RESIDENTIAL APPLICATIONS OF REAL TIME PRICING

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INTRODUCTION

Peak electricity demand in the downstate region of New York State is increasing at an average rate of 1.5-2% per year. The peak demand experienced by the New York Power Pool (NYPP) during the winter and summer of 1988 reached record levels. Temperature and other weather-related commercial and residential electricity loads are important contributors to this peak demand.

As a potential means for deferring the need for new generation facilities, the New York State Public Service Commission (PSC) and State Energy Office (SEO) are actively encouraging utilities to evaluate various demand side management (DSM) strategies for reducing peak loads and facilitating more efficient use of electricity.

In November of 1985, the New York State Energy Research and Development Authority (NYSERDA) sponsored a workshop for New York utility, PSC, and SEO staff to explore the potential role of real-time pricing and related load management programs as one potential DSM strategy for New York. Although it was generally agreed that real-time pricing programs offered a number of conceptual DSM benefits, the workshop participants identified the following uncertainties as major obstacles to its widespread, cost-effective use by utilities in industrial, commercial and residential applications: (1) customer acceptance and ability to shift electricity use in response to real-time pricing incentives; (2) the role of supporting technologies such as energy management systems, energy storage, etc., to facilitate customer response; and (3) whether the net demand side management and associated benefits are sufficiently great to offset the communications, metering, information display and control equipment and the utility operations and DSM administrative costs required to implement it. Moreover, from a resource allocation standpoint, the cost effectiveness of real-time pricing must be compared to other DSM alternatives available to the utility.

Following this workshop, NYSERDA initiated discussions with several New York utilities regarding possible R&D to examine these uncertainties and improve the cost effectiveness of these supporting technologies. Both Orange and Rockland Utilities (ORU) and Central Hudson Gas and Electric Company (CHG&E) expressed interest in investigating the potential viability of residential applications of real time pricing. The significant contribution of the residential sector to ORU's and CHG&E's peak demand was a major factor in their decision. Other factors contributing to this interest included: (1) ORU's previous experience with a peak activated rate (PAR) field test; (2) the preliminary results of real-time pricing and related demand subscription service (DSS) experiments conducted by Georgia Power and Light (Rosenfeld, Bulleit and Peddie, 1986) and

Southern California Edison (1985 Interim report), respectively; and (3) the development of the Credit and Load Management System (CALMS) in the United Kingdom (Peddie and Fielden, 1986). These projects provided heuristic evidence of potential customer interest in responding to real time pricing incentives.

R&D PROGRAM GOALS AND COMPONENTS

The overall objectives of the R&D program which NYSERDA initiated with CHG&E and ORU are two-fold: (1) to develop a low-cost residential energy and load management system (RELMS) which would facilitate customer response to various real-time pricing strategies; and (2) to evaluate the major areas of uncertainties described in the Introduction of this paper through the conduct of field test experiments using RELMS.

The major elements of this R&D program include: (1) residential customer market research; (2) a preliminary benefit-cost analysis to estimate the "allowable" cost of RELMS; (3) development of RELMS functional performance specifications; (4) securing the interest of equipment manufacturers in developing RELMS hardware and software which meets these specifications; (5) conduct of engineering tests and pilot-scale field tests to evaluate RELMS equipment performance, customer load management response and the acceptance of various real-time pricing incentive programs; and (6) an assessment of the overall benefits and costs of deploying RELMS based on actual field test results.

This paper will describe the results obtained from program elements 1, 2, 3, and 4. Preliminary plans for the initiation of elements 5 and 6 are also described. Conclusions derived from these activities are discussed.

Other New York utilities, the Electric Power Research Institute (EPRI), and the Empire State Electric Energy Research Corporation (ESEERCO) have assisted NYSERDA, CHG&E and ORU in the design and conduct of this R&D program. New York State Electric and Gas Company (NYSEG) assisted CHG&E and NYSERDA in the area of market research. Consolidated Edison of New York (CE) assisted NYSERDA, CHG&E, and ORU efforts to secure the interest of equipment manufacturers in developing RELMS. In addition to NYSERDA, CE, CHG&E and ORU, funding support for RELMS engineering and field tests is being provided by the Long Island Lighting Company, EPRI and ESEERCO.

IMPORTANT FACTORS IN PROGRAM DEFINITION

ORU's prior experience in demonstrating customer acceptance of a peak activated rate (PAR) illustrates both the potential customer and utility benefits of real-time pricing and the practical problems of implementation. The lessons learned were major considerations in the development of RELMS system specifications and other program design considerations.

ORU had recruited 150 residential customers to participate on a voluntary basis in a pilot-scale test of PAR. A control group consisting of a representative cross-section of residential customers was also selected. With PAR, participating customers received a one cent per kilowatt hour reduction in the rate charged for electricity use during hours of "normal" electricity supply and demand conditions. Normal conditions prevailed when ORU's system demand was less than a pre-specified threshold level. Whenever system demand exceeded this threshold, customer electricity use was charged at the peak-activated rate of 40 cents per kilowatt hour. Times when PAR was in effect typically occurred for a 2-3 hour period between 12 noon and 6:00 p.m. on hot, humid weekdays in the summer. The total number of hours in the summer when PAR occurred varied from 33 to 89 hours over the three-year test period (which included the summer months in 1982, 1983 and 1984).

Customers were notified when the peak activated rate was in effect by a five-second tone and a red light emanating from a customer terminal that was installed in the kitchen. At the end of the PAR period, another five-second tone was activated. The red light was activated for the full duration of the peak pricing period.

Except for a small discount to stimulate voluntary customer participation, the PAR rate was designed to be revenue neutral for the average residential customer. Consequently, if the customer reduced electricity use during the PAR period, the customer would be expected to reduce annual electricity costs as compared to a conventional flat rate. During the three-year pilot test, annual customer savings were in the 5-10% range.

Typical customer actions to reduce electricity use during the high rate period included shedding room air conditioners, adjusting the thermostatic set-point of a central air conditioning system, and manual control of appliances such as electric ranges, clothes dryers, dishwashers, and washing machines. Although time of day rates also provide incentives to control usage during the higher rate period (e.g., from 8:00 a.m. through 8:00 p.m.), the relatively small difference between the on-peak and off-peak electricity rates is a relatively poor incentive to reduce electricity use during high demand periods which occur relatively infrequently. However, with PAR, the utility is only discouraging consumption during the peak demand periods.

During the first two years of the PAR experiment, the average load reduction coincident with the system peak was 0.5-0.6 kW compared to a control group. This reduction represented 40-47% of the average ORU customer load coincident with system peak. During the third year (1984), the system peak day occurred early in the summer season and customers were not conditioned to respond. Consequently, the average load reduction was only .25 kW. Customer surveys taken after the summers of 1982 and 1983 indicated that 79-83% of participating customers expressed a strong interest in continuing in the PAR program. (ORU Economic and Rate Research Report, 1986.)

The following paragraphs summarize several of the conclusions derived by NYSERDA, ORU and CHG&E from this field test experience. These insights impacted the design of the R&D program:

(1) Although a high level of customer acceptance was obtained, an individual customer's self-selection bias may have been a significant contributing factor. This potential effect precluded extrapolation of the high level of

customer satisfaction in the experimental group to the general population. Consequently, market research is needed to obtain a statistically valid understanding of potential customer interest in PAR and other real-time pricing incentive programs directed at reducing peak loads. Moreover, because of the desire to increase the load reduction response to PAR, it was concluded that this market research effort should focus on those residential customers that are likely to consume more electricity during peak demand periods. It was hypothesized that these customers would have a greater technical potential to reduce electricity use in response to real-time pricing.

(2) Another potential means for increasing the load reduction response is to incorporate automated load control and information display features in the customer premises equipment. (Rosenfeld, Bulleit and Peddie, 1986) Although market research could provide useful insights into customer perceptions of these RELMS features, it was concluded that field tests are needed to fully evaluate customer acceptance and the resulting load reduction response that would be obtained from using such a RELMS system.

(3) Customers were concerned about the installation of equipment in their homes which involved making hard-wired connection among the utility meter, load controls and the customer display terminal, particularly if holes needed to be drilled between floors or the skin of the building was punctured. The high cost of equipment installation was also of concern to the utilities. Consequently, there was considerable interest in utilizing the existing house wiring, short-range radio or other communications approaches to transfer commands and data between the metering, customer information terminal, and other customer-premise subsystems.

(4) Significant maintenance and repair problems were experienced with the communications and customer-premise equipment used in the experiment. Moreover, because of poor market acceptance of this equipment by utilities, the manufacturer discontinued maintenance and repair support of the equipment. Despite growing customer acceptance, ORU could not expand the PAR program because other manufacturer support groups did not exist. (ORU Electric Engineering Department Report, 1985). Consequently, it was concluded that it would be desirable to have at least two viable RELMS suppliers which could provide interchangeable equipment, at least from a subsystem interface perspective.

(5) Finally, it was concluded that power line carrier communications from the utility substation to the residence involved considerable maintenance, special training and test equipment expenditures as well as electricity distribution system operational problems. Although other radio and telephone communications options were examined by ORU as a potential means of eliminating these problems, the cost to achieve the desired level of spatial coverage within specified time limitations still constituted a major area of uncertainty.

MARKET RESEARCH

NYSERDA collaborated with ORU and CHG&E in the conduct of separate market research studies to accomplish the following objectives: (1) assess customer attitudes and preferences regarding various real-time pricing and related demand side management programs; (2) segment the customer population into various groups depending on their perceptions of these programs; and (3) evaluate customer attitudes and preferences for various information display, load control and other features which might be provided to assist customers in responding.

The ORU effort emphasized primarily the first two objectives while the CHG&E study included all three. Both studies included the use of focus groups (to identify the relevant issues) and a survey of the residential customer population. Because of the complexity of the pricing programs and potential RELMS features being examined, a phone-mail-phone survey methodology was used.

Both market research studies utilized factor analysis techniques to identify what factors the customer perceived to be important in evaluating participation in various real-time pricing programs. Several of the most important factors included: (1) comfort; (2) willingness to participate because of the resource conservation or other perceived community benefits; (3) concern about electricity costs; (4) skepticism about savings; and (5) the complexity associated with participation.

Market segmentation involves grouping respondents together based on the similarity of their views about these and other perceived factors. Cluster and multiple discriminant analysis techniques were used to achieve this grouping.

In the ORU study (Opinion Research Corporation, 1987), six customer segments were identified as summarized in Table I. The primary characteristic that differentiated the groups is the willingness to sacrifice for the good of the community (the "Social Savers" at the left of Table I) versus a desire to maintain comfort (the "Upscale Hedonists" at the right. The next two interrelated qualities are skepticism about the money saving potential of these programs and concern about electricity costs. The segment called the "Cynics" are concerned about comfort and energy costs but are skeptical about savings. The "Money Savers" are quite willing to sacrifice comfort if savings can be achieved. The "Comfortable Middle" is generally unconcerned about energy costs in the overall scheme of things. However, they are a potential target because they believe these programs will achieve energy savings and are more likely than other customers to have setback thermostats. A remaining factor which separates the "Concerned Homemakers" from the "Money Savers" is an uncertainty about the effects of this program on their lives.

Following a review of the attributes of various real-time pricing programs, including estimates of monthly savings on their utility bill with each option, customers were asked about their level of interest in the program if it were offered. The bottom portion of Table I shows the percentage of ORU customers who indicated that they would definitely participate in these programs.

Several important conclusions about customer attitudes and perceptions were derived from both the ORU and CHG&E market research efforts. The market research firm that conducted the ORU study projected that approximately 15% of its residential customers were likely to adopt PAR if ORU were to offer it.

Table I. Factor Importance and Anticipated Participation for Each Market Segment

Segment Description	Social Savers	Money Savers	Concerned Homemakers	Comfortable Middle	Cynics	Upscale Hedonists	Net**
Percent of Population	15.1%	12.8%	16.6%	24.1%	20.3%	11%	
Important Factors							
Comfort	Low	Low	Low	High	High	High	
Resource Conservation	High	High	High	Average	Low	Low	
Concern About Electricity Costs	Low	High	High	Low	High	Low	
Skepticism About Savings	Low	High	Average	Low	High	Low	
Complexity	Low	Low	High	Low	High	High	
Program Type							
Central Air Conditioning DLC with Override	32/27%*	15/7%	13/13%	8/24%	7/17%	4/13%	8.0%
Time of Day Rates	31/41%	19/32%	6/24%	9/34%	3/24%	1/12%	14.7%
Peak Activated Rates	27/44%	21/29%	5/35%	8/37%	1/25%	1/17%	15.3%
Subscription Level Service	14/34%	10/29%	3/22%	6/25%	4/14%	1/11%	9.9%
Light Bulb Replacement	37%	44%	38%	20%	23%	16%	

* Definitely Participate/Probably Participate

** Opinion Research Corporation {12} estimates that 50% of definites and 25% of Probables actually participate assuming they carefully evaluate the opportunity.

This conclusion assumed that a well designed recruiting program was implemented to capture the maximum potential predicted by the data collected from the survey. "Social Savers" and "Money Savers" are potential targets of a recruiting program. This market research has helped to identify the demographic characteristics, "potent messages" to which they might respond and the sources of information which they use.

A second major conclusion is that customer interest in these programs might be enhanced if several perceptions of various market segments could be changed. For example, comfort is an important concern to the "Comfortable Middle", "Cynics" and "Upscale Hedonist" segments. The use of new space conditioning set-point control strategies such as currently being developed under EPRI support (Schweppe etal, 1988) might be incorporated into RELMS. Rather than turning off a room air conditioner or altering the setpoint of a central air conditioning unit when a high rate period goes into effect, a pre-cooling strategy might be used to reduce the impact of these programs on comfort. Therefore, field test demonstrations of such control strategies could help in collecting performance data and customer experiences which could be used to alter the perceptions of these segments regarding comfort.

A third conclusion is that automated control may also be important for simplifying customer response to these programs. By pre-programming the operation of space conditioning equipment and appliances as demonstrated in the Georgia Power & Light project (Rosenfeld, Bulleit and Peddie, 1986), customer perceptions of complexity could be significantly reduced.

A fourth conclusion is that field test demonstrations can play an important role in quantifying energy savings benefits and collecting other market research data which would directly address customer perceptions of value which limit potential penetrations. There are clearly some difficult hurdles such as "lack of concern over energy costs" of the "Social Saver" and "Concerned Homemaker" segments which may be difficult to overcome, but attacking these other perceptions is a major goal of our efforts.

In addition to an evaluation of customer perceptions and attitudes, and the identification of similar market segments using factor, cluster and discriminant analysis techniques, the CHG&E market research effort (Applied Management Sciences, 1988) also evaluated customer preferences for the specific attributes of a real time pricing program and the hardware design. Furthermore, based on this preference and attitudinal data, a predictive model is being developed to compute the expected acceptance of each program configuration (as described by the specific attribute parameter appropriate for that configuration). This will facilitate an evaluation of the tradeoffs between the potential penetration of each program, its anticipated (or measured) load impacts, the load control and other features provided with RELMS. These features are expected to significantly impact the load reduction response, and as a result, the long-term demand side management benefits obtained. For example, a PAR may achieve a higher level of acceptance and penetration than a DSS program. However, future field tests may demonstrate that DSS will achieve greater demand reduction and/or greater reliability of load reduction than PAR. This predictive model will be linked with an overall benefit-cost model and eventually with measured field test data to assess the overall benefits and costs of various program configurations, either individually or in complementary combination. Nevertheless, because these preference functions have been determined based on current customer perceptions of these program options (possibly without a full appreciation of the benefits of automated load control and other customer premise equipment features), it will also be important to track changes in these preference functions based on field test experience.

PRELIMINARY BENEFIT-COST AND ALLOWABLE RELMS COST ANALYSIS

In developing the specifications of the RELMS system, a critically important issue is the tradeoff between performance and allowable cost. A first-order benefit-cost analysis model was developed to evaluate the allowable cost of RELMS as a function of the critical electricity supply and demand side management factors involved. (Cole, 1987).

A particular case study example is described in this paper to illustrate the major categories of benefits and costs from offering a residential real-time pricing program in conjunction with RELMS as an alternative to constructing new generation capacity.

The utility is assumed to offer this voluntary program to its residential customers and that 12,000 customers sign-up each year over a five-year program roll-out. Program administrative costs of $500,000 per year are assumed to be required to recruit customer, replace dropouts, and provide ongoing customer service.

Assuming that 2 kW of end-use load reduction is achieved coincident with system peak when the pricing incentives are activated and that peak load distribution losses are 15%, the need to build 135 MW of peak generation capacity is deferred for 5 years based on the baseline load growth parameters considered in this example. If the installed cost of new generation is $700 per kW, then the net present value of the avoided capacity benefits is $103.6 million over a 30-year study period as illustrated in the first column of Table II. The net present value of the avoided fuel cost and the operation and maintenance cost savings obtained (net of that incurred with RELMS) is also shown in the first column of Table II. An average discount rate of 10.9%, an average fuel cost escalation rate of 10% and an average inflation rate of 3% are assumed over the study period.

The second column shows the net present value of various costs associated with offering the real time pricing incentive rate with RELMS. Key assumptions include an initial RELMS acquisition cost of $500 per unit and separate installation and customer training costs of $300 per unit and annual O&M costs equal to 4% of installed RELMS equipment costs (as compared to 2% for the generating equipment). The RELMS equipment is assumed to have a service life of 10 years and old units are replaced at the end of their service life with newer models.

Table II. Net Present Value of Benefits and Costs ($ million).

Component	Benefit	Cost
Avoided Generating Capacity	103.6	
Avoided Fuel Costs	27.8	
Avoided Net O&M Costs	17.1	
RELMS Equipment and Installation		60.3
Incentives for Program Adoption		47.3
Lost Revenues during Interruption		13.1
Program Administration		5.8
Avoided Meter Reading Expenses	7.1	
Total Benefits and Costs	155.6	126.5
Net Benefits	29.1	

The incentive for adoption component assumes that the customer will receive average annual cost savings of $80 per year which is approximately a 10% savings for the average ORU residential customer. This $80 annual bill reduction incentive could either be interpreted as the revenue lost by the utility if a PAR rate discount is given during "normal" hours or a direct incentive to adopt a demand subscription service-type rate. The Lost Revenue During Interruption component estimates the revenue impact of lost energy use which is not consumed following the interruption. A credit for Remote Meter Reading is listed in the Benefit column. The net present value of the benefit over a 30-year study period is $29.1 million in this example.

Based on analysis of the results obtained using this model (Cole, 1987) for the range of parameters of interest, a preliminary estimate of the allowable RELMS cost of $500 per unit was established as an initial target.

In conducting this preliminary analysis, only peak load reduction benefits were considered. If a three- or four-level real-time pricing rate is used, (e.g.; a PAR component during peak demand hours and also provides differential pricing incentives (related to various marginal electricity supply costs) during other time periods), the customer might achieve additional operating cost savings by shifting demand. In addition, this analysis does not consider other long-term energy management benefits such as purchases of more efficient appliances, insulation, etc., which may occur as customers become more aware of their electricity consumption patterns. As described above, a more comprehensive benefit-cost analysis model is being developed as part of a joint project between NYSERDA and CHG&E which will examine the issues considered above in more detail. Moreover, customer load response and survey data collected during the field tests will be used in this model to assess the overall benefits and costs of using RELMS and ultimately determining its break-even cost.

TECHNOLOGY ACQUISITION

Securing the interest of equipment manufacturers in developing RELMS to meet our technical performance and cost requirements was a critical need in accomplishing our goals. Despite the initial impressions of some PSC staff that RELMS technology was readily available at a reasonable R&D acquisition cost within a short time period, this proved not to be the case. Considerable efforts were expended by NYSERDA, CHG&E and ORU to acquire RELMS technology with desired functional performance characteristics. Contacts were initiated with several technology developers during the Spring and Summer of 1986 for the dual purpose of assessing the state-of-the-art in RELMS subsystem components as well as soliciting their interest in working with us in developing RELMS. Many equipment developers cited the limited commercial market for RELMS over the near-term as a significant barrier to private sector R&D efforts. Although various utilities were conducting pilot projects, there were significant variations in system specifications. Consequently, they perceived the development risk to be too great to invest their limited resources. Several developers of electronic equipment in markets related to RELMS expressed an interest if we paid their development costs; others indicated that the lost opportunity costs in not pursuing existing markets were too great to work with us at this time.

In the third quarter of 1986, NYSERDA collaborated with ORU and CHG&E in the development of minimum RELMS system performance specifications which are summarized as follows:

- Capable of Supporting PAR, 4-Level RTP and Premium Rate DSS; Digital Metering and Data Storage Preferred.
- Real-Time Communications From Utility to Customer to Download Pricing System Operational Commands
- Software Programmable Load Controls To Automate Customer Response
    - Control Set Point of Central Air Conditioning and Heating
    - Control Operation of 4 Major Loads (Water Heater, Room A/C,etc)
    - Control Operation of 4 Minor Loads Using Plug Interrupts (PID)
- Customer Terminal To Display Pricing Information, To Input Load Control Instructions, and To Monitor Load Response
- In-House Power Line Carrier Communications (or Equivalent) To Transfer Commands and Data Between Subsystem Components
- Software Programmability of Major RELMS Functions
- Remote Meter Reading

- o Customer Premise Activation of Communications Over Customer's Telephone For Uploading and Downloading Data, Software Instructions and Commands

- o Automated Diagnostic Check-Out of Equipment Performance

As part of a joint effort with NYSERDA, CHG&E issued a Request for Proposals (RFP) to develop and test 200 residential units of RELMS. Despite numerous contacts with equipment developers prior to issuing the RFP, only one technically acceptable proposal was received. Moreover, the technology offered in this proposal consisted of existing components developed for other applications packaged into an expensive system ($5000 per unit) which did not appear to have a significant cost reduction potential. Consequently, this bid was rejected. During the first and second quarters of 1987, contacts were made with equipment developers who received the CHG&E RFP to assess why they did not submit a bid. Essentially, the same reasons listed above were given for their lack of interest.

In mid-April of 1987, the PSC requested that the New York utilities submit a plan for the future development of a residential load management system. One outcome of ORU and CHG&E efforts to respond to this order in cooperation with NYSERDA was the decision to formally join forces in this effort. Another outcome was a decision by Consolidated Edison (CE) to join this consortium.

A series of meetings were then held by the consortium (NYSERDA, CE, CHG&E, and ORU) with equipment developers to solicit their interest in responding to a second RFP, which would be developed by the consortium and issued by NYSERDA. A preliminary plan for a RELMS development and field test to be incorporated in the RFP was discussed with these equipment developers. This plan called for: (1) 10-unit engineering tests of two prototype RELMS systems; and (2) a 200-unit field test of customer response and acceptance of several real-time pricing incentive programs. The specifications for RELMS incorporated in this RFP were essentially the same as the previous CHG&E, although increased emphasis was given to subsystem functionality and software programmability. Several equipment developers indicated that these requirements appeared to be reasonable and expressed an intent to submit a bid in response to the RFP.

Following a second series of meetings with other equipment developers and other telephone contacts in early Fall of 1987, the RFP was finalized by the consortium and issued by NYSERDA. Six proposals were received and evaluated by members of the consortium. The major evaluation criteria included: (1) technical quality of proposed system design for meeting RELMS functional specifications; (2) potential to meet RELMS cost requirements in large production quantities; and (3) ability to meet field test requirements. Other important evaluation criteria included corporate qualifications and experience and proposed project cost. Meetings were held in early 1988 with three finalists and the decision was made to select two proposals for contract negotiations. In making the final selection, considerable emphasis was given to assessing the ability of both developers to achieve substantial cost reductions at the 10,000 and 100,000 stages of cumulative production. Both developers emphasized that unit costs in the range of $500-$1,000 were achievable with these large production quantities. Moreover, one developer indicated that $300 per unit was potentially achievable at 1 million units of cumulative production.

Proposals submitted by Quadlogic and Electrotek were selected to conduct the 10-unit engineering tests. If the Electrotek engineering test scheduled for the late Summer and early Fall of 1988 is successful, current plans call for a 400-unit field test beginning in the late Spring of 1989, 200 units each by ORU and CHG&E. Although the system to be provided by Electrotek in the engineering tests is essentially the same as the EPRI Load Control Emulator system, several system design changes directed at achieving progress toward a low-cost, commercializable RELMS were proposed by Electrotek. The Quadlogic effort will involve the development of an integrated RELMS system based on its commercial submetering system and communications technologies being developed with CE and other utilities; the engineering test of this system is expected to be initiated in the Summer of 1989.

If the results of these field test efforts are successful, it is anticipated that ORU, CHG&E and other New York utilities will have two technologically proven and tested RELMS options available in 1990 and 1991. Based on the analysis of RELMS break-even costs discussed in the previous section, the commercialization potential of these RELMS options can be evaluated.

CONCLUDING REMARKS

NYSERDA and the New York utilities have made significant progress in accomplishing the R&D program goals described above. The lessons learned from conducting the first four program components have been summarized in this paper. However, considerable technology development, field test validation, customer acceptance and benefit-cost evaluation work remain to be accomplished. In addition, several major areas of uncertainty must be resolved before the commercialization potential for RELMS and real-time load management can be established. These include the following:

1. A determination of the load reduction response that can be achieved during peak load hours for various types of residential customers and real-time load management incentive rates;

2. An assessment of long-term energy management benefits;

3. An evaluation of customer acceptance of RELMS;

4. The evaluation of various real-time communication system options for downloading pricing data, load management and remote meter reading commands, and automatic diagnostic check-out/reporting commands from the utility to the RELMS customer-premise equipment;

5. A determination of the potential to integrate RELMS with end-use energy conversion and storage technologies to enhance customer cost savings and acceptance (Cole, 1988); and

6. A determination of the potential to reduce the cost of RELMS sufficient to achieve commercial feasibility.

Nevertheless, the ultimate success of this residential real-time pricing and RELMS development effort is dependent on collaborations with utilities, regulatory and energy R&D organizations in other regions as well as nationally. In particular, the development of a common set of functional system and subsystem specifications, communications and software protocols, and other requirements can enhance equipment manufacturer interest and help reduce RELMS acquisition costs. We are interested in collaborating with others in such efforts.

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