Comprehensive Residential Lighting Retrofits: A Case Study

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As part of a New York State residential lighting program designed by Orange & Rockland Utilities, Inc. and a New Jersey residential lighting program designed and implemented by the Free Lighting Corporation, 7,700 homes have received comprehensive lighting retrofits. Equally important, a detailed lighting census of each house and retrofit has been prepared, providing data on residential lighting not previously published or available.

Considering the enormous size of the residential lighting marketplace, there is remarkably little field data available on the actual end-use or on the potential for comprehensive retrofit. This paper will detail the information learned to date from the comprehensive retrofit of 7,700 homes, with an average of 14.2 bulbs per house installed, several times that normally projected as being feasible.

The paper provides details on the number of incandescent bulbs in each house, the wattage distribution, and the specific rooms which are most likely to have high lighting use. These will be analyzed by house size and number of occupants. All of this data has extreme importance in analyzing cost-effectiveness of lighting programs. Details are provided on the methods used to avoid the cream-skimming, lost opportunities and savings "guesstimates" that have plagued earlier residential lighting efforts.

Equal attention will be paid to the actual installations. An analysis of the proportion of each lamp type replaced, the types and wattage of bulbs installed, average hours use by location, average wattage reductions and energy savings, and cost-benefits will be explored. Finally, we will review market penetrations and participation satisfaction, as measured by post retrofit surveys.

This data is based upon a census of 7,700 treated homes containing 287,000 lamps, of which 109,000 were replaced at a total cost of about 4 cents per kilowatt hour saved.

Introduction

The two treatment groups of homes that comprise the 7,700 homes treated in 16 months come from two different programs: (a) a utility-designed direct bulb installation project in which the contractor is paid based upon a set price per light bulb installed; and (b) an ESCO-designed performance contract in which the contractor (energy service company, or ESCO) is paid per lifecycle kilowatt hour achieved. Each program involved the same contractor (the Free Lighting Corporation of Ramsey, New Jersey) and the same utility (Orange & Rockland Utilities, Inc. of Pearl River, New York). The service areas targeted were two counties in New York and the adjoining two counties in New Jersey, respectively, and in each, only "basic service" customers (those without either electric heat or electric water heating) were targeted.

The utility-designed project (New York) treated about 4,900 homes from January through October 1991, when it was terminated; the results from the ESCO-designed project (New Jersey) reflects the 2,800 installations completed from November 1991 through May 1992. This program is scheduled to continue through 1993 and install a total of about 450,000 bulbs in 30,000 residences, about 60% of the utility's New Jersey service area. As of August 1, 1992, we project that 105,000 bulbs will have been installed in 6,000 to 7,000 residences.

The New York project restricted replacement to locations lighted for at least three hours daily, limited bulbs (and payment) to contractually specified models, and designated specific target communities and residences. With the exception of its dedication to comprehensiveness, this approach is that which utilities typically pursue for direct installation programs.

The New Jersey project did not limit or pre-specify types of bulbs, participation or hours use. However, the contractor is being paid strictly upon verified and persistence checked lifecycle kilowatt hour savings. Only the New Jersey project includes penalties for any resultant lack of persistence, which is to be measured annually over a ten year period.

Despite these differences, both projects had the same ultimate goals: (1) deliver significant conservation services to the previously ignored residential basic service customer, who has neither electric heat nor electric water heat; (2) provide demonstrable utility bill savings to participants; and (3) encourage a radical transformation of the local residential lighting market place.

Research and Methodology

The research for both the New York and the New Jersey projects reflect the same key survey data collected in each home. A trained lighting installer physically surveyed the number of incandescent bulbs in the home prior to retrofit and the wattage distribution of the bulbs. Upon installation, the installer also recorded the types and wattage of bulbs installed and the lamp wattage removed, along with the specific rooms in which the relamping occurred. With this data collected, residence-specific wattage reductions and estimates of energy savings, and cost-benefits can be calculated.

In the earlier New York homes, each homeowner was also questioned on daily average hours use per location, number of rooms in the house, and number of occupants. All participants were given an opinion and satisfaction questionnaire to complete and mail back to the utility.

As part of the verification and inspection procedure, post-retrofit personal surveys were conducted by phone interviews or by site visits for 50% of the installations to verify participant satisfaction and market penetration. These results are also being documented. The utility also conducted independent site inspections about two months following each set of installations. In the New Jersey project, the utility is also following up with annual surveys of treated residences to determine long term persistence. That process is expected to begin later this year.

Results

The Baseline: Lighting in the Typical Residence

Bulbs Per Residence, Per Room, Per Occupant. The first key finding was the large number of incandescent bulbs actually being used in the typical residence. There was, in the 7,700 residences treated, an average of 37.6 incandescent bulbs per house. However, there was a significant variance in bulbs per household.

Table 1. Frequency Distribution of Bulbs Per Household

Incandescent Bulbs At Least	Percent of Households
10	96%
20	80%
30	59%
34	50%
40	37%
50	20%
60	11%
70	6%
80	3%
100	1%

As might be expected, there was a positive correlation between bulb count and house size and between bulb count and number of occupants. The correlation is extremely strong with house size as measured by number of rooms. While a cross-correlation between house size and family size has not been undertaken, it appears that the variance is almost totally due to house size. On average, there are 3.9 incandescent bulbs for each room in the house. This average is remarkably stable. Whether for houses of 3 or 13 or 23 rooms, you can almost count on seeing about four bulbs per room.

The average bulb count per single family house (37 average and 34 median) is consistent with earlier studies, which showed levels of 38.3 bulbs (Manclark and Nelson 1992), 33.6 bulbs (Dethman and King 1991), and 32.1 bulbs (SESCO 1991).

Connected Loads and Wattage Frequency Distribution. Based upon the lighting census, the average connected load for lighting is 2.5 kilowatts per residence, although there is great variance from residence to residence. The recent Grays Harbor study confirms this average number, reporting an average connected load of 2,525 watts in the houses surveyed.

What is of particular importance is the wattage distribution of the installed bulbs. Low watt bulbs (less than 60 watts) represent 25% of the bulbs, but only 14% of the wattage. The higher wattage bulbs represent a disproportionately large amount of the total load.

Table 2. Wattage Distribution of Residential Bulbs and Connected Load

Existing Bulbs	% of Total	% of Load
>40 w	9%	4%
40 w	16%	10%
60 w	37%	34%
75 w	20%	22%
100 w	12%	18%
150 w	5%	10%
150+w	1%	2%

Average 66.3 Watts/Bulb

The only significant variance of this distribution among the subgroups is that the percentage of bulbs in the higher wattage categories tends to increase as house size decreases.

Potential For Cost-Effective Replacements

Most residential lighting programs have placed some artificial limit on the number of bulbs installed per customer or per residence. While some utilities placed this limit as high as ten or even fourteen bulbs (New York State Gas & Electric Company), most were on the order of two to six bulbs per household (Robinson). These limitations tend to be more common with direct installation, but also exist for many catalog sales and/or retail rebate programs. Rather than limit the program to a few high use bulbs, these programs were designed for comprehensive, whole house lighting retrofits so as to assure that such cream-skimming and lost opportunities were minimized.

Physical Limitations Minimized. The program emphasized the installation of a variety of bulb types and wattage, along with various harp adapters, reflectors, extenders, etc., to assure that physical limitations to cost-effective installations were minimized. By using direct installation, the programs assured proper placement and availability of needed accessories, matching the individual fixture and lighting need, while eliminating improper installations that could potentially "turn off" a participant.

In a Springfield, Massachusetts test to determine maximum feasible penetrations and customer acceptance, SESCO, Inc, an energy service company under contract to Western Massachusetts Electric Company, installed an average of 22.1 bulbs in 215 houses.[1] Nearly 69% of the incandescent bulbs were replaced by energy efficient models. The only limitations were customer acceptance and physical conformity with the fixture. That ESCO is currently installing an average of up to 12 bulbs per house in certain types of residences (SESCO and Reeves 1991). The lessons learned from this approach were applied to programs in both New York and New Jersey.

The April 1992 Grays Harbor PUD Compact Fluorescent Maximization Study (Manclark and Nelson 1992) revealed that an average 22 of 44.5 incandescent bulbs were replaced by compact fluorescents. 58% of the incandescent sockets were converted to compact fluorescents by the trained installers (for a reduction in total wattage of 46%!).

From the two programs reviewed here and from the three outside studies, it is apparent that there is no reason to limit bulb replacements due to either customer acceptance or to physical limitations on opportunities or the capabilities of existing fixtures to accept them. Relatively low cost, non-intrusive adapters can readily allow replacement of a large number, perhaps even a majority of bulbs.

To justify the limitations placed on the number of bulbs, most utility programs have explained that they are making sure that only high use bulbs are replaced--a typical cream-skimming strategy.

Can you imagine the reaction were weatherization programs to be limited to weatherstripping only two windows per house, regardless of how many needed it? Can you imagine any commercial or industrial lighting program being limited to only four bulbs or even to forty bulbs? No, of course not. In each case, what is important is to secure all of the cost-effective savings available, not merely those couple of installations that offer the very highest savings.

To do this, an effort was made to determine where the actual cut-off was for cost-effective savings with respect to residential lighting programs.

Daily Hours Use Irrelevant to Cost-Effectiveness. The average hours use is almost irrelevant in determining cost-effectiveness. Hours use per day only indicates how many kwh of savings will occur in any single year. The total kwh savings of the bulb depend upon the total hours use of the bulb's life multiplied by the wattage savings, i.e., the lifecycle savings.

Fewer average hours use per day only means that the kwh savings will be spread over more years, but the total kwh savings will be essentially the same. There may be some deterioration in cost-effectiveness if the utility's financial discount rate is much higher than the projected inflation rate of avoided cost benefits, but this is usually not significant except in extreme circumstances. Orange and Rockland's avoided cost pattern is fairly typical; the following shows the difference in cost-effectiveness for that utility depending upon various annual and daily usage levels:

Table 3. Utility B/C Ratio for Residential Lighting by Hours Use Per Year, Per Day

Hrs/Year	Hrs/Day	B/C Ratio
2,555	7	1.68
2,500	6.8	1.68
2,190	6	1.68
2,000	5.5	1.69
1,925	5.3	1.69
1,825	5	1.69
1,500	4.1	1.67
1,460	4	1.62
1,095	3	1.59
1,000	2.7	1.58
730	2	1.45
500	1.4	1.24
365	1	1.07

This pattern, which indicates little lifecycle benefit/cost variance with the annual hours use, is common among utility avoided cost tests. A similar pattern was found in similar evaluations for Western Massachusetts Electric (1989), Central Maine Power (1989 and 1992), Niagara Mohawk Power (1990), Jersey Central Power & Light (1990), Rochester Gas & Electric (1991), Bonneville Power Administration (1991), Central Hudson Electric & Gas (1991), and Puget Sound Power & Light (1992). In almost every case, residential lighting was found to be cost effective at all levels until the average bulb replaced dropped below about 300-500 hours use annually.

The comprehensive treatments provided in these two examples produced average annual hours usage of about 1,000 hours in New Jersey and over 1,900 hours in New York.

An anomaly in the sponsoring utility's DSM Incentive under New York regulations allows them to earn a profit only on energy savings during the next three years. Consequently, the utility limited installations to locations with usage of at least 3 hours, resulting in an average usage level of 5.3 hours, or about 1,930 hours annually. In New Jersey, DSM incentives are calculated on lifecycle net benefits, so there is no need to concentrate on short-term savings at the potential expense of lifecycle benefits. Nevertheless, the program has been limited to locations in use at least one hour daily, resulting in an average daily usage estimated at 2.75 hours (1,000 hours annually).

The hours use are taken solely from room-by-room surveys as reported by participants. While this is the most common procedure, we are not confident of the accuracy of this procedure. Other organizations, such as Massachusetts Electric Company (Massachusetts Electric 1991) and the Grays Harbor/Bonneville group are placing run hour meters on various lights to better determine hours use and annual savings. However, since the annual rate of savings has had relatively little impact on the lifecycle benefit-cost study, this has not been a high priority for this evaluation.

Bulbs Installed, Bulbs Replaced

The average number of compact fluorescent bulbs installed per residence is 14.2 bulbs, 12.8 in New York and 16.6 in New Jersey. This differential was caused by slightly larger average sizes of New Jersey houses treated to date and by the greater flexibility offered by the New Jersey performance approach. The most important of these flexibilities was the ability to install bulbs in New Jersey locations with reported average usage as low as one hour, compared to a minimum of three hours in New York. The other flexibility had to do with the contractual pre-specification of particular bulbs and bulb prices in the New York project. Although the contractor offered these prices at the time the contract was negotiated, this had the effect of locking those attributes into the process, instead of allowing the contractor or the utility greater flexibility to design the most comprehensive, cost-effective lighting installation.

Under the New Jersey "performance" approach (designed to maximize cost-effective kwh savings), there were a much larger number of higher wattage and two-piece units installed when compared to the payment per bulb approach used in New York. Under the performance contract, which pays for life-cycle energy savings, there is an incentive not only to maximize initial savings, but also to assure long term persistence. For this reason, there is a higher proportion of high lumen output bulbs and of longer lived two piece units. In addition, there was a greater diversity of bulbs installed.

Table 4. Types of Bulbs Installed By Project

Bulbs Used	New York	New Jersey
Total/House	12.8	16.6
15 w	64%	48%
18 w	22%	10%
22 w	6%	31%
27 w	7%	11%
Average	17.0 w	18.8 w
2-piece	10%	37%

It is also evident that the wattage replaced shifted to a higher level of wattage savings:

Table 5. Bulbs Replaced By Project Type

Bulbs Replaced	New York	New Jersey
>40 w	0%	0%
40 w	15%	0%
60 w	50%	49%
75 w	49%	53%
100 w	47%	57%
150 w	29%	32%
150+w	10%	21%
Average	37.2%	39.3%
Average	70.9 w	77.2

In a comprehensive retrofit program, the proportion of bulbs replaced averages about the same, roughly 38%, regardless of the type of program. However, in the performance program (NJ), the contractor had the incentive to concentrate upon the high use bulbs where the greatest savings occur. Thus, despite a slightly higher average wattage per installed bulb in New Jersey, that program saw much greater net savings: an average of 58.4 watts vs. 53.9 watts net in New York. Similarly, the average lifetime of the bulbs installed were higher in New Jersey, 9,800+ hours vs. 9,100 hours in New York.

Demand Savings, Energy Savings

Savings Per Treated Household Accurately Determined. Under most programs where the lighting improvements are installed by the resident, such as retail store or catalog sales, DSM planners must rely upon savings "guesstimates" to calculate savings. This is usually done by using the manufacturers' recommended replacement strategy and assuming that this is what is taking place in the field. However, studies have shown that consumers seldom use the bulbs offered to replace the bulbs they are designed for.

Because both of the direct installation programs we evaluated used direct installation exclusively, it was possible to determine savings with great accuracy. Under programs which do not use direct installation, such as retail or catalog sales (Bourget 1992), mail order or bill insert offers (Goett, Van Liere and Quigley 1992) or door-to-door sales (Sabo, McRae and Parfomak 1991), the potential is very great that replacement bulbs do not match those they were intended to, often reducing savings levels. For example, the CMP Lions Club program resulted in 34% of the bulbs not being installed (Sabo, McRae and Parfomak 1991). Of those that were installed, 72% replaced the wrong sized bulbs. Of those that were installed, 57% were installed in locations which were not cost-effective, based upon the utility's avoided costs.

Participants will install purchased bulbs wherever it will save them energy without lowering the lighting amenities, usually lumen output. And if they can get both lower costs and higher lighting levels, they may consider themselves far ahead of the game. For example, in the CMP program, the 20 watt compact fluorescent was designed to replace a 75 watt incandescent and was cost-effective at that level. However, over half were used in 40w and 60w replacements.

The consumer who replaced a 40 watt saw much higher lighting levels and utility bill savings twice the purchase price. Unfortunately, to cost-justify the effort, CMP (and its ratepayers) needed this bulb to replace 75 watt incandescents. A similar situation occurs with catalog sales (Bourget 1992).

In direct installation, each bulb installed is placed in a location that will be cost-effective and that is appropriate to the light levels being replaced. During the installations, the installers recorded precisely the wattage of each bulb removed and that which replaced it, along with the type and the expected life of the bulb. From this site specific data, we are able to determine the life-cycle savings with great accuracy, multiplying the wattage differential recorded by the hours use. As mentioned earlier, we must still use engineering estimates to determine peak demand reductions.

On a lifecycle basis, the savings per bulb in both programs were significant: 528 kwh per bulb overall; 491 kwh per bulb in New York and 577 kwh per bulb in New Jersey. The connected load reduction is 55.8 watts per bulb; 58.4 in New Jersey and 53.9 watts in New York.

On a per household basis, the lifecycle energy savings totals 7,500 kilowatt hours per treated residence (14.2 bulbs times 528 kwh per bulb); in New Jersey the savings total 9,575 kwh per residence, in New York, the savings total about 6,285 kwh per residence.

Table 6. Energy Savings Per Bulb in Each Project

Savings/Bulb	New York	New Jersey
kWh/Life	491	577
Watts	53.9	58.4
Hrs/Life	9,000	9,860
Hrs/Years	1,930	995
kWh/Year	104	58
Yrs/Life	4.7	9.9

The customers are asked to estimate the hours use of lights in the rooms treated. Aside from sub-metering the lighting habits of the homes to be treated on a before and after basis, there does not exist any way of verifying this customer reported data, which makes us skeptical of the validity of this approach. Nevertheless, based upon this approach, the usage in New Jersey is 2.7 hours daily and 5.3 hours in New York, providing an estimated life of bulbs equal to about 9.9 years in New Jersey and about 4.7 years in New York. Of the two, we believe that the New Jersey average has the greater accuracy.

On a per household basis, the projects provide an average annual savings of about 967 kwh annually for ten years in New Jersey; the average savings per household in New York was about 1,337 kwh per year for nearly five years. If looking for estimates of potential annual savings, the recommendation is to use the New Jersey averages.

The reduction in connected lighting load is also very significant, about 33%. On average, it totals about 0.8 kilowatts; about 0.97 kW in New Jersey, and 0.69 in New York. Either of these numbers is still much lower than could be accomplished by a maximum penetration effort, such as undertaken by the Grays Harbor PUD. In that example, the PUD, by eliminating even the 1 hour guideline, was able to replace a much higher number and proportion of bulbs. They also reduced connected load by 1.16 kW, or about 46% (Manclark and Nelson 1992).

No estimate of peak demand reduction can be made because there is no measurement of the coincidence factor of this load with the utility's system peaks. There have been a number of different values, dependent largely upon whether the utility is a summer peaking system (coincidence factors usually about 10%-25%) or a winter peaking system (coincidence usually about 75%-90%).

Installations by Rooms. Both projects collected data on the number of installed bulbs by rooms in the house. In examining this data, it is important to realize that many of the homes did not have some of these rooms (e.g., family rooms) or that others may call the same room by different terms (e.g., family room vs. finished basement). The following presents a listing of the proportion of bulbs installed by room, assuming at least 5% of the bulbs were installed in those rooms:

Table 7. Locations by Room of Bulb Replacements

Room	% Installed
Occ. Bedrooms	26%
Bathrooms	14%
Living Room	13%
Kitchen	10%
Fam/Finish Bsmt	10%
Exterior	6%
Miscellaneous	21%
Total	100%

Efforts at Assuring Savings Persistence

Direct installation assured accuracy of savings and comprehensiveness of treatment. But one of the major reasons for its use was to help assure greater savings persistence. Other residential lighting strategies (e.g., catalog or retail sales, door-to-door distribution, etc.) have had notoriously poor savings persistence. For example, Central Maine Power found that 34% of the bulbs purchased through a service sales program were never even installed (Sabo, McRae and Parfomak 1991). While the Northeast Utilities study revealed that 36% of the catalog purchased lighting products similarly were not installed (Bourget 1992). And the PG&E study found that 39% of the mail order purchased bulbs were not installed (Goett, Van Liere and Quigley 1992). Again, the New York and the New Jersey programs were designed to overcome this problem by assuring that each bulb was physically installed at the residence.

The prime concern with residential lighting persistence has been the problem of customer removal or even lack of initial installation. Studies at CMP, NU and PG&E found that somewhere between 30% and 40% of the bulbs were never installed and some other fractions (2% to 6%) "emigrated" from their service areas, primarily as gifts. However, the long run persistence is also to be questioned because so many of the bulbs that were installed have been placed in the wrong applications. In the case of CMP, 72% of the bulbs installed were used to replace the wrong sized bulbs; at NU, 57% of the installed bulbs were improperly sized; and at PG&E, 67% of the installed bulbs were improperly sized. This type of problems may well lead to customer dissatisfaction and eventual removal.

The programs shown herein tried to overcome that problem by assuring that each bulb installed was appropriate to the task for which it was used and that it was used to replace the appropriate sized bulb.

To assure persistence for the comprehensive installations, customer education and satisfaction were emphasized. During and after installation, customers turned each light on to assure the lighting level was similar and reasonable. Customer satisfaction with the appearance of the installations was also requested. Any bulbs that were not satisfactory either then or during the ensuing year are picked up and a replacement provided. A warranty was provided by the contractor. In New York, the warranty is for one year. In New Jersey, the warranty is for the projected life of the bulbs.

Significant effort is made to assure the customer understands the lighting pattern of each bulb. For example, they are alerted to any expected "flicker" and to the need to wait a very short period for full lumen output. Most important is an explanation of the projected utility bill and bulb purchase savings.

We seek to do follow-up phone verification and/or on-site inspections on at least 50% of all installations. Satisfaction surveys are also provided to every participant for mailing directly to the utility. Any dissatisfaction with the installation or the bulbs are reported back very quickly. An installer can be dispatched to correct the problem or to remove the bulbs, if necessary. The bulb counts reported in this evaluation are the net results following this initial verification series. Given the type of attention at the time of installation, it is believed that there will be very few persistence losses beyond the first few weeks.

The New Jersey performance contract does contain a severe penalty to the contractor should persistence ever fall below 90%. However, based upon inspections to date, including many undertaken 2 to 5 months following installation, the persistence has been much higher. Based upon its evaluations of the persistence during the first year and upon the "Residential Evaluation Study" conducted by Synergic Resources Corporation for the utility, the utility is projecting that the average persistence will be about 95% over the first five year period. However, the utility will be undertaking annual surveys each year for up to ten years to ascertain the specific persistence levels. Should they drop below the 90% cut-off, the contractor is responsible to replace the differential or to reduce their payment to compensate.

The utility's projected persistence levels of 95% following the initial losses in the first several months is consistent with the findings in PG&E's study (Goett, Van Liere and Quigley 1992). In that study, the researchers found that after a large proportion were lost (or never installed) during the early months, customers reported that they expected to further remove only about 3-5% more. The prime reasons given for dissatisfaction with existing bulb installations are poor fit and lowered light levels. By assuring that each bulb is installed with a proper fit and accurately matching new bulbs to those removed, direct installation can eliminate some of these major impediments to long persistence.

Based upon information from other studies, persistence beyond the initial ten year tracking period may not be as serious an issue as originally thought. It may be that the lower use bulbs replaced, e.g., those with use below 1,000 hours annually, will not actually take 15+ years to be "used". While those installations are fully cost-effective, even if we assume the need for a 10-15-20 year term, it is more likely that these bulbs' lifecycle savings will occur in a shorter time because of the "replacement phenomenon" originally observed in the CMP study (Sabo, McRae and Parfomak 1991). Once the high use bulbs originally installed burn out, a significant fraction are likely to be replaced with other high efficiency bulbs already in their house, including some which might have not yet been installed. Thus, the low use bulbs installed are likely to benefit from the "bulb snatching" so common in many of our homes, allowing them to deliver their lifecycle savings in a much shorter time. The PG&E study showed a similar pattern.

Customer Satisfaction High

Following installation, each customer is presented with a satisfaction survey concerning various aspects of the installations, the contractor, the bulbs and future plans. This survey is to be completed and returned to the utility in a postage prepaid envelope provided. Several thousand surveys have been returned to date.

Of those returning the surveys, 98% or more found the installers courteous and professional and their work safe, clean, etc. 89% said that as a result of the visit, they now had an increased conservation awareness. And most important, 88% found the light at least satisfactory, and 84% said they will purchase the energy efficient bulbs when they need additional bulbs.

This very high satisfaction rate is to be expected under the direct installation approach. Any customer dissatisfaction problems that may occur with or during the installation are eliminated immediately, during the actual installation. In addition, over 50% of the installed jobs (and a much higher proportion of those with above average bulb numbers) are contacted soon after installation to check on satisfaction levels and to verify the installation. This allows the vast majority of problems to be caught and corrected or the bulbs removed before they have a chance to "fester." The end result is not only a very satisfied customer, but a very positive group of referrals to assist with word of mouth acceptance of the program and the technology.

Program Penetrations Very Strong

Marketing efforts have been concentrated in seven specific communities, four in New York and three in New Jersey. In New York, about 41% of the residences solicited were treated. FLC believes that repeated "sweeps" through these areas could have increased penetration levels to 60-70% or more.

In New Jersey, there has been only one community "sweep" completed to date. Of 4,047 eligible customers, 876 had no phone, leaving 3,171 target eligibles during this time period. Of these, 2,037 have been treated or are scheduled for treatment. This is a penetration rate of 64% of those solicited, and 50% of the entire community. It is expected that this penetration will increase during the upcoming installation period.

For comparison, many other utility lighting programs commonly have penetrations of 1%-3% of those targeted and then only a small proportion of the potential lighting applications in each residence. In New Jersey, the performance lighting project is expected to actually treat 50-60% of all residential customers in the service area. And a projected 27% of all lights in the service areas will be replaced with compact fluorescent bulbs during the two year program. By comparison, no other utility in New York or New Jersey is expected to exceed one half of one percent penetration of their lighting market during the same time period.

Serving the "Missing Customers" Cost-Effectively

Residential conservation programs by electric utilities are traditionally weighted disproportionately to serve the electric heat customer and new construction customers. To a lesser extent, there are often programs for the electric water heating customers and those who are in the market for new major appliances. However, in utility conservation efforts, the basic service customer, the one who has neither electric heat nor electric water heating, is usually the "missing customer." Utilities have not helped this customer in the past because there was a presumption that there was little that could be done for the basic service customer in a cost-effective manner. The only time the basic service residential customer is not "missing" is when the system uses the rates paid by that customer to finance comprehensive conservation efforts for other customers.

The use of a comprehensive lighting retrofit has allowed the utilities to deliver a meaningful reduction in those basic service customers' utility bills and to provide them with significant long term benefits. And the programs have been very cost-effective. In 1992 dollars, the programs are delivering savings at a total cost (installation, materials, marketing, verification and all other administrative costs) for about four cents per kilowatt hour (Orange and Rockland 1991,1992).

Although this cost is lower than many other direct installation programs (Shirilau, Espinosa and Kast 1992), the ability to conduct a comprehensive installation at each residence has allowed the utility and the contractor to keep costs to a minimum.

The ability to pursue a large scale, comprehensive residential lighting program has assured not only a lower cost per bulb, but also assured a large amount of conserved kilowatt hours is realized.

Over the three year life of the combined direct installation programs, slightly over 450,000 bulbs will be installed. Annual savings of 28 million kilowatt hours will be realized. And over the savings life of the installed bulbs, about 250 million kilowatt hours will be saved. Nor was

Table 8. Average Prices for Direct Installation Programs

Total Costs	New York	New Jersey
Cents Per kWh	4.30	3.95
$/Bulb	$21.10	$22.50

(1992 PV$; includes overheads and administration.)

this project being conducted in a large utility. In fact, the New Jersey service area, which will receive over 80% of the savings contains fewer than 60,000 residential customers.

Table 9. Annual Bulb Installations and Savings

	Bulbs	MWH/Yr
1991	82,441	7,303
1992	170,000	9,700
1993	202,000	11,500
Total	454,000	28,500

Life-cycle Savings 250,000 MWH.

In Conclusion

The potential for comprehensive cost-effective residential lighting retrofits has been enormously underestimated in current utility sponsored lighting programs. The two different direct installation programs described in this report have successfully installed an average of over 14 bulbs per house in a cost-effective direct installation program that overcomes many of the potential problems common to residential lighting efforts. The most important of the problems overcome were cream skimming and lost opportunities, low installation and retention rates, poor ability to accurately estimate savings and below standard customer satisfaction.

Equally important, these programs are providing an enormous and perhaps unique data base of information on many different aspects of residential lighting. We hope that this data base will allow others to further improve programs to provide for direct installation of even more comprehensive, cost-effective residential lighting programs.

Following the example of Orange and Rockland, Atlantic Electric is openly evaluating a similar program. An even larger, but similar lighting program has already been announced by Puget Sound Power & Light. And the nation's largest residential lighting program, involving direct installation of up to 3 million bulbs is being evaluated by Bonneville Power Administration.

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Endnote

1. The Springfield, MA study information was provided in a personal communication with Mr. Richard M. Esteves of SESCO, Inc. The results are from an unpublished study conducted in Springfield, MA. by SESCO, Inc., as part of a performance conservation contract with Western Massachusetts Electric Company; installations were completed in the fall-winter 1987-88.

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