participants when the price the next day is expected to be greater than or equal to 10 cents per kilowatt hour. The hourly price elasticity model described above revealed that these high-price notifications do indeed increase a customer's response to prices, particularly if the high prices occurred during the late afternoon and evening.

The more detailed results report examines these individually-estimated elasticities and determines how these price responses are related to air conditioner cycling, notification success rate, customer characteristics (primarily from the census tract demographics), and air conditioner type (from participant database).

[4] Participants are on hourly electricity prices throughout the year.

These results demonstrate that residential customers do indeed respond to hourly electricity prices, and overall this response is consistent across years, despite great variation in weather and energy prices. This analysis has also shown that the degree to which residential customers respond to prices varies by the time of day, as well as by several observable characteristics of the customer.

ES.4 RTP Impacts on Energy Use

The overall results of the Energy Smart Pricing Plan, which provides customers with hourly prices that allow them to manage their energy bill and change their on-peak energy use, are shown below:

Key Findings

- ESPP participants continue to respond to hourly electricity prices in a manner similar to prior years, with an overall price elasticity of -4.7%. This means that a doubling of electricity prices results in a decrease in their hourly electricity use by nearly 5%.
- Participants' response to hourly electricity prices varies by the time of day, with lower responses during the day, and higher responses during the late afternoon/evening.
- ESPP participants' overall monthly summer energy (kWh) usage suggests a conservation effect, that is, a reduction in usage of 3% to 4%, relative to what their usage was estimated to be had they not received hourly electricity prices.

Additional Findings

- Participants continue to show a significant response to the high-price notifications (i.e., when prices exceed $0.10/kWh). For example, on July 25, 2005, the day with the highest prices of the summer, participants reduced their peak hour consumption by 15% relative to what their consumption would have been on the standard flat ComEd residential rate
- Participants reporting successful notifications essentially double their average response to changes in electricity prices.
- Automatic cycling of the central-air conditioners (turning the compressor on and off for short periods of time via remote control) during high-price periods added to a participant's response to electricity prices by as much as 2.2% for a total price response of 6.9%.
- Specific observable variables (or characteristics) that influence the participant's response to hourly prices were identified. For example, households with numerous individuals at home during the day are likely to be more price-responsive during the day, and customers who receive high-price notifications via e-mail are 2% more responsive (adding to their price response) on high-priced days.
- Customers' response to high-price notifications does decline somewhat as the number of consecutive notification days during the summer increases and as the length of a given high-price period increases, but there is a "recharge" effect as the number of days between high-price notifications increases, where customers' response recovers to initial levels.

1 INTRODUCTION: IMPACT RESULTS

This report presents the results of the impact evaluation of the Community Energy Cooperative's Energy-Smart Pricing Plan^SM (ESPP) residential real-time pricing (RTP) program for 2005. This analysis is a direct continuation of the impact evaluation of ESPP conducted by Summit Blue Consulting in 2003 and 2004.[5]

This effort is particularly timely given the passage of the U.S. Energy Policy Act of 2005.[6] Sections 1252(e) and (f) of the U.S. Energy Policy Act of 2005 (EPACT) state that it is the policy of the United States to encourage "time-based pricing and other forms of demand response." In addition, EPACT states under its amendments to the PURPA provisions that **each *State regulatory authority*** shall conduct an investigation and issue a decision whether or not it is appropriate for electric utilities to provide and install time-based meters and communications devices for each of their customers which enable such customers to participate in time-based pricing rate schedules and other demand response programs (Section 115(i) of PURPA). This is to be undertaken within 18 months of the passage of EPACT. This legislation along with increasing pressures on energy costs has resulted in many regulatory jurisdictions taking an interest in time-based pricing such as the Community Energy Cooperative's day-ahead RTP Energy-Smart Pricing Plan. This impact assessment of the ESPP should be an important part of what should be a growing body of literature on time-based rates across all sectors.

Section 1.1 presents an overview of ESPP stressing the differences between market conditions between 2003 and 2005. Section 1.2 presents the objectives of this evaluation, and Section 1.3 describes the organization of the report.

1.1 Background on the Energy-Smart Pricing Plan^SM

The Community Energy Cooperative (Cooperative) is a non-profit organization committed to offering its members programs and services to reduce costs of energy services, and improve neighborhood electrical reliability. To that end, the Cooperative has collaborated with Commonwealth Edison (ComEd) and the Illinois Department of Commerce and Economic Opportunity (DCEO) to test residential customers' responses to day-ahead, market-based hourly pricing (also known as real-time pricing) through a three-year pilot program offered to the Cooperative's members through a new ComEd tariff. DCEO provided funding for the interval meters, programmable thermostats, and for this Evaluation Report.

This program, the Energy-Smart Pricing Plan, was started in January 2003, and was the first time in the nation that residential customers were given the opportunity to pay market-based electricity prices. By exposing residential customers to the market price of electricity, customers are given the opportunity to

[5] The reports can be found at http://www.energycooperative.org/how-it-works.php

[6] Public Law 109-58, August 8, 2005.

make informed decisions about electricity use. Renewed recognition of the value of time-differentiated rates has increased the need to better understand how customers respond to different rate offerings. The ESPP program has special significance for several reasons:

1. The ESPP real-time pricing rate is unique in its focus on **residential pricing that varies by hour.** To date, it is the only hourly residential RTP rate that has been tested at any scale.[7] Other price-responsive programs for residential customers have emphasized time-of-use (TOU) rates or critical-peak pricing (CPP). Time-of-use rates vary by time period, but are constant from one day to the next. With the CPP rate, there is a critical peak rate that reflects emergency conditions and is set much higher — sometimes as much as 10 times higher. ESPP's RTP pricing allows customers to make informed decisions about their energy use in response to market conditions every hour of every day, rather than for a few critical hours.

2. The ESPP program is unique in its focus on a **low technology approach**. It tests the hypothesis that meaningful benefits can be obtained from RTP in the residential sector without expensive technology such as meters with two-way communications capability and energy management systems that automatically respond to price signals. In contrast, a project in California has as its hypothesis that, "To develop this demand response capability, homes will have to be equipped with a new generation of electric meters, thermostats, and control devices … that would allow users to optimize energy usage and reduce cost," and includes wireless technologies throughout the house to communicate with heating and air conditioning systems, lights and other building systems.[8] The more common technology-driven approach involves much higher investment cost, reducing the payback to customers and the broader system, and perhaps excluding all but the largest residential users from participating. ESPP is a pricing program that does not require these technologies.

3. ESPP is unique in its focus on the **full range of residential customers, including low-income customers.** The conventional wisdom was that only higher income customers and larger homes will have the capability to respond to real-time prices. Since ESPP is open to all types of residential customers, this program can test these conventionally held assumptions. For consumer advocates that represent low income customers, this information is of particular importance.

4. Illinois passed the Electric Service Customer Choice and Rate Relief Law (HB 362) in 1997.[9] This legislation was designed to allow customers to choose their retail electricity provider. However, to date, few options have emerged for residential customers. ESPP was designed in part to **offer mass-market**

[7] Residential customers in the San Diego Gas & Electric service territory were exposed to real-time prices for several months when regulatory price caps expired under California's restructuring laws, but the California PUC quickly changed the residential rate to reflect the traditional rate that had been in effect. As part of re-structuring, real time pricing was also briefly in place in Ontario, Canada, but this was also short lived as a newly elected government changed electric rates back to the previous rate structure. No study of the effects of these rates or the benefits and costs from residential real-time pricing was conducted.

[8] This comes from the description of the "Demand Response Enabling Technology Project," Center for the Build Environment, California Institute of Energy Efficiency (CIEE). This effort is a collaboration of the Center for the Built Environment (CBE), UC Berkeley Wireless Research Center (BWRC), Berkeley Sensor and Actuator Center (BSAC), and the Intel Research Laboratory at Berkeley. While the development of these technologies will undoubtedly have applications in the future and in residences where the technology proves to be economic, it may not have widespread applicability across the full range of residential customers.

[9] On June 30, 1999 Illinois Governor George Ryan signed into law SB 24, an act that amends the 1997 electric restructuring act. Provisions of the new act including an acceleration of retail choice for commercial and industrial customers (from December 2000 to June 2000 for some and October 2000 for others).

customers a different type of choice. In this case, while customers may not be able to choose an alternative electricity provider, they can choose an alternative rate. They can also choose how they will adjust their electricity use in order to respond to market conditions and save money on their bills. As a result, the ESPP experience provides insights that may apply in other restructured states where the mass market has not yet benefited from the move to retail choice.

In 2003, more than 750 customer members were enrolled in the program. To aid in the first impact evaluation of ESPP, the Cooperative randomly assigned ESPP enrollees into two groups: participants (651 members), who were exposed to the hourly market prices, and a control group (103 members), whose members had an interval meter installed, but did not receive any of the ESPP educational information and continued to pay a flat rate for their electricity   In 2004, the control group participants were transferred into the ESPP group and began paying for their electricity using Rate RHEP, and additional customers enrolled in the program. This resulted in an enrollment of over 1,000 customer members in the ESPP program. In 2005, additional applicants were allowed to enroll in the program and a concurrent participation population of 1,417 was reached (more than 1,500 participants were enrolled in ESPP over the three years, but 1,417 was the maximum concurrent enrollment due to attrition from customers moving).

Another feature of ESPP is the day-ahead notification of high price days, where the price of electricity will be over $0.10/kWh. This notification is done by telephone or e-mail. The purpose of this notification was to provide a mechanism for participants to become aware of relatively expensive prices and to adjust their consumption accordingly without relying upon expensive technological monitoring systems. Other noteworthy aspects of the ESPP include:

- Day-ahead prices. Prices for the next day are posted on the website or available by phone after 5 p.m.

- Price protection cap. The Cooperative includes a price limit hedge at $0.50 per kWh, meaning that no customer participating in ESPP will see a net hourly price greater than $0.50 per kWh.

- Energy management and price response information. The Cooperative provides:
    - Information about usage that is available on a monthly basis. A website allows participants to see their hourly usage, prices and costs in both tabular and graphical formats.
    - Instructions and tips on how to reduce usage during peak periods. See: http://www.energycooperative.org/pdf/summer-readiness-2006.pdf for an example of such materials.

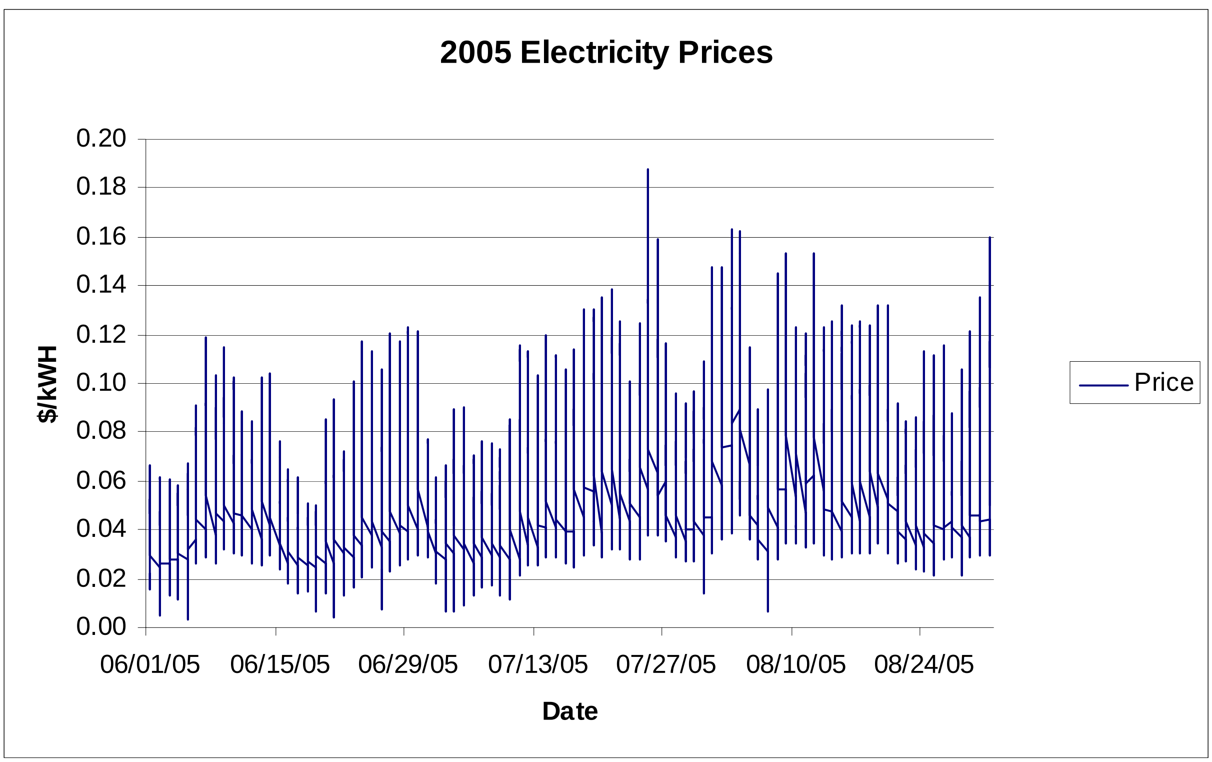
This program uses ComEd’s Rate RHEP - Residential Hourly Energy Pricing (Experimental). The program’s pricing was initially set using prices as provided daily from Platts Global Energy for the ComEd day-ahead hourly prices using PJM load shapes. In June 2005, the prices were changed to the PJM ComEd Zone Day-Ahead Hourly LMP’s, now available due to ComEd joining the PJM Interconnection, LLC. In addition to the hourly electricity price, participants’ bills contain an access charge that is adjusted yearly, but is capped at 4.881 and 5.367 cents per kWh for single-family and multi-family homes, respectively. The June 2005 through May 2006 access charges are 3.307 and 3.734 cents per kWh for single-family and multi-family homes, respectively. Program participants’ rates are reduced by 1.4 cents per kWh so that the access charge would be more representative of a distribution charge in a market-based rate.

A new feature of ESPP during 2004 and continuing into 2005 was the addition of the installation of cycling switches on the central air conditioners of 57 participants. These switches were set to cycle the air conditioner 50% of the time during a high-price period. This automatic cycling was an experiment to see how this type of direct intervention compares to giving participants their choice of whether or not to use an air conditioner during the high-price periods.

During the first year of ESPP (2003) weather conditions were relatively mild, and hourly electricity prices rose above 10 cents per kilowatt-hour on only 20 days, and usually for only three or four hours each day. The summer of 2004 was even milder (in fact, it was the fourth coolest summer in the previous twenty-five years) and there were only 19 hours, spread over seven days, when prices were over 10 cents per kilowatt-hour.

The weather conditions changed dramatically in 2005. June and July of 2005 were ranked as the sixth warmest of all comparable months on record since 1871. This extreme heat resulted in record peak electricity demands. In addition to the extreme weather, the prices for natural gas, an input to the production of electricity, were also high reflecting world events and concern over the potential effects of hurricanes on supplies of natural gas. Higher gas prices translate into higher electricity prices, independent of weather. Taken together, they provided a set of market conditions that resulted in relatively high hourly electricity prices throughout the summer. During the summer of 2005, there were 57 days from June through August where prices exceeded $0.10/kWh (commodity portion only), with prices staying over this level for as much as 13 hours per day (for a total of over 360 hours of high prices). The highest price was just under 19 cents per kilowatt-hour for one hour.[10]

Exhibit 1. ESPP Hourly Electricity Prices, Summer 2005



[10] In 2001 and 2002 (prior to ESPP), the highest hourly energy price was $0.38/kWh.

The summer of 2005 represented an opportunity to examine how residential customers respond to hourly changes in electricity prices under these market conditions including their response to repeated high-price notifications and long periods of relatively high electricity prices.

1.2 Objectives of the Impact Assessment

The focus of this assessment was to conduct an impact evaluation of ESPP during summer 2005. The impact evaluation used interval metered consumption data and weather data to determine how the ESPP affects hourly energy usage and what, if any, difference was the response from that found in prior evaluations.

While there is a general consensus that there are significant economic efficiency benefits associated with retail electricity prices that reflect the time-varying costs of electricity, there is some controversy as to the practicality of implementing such prices, particularly for the residential sector. One aspect of this argument is that residential customers cannot respond to hourly prices because they cannot easily alter their consumption in response to price changes.[11] The previous evaluations of ESPP have shown that residential customers do indeed respond to hourly prices. In this third year, the purpose of the evaluation was to determine if customers continue this trend and how this changes under different market conditions (e.g., the extreme summer weather and higher prices during 2005). In addition, the impact evaluation addressed the following key issues:

- What is participants' price elasticity, and how do they respond to high price notifications?
- Are there any differences in price response between participants who started in 2003, 2004, and new participants in 2005 given the different conditions in each year?
- How does the response to price vary by house types (single family and multifamily) and air conditioning technology (central, window, and none) and other customer characteristics?
- Have differences in the responses of participants in the Central Air Conditioner Cycling Option occurred, particularly when they have been controlled for very long periods of time?
- Does this program have an effect on energy consumption (in addition to the above demand impacts)? Does hourly energy pricing contribute to conservation?

In order to address these issues, several econometric models were developed combining monthly and hourly electricity consumption with the hourly electricity prices, census data, survey responses, and weather data.

1.3 Background: Potential Benefits of Residential Real-Time Pricing

Electricity prices are the most volatile of any market commodity. Driving this volatility is the fact that electricity can not be stored in significant quantities. As a result, during periods of high demand (hot summer days for example), hourly electric prices can vary substantially over just a 12-hour period. On extreme days, price spikes during resource constrained periods can see increases of by a factor of 50 or

[11] This has led to the belief that residential customers can only respond if they have access to complex energy management systems. ESPP was specifically designed without such technology and the past evaluations have shown that these systems are not necessary for an effective response.

more if there is not enough demand-side response to mitigate the system and supply-side factors that are driving prices up. These prices, even though they may occur only during a few hours each summer, can represent a substantial cost to all the customers in the regional electricity market.

While the costs of electricity in wholesale markets can vary dramatically, retail pricing, particularly for residential and small commercial customers, has largely remained subject to regulated tariffs. These tariffs typically have provided customers with fixed rates, i.e., they pay the same price for electricity regardless of when and how much is used. This fixed rate does not reflect the true cost to the economy of consuming electricity at a given point in time, and therefore it distorts key market decisions.

An important near-term challenge facing electricity markets is the rational pricing of retail electricity. The goal of any market—regulated or unregulated—is to allocate resources equitably, promote efficient investment, and provide incentives for innovation. Prices provide the market signals that are used to allocate resources. Specifically, the key is to appropriately price what is scarce. For electricity markets, what is scarce is on-peak energy. If the market is not designed to appropriately price what is scarce, the market will not be efficient and disconnects between demand and supply can occur, resulting in price spikes. Clearly, non-time-differentiated electricity rates cannot reflect the true costs at the wholesale level of on-peak electricity. With flat rates, customers have price signals indicating the actual cost of electricity at any given time and they are not able to make choices regarding conserving a scarce resource. As a result, they cannot make decisions regarding the appropriate use of electricity required for an efficient market.

Innovative pricing, such as real-time pricing (RTP), is one method of allowing for the interaction of demand and supply needed for efficient markets. Research on time-differentiated pricing is growing as the benefits of these pricing options are becoming better recognized. These options allow customers to see the real wholesale costs of electricity and make decisions regarding their energy use based on market conditions. Overall, customers who see real prices and adjust their demand in response to these price signals can make the electricity system more efficient and stable.[12] As a result, retail electric prices that better reflect the costs of obtaining power in wholesale markets can provide benefits to electricity markets, including the following:

- **Increased system reliability** as price mitigates demand when resources become scarce.
- **Reductions in costs** of electricity to all customers in a regional market as a result of better management of scarce supplies and reductions in capital costs incurred to meet peak demands.
- **Risk management** by allowing customers to manage a portion of the electricity price and commodity risks and be compensated for this service.
- **Environmental benefits** by promoting efficient use of resources and price signals to manage demand.
- **Customers benefit** from being on an RTP rate since now their ability to use electricity flexibly across on-peak and off-peak periods is valued, i.e., a key attribute of their energy use – flexibility in time-of-use – is given a value.
- **Market power mitigation** by providing a demand response to offset high prices for generated electricity.

[12] One of the lessons gleaned from California's energy crisis in 2000/2001, as well as the electricity price spikes and shortages in the Midwest in 1999/2000, is that the lack of demand response in retail markets makes it very difficult to balance demand and supply in wholesale markets at reasonable prices. Prices in wholesale markets vary dramatically by day and by hour, yet the vast majority of rates retail customers see do not reflect this price variation.

- Providing the **incentives for innovation** needed to create technologies and value propositions for load management and peak demand response.
- RTP better reflects the actual cost of service, allowing a **more equitable distribution of costs** across customers and customer classes.
- Unlike conventional load control or curtailable/interruptible incentives, dynamic tariffs such as RTP can be made **available to all customers,** regardless of usage level or appliance ownership.

These benefits from RTP options accrue to a number of entities:

- **Participants.** RTP participants benefit by having the ability to make more informed choices regarding how they use electricity. They also have the opportunity to lower their monthly bills.
- **Electricity customers not participating.** The RTP rate also benefits all customers (participants and non-participants) in a regional electricity system because a relatively small fraction of price-responsive demand can have sizeable impacts on market-wide price spikes and electric system efficiency.
- **Utilities.** Utilities can benefit by improving load factors on existing equipment and not having to make additional capital investments.

Recognition of these potential benefits has led to a number of pilot programs and a move towards time-differentiated rates for large customers.[13] In addition, interest among the regulatory community is increasing. A recent study of State Public Utility Commissions (PUCs) found growing regulatory support for time-differentiated pricing programs with 70% of the respondents (out of 25 PUCs contacted) indicating that they believe time-differentiated rates "provide tangible benefits to both electricity markets and end-use customers."[14]

1.4 Layout of the Report

Chapter 2 of this report presents the methods used and the results of the impact evaluation of the ESPP program during summer 2005 and presents the overall conclusion.

The appendices to the impact report contain the complete estimation results of the models used in the evaluation.

[13] The California Energy Commission created several working groups to examine innovative rates. Working Group 2 examined price-responsive tariffs for customers over 200 kW and Working Group 3 examined price-responsive tariffs for residential and mass market customers (i.e., those with demands under 200 kW). Reports on the applications of these tariffs can be found at the California Energy Commission's website. The work in California is just an example of the nation-wide interest in this issue. Southern Company, the utility which serves much of the Southeast, has used time differentiated rates for years for its larger customers, and recently through its subsidiary Gulf Power a residential rate was developed that varied prices across hours, but in a fixed manner. Both New York and California are exploring technologies to enable customers to allow customers to more easily adjust their electricity demands in response to price.

[14] See: B. Barkett, "Electricity Pricing Programs that Make a Difference," Energy User News; August 24, 2004.

2 IMPACT EVALUATION – METHODS AND RESULTS

This chapter presents the results of the impact evaluation of the third summer of the Energy-Smart Pricing Plan program. Since the electricity market conditions during the summer of 2005 were more extreme compared to the previous years, the analysis was able to delve more deeply into the nature of residential customers' response to hourly electricity prices. Therefore, this analysis was able to develop several insightful and unique modeling approaches.[15]

As in the prior evaluations of these programs, the impact evaluation relied upon hourly consumption data for participants, weather data, and hourly electricity prices to capture, *ex post*, the response to prices. The details on how these data are combined within regression models to understand participants' behavior is presented in the next section.

2.1 Hourly Price Response

The fundamental approach which this (and the previous) analysis used to determine how participants respond to hourly electricity prices is the estimation of the price elasticity of demand for electricity. Price elasticity is defined as the percentage change in demand associated with a percentage change in price. For example, a price elasticity of -10% implies that a 100% increase in price will reduce demand by 10%.

While the concept of price elasticity is straightforward, estimation of it is not. The problem is that there are other things changing hourly besides the price of electricity which can significantly affect the demand for electricity. While there are many such things occurring for any given household (such as people coming and going), the only variables that can readily be measured are those relating to weather. In order to control for the effect of these non-price variables, a regression model was used which statistically models hourly energy use as a function of the hourly price of electricity and the hourly weather conditions.

There are many ways in which such a regression model can be specified. In the two previous analyses done in 2003 and 2004, a pooled model was used which combines data across households (i.e., cross-sectional) with data over time (i.e., time-series) into a single regression equation. Any differences across homes that do not vary over time were captured through house-specific intercept terms, as discussed below.

[15] Some of this work was based upon Summit Blue's evaluation of the Large Customer Critical Peak Pricing programs in California (http://www.energy.ca.gov/demandresponse/documents/index.html#group2).

The fixed effects model can be viewed as a type of differencing model in which all characteristics of the home, which (1) are independent of time and (2) determine the level of hourly electricity use, are captured within the house-specific constant terms. In other words, differences in housing characteristics that cause variation in the level of energy consumption, such as building size and structure, are captured by constant terms representing each unique household.

Algebraically, the fixed-effect panel data model is described as follows:

$$\ln(y_{it}) = \alpha_i + \rho \ln(price_t) + \beta x_{it} + \varepsilon_{it}, \qquad \text{(Eq. 1)}$$

where:

$ln(y_{it})$	=	The natural log of electricity consumption for home *i* during hour *t*
α_i	=	the estimated constant term for household *i*
ρ	=	the price elasticity of electricity demand
$ln(price_t)$	=	The natural log of the price of electricity during hour *t*
ß	=	vector of estimated coefficients
x_{it}	=	vector of variables that represent factors causing changes in the electricity consumption for home *i* during hour *t* (i.e., weather)
ε_{it}	=	error term for home *i* during hour *t*.

This hourly demand model was estimated over all ESPP participants during the months of June through August. Since there was little price variation in early morning hours, the estimation included hours after 9:00 am. Thus, the model was estimated for nearly 854,000 hourly observations from 1,359 participants.[16] The estimated model for 2005 is presented in Exhibit 2. The resulting price elasticity estimate is -4.7% (with a t-value of -16.82), suggesting that this response is statistically significant at the 95% confidence level). Thus, a 100% increase in the hourly price of electricity would produce, on average, a 4.7% decrease in hourly energy use across all participants. This result was very robust across different specifications and different subsets of participants.[17]

Exhibit 2. Elasticity Model. Dependent variable is log of hourly kWh. (Summer 2005)

Independent Variable	Coefficient	t-value
Natural log of hourly price	-0.047	-16.8
Temperature lagged one hour	1.34	125.0
Sample Size	859,953 (1,359 homes)	
R-squared		
Partial (ignoring customer effects)	2%	
Full	61%	

This estimated elasticity is similar to the elasticity found in the 2003 impact evaluation (-4.2% with a t-value of 12.6). Thus, residential customers clearly respond to hourly changes in electricity prices, and this response is consistent over time. This is true even when the prices for electricity are relatively volatile with repeated high price periods.

[16] This is fewer than the total number of 1,417 participants due to missing data from sources such as estimated bills.

[17] This model also incorporates corrections for heteroskedasticity and autocorrelation.

The next section investigates how customers responded to high-price notifications, as well as how the price response varies by customer as well as the time of day.

2.2 Response to High-Priced Hours

The model presented in the previous section showed that customers have a consistent response to hourly electricity prices based upon the estimated price elasticity. Unlike previous years where the cool weather conditions resulted in limited changes in electricity prices, 2005 was characterized by significantly more periods of relatively high prices. This volatility allowed us to extend this base model by investigating whether or not this price elasticity varies over the day. In addition, the previous model does not address the impact of high-price notifications. By investigating different blocks of time, it was determined that there was indeed a variation in price elasticity over the day, with two blocks of time:

- The hourly electricity price for daytime hours (8 am to 4 pm)
- The hourly price for late afternoon/evening hours (4 pm to midnight)

To capture the effect of high-price notifications, two additional variables were used:

- A binary indicator for high price hours during the day
- A binary indicator for high price hours during the late afternoon/evening hours

In addition, one of the goals of previous analyses of this program was to try to differentiate between "high" responders and "low" responders. The analysis in the past relied upon *ad hoc* definition of what constitutes a high or low responder. In this analysis for 2005, it was decided to move away from this artificial distinction, and develop individual elasticity estimates. The estimation of this model is discussed in this section. One of the many benefits of evaluating individual elasticity is that one can estimate the factors that affect the differences in individual elasticities. That analysis is presented in the next section.

The model that was used to estimate individual elasticities is very similar to the previous model, the only difference being that data is no longer pooled together. Thus, instead of one pooled regression equation, there are now 1,354 regression equations, one for each participant. Rather than presenting over 5,000 elasticity estimates (1,354 customers with four types of elasticity), Exhibit 3 presents the weighted average elasticity estimates (the individual models as well as the complete models for this analysis are included in the Appendix). The weighting used in this table is the one over the relative variance of each estimate.[18]

[18]The models include maximum likelihood autocorrelation corrections. However, since each model has only one customer, there is no possibility of heteroskedasticity in the model.

Exhibit 3. Weighted Average Elasticity Estimates (Weighted by individual variance)

Period	Elasticity Estimate	T-Value
Daytime	-1.5%	60.42
Late Daytime/Evening (4pm or later)	-2.6%	106.42
Additional Response from High Price Alerts		
Daytime High-Price Notification (additive)	-0.5% (-2.0% total)	5.77
Late Daytime/Evening High-Price Notification (additive)	-2.2% (-4.8% total)	26.61

These results showed that the elasticity is lower in the morning than the evening, a finding which makes sense for the residential sector. The results also show that high-price notification has a significant impact on a customer's electricity demand. High-price notification in the daytime results in a -2.0% elasticity, and notification during the late daytime/evening results in a -4.8% elasticity.

One aspect of the high-price notification that was not an issue in the prior years' evaluations is the sheer number of notifications (57 days with high prices) and how this may affect participants' response. There are three aspects of this possible response. First, there is a decay which is related to the number of high-price hours within a given high-price block. This is the type of response that was addressed in the 2003 analysis, where after four hours, participants no longer responded to the notification. The second type is a decay related to the number of concurrent days in which there where high-price notifications. As the number of notifications increase, the hypothesis is that the response will decrease. Finally, there is a "recharge" aspect, where the response to a given high-price notification will increase as the number of days between notifications increases. The prior evaluations were not able to address these latter two effects because the number of high-priced days was quite small.

In order to address this response decay and "recharge", the individual electricity demand models discussed above were expanded to include variables denoting:

- The length of time between high-price periods
- The length of a given high-price period (number of continuous hours)
- The number of high price periods during the summer

The weighted average of these estimated effects (weighted again by one over the variance) is presented in Exhibit 4. The possibility of rebound, where customers significantly increase their consumption after a high-price period in an effort to "catch" up with cooling (for example), was also investigated, and it was found that there was no statistically significant indication of this effect.

Exhibit 4. Weighted Average Decay Estimates (Weighted by individual variance)

Period	Estimated Coefficient	T-Value
Number of high-price notifications interacted with high-price notification	3.2%	6.82
Number of continuous high-priced hours interacted with high-price notification	0.7%	3.90
Number of days between high-priced notifications interacted with high-price notification	-2.4%	6.58

The sign of these results conform to the expectations discussed above. The estimated coefficient is the percentage change in electricity use given an increase in the variable. For example, for each additional hour within a given high-price block, electricity use will increase by 0.7% irrespective of any price elasticity effects. Overall, these decay effects are relatively small, suggesting little response decay over the summer, and they are well below the decay found in the 2003 analysis.[19]

These results suggest that residential customers can quickly and easily respond to repeated price notifications. If repeated notifications become expected, the response becomes routine over time. This is contrasted with the commonly assumed exhaustion, where customers become completely insensitive to repeated notifications.

The next section investigates more closely the individual elasticity estimates in order to determine if there are any consistent relationships that can be used to better understand participants' behavior.

2.3 Determinants of Elasticity

The previous review of the results from the individual elasticity models showed that there was a wide variation in elasticities across participants. The natural next step is to determine if any meaningful relationships can be found that can be used to predict and classify participants into groups with similar response to hourly prices. In order to conduct such an analysis, the individual elasticity estimates (for each of the four types of elasticities) are used as the dependent variable, and customer, program, and neighborhood characteristics are used as the independent variables.

The estimated coefficients are presented in Exhibit 5.[20] The model uses weighted ordinary least-squares to correct for heteroskedasticity. Some of the variables included in this model are based upon U.S. Census data (the variables that include "neighborhood" in their title). These variables do not represent data specific to an individual; rather they represent characteristics of the Census tract in which the participant is located. This information is useful for determining customer characteristics without having to survey customers. Thus, it is available for all customers, and can be easily used to forecast price response for customers and areas which have heretofore not been part of the ESPP.

[19] This type of decay model has not been estimated for other price notification (like critical peak pricing) programs, so these results cannot be compared to results from other studies.

[20] The vector of independent variables is constant across all models even though not all variables are statistically significant. This was done to allow comparison of the effects of each variable across elasticities. In addition, including irrelevant variables only increases the noise in the model, while not including relevant variables will cause biased coefficients.

Exhibit 5. Factors influencing Elasticity (Additional factors considered are detailed in Appendix) (Dependent variable is estimated elasticity, sample size = 1255)

Variable	Daytime		Late Day/Eve.		High Price Day		High-Price Late Day/Eve	
	Coeff.	T-value	Coeff.	T-value	Coeff.	T-value	Coeff.	T-value
2005 Participant	0.0086	2.55	0.0114	3.57	-0.0115	-0.83	-0.0118	-0.90
A/C cycling	-0.0024	-0.47	-0.0023	-0.49	-0.0402	-1.94	-0.0220	-1.10
Notified via E-mail	0.0001	0.03	0.0012	0.57	-0.0220	-2.50	-0.0149	-1.76
Multifamily	0.0000	0.00	-0.0009	-0.36	0.0093	0.89	0.0072	0.73
Has central A/C	-0.0005	-0.19	-0.0069	-2.59	0.0532	4.60	0.0573	5.24
Has a computer	-0.0004	-0.32	0.0003	0.31	-0.0113	-2.25	-0.0107	-2.20
Average neighborhood income	0.0000	-0.03	-0.0011	-1.51	-0.0039	-1.19	-0.0060	-1.91

Shaded cells are statistically significant at the 90% level of confidence.

Some conclusions that can be derived from these results are:

- Cycling the air conditioners during high price periods increases the elasticity, adding 4% during the day and 2% during the evening, on high-price days. This is consistent with the expectations for an automated control system.
- Participants who were new in 2005 tend to have a lower price elasticity relative to other participants. It is unclear if this is because of a time lag in learning how to respond to prices or because of changing demographics.
- Participants who received e-mail notification had a higher elasticity during high-price periods than participants who received notification via telephone. It was not clear if this is because of the mode of notification itself, or because of the selection bias of participants for one mode or the other.
- Participants with central air conditioners are less sensitive to high-price notifications relative to other participants. This may be because they have permanently programmed their thermostats to be at a higher temperature, especially when not home.
- Participants with a computer in their home are more responsive to high-price notifications, over and above the increase associated with e-mail notifications.
- The elasticities of single family and multifamily home participants were similar, even though multifamily homes tend to be lower overall consumers of power.
- Neighborhood income has little effect on price responses. Low income participants were as demand responsive as higher income participants.

One of the benefits of this model is that it allows one to simulate the expected elasticity for a given customer or group of customers by setting the appropriate value for each of the independent variables. A spreadsheet tool was constructed to allow for such simulation. This spreadsheet allows for the estimation of elasticity as well as the total kW savings. This spreadsheet was provided to the Cooperative for use in ongoing research on modeling participant demand response.

2.4 Energy Effects

The analysis presented above was concentrated only on the response to hourly electricity price changes. Thus, the impacts are only demand (average kW). Another aspect of electricity usage is energy (kWh). So while it is clear that the ESPP reduces demand when prices are high, the next question which will be addressed is how does the ESPP program affect energy usage, more specifically monthly kWh usage?

Determining the effect of this program on energy (kWh) consumption, a regression-based model was estimated that used monthly electricity consumption for each participant going back to 2002 (so as to include consumption for both before and after participation in the program) as the dependent variable. The independent variables include the monthly weather conditions and two program effect variables: one variable which is equal to 1 for every month the person has been a participant in ESPP, and a second variable which is equal to 1 if the person is a participant and the month is June, July, or August. A fixed-effects specification for the regression model was used which pooled across customers and over time. The model was also corrected for autocorrelation and heteroskedasticity. The results are presented in Exhibit 6.

Exhibit 6. ESPP Energy Impacts (Dependent variable, monthly energy use, 2002 to 2005)

Period	Estimated Coefficient	T-Value
Participating in ESPP	1.8	**0.78**
Participating in ESPP Summer Months	-37.0	**-12.92**
Sample Size	58,918 (1,478 participants)	
R-Squared	1.00	

The estimation results show that ESPP participants consumed 35.2 kWh less per month during the summer months under the ESPP relative to individuals not on the ESPP rate (1.8 kWh year round plus -37.0 kWh specific to the summer months). This represents a savings of 3 to 4% of summer electricity usage. This result is statistically significantly different from 0 at the 95% confidence level. During the winter months,[21] there was no statistically significant difference in monthly energy use between ESPP participants and individuals not facing hourly electricity prices. Therefore, ESPP results in a net decrease in energy consumption.

2.5 Results/Conclusions

In conclusion, the impact evaluation of the ESPP program during the summer of 2005 has shown the following:

[21] Participants are on hourly electricity prices throughout the year.

Key Findings

- ESPP participants continue to respond to hourly-electricity prices in a manner similar to prior years, with an overall price elasticity of -4.7%. This means that a doubling of electricity prices results in a decrease in their hourly electricity use by nearly 5%. This level of response is strong and is comparable to those found in other programs that use price signals to motivate changes in consumer behavior.

- Participants' response to hourly-electricity prices varies by the time of day, with lower responses during the day and higher responses during the late afternoon/evening.

- ESPP participants' overall monthly summer energy (kWh) usage suggests a conservation effect, that is, a reduction in usage of 3% to 4% relative to what their usage was estimated to be had they not received hourly electricity prices.

Additional Findings

- Participants continue to show a significant response to the high-price notifications (i.e., when prices exceed $0.10/kWh). For example, on July 25, 2005, the day with the highest prices of the summer, participants reduced their peak hour consumption by 15% relative to what their consumption would have been on the standard flat ComEd residential rate.

- Participants reporting successful notifications essentially double their average response to changes in electricity prices. Success in notifying participants correlated to an increase in their price responsiveness during non-high priced hours as well.

- Automatic cycling of the central-air conditioners (turning the compressor on and off for short periods of time via remote control) during high-price periods added to a participant's response to electricity prices by as much as 2.2% for a total price response of 6.9% during the late afternoon/evening hours.

- Specific observable variables (or characteristics) that influence the participant's response to hourly prices were identified. For example, households with numerous individuals at home during the day are likely to be more price-responsive during the day, and customers who receive high-price notifications via e-mail are 2% more responsive (adding to their price response) on high-priced days.

- Customers' response to high-price notifications does decline somewhat as the number of notifications during the summer increases and as the length of a given high-price period increases. However, as the time between high-price periods increases, their response to price notification will increase. Overall, customers continued to respond to high-price notifications throughout the entire summer of 2005 despite repeated notifications. The estimated decline in response was actually less than was observed in 2003.

The continuing findings from the Community Energy Cooperative's Energy-Smart Pricing Plan, as detailed in this evaluation, are important, given the national need to develop estimates of price responsive load in mass markets. These results will augment the few studies that have been conducted examining these mass market customers.