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Impacts of Prepayment Meters and Energy Efficiency Measures on Electricity Consumption and Loss Reduction in Monrovia, Liberia

MAY 2013

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Impacts of Prepayment Meters and Energy Efficiency Measures on Electricity Consumption and Loss Reduction in Monrovia, Liberia Final Report

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Section 1 Executive Summary

The United States Agency for International Development (USAID) and the Liberia Electricity Company (LEC) implemented the Electricity Affordability, Safety and Loss Reduction to assess the extent to which introducing energy efficiency interventions and prepayment meters would impact customer consumption. It was anticipated that switching from conventional electronic meters to prepayment meters, educating customers on energy efficiency opportunities, and exchanging incandescent bulbs to Compact Fluorescent Lights (CFL) interventions would reduce consumption and increase the affordability of service for LEC customers. The project also aimed to assess the impact of these interventions on LEC's non-technical losses due to theft, graft, and poor customer payment performance. To conduct this evaluation, a third of LEC's existing customers were switched from conventional meters to split pre-payment meters (PPT) and energy efficiency measures were introduced to a sub-set of those switched.

Evaluation results found that, on average, switching to pre-payment meters reduced customer consumption on the order of 25% with greater benefits for those having their inefficient incandescent lights exchanged for CFLs (savings ranging from 27% for residential customers and 36% for commercial customers). Pre-project and post-project surveys found that switching to pre-payment meters in a context of high electricity tariffs ($.54c/ kWh) was a strong catalyst in itself to incentivize customers to reduce consumption, either through behavior changes (turning off lights, etc.) and/or investing in CFLs. In fact, many of the customer sub-set targeted for bulb exchanges under the project had already switched to CFLs on their own, as had many that only received a prepayment meter.

The value to LEC of the interventions undertaken was three-fold: the consumption reductions make it possible to serve more customers with the same generation capacity, to avoid troublesome long-term arrears, and to reduce its costs of service through eliminating billing, collection and disconnections for non-payment. The project also helps LEC to better understand its customer base and the value to customers of actions that it could take in the future to improve customer relations and consumption affordability. The potential benefits of theft reduction (from split prepayment meters) did not ensue primarily due to continuing problems with theft and graft that may be more effectively addressed once the distribution grid re-configuration is complete. This will extend the deadly medium voltage lines and situate them below the low voltage lines, which will deter climbing poles to tap into the low voltage lines or bypass the pole-mounted split prepayment meters.

The results of the project will be disseminated to other electricity companies and government policy makers to help them decide upon the merits that might accrue from taking similar actions elsewhere. There are large potential impacts in cases where: power availability is costly and limited and there are potential customers waiting to connect; there is an existing customer base that has not been converted to prepayment and exhibits poor payment performance; and limited

ability by the company to disconnect customers or take legal action to collect arrears. Such conditions exist in many parts of Africa and Asia, island nations, and other countries with power shortages, low customer coverage, theft and poor payment performance.

Section 2 Background and Project Descriptions

2.1 Liberia Electricity System

A civil war ravaged Liberia between 1989 and 2003, and over time the Liberian power grid was completely destroyed by looting for parts and scrap metal. Before the war there was a total installed electricity generation capacity of 202 MW (90% around Monrovia) serving around 39,000 customers. As the lights went out, higher income consumers began generating electricity with costly generators running on diesel fuel or gasoline. The rest of the population resorted to traditional fuels, kerosene and candles.

After the election of President Ellen Johnson-Sirleaf in 2006 the Liberian Electricity Corporation (LEC) began to receive support from donors for restoration of the electricity system – which included emergency capital expenditures, some operating budget support for fuel, and technical assistance – through the Emergency Power Programs (EPP) I and II. The donors included USAID, the Government of Norway, the World Bank, the Government of Ghana, and the European Community among others.

The next step was substantial additional donor funding and assistance to improve the management effectiveness of LEC (led by the International Finance Corporation), provide adequate and reliable generation capacity (starting from a base of around 4 MW prior to an additional 10 MW commissioned in late 2010) and to increase the number of connections to lower-income households in Monrovia. Manitoba Hydro International (MHI) won the international bid to take on the management of LEC for 5 years starting in mid-2010.

By that time, the customer base was about 2,000 and comprised mostly commercial and institutional customers with some residential and mixed residential /commercial customers. Most of these customers were those providing essential services to the population, such as GoL facilities and the hospital, and all were situated near EPP-installed emergency generation installations and distribution lines. Additionally, commercial and residential customers were required to have legal tenancy and sufficiently substantial structures that could meet Government of Liberia (GoL) and LEC safety requirements as well as sufficient funds to pay the connection fees and a security deposit based on their estimated monthly consumption. Thus, commercial customers were those located in the main commercial areas and operating their businesses continuously since the end of the war while residential customers tended to come from middle and high income strata.

2.2 Project Description

The USAID/LEC Electricity Affordability, Safety and Loss Reduction Project was conceived during 2010 when the new MHI management team at LEC was taking on the enormous challenge of meeting their contractual performance targets for new connections, loss reduction, and collection rates (see Table 1). LEC's new management opted to connect all new customers

via individual "split" pre-payment meters. Split prepayment meters differ from conventional electromechanical meters in that the actual meter is located on a pole outside the structure while the digital information display or Customer Interface Unit (CIU) is located within the structure in a location where occupants can monitor their consumption and remaining electricity units. The CIU has a keypad by which the kWh purchase information is entered and the meter recharged. In Monrovia, vendors located throughout the city would be the interface between LEC and the customer for this purchase.

Table 1: MHI's Contractual 5-year Performance Targets for LEC

Contract Baseline Target	Year 1	Year 2	Year 3	Year 4	Year 5
Total Losses (%)	23%	15%	12%		
Collection Rate (%)	94%	95%	97%		
New Connections	3,000	5,000	7,000	8,000	10,000

"This project concept represents the opening of a new and needed "chapter" in the restoration of electricity service to Monrovians."

Mr. Shahid Mohammad, CEO, Liberia Electricity Company, said when referring to providing energy efficiency and safety assistance to customers. November, 2010

At the time of the management changeover, power theft by existing customers had unfortunately been occurring with increasing regularity, causing significant total energy losses on the order of 26 to 29% (for the year 2009) and arrears were significant.

Customers were served by conventional "credit" electromechanical meters whereby LEC would read the meter monthly and deliver a bill for that month's consumption to each customer.[1] These can be quite vulnerable to tampering and will not automatically disconnect in the case of non-payment. LEC has had to launch major actions (called "sweeps") to identify and eliminate illegal connections (i.e., both meter bypass and direct connection to the low voltage power lines) on a periodic basis. Likewise, arrears were and continue to be common, large and difficult to deal with.

This evaluation of the USAID project assesses the impact on LEC customers' electricity consumption of switching to split prepayment meters, which can under the right circumstances be more difficult to tamper with, and determines whether introducing energy efficiency information and measures to help improve customers' affordability of service (in addition to prepayment) can contribute meaningfully to reducing LEC's non-technical losses from customer theft.

[1] Mail service has not been re-established in Monrovia yet. In order to receive service initially, the customer on a conventional meter was required to make a bank deposit in advance of the approximate amount of funds to cover at least one month's consumption and then pay monthly bills thereafter at the same bank. This was a form of prepayment but was not popular as it tied up the deposit indefinitely and banks were not always conveniently located.

A project Memorandum of Understanding (MOU) between LEC and Nexant[2] outlining respective roles and responsibilities was concluded in mid-November, 2010. The following activities were agreed to:

1) Replacement of the conventional meters with split prepayment meters for 750 – or about one-third – of LEC's customers connected with conventional meters at the time of project initiation.[3]

2) Provision of electricity efficiency and safety improvement assistance via Energy Efficiency and Safety (EE&S) Assessments to a subset of these customers. This included technical advice and direct replacement of inefficient lighting (for either residences or small businesses) with more efficient lights called compact fluorescent light bulbs or CFLs. The technical advice included educational brochures (on prepayment and electricity efficiency and safety), site assessments and recommendations on specific habit changes that could save the customer money, the cost/benefits of more efficient appliances and equipment and need to correct electrical safety hazards.

Box 1: Key Milestones in the Project

- Project concept and responsibilities established in MOU November 2010
- Materials specification and procurement December 2010 through October 2011
- Pre-Project Poll June 2011
- Market survey of locally available efficient lighting and appliances June 2011
- EE&S Assessor Training June 2011
- Master database established in June 2011 with data collected through January 2013
- PPT meter installation November 2011
- Vending System: 2 vendors in place November 2011. Increased to five vendors in May 2012
- Energy Efficiency and Safety Assessments: January 2012 through July 2012
- Quiet period: August 2012 through January 2013
- Post-Project Poll: November-December 2012
- Evaluation completed: April 2013

3) Evaluation of the lessons learned and the effectiveness of providing such assistance to customers and dissemination of results for the use by other distribution companies having problems with theft and non-payment in similar situations.

Key milestones for the project are listed in Box 1. For documentation and evaluation of the impact of the above activities, key performance indicators (KPIs) were jointly developed against which to measure project results. These KPIs are summarized in Box 2. LEC provided baseline consumption data on the customers selected to participate for later evaluation of the impact of

[2] Nexant Inc. is a USAID contractor responsible for implementation of this project.

[3] These customers were ones that had been regularized and connected to the grid prior to the start of the LEC Management Contract in July 2010. During project execution, it became necessary to add 275 more customers who were connected to the LEC grid with conventional meters after July 2010 but at least 6 months before the project exchanged their meter for prepayment. These customers were added to take the place of some in the original sample that had very poor consumption data sets, were unable to be located for meter exchange and/or were unwilling to change to prepayment.

the interventions on the KPIs. LEC later provided post-meter-exchange consumption data, and Nexant processed and analyzed it to assess the impact of the project's interventions.

Box 2: Key Performance Indicators for the Project

Customer Impacts

- Improve the affordability of electricity for participating customers (monetary savings)
- Improve customer electrical safety
- Improve customer satisfaction with LEC's service: e.g., power quality, system safety and cost

LEC Impacts

- Improve LEC profitability by reducing non-technical losses and operating costs
- Increase the number of customers that can be served with existing electricity generation capacity
- Improve customer payment performance
- Cost-effectiveness of investments of project investments

The first step to prepare for the evaluation was to select from LEC's database existing customers that had an established billing and payment history and were served through conventional electromechanical meters. Efforts were made to minimize upper-middle class residents and large businesses in order to increase the positive impacts on lower income residents and businesses who presumably would have the greatest difficulty paying their electricity bills. Many of these customers had a history of disconnection and reconnection, either because of discovered theft or non-payment, which was degrading LEC's financial performance.

As socio-economic data was scarce or non-existent the customers were randomly selected from the total sample stratified by the information that could easily be derived from the LEC customer database: i.e., type of customer (residential and commercial), geographic location (within Monrovia), and consumption levels. Customers with nominal or no consumption were eliminated because their consumption indicated that they would be unlikely to be able to take advantage of the project's interventions on energy efficiency and safety improvement. All three-phase commercial customers and those with consumption over about 1000 kWh per month were eliminated because the prepayment meters were not adequate for their level of consumption and because the project's objective was to help those struggling with bill payment and needing energy efficiency and safety improvement assistance and/or because the customer may be more likely to use other sources of power (e.g. self-generation).

Three different interventions were planned for the participating customers:

1) Group 1: Those that received a prepayment meter but no other intervention,
2) Group 2: Those that received a prepayment meter and EE&S assessment but already had efficient light bulbs (CFLs or LED[4] bulbs), and
3) Group 3: Those which got all three interventions – prepayment, electricity and safety assessment and CFLs replacing their remaining inefficient incandescent lights.

[4] LED stands for light emitting diode.

The starting hypothesis was that the first group would consume less from just the meter exchange; the second group would consume even less than the first group due to the advice provided on what electricity savings measures could be taken; and the third group would achieve the greatest drop in consumption as a result of benefiting from the meter exchange, the EE&S assessment, and CFL exchange. A control group was also identified but was not able to be maintained throughout the project.

A master database (MDB) was developed in June 2011 and meticulously prepared so that all interventions could be tracked and cross-tabbed with pre- and post-consumption data for the evaluation. After all interventions were completed, customers were grouped for the evaluation according to the intervention they received.

A pre-project survey (PRE-poll) was developed and administered by the Center for Sustainable Energy Technology (CSET), a Liberian subcontractor to Nexant, in June 2011 to a sub-sample of 100 participating residential and commercial customers. The purpose was to establish a baseline on the socio-economic characteristics and opinions and attitudes against which results from a similar poll after the project's interventions would be compared and analyzed against the hypothesis and the project's KPIs. A post-project survey (POST-poll) was developed in October 2012 and administered to another sub-sample of 100 participating residential and commercial customers in November/December 2012. The same socio-economic and business indicators were included and supplemented with questions about the quality and value of project interventions. Key results and data are included in the upcoming Section II: Results and Evaluation of Impacts.

Market reconnaissance carried out by the local project manager revealed that CFLs were being sold at numerous stores and informal markets but that there was a wide range in the quality of the CFLs available. Some of the larger electrical goods suppliers had stocks of CFLs that would meet the project's specifications for lifetime and illumination. While none of them are as high quality as those now sold in the US and Europe, local vendors indicated that they would not carry the more expensive CFLs as they would not be affordable to their customers. The CFLs were procured by the project locally to avoid additional transportation costs and to support the local CFL market. Stocks of appliances were of varying ages, manufacturers and origins. Availability of energy efficient appliances was extremely limited, and sales personnel were unable to identify the more efficient ones if indeed there were any in the store.

The training of Energy Efficiency and Safety (EE&S) Assessors took place in June 2011.[5] Nexant and CSET carried out the on-site two-week training of local technical support to carry out EE&S assessments. Each of the ten days of training included a half day of class instruction and a half day of field work. The curriculum covered the range of the basics of electricity generation to quantitative calculations of savings that could be achieved by making lifestyle or technical changes. The first week of the field work entailed practice assessments with the

[5] There was no expertise of this sort available within Liberia when the project started.

instructor leading the assessment and a small group of trainees observing the problems found in the field and the technical issues that were encountered and how to handle them. During the second week of field work, the instructor watched and coached the trainees while they performed assessments on non-project customers. Brochures on prepayment and electrical efficiency and safety tips were prepared for distribution during the EE&S assessments.

The assessments were carried out over a period of eight months and were completed at the end of July 2012. They covered the condition of lighting, appliances and structures affecting safe and efficient electrical use, and specific recommendations were made on electricity savings opportunities that could be obtained from changing habits and replacing inefficient equipment and appliances. Unsafe electrical equipment and other electrical safety hazards were identified and recommendations for improving safety were made. Data was gathered during the assessments as inputs to the evaluation, e.g., regarding the amount of inefficient lighting encountered and the quantities and wattage of the incandescent bulbs removed and the number of CFLs replacing them (only a single wattage of CFL was supplied).

By the end of July 2012, 750 customers had received prepayment meters funded and installed by the project and 381 assessments had been completed, during which 117 customers received 410 CFLs in exchange for their incandescent light bulbs. These outputs, both planned and actual, are presented in Table 2 below for each group.

The total number of assessments (with and without CFL replacements) was fewer than planned primarily because of the inability to make initial contact with many of those receiving prepayment meters and a few refusals. Light bulb exchanges were fewer than expected as it was found that two-thirds of those assessed had already changed all of their lights from incandescent to CFLs. Only one third of those assessed still had all or some incandescent lights, averaging 3.5 per customer.

Table 2: Outputs of the Project

Interventions	**# Planned**	**# Actual**	**# Resulting Datasets for Evaluation**
Group 1: Prepayment Meter Exchanges only	250	771[6]	599
Group 2: Electricity Efficiency and Safety Assessments (plus PPT) only	250	264	208
Group3: Efficient Light Bulb Exchanges (plus PPT and Assessment)	250	117	100
Total	**750**	**1152**	**907**
# of Light bulbs exchanged in Group 3	2250	410	Not Applicable

[6] USAID/LEC project purchased 750 PPT meters and paid for their installation. In parallel, LEC worked with another donor to replace conventional meters of other existing customers, some of which were included in the original dataset. As noted earlier, the original database included 250 control group customers. However, most of these were converted to prepayment before the project could be completed because of the urgency of LEC to meet its loss reduction and customer connection goals. Hence the number of customers that fell into Group (prepayment only) was much larger than originally planned.

To collect post-project consumption data, in which no further project interventions took place, a "quiet period" extended from August, 2012 through January, 2013. This allowed for up to six months of complete consumption datasets for 907 customers once problem datasets were eliminated.[7]

[7]Approximately 245 of the 1152 datasets were eventually eliminated due to data difficulties. Problem datasets were those that had discontinuous or no data in either the pre- or post-intervention periods. Incomplete datasets arose when the customer was connected originally but never or rarely used LEC power. Other datasets had large gaps, probably due to disconnections for non-payment or theft or reversion to self-generation during periods when vending services were not completely operational, mostly prior to the start of the "super-vending" service initiated in mid-2012. Problem datasets affected the number of customers that could be evaluated in all three groups.

As noted in Section I, the project conducted a systematic evaluation of the relative effectiveness of energy efficiency and safety assistance, CFL exchanges, and prepayment meter exchange. The results of the evaluation described in this section are organized according to the Key Performance Indicators listed in Box 2: Key Performance Indicators for the Project.

3.1 Profile of Participating Customers

As shown in Tables 3 and 4, the pre- and post-project surveys provided an informative description of the socio-economic characteristics of the LEC customers targeted under the project. Residential customers were mostly from the middle income level of Monrovian society and were highly educated; about half owned their own residences which were substantial structures with indoor bathrooms, metal roofs, and on average five rooms; almost all worked in the formal business and service sectors; and they possessed numerous appliances including air conditioners and around 67% owned at least one car and, of these, about half owned two cars. The socio-economic index created for the project indicates that about 32% were lower-middle income and 60% were upper-middle income while 6% fell into the low income category.[8]

Commercial customers were small businesses and service providers with relatively small spaces (average 300 sq. feet) with an average of four employees including the owner. About half had no vehicle but the rest averaged two vehicles in use in the business. According to the "business prosperity index" constructed for them based on the customer polls, well over three quarters fell into the two lowest strata as shown in Table 4. The businesses included in the project were a better match than the residential customers to the objective of the project to reach low-income customers.[9]

[8] A socio-economic index was created for this project for the residential customers polled. As socio-economic data were not available and customers were reluctant to state their income, the index was based on "proxy means." That is, those observable features or possessions that indicate that there is disposable income for their purchase. The items included in the residential socio-economic index were educational achievement, employment (formal or informal), key appliances owned, vehicle ownership, bathroom (inside or outside), number of bedrooms, and total monthly expenses as reported in the customer poll.

[9] This concords with the original "emergency" service concept adopted by LEC and the EPP partners. Very large businesses were capable of supplying their own power while medium to small businesses were likely to have substantial load but not enough to overwhelm LEC's extremely limited generation capacity in the initial years after the end of the conflict.

Table 3: Key Data Extracted from the Residential Polls		
Item	Pre	Post
Number polled	68	47
Education level	50% university graduates	75% university graduates
Marital status	70% married	67% married
Average years in home	7.5	11
Status in structure	55% renters 45% owners	50% renters 50% owners
Type of residence	Collected but not included in database	50% single family; 25% separate apartment single meter; 25% multi-family structure with single meter
Average # of residents in household	5.5	5
Average # of rooms in residence	5.5	6
Bathroom	97% inside	100% inside
Proportion sharing with another unrelated family	4% (average number sharing was 3 families)	6% (average number sharing was 2 families)
Occupation	67% working mostly in the formal business and service sectors 10% working in informal sector 20% not working	95% working in formal business and service sectors 5% working in informal sector
Vehicle ownership	Not collected	Only 3 owned motorcycles but around 67% owned at least one car and about 33% owned 2 cars
Reported monthly expenses	Monthly expenses: $900 Of which, electricity: $245 Proportion for electricity: 23%	Monthly expenses: $600 Of which, electricity: $170 Proportion for electricity: 29%
Appliance ownership	Data collected but sporadically (due to customer resistance to report)	Refrigerator: 47% Freezer: 38% Fan: 79% AC: 38% TV: 98%
Socio-economic stratification	Not computed	Strata (points) Highest income (31+): 6% Upper middle income (21-30): 60% Lower middle income (11-21): 32% Low income (0-10): 6%

Table 4: Key Data Extracted from the Commercial Polls		
Item	Pre	Post
Number Polled	32	53
Number of years in business	Not collected	Average 7 years Range 1 to 30 years
Number of years LEC customer	3.75	3.5
Education Level Attained	Median: High School	Not Collected
Degree of Formality (with license or not)	Less than 10% said that the business was informal	Around 10% said that the business was informal
Size of Premise [sq. ft. estimated]	Data not usable	Average: 660 sq. ft. Median: 300 sq. ft. Almost 50% fell in range 101 to 500 sq. feet
# of employees including self	Range: 1 – 36 Average: almost 5	Range: 1 to 24 Average: 4 full time and 1 part time
Building type/occupancy	67% in dedicated building, 50% share with another business, 25% share with their own residence	10% share commercial space with another business, 20% share building with own residence, 33% share with other residences
Proportion of customers segmented by average monthly electricity consumption (**from LEC consumption database)**	<100 kWh/month: 29% 101 to 500 kWh/month: 56% 501 to 1000 kWh/month: 12% >1000: 3%	<100 kWh/month: 30% 101 to 500 kWh/month: 57% 501 to 1000 kWh/month: 10% >1000: 2%
Monthly Business Expenses (**as reported by customer**)	$1000	$1600
Monthly electricity expense per LEC consumption database/ % of total expenses	$183/18%	$141/9%
Appliance ownership	Data collected but sporadically (due to customer resistance to report)	Fan: 60% AC: 33% (average 2 per customer) Refrigerator: 20% Freezer: 25% TV: 50%
Vehicle ownership	About 33% reported having one vehicle	50% had no vehicle; those with vehicles had on average 2

3.2 Performance against the KPIs

The evaluation of each KPI uses a combination of sources of data: the project consumption database (provided by LEC), the PRE- and POST-poll database (provided by CSET), the assessment database (provided by CSET), and ancillary data on losses, arrears and financial information provided by LEC.

3.2.1 Project Impact on Customers

Three KPIs relate to the impact on customers: 1) improve the affordability of electricity for participating customers, 2) improve customer electrical safety, and 3) improve customer satisfaction with LEC's service.

KPI #1: Improve affordability of electricity (i.e., monetary savings) for participating customers

Customers in general saved significant amounts of electricity and expense from the investment made by LEC and the Project. Analysis of the pre- and post-intervention consumption data shows that on average there was a 25% reduction in consumption attributed to the three combined interventions for commercial and residential customers evaluated. This represents roughly 700,000 kWh on an annualized basis and translates to roughly $380,000 saved by participating customers. The biggest savings by far came from the meter exchange and the ability for customers to observe and control consumption that the prepayment meter made possible. Energy efficiency advice improved savings marginally for an already quite electricity efficient group, and CFL replacement was very effective in delivering savings in those cases where they were still needed.

The POST-polls corroborated in general that residential and commercial customers enthusiastically endorsed the new prepayment system for its assistance in controlling consumption and reducing their overall expenditures on electricity. Those receiving assessments credited them for helping them reduce consumption and many said that they had heeded the advice and were able to cite specific examples of actions that they had taken as a result (e.g., turning off lights and appliances when not in use).

Disaggregated results by intervention and customer type reveal some additional lessons to be learned from the project. These results are shown in the following Tables 5 and 6.

Table 5: Commercial Impact Analysis		**Pre**	**Post**	**Savings**	
Commercial	**# of Customers**	**Consumption**	**Consumption**	**kWh/month**	**%**
Group 1	187	271.5	222.9	48.6	18%
Group 2	114	240.4	184.5	55.9	23%
Group 3	49	341.9	217.3	124.6	36%
Groups 1,2 and 3	**350**	**271.2**	**209.6**	**61.6**	**23%**

The commercial groups exhibit substantial overall savings of 23%. There is a progression from the large impact from prepayment alone (18% saving), to a larger saving for the group with prepayment plus assessment (23% savings) and finally, the greatest savings to prepayment plus assessment and CFL exchange (36% savings).

The higher pre-intervention consumption for those getting CFL exchange (Group 3) can only partly be attributed to the incandescent bulbs that were contributing significantly to their consumption but nevertheless those commercial customers who accepted the opportunity to have an assessment and to have CFL exchange (for free) were the greatest "savers." From the POST-poll we know that 60% of those commercial customers getting CFL exchanges also had one or more AC unit. The calculated savings provided by CSET for the CFL exchange for those in Group 3 was on average 31 kWh/month/ customer (as shown in Table 6). So it is also clear that the majority of the savings in this group came from other changes made in response to the two other interventions that they received (prepayment and the assessment and resulting recommendations). Indeed, the POST-poll commercial customers with AC reported switching to fans and shutting off AC as one of the actions they took after the meter exchange, and others with refrigeration devices reported shutting them off whenever possible.

Table 6: Calculated Savings from CFL exchanges alone (from Assessments)

Type of Customer	Avg kWh saved per year	Avg kWh saved per month
Commercial	369	31
Residential	386	32

Group 2 would be expected to have lower pre-consumption than either Group 1 or 3 because Group 2 comprises only those who had already replaced their lights with CFLs (along with other consumption reduction techniques) prior to the meter exchange while only some of Group 1 and all of Group 3 had not done so. All groups reported taking some energy saving actions before receiving pre-payment meters. Group 2 benefited from the additional advice provided by the assessments since their savings were higher than Group 1 but only to a small degree: the incremental monthly kWh saved over Group 1 was on average, 6 kWh.[10]

The customer polls and the assessment results provide additional insight on the benefits of the interventions. Commercial customers spent on average $183 per month for electricity or about 18% of reported total business expenses prior to the interventions, and their post-intervention

[10] This result is in line with those experienced by electricity companies providing energy audits for their customers in the United States. For example, in California, companies reporting the savings achieved by their energy efficiency programs cannot attribute any saving to energy audits alone. That is, savings can only be assigned to actual proven actions taken, such as purchase of an energy efficient replacement appliance.

consumption dropped to $141 or 9% of expenses.[11] This could be seen as a boost to economic development by reducing business expenses.

Overall, residential customers achieved a slightly greater percentage savings (26%) than commercial customers (23%), as shown in Table 7. Their higher pre-project consumption averages can be explained by the higher socio-economic strata on average that the residential cohort represents and the subsequent higher ownership of energy intensive appliances such as air conditioning (AC), refrigerators and freezers. Commercial Group 3 customers had a higher reduction in electricity consumption than Residential Group 3 customers which may be attributed to the commercial customers' higher usage of lighting (and where applicable AC) during their business' operating hours whereas residential lights and AC would be off during the day (as corroborated by the PRE- and POST-polls).

Table 7: Residential Impact Analysis		**Pre**	**Post**	**Savings**	
Residential	**# of Customers**	**Consumption**	**Consumption**	**kWh/month**	**%**
Group 1	412	355.1	258.8	96.3	27%
Group 2	94	226	179.4	46.6	21%
Group 3	51	307.5	225.7	81.8	27%
Groups 1,2 and 3	**557**	**328.9**	**242.3**	**86.6**	**26%**

It is not clear why Residential Group 1 has a much greater pre-consumption than Groups 2 and 3. It is possible that the original random selection of customers assigned to each group was upset by the inclusion of additional customers to Group 1 mid-project. Additionally, not all assessments could be completed as a result of acute problems with contacting customers, which may have biased Groups 2 and 3. Nevertheless, a check of the socio-economic strata of the three residential groups finds them to have total social index scores that are quite close (ranging from 22 to 25, which places them in the middle of the second highest strata of 21 to 30 points) .

Like Commercial Group 2, Residential Group 2 had the lowest pre-consumption, most likely as a result of this group already using CFLs, which might also be indicative of them being a more efficient customer and actively seeking out opportunities to reduce consumption. This is corroborated by the EE&S assessments. Residential Group 2 had already taken many of the efficiency actions that were recommended in the assessments, including exchanging CFLs, prior to receiving prepayment meters. As a result, Residential Group 2 had fewer opportunities for reducing consumption after moving to prepayment. Nevertheless, Group 2 did find additional actions to take above and beyond its pre-project efforts and achieved a significant savings of 21% but the savings can only be attributed to the combined interventions of the meter exchange and assessments, not disaggregated.

[11] Actual costs of electricity consumed (not those estimated by customers) were used for this comparison.

> *"I really like that I can easily see how much current I am using. Now I can control my current better. And, I am saving a lot of money! Also it is so much better than having to pay a deposit to LEC tying up my money indefinitely!"*
>
> A residential customer during the POST-poll, November 2012 on the advantages of prepayment.

Comparing responses about energy saving from the PRE- and POST-polls, all groups reported taking more energy saving actions after prepayment than before. According to the POST-polls and the assessments, the only investment reported was exchanging incandescent bulbs with more efficient CFLs. Residential Group 1 included both those with CFLs and those with incandescent lights and therefore, overall, had more potential for electricity savings than Residential Group 2. Both Group 1 and Group 3 replaced inefficient bulbs with CFLs after meter exchange. For Group 3, half of respondents said that they had exchanged some incandescent for CFLs prior to conversion while all said that they did after prepayment conversion as would be expected since the project did the exchange for them. Prior to prepayment, 15% of Group 1 respondents indicated that they had done CFL exchanges while 40% said they exchanged bulbs after prepayment. It appears that prepayment by itself (i.e. without the benefit of the EE&S assessments), in the context of high electricity tariffs, can be a powerful and effective tool to catalyze customers' conservation actions and investments in efficiency measures. EE&S assessments can be effective at identifying customers that have not switched their lights to CFLs and pointing out habit changes that they might not have yet adopted but from these results, they cannot be counted on to provide savings to the electricity company without additional interventions, such as CFL exchanges.

KPI # 2: Improve customer safety

In both PRE- and POST- polls, almost no one reported any electricity related accidents to their knowledge. Less than 10% of commercial customers thought that their electrical installations were unsafe or had electricity related incidents in the last 6 months. Respondents were less sure about the electrical safety of the commercial structures in their neighborhood but in general thought that they were safe. There was only one electricity-related accident reported in the POST-poll.

Nevertheless, assessors found numerous safety hazards. Their advice on improving safety was well remembered, highly appreciated, and heeded. In the POST-poll, many reported that they had taken the advice. The actions taken as a result included quite a range:

- Checking the power rating of any equipment, reducing the load on, or no longer using extension cords and plugging appliances directly into wall plugs,
- Putting plugs on appliances, replacing burned out sockets, renewing wiring, and only using electrical tape for splices or junctions,
- Installing switches on lights and putting the right bulb size in fixtures,
- Using trained electricians,
- Covering the panel box, and
- Replacing old and/or dirty breakers.

The project found that there are many unsafe conditions even in those structures already connected to LEC. It appears that safety risk was substantially reduced by the actions of the project. A safety improvement campaign by LEC could create better customer relations while reducing electrical safety risks.

KPI #3: Improve customer satisfaction with LEC (i.e., service, quality, system safety and cost)

Prior to the project, opinions of LEC service were generally negative even though most customers highly appreciated having electricity service. As shown in Table 9, the LEC service issues that customers most often raised in the PRE-poll were poor power quality and reliability, followed by lack of attention to customers and high costs. Only about 20% of respondents stated that LEC service was good or improving.

Table 8: Opinion of LEC Service PRE-Poll

Customers' Unaided Statements	% Who Had This Opinion
Poor power quality/reliability	35
Service is poor; need more attention to customer	25
LEC is OK/good/improving	20
Bill too high; need to address costs	20

There was a clear positive change in the perception of LEC from the beginning of the project to the POST-poll. In the PRE-poll, 66% of commercial customers reported that they had received visits of varying frequency from LEC. In rating LEC's service, the behavior/manners of LEC personnel and the way they approached the owner and employees were rated very good, but LEC's knowledge of the business's needs, ability to help reduce the bill without reducing business level and efficiency with which problems were resolved were given much lower ratings (a neutral 4-5 out of 10, which was some of the lowest average ratings for all opinion questions asked in the polls).

In their overall assessment of LEC's customer service in the POST-poll, about 66% felt that service in the last six months was better while the remaining 33% said that it was worse. Service issues that were specifically negatively addressed in the POST-poll (i.e., respondents were specifically asked about them) included the meter exchange process, the vending system, the quality of service after meter exchange, and LEC's follow up on problems encountered. Customers spontaneously mentioned the following as needing improvement (most mentioned items listed first): problem resolution, power quality, response time, customer relations/service, vending convenience and reduction in power theft. Quality issues raised were mostly related to voltage instability which caused appliances and machinery to function improperly and/or burn out. The safety of the electricity distribution system was not considered to be a problem for either residents or businesses. When asked about the cost of LEC electricity service as compared to the perceived value of having the service, most found the cost high but still highly valued having power service.

Customers were generally favorable about prepayment. The two top scoring features mentioned were the ability to control the amount used (saving money) and not having to pay a deposit to LEC. The ease of use was also well appreciated. The two negative aspects mentioned most frequently had to do with the quality and hardiness of the new meters and the poor follow-up and problem resolution by LEC after installation. One troublesome aspect that should be resolved is the numerous complaints by those polled that meter failures where the credit on the meter is "lost" were resolved in favor of the company (no lost credit was provided to the customer). This policy might be reviewed in order to come to a compromise that the customer feels is fair for both sides.

The EE&S Assessments were well appreciated. About 50% of those who said they got an assessment also said that they had made changes as a result. Around 60% found the safety information useful and 90% thought that the EE&S brochures were useful. The specific items that they recalled from the assessment (unaided) were evenly divided between safety and electricity efficiency. General satisfaction for the advice given was a median of 8 out of a possible 10. When asked specifically about the CFLs, recipients deemed them attractive, adequate, still working and helping reduce electricity costs.

Customers themselves were somewhat worried about electricity theft. In the PRE-poll the unprompted question about negative aspects of life in general elicited a number of issues, including theft of electricity, crime in general, noise, and poor sanitation; while the POST-poll answers echoed concern about crime, crowding and noise, social neglect (people dying in the street), and the poor exchange rate.

In sum, within the generally improved perception of LEC's service and appreciation of the changes, those that still vexed customers were poor power quality and customer service. The project helped LEC in its efforts to improve its public image, but there is more that it could do, particularly for commercial customers who were the most vocal about the lack of knowledge of their needs and need to improve responsiveness to urgent problems such as faulty meters and transformer outages. Finally, while theft reduction may seem like an uphill battle to LEC, there is definitely quiet support among customers for reducing theft. Ways to harness this support might be considered.

3.2.2 Project Impact on LEC

The following KPIs recognize that there are at least three main ways that the project might improve LEC's profitability: 1) reducing non-technical losses, especially those associated with power theft by customers, 2) reducing operating costs, and 3) reducing persistent arrears.[12] KPI # 4 covers non-technical loss and operational cost reduction while KPI #5 covers improving customer payment performance to reduce arrears. KPI # 6 considers reducing the need for

[12] Arrears that become uncollectable are a commercial loss that appears as a "payable" on the company's balance sheet. LEC reports the number of kWh billed or sold and then the income derived from collections/payments. Losses due to theft enter the balance sheet as expenses paid for fuels and other inputs to generating and delivering the electricity. The losses shown in Graphic 1 only include non-technical losses and not arrears.

capital investment for new generating capacity and KPI # 7 integrates the findings from KPIs 4 through 7 by considering the overall cost-effectiveness of the investments associated with the project.

KPI # 4: Improve LEC profitability by reducing non-technical losses and operating costs

The project interventions of installing split prepayment meters and reducing customer electricity consumption and costs to reduce the temptation and need to steal electricity were expected to contribute to the KPI to reduce the non-technical losses[13] that LEC experienced prior to the project. However, non-technical losses have seesawed over the period that MHI has been working to improve LEC's operations (between about 5% upwards to 28% and back down again several times in the time period covered by the project), as shown in Graph 1.

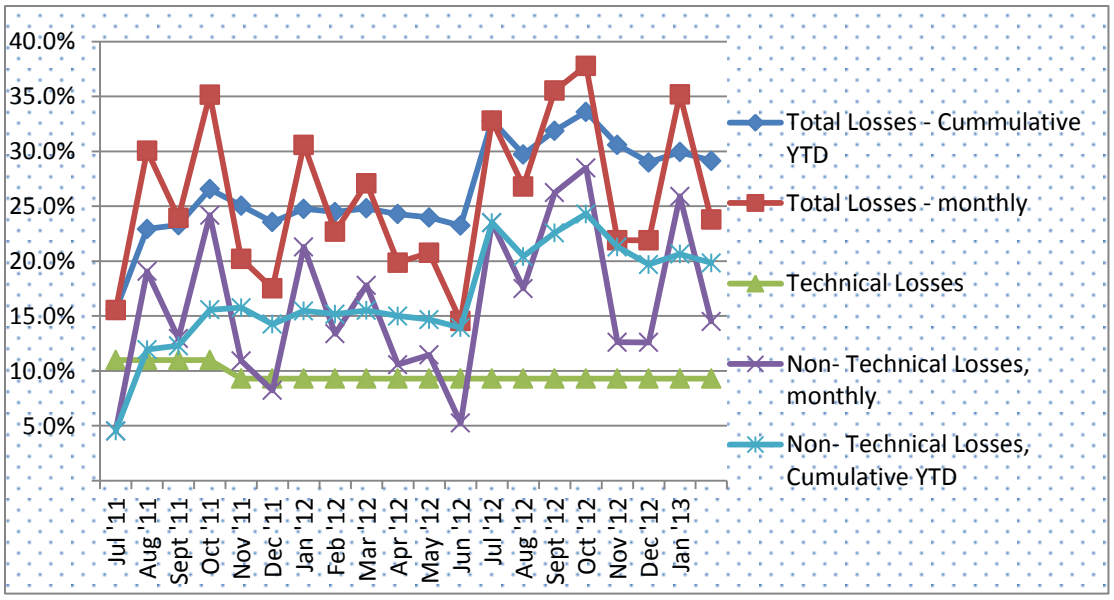
The dips correspond to LEC personnel's "sweeps" through the areas where theft can be observed to be on the rise again and disconnecting all illegal taps and bypasses that they discover. LEC finds that the sources of losses are numerous: by-passing meters (even the split meters) and so-called flying connections (tapping) made by illegal agents or the customers themselves, and by-pass at time of installation (graft with installers or LEC personnel). Thus, it is not possible to isolate the effects of the project's interventions from these types of measures taken by LEC to reduce theft and non-technical loses.

LEC's conversion of its existing customers to prepayment for the project was first focused on the densest commercial and residential areas where the initial distribution system rehabilitation work had taken place. Often poles were too short, the distribution system was poorly designed and connections were somewhat haphazard and confusing due to meter placement within the structure. These conditions made the lines difficult to follow and police, resulting in ample opportunities for theft which customers were willing to take advantage of. For these reasons, LEC targeted these areas for conversion to prepayment first.

LEC's original plan for its "theft proof" system configuration to reduce theft by meter tampering or bypass or tapping into low voltage lines comprises split prepayment meters in the broader context of a new distribution system configuration. The new configuration would have made tampering and tapping much more dangerous because the deadly medium voltage lines would have been situated below the less deadly low voltage lines (a proven deterrent to climbing poles to tap into distribution lines or bypass the pole-mounted split prepayment meters). If this full configuration had been in place in the areas where existing customers were located, theft may have been less prevalent. Currently, LEC has seen theft increase with the expansion of their distribution network. In addition to the split pre-payment meters, theft will likely be reduced when LEC has fully deployed its new system configuration and can enhance its reconnaissance of customer consumption data to spot anomalies that indicate potential theft situations.

[13] Non-technical losses consist primarily of electricity theft, non-payment by customers, and administrative and accounting errors.

Graph 1 - Losses as Tracked by LEC over the Project Period



Another way that LEC's profitability would be expected to improve with prepayment would be from reduced costs associated with billing, collections and disconnections as well as improvements in collections from eliminating any accumulation of arrears prior to disconnection. During the project period, LEC's records of the reasons for disconnection rarely distinguished between non-payment, meter dysfunctions or theft. So, it was not possible to quantitatively capture any changes in revenues from improved customer payment performance and theft reductions after the meter exchange and other interventions. However, LEC does report satisfaction with the reduction in the associated operating costs and with improved cash flow.

KPI # 5: Improve customer payment performance:

At present new arrears are only incurred from those customers that are still on conventional meters. LEC's arrears change dramatically month to month due mostly to irregular lumpy payments by the Government of Liberia (GoL) institutions as they catch up on arrears and then fall back into arrears again. Extracting GoL accounts from the rest provides a more consistent pattern. LEC distinguishes arrears by how long they are past due according to industry standards. The longer the period overdue, the less likely that LEC will recover the payments due.

Once existing or new customers are connected via prepayment they have no choice but to pay in advance whenever they use electricity. Thus, LEC's arrears for its prepayment customers have been reduced to zero while arrears for customers remaining on conventional meters continue to be a very significant drain on LEC's funds. Prior to being moved to prepayment, however, there were significant arrears by many of those converted. Their arrears have not yet been completely repaid. LEC continues to pursue payment, but most of the remaining arrears now fall into the 120 day+ period which is the most difficult to collect.

Over 90% of LEC's overall arrears (less those of GoL which are considered and handled as a separate case) are attributable to residential and commercial customers (37% and 55% respectively)[14]. Over 77% of residential and 61% of commercial arrears are over 120 days past due, indicating a large likelihood that collection will be difficult if not impossible.

To give an idea of the magnitude of the long term arrears associated with commercial and residential customers, the arrears carried by LEC in January 2013 for these customers is equal to almost two months of energy billed to all customers. Many of these customers have had to be disconnected, leading to a high likelihood that they will be good candidates for power theft "services". Conversion to prepayment has already contributed to a reduction in arrears, particularly those that are past 120 days.

A rough calculation of the long-term arrears reduction attributable to the project (based on the statistics provided by LEC) yields a reduction in long term arrears of roughly 17% of what would have been billed over a year. Using the customers participating in the project as an example, this represents about $400,000 that might not have been collected if LEC continued to keep them on conventional meters. Avoiding this revenue loss is a substantial additional benefit to LEC. Nevertheless, as LEC points out, the savings in reduction in arrears by prepayment conversion to date is still a drop (8%) in accumulated arrears which was roughly $6.4M by January 2013.

The way forward on reducing arrears will clearly continue to include prepayment conversion as one of several actions that LEC can take to reduce them. A study of the efficacy of prepayment compared with other means of reducing arrears is beyond the scope of this evaluation but should be considered in any strategy that aims to reduce arrears.

KPIs #6 and #7: Increase the number of customers that can be served with existing electricity generation capacity and the cost-effectiveness of the investment

The roughly 700,000 kWh saved on an annual basis by project interventions would be enough kWh to power another 300+ small commercial and low to middle income residential customers. For every 1,000 customers switching to prepayment, approximately an additional 250 customers (about 25% more customers) could be served with the same amount of power.

The increase in the number of customers that could be served with the same amount of generation is a significant benefit for LEC and donors, as well as the residents and businesses in Monrovia given the financial constraints on the ability of LEC to add new customers while improving power quality. Assuming that it takes roughly 1 MW of generation to serve 1,000 customers and that 1 MW of generation costs approximately $1 million, being able to serve an additional 250 customers with the same amount of generation would be worth about $250,000 in avoided costs.

[14] The other non-GoL customers with arrears are listed by LEC as being either NGOs, pubic corporations or tax exempt entities.

Furthermore, the cost-effectiveness of conversion to pre-payment is improved by the avoidance of arrears, which adds approximately another $400,000 to the bottom line of savings. Although not quantified in this analysis, financial benefits would also likely accrue from the reduced cost of collections and disconnections for non-payment. These savings are well in excess of the project costs for the conversion to prepayment, the assessments and bulb exchanges, which was on the order of $150,000.

The savings achieved as a result of the project interventions represent a "quality of life dividend" (i.e., more money in the pocket for other purposes) for residential customers, a "boost for business net revenues" for commercial customers, more generation capacity to serve new customers and reduction in arrears and operating costs. For a group of customers that was already connected to LEC and already paying very high prices for its electricity, reductions in consumption on the order of 25% are impressive. Thus, prepayment is not only a powerful tool for the consumer but also for the electricity company even if it is not sufficient in itself to stop power theft by customers.

4.1 Impact on Customers

Prepayment was generally well appreciated by customers, especially those with lower incomes who most need to reduce their costs. They take advantage of its features, particularly the ability to see how much they are using and ration as necessary.

Assessments help some to reinforce what they were already doing because of the high cost of power in Liberia, i.e., turning electrical devices and lights off more conscientiously as evidenced by their reported increased watchfulness and habit changes and replacing inefficient light bulbs with more efficient ones. Where assessments uncover customers that have not fully implemented such electricity saving measures, the information provided in the assessments about the very large savings from and quick payback of investing in CFLs could nudge them to make additional investments in CFLs. Although no electricity-related accidents were reported, the EE&S assessments uncovered ample evidence of unsafe electrical conditions. They could be used as a tool by LEC to identify and address hazardous conditions that could lead to fires and injury.

In Liberia, many customers have already taken advantage of the savings offered by exchanging inefficient lights with CFLs. Many reported CFL replacements even within the groups that did not get a free exchange. Indeed, a remarkable 70% of those assessed had already replaced theirs before the prepayment meter exchange. The high proportion of CFLs and other efficient lights is perhaps unsurprising given the very high costs of power in Liberia. As a result, the potential to make significant additional electricity consumption reductions through CFL exchanges may be quite limited.

As noted, behavior changes such as turning off appliances and lights when not in use were the primary methods used to control consumption. No residential or commercial customers reported replacing their inefficient appliances for more efficient ones. Lack of market availability of more efficient appliances could be overcome (i.e., by creating greater demand or by standards imposed by GoL) in order to induce investments in greater electricity efficiency beyond CFL

exchanges. Air conditioners and refrigerators could be targeted based on the relatively high saturation of these appliances among middle- and upper- income customers in Monrovia.

4.2 Impact on LEC

Conversion to split prepayment meters will not by itself eradicate theft. Sweeps are still required, particularly where low voltage lines are easily accessible. LEC is working to complete its new system configuration, which includes extending the medium voltage lines and then placing the low voltage lines above them, throughout its service territory which should help reduce incidence of meter tampering and bypass.

Prepayment does contribute to reducing arrears. LEC's arrears are particularly large for the middle and high income residential strata and larger commercial customers that can afford more electricity intensive appliances like refrigerators, freezers and AC. Extending prepayment to them would reduce arrears as well as costs in bill delivery, collection and disconnections for non-payment that still exist for these customers. The benefit of being able to serve more customers or support more load without additional investment in new generation and reduced load on existing infrastructure is a compelling argument for prepayment and energy efficiency assistance.

As for theft reduction through graft, the "cost equation" that customers face when offered an illegal connection may be difficult for them to turn down. For a few dollars, a meter can be bypassed, which is much less than the average cost of electricity for just one month, and will last more than a month if LEC keeps "sweeping" on a quarterly basis. As reported in the POST-poll, the general populace expresses concern about power theft, but concern does not seem to translate into a spontaneous societal will to shun theft opportunities or to turn in neighbors who are openly doing something illegal. As theft reduction is still an uphill battle for LEC, mechanisms for harnessing support among honest customers for reducing theft could be studied for a possible campaign to elicit more awareness and willingness to put pressure on those succumbing to theft at the neighborhood level.

4.3 Efficacy of Energy Efficiency Measures Compared with Prepayment Alone

The analysis shows that prepayment in itself can stimulate customers to control consumption and is a useful means for the electricity company to eliminate operating costs such as billing and collections and revenue losses from uncollectable arrears while greatly benefitting customers with a quality of life "dividend" or a business "boost" from the monetary savings that result. Split-meter prepayment offers greater potential for theft reduction, particularly if the network design deters tapping and pole climbing by placing the medium voltage lines below the low voltage lines.

Adding energy efficiency interventions (both the EE&S assessments and the CFL exchange) resulted in even greater reductions in consumption for commercial customers. This was not observed for the residential customers where Group 2 and 3 had the same or lower percentage reductions in consumption than Group 1 which did not benefit from the EE&S assessment and

bulb exchanges. As discussed in Section II, this may be due to the commercial customers being more motivated to reduce costs to enhance their business profitability and may have used lighting during their business operations for longer periods of time than residential customers. However, the EE&S assessments were well-appreciated by all customers, according to the POST-poll, and some of their recommendations were reportedly adopted. At the very least, they could be an effective means for LEC to improve customer relations. EE&S assessments might be more efficacious if they were targeted to those customers with large air conditioning and refrigeration loads, which could be better managed, and inefficient lighting systems. In LEC's case, many customers without prepayment meters have much higher consumption levels than those included in the project and could also be targeted for assistance in identifying opportunities for reducing their consumption and electricity bills.

An electricity efficiency promotion effort by LEC could comprise a staged approach:

1) Converting customers to prepayment to remove the potential for arrears to accumulate and providing energy efficiency and safety brochures at the time of conversion or new connection (as noted above, 90% considered the EE&S brochures to be useful),

2) Conducting EE&S assessments on a targeted basis to help identify the sources of high consumption for those customers that find that they need help in identifying and eliminating them (whether they are on prepayment or a conventional meter).

3) Promoting the importation and use of higher efficiency appliances (AC, refrigerators, and freezers).

This strategy might be appropriate for other utilities facing similar conditions as LEC: power availability is costly and limited; there is an existing customer base that has not been converted to prepayment and exhibits poor payment performance; and limited ability by the company to disconnect delinquent customers or take legal action to collect arrears.

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