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J. Sathaye, R. Friedmann, S. Meyers, O. de Buen, A. Gadgil, E. Vargas, and R. Saucedo

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J. Sathaye, R. Friedmann, S. Meyers,
O. de Buen, and A. Gadgil

Energy Analysis Program
Energy and Environment Division
Lawrence Berkeley Laboratory
University of California
Berkeley, California, U.S.A. 94720

E. Vargas, R. Saucedo

Comisión Federal de Electricidad, México

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Abstract

A higher penetration of compact fluorescent lamps (CFLs) for household lighting can reduce growth in peak electricity demand, reduce sales of subsidized electricity, and lessen environmental impacts. This paper describes an economic analysis of a project designed to promote high penetration rates of CFLs in two cities in Mexico. Our analysis indicates that the project will bring substantial net economic benefits to Mexico, the utility, and the average customer. In the absence of any subsidy to CFLs, most customers will see a payback period longer than two years. By sharing some of the anticipated net benefit, CFE, the utility company, can reduce the payback period to a maximum of two years for all customers. CFE's role is thus crucial to the successful implementation of the project. Expanding the Ilumex project to a Mexico-wide program would make a significant contribution towards meeting the planned addition of generation capacity by the year 2000.

Acknowledgments

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I. Introduction

The compact fluorescent lamp (CFL) offers a considerable increase in energy efficiency compared to conventional incandescent lamps, but its much greater first cost tends to deter purchase by households. To encourage higher penetration of CFLs, many electric utilities in the U.S. and Europe have offered a variety of incentive programs.[1] In developing countries, studies have shown that CFLs offer large economic benefits,[2] but subsidized residential tariffs and low household incomes are a severe constraint to the purchase of CFLs, and there has been little effort on the part of utilities to promote their use.

This paper presents the results of an economic feasibility analysis of the first major utility-sponsored CFL project in a developing country. The Ilumex project is designed to promote high penetration of CFLs in households in two Mexican cities: Monterrey and Guadalajara.[3] Household lighting demand is a major component of Mexican peak electricity load.[4] Achieving a high penetration of CFLs for household lighting will reduce growth in peak electricity demand and permit the deferral of costly investments in electric supply, save fuel and reduce sales of subsidized electricity, as well as reduce environmental impacts. The goal of the project is to disseminate 1.5-2 million CFLs in the two cities over a two-year period, particularly among households using less than 200 kWh/month, for whom electric rates are heavily subsidized and low incomes make direct purchase of CFLs unattractive. In this way, the utility can reduce its subsidy loss and also provide a public service by reducing lighting costs for low-income customers.

The Comisión Federal de Electricidad (CFE), a public company and the main generator and distributor of electricity in Mexico, anticipates that the experience gained in developing and implementing the Ilumex project will lead to a nation-wide program. The two cities are the largest cities that CFE serves.[5] Their size and utility infrastructure help assure a good measure of control and ease of implementation with the project.

The purpose of the economic feasibility study of Ilumex was to examine the economic viability of the compact fluorescent lamps from three perspectives: society, CFE, and different classes of customers. The results of the analysis have been used by CFE to refine the program design to better meet its goals.

II. Background on the Ilumex Project

Since 1991, CFE has been involved in the design and implementation of seven small-scale pilot residential CFL relamping projects in various Mexican communities. [6] These projects were designed to examine the impact of CFLs on the electric grid and consumer electricity use, test various delivery mechanisms, assess consumer acceptance of compact fluorescents, and gain an administrative capacity to market energy efficient devices to the residential sector.

In August 1991, CFE initiated discussions with the World Bank on support for a larger demonstration project by the Global Environmental Facility (GEF). CFE proposed to undertake a $20 million CFL project. GEF approved the project for funding; however, before the funds could be released, a careful feasibility analysis of project implementation was required. In the summer of 1992, in consultation with the World Bank, the U.S. Agency for International Development (AID) provided a team of consultants to assist CFE in designing the project, developing technical specifications for selecting CFLs for the project, and preparing the feasibility study. The economic analysis reported in this article was part of that study.

In order to base the project on the actual conditions in Guadalajara and Monterrey, the Ilumex team of consultants undertook a survey of about 500 homes (1 out of 1000 households) in each of the two cities to determine household lighting characteristics, market saturation/acceptance potential of compact fluorescent lamps, energy conservation potential, and purchasing preferences of consumers.[7] The surveys indicate very minimal penetration of the market by CFL technology to date,[8] but suggest a strong consumer desire to purchase CFLs if they were more affordable and if better information were available about their performance and capability. The surveys indicated that approximately 1.7 million CFL retrofit opportunities exist in the two cities (see Table 1).[9] These "opportunities" are defined to equal the number of incandescents that are physically replaceable by CFLs, are of at least 40 W, and operate at least four hours per day. Including lamps used at least two hours per day, close to 3.5 million opportunities exist.

The Ilumex project is structured to utilize the lowest cost method of CFL distribution. Thus, the initial sales effort will be limited to direct sales at the existing CFE offices. Local offices, familiar to customers, are designed to deal with walk-in business and can offer a support network of staff and equipment. The project design includes a series of delivery method adjustments that can be activated incrementally to effectively improve penetration for a given sector of the market, should the computerized monitoring and evaluation process point to shortfalls relative to the project goals. These adjustments include changes in the payment terms of the lease arrangement, adjustments to the price at which each lamp is sold, use of a mobile sales office to sell directly to targeted neighborhoods, and mobilization of a direct sales and installation force (or door-to-door/direct sales). Each of these adjustments in the method of delivery would involve a slightly higher implementation cost. These adjustments will be used, if necessary, to fine-tune project impact while maintaining the lowest possible administrative costs.

Under the initial project guidelines, residential customers would be eligible to purchase up to six CFLs. The customers may purchase the CFLs outright by paying cash at the local CFE offices or they may choose to finance their purchase over a two year period for an additional 12 percent financing fee (equivalent to CFE's cost of capital). Customers choosing to finance CFLs would be required to pay an initial 5 pesos per lamp (about US $1.65) and will be billed for the balance in conjunction with their bi-monthly utility bill.

One of CFE's key objectives is to target customers in the low income groups. To assure saturation of this portion of the market, CFE has designated that a mobile neighborhood outreach office will be activated if these customers are under-represented among CFL purchasors at local offices, or if CFL sales lag behind expectations. The neighborhood outreach office will be a converted trailer. It will be able to finance customers' purchases of CFLs and distribute and/or install CFLs on a door-to-door basis. The neighborhood outreach office will also operate as an extension to local office operations should demand at local offices exceed capacity or should customers need installation assistance.

Because of the novelty, benefits, and practical usage of CFLs, CFE has developed an extensive educational and marketing component within the Ilumex project. Such an effort is essential because CFE has chosen not to do a direct installation project initially, instead opting for activating a succession of delivery methods with increasing costs. The public information campaign will help assure that the sold lamps are installed in fixtures that receive high use. The marketing effort will also help ease the longer term transition to retail sales of CFLs without the benefit of CFE participation.

An elaborate evaluation program will be operated simultaneously with Ilumex. The evaluation will not only monitor CFL sales to different customer groups, but also include follow-up to ensure CFLs are used properly and to examine customer acceptance, satisfaction, and lamp usage.

III. Methodology and Data

The economic value of use of CFLs differs for society, the utility, and residential customers. Neither the benefits nor the costs are identical in each case, and the discount rate that is appropriate to derive the present value of future benefits and costs varies among them as well. In addition, the benefits vary among residential customer groups because they face different marginal electricity prices.

Societal benefits arise because the same amount of lighting service will be delivered at a lower overall societal cost than before. The societal benefits from the use of CFLs include deferment of investment in new generation, transmission, and distribution capacity; fuel savings from avoided electricity generation; avoided purchase of incandescent light bulbs; and associated reductions in environmental impacts. The society will incur the cost of CFLs and of administering the program.

From the customer's perspective, the benefits are reduced electricity bills and foregone purchases of incandescent bulbs, while the cost is the purchase price of the CFL.

For CFE, the benefits from reduced electricity generation are the same as for society. The costs depend on the share of the CFL purchase and program costs that CFE absorbs. CFE will lose revenue because it will sell less electricity.[10] These "lost revenues" are not a cost, properly speaking, but their loss affects CFE's finances because there are no mechanisms in place that would permit CFE to recover the lost revenues or program costs through rate increases, nor is there unmet demand that could pay for the saved electricity. In presenting CFE's perspective, therefore, we count lost revenues as a cost. The utility perspective presented here is equivalent to the "ratepayer impact measure" test, which is used in the U.S. to determine whether rate levels should increase as the result of a utility program. If the decrease in revenues is larger than the decrease in total costs, then rate levels may have to increase because the difference must be recovered from a smaller number of kWh sold.

Table 2 shows the data and assumptions used in the economic analysis, with costs and benefits listed as appropriate under each of the three perspectives. The values in Mexican currency refer to new pesos (one new peso = 1000 old pesos). An exchange rate of 3.0 new pesos (N$) per U.S. dollar was used where needed.

Lamp Savings and Costs. The results of the household surveys in Monterrey and Guadalajara indicate that the average installed incandescent lamp wattage is 67.2 watts. [11] To substitute for the incandescents, CFLs with an average of 16.8 watts would be needed and would save 50.4 watts per lamp. Based on the surveys, we conservatively assumed a peak coincidence factor of 0.8 (i.e., 80% of the CFLs are in use during the peak hours of around 7 to 10 pm). We assume that the move to more efficient lighting does not lead consumers to use the CFLs more than they used the incandescent lamps.

Based on experience with bulk procurement of CFLs in Southern California, the Ilumex team conservatively estimated that CFLs could be purchased by CFE at an average price of not more than 30 new pesos (US$ 10) per unit. CFLs are assumed to carry no taxes, so the price to society and consumers is the same.[12] The team estimated that the program costs, which include program execution and evaluation, would amount to 4.92 N$ (US$ 1.64) per lamp.[13] These costs would increase to 6.1 N$ (US$ 2.02) per lamp if all the CFLs had to be sold with mobile trucks at neighborhood locations.

Purchase of incandescent bulbs is avoided at the beginning and again every 750 hours of CFL use, which is the assumed life of the incandescent bulb. The bulb price is fixed by the government at 1.42 N$ (US$0.47). The extent of subsidy, if any, was not available to the authors.

The period over which savings will accrue is the useful life of the CFL, which is assumed to be 9000 hours. This amounts to about six years at four hours of use per day. The voltage fluctuations that could degrade CFL lifetime in some developing country applications are not a major problem in the two cities chosen. Moreover, the technical specifications for the CFLs will require that the lamps be able to withstand some degree of voltage fluctuation (±10%). A long-term involvement by CFE in the promotion of CFLs could help to ensure that users replace worn-out CFLs with similar products.[14] We assumed that half of the 1.5 million CFLs will be installed in the first year, and half in the second year.

Avoided Power Sector Costs. Residential lighting demand coincides with peak system load. Thus, use of CFLs will reduce the need for investing in relatively expensive peak generation. The most realistic technique for estimating the savings in power sector costs from the Ilumex project entails simulating utility operations and system requirements under the conditions of lower peak load that the project would cause. The resulting fuel savings and deferment of capital investment (relative to a base case) would then provide a basis for determining the benefit to CFE and society. Unfortunately, we were not able to conduct such an analysis. As a substitute method, commonly used in analysis of DSM program cost-effectiveness in the U.S., we used estimates of the long-run marginal cost of on-peak energy and capacity that had been determined in a recent tariff study for CFE.[15] For residential customers, the annualized on-peak marginal capacity cost was estimated at US $132.5/kW and the on-peak energy cost at US 6.2 cents/kWh. These values include the cost to transmit and distribute electricity to residential customers. Since the marginal costs reflect the effect of small changes in load, they are appropriate for a project like Ilumex, whose total impact is equivalent to around nine months of normal demand growth in the CFE system.

Consultation with CFE experts indicated that generation from thermal power plants would most likely be avoided given CFE's supply configuration.[16] Thus, fuel savings and reductions in emissions of airborne pollutants were estimated on the basis of avoided use of power plants using fuel oil.

Discount Rates. Since the use of CFLs involves a tradeoff between a higher initial investment and a stream of future savings, the choice of a discount rate has an important impact on the results. We use a 10% (real) discount rate for the societal perspective. This value is higher than the figures that are commonly used in the industrialized countries (5-7%) due to the higher cost of capital in Mexico. We use a 12% (real) discount rate for the utility perspective, which is consistent with current practice at CFE and at the World Bank for CFE projects.[17]

In choosing an appropriate discount rate for the customer perspective, one approach is to use the opportunity cost of capital taken as either the cost of paying off an existing loan or the return from investing money. Another is to use the subjective rates of time preference derived from observed purchase decisions. We are not aware of any studies of implicit discount rates in Mexico. Credit card rates in early 1993 were around 36% and rates for short-term savings accounts were around 24%. Given current inflation of around 12%, these figures suggest use of a real discount rate between 11% and 21%. We have chosen 18% as the discount rate for the average customer, but we also show results using lower and higher discount rates.

Electricity Prices. The residential electricity tariff in Mexico is divided into 5 categories according to summer ambient temperatures.[18] Within each category there are 6 to 7 blocks; the price per kWh rises with consumption. To estimate the avoided electricity cost for the average customer and the reduction in CFE's revenue in that case, we derived a weighted-average marginal price for residential customers.[19] For each city, we weighted the energy charge applied to each consumption level (in the winter tariff common to both cities, these range from 0.056 N$/kWh for monthly use of 0-25 kWh to 0.433 N$/kWh for monthly use over 200 kWh) by the percent of customers falling within a particular consumption block.[20]

We used the marginal price of electricity since in most cases CFLs will decrease customer bills at their marginal tariff. We assumed that the energy savings would all occur within one tariff block. We conservatively assumed that real electricity prices would not increase over the six-year life of a CFL used 4 hours/day.

IV. Results

In the following sections, we present results of the benefit-cost analysis assuming that the program costs are distributed over 1.5 million CFLs.

A. Societal Perspective

If 1.5 million CFLs are used an average of four hours per day, the total peak capacity savings from the project amount to 78 MW and the avoided electricity generation is 135 GWh per year (Table 3). Annual fuel savings are 265,000 barrels of oil equivalent.

The net present value (NPV) of benefit at a 10% discount rate is 115 N$ (US$ 38.3) per lamp. For the 1.5 million CFL program, this translates into a total NPV of 172 million N$ (US$ 57.5 million). The corresponding internal rate of return (IRR) is 1300%, since the cash flow is slightly negative only in the first year. If all the CFLs are sold house-to-house, the societal NPV only decreases by about 1%.

If CFLs are used an average of two hours per day (on-peak) and CFLs are assumed to last 12 years rather than six, the societal NPV per lamp increases by 21% over the four hour per day case. Although the present value of the savings from avoided fuel use is reduced in this case, the benefit from defering investment in capital-intensive peak capacity (for 12 years rather than six) more than outweighs that reduction. If the CFLs last less than 12 years (perhaps due to more frequent on-off switching) or some of the usage is not coincident with the peak load, the increase would be somewhat less.

B. Customer Perspective

We first present the customer perspective if the customer were to pay the full cost of a CFL, as well as program costs.

At four hours per day of CFL use and 18% discount rate, the NPV per lamp for the average customer (whose monthly electricity use is in the 200-250 kWh range) is around 20 N$ (US$ 6.70) (Table 4). The NPV ranges from 15.1 N$ at a discount rate of 24% to 27.1 N$ at 12%. The discounted payback period (the number of years before the customer recovers the initial investment of 34.9 N$ per CFL) is 3.7 years at 18% discount rate and ranges from 3.2 years to 4.4 years at the 12% and 24% discount rates, respectively.

The NPV and payback period vary for customers facing different marginal electricity prices. For customers in the lowest tariff class, who account for around 18% of all customers, the payback period is roughly eight years. This is longer than the expected life of the CFL, and the payback period is roughly eight years. This is longer than the expected life of the CFL, and their NPV is negative. These customers face a low (and heavily subsidized) marginal electricity price and thus gain relatively little or no benefit from CFL use if they have to pay full cost. Only customers using more than 75 kWh per month have a positive NPV. In contrast, for households in the highest tariff class, who account for around 13% of all customers, the payback period is just over one year.

If CFLs replace incandescent lamps that are used only two hours per day, the benefit for customers decreases considerably, since energy savings are extended farther into the future and their present value is thus lower. For the average customer (18% discount rate), the payback period is 7.3 rather than 3.2 years.

There are no firm indicators of the acceptable payback period for Mexican households, but it seems unlikely that large numbers of customers would purchase CFLs if their payback period was greater than two years. CFE decided to pay a portion of the costs. The current amount of 18 N$/CFL ensures that customers in the 75 to 100 kWh per month range, who choose to buy the CFL under a two-year payment scheme, will face a reduction in their bill equal to the CFL payments. In this case, all customer classes would benefit from CFL use, and the payback period for the average customer is only 1.5 years.

C. CFE Perspective

The attractiveness of the project to CFE depends on the amount of lost revenue and thus on the tariff-class of customers that purchase the CFLs. As shown in Table 5, CFE gains the most from CFLs purchased by customers in the lowest tariff category, since these customers pay a marginal tariff much below the avoided costs. In contrast, CFE suffers a net loss on CFLs purchased by customers in the highest tariff class. If the distribution of CFLs reflects the costs and benefits applicable for the average customer, CFE would receive a NPV benefit of 122 million N$ from the Ilumex project, if it were to fully recover all costs in the price charged to customers, and 98 million N$ if it pays 50% of the costs.

D. Discussion

From the societal perspective, the net gain from Illumex will be considerable regardless of what type of residential customer purchases a CFL. For CFE as well, the avoided costs are approximately the same whether a CFL is used by a low- or high-income customer. However, CFE's residential tariffs are much less than marginal cost for most customers (those using under 200 kWh/month), so CFE gains when these customers conserve electricity. In contrast, CFE suffers a net loss when customers in the highest tariff class use CFLs.

It is in CFE's interest to sell as many CFLs as possible to customers in the lower tariff categories. Along with discounted price, the option of spreading out payment for CFLs over time may help overcome the first-cost barrier for many households in the middle or even lower tariff classes. Even without these options, customers in the highest tariff class have a very strong households are disproportionately represented in the program, the result would be a smaller project benefit for CFE. The survey results indicate that customers in the highest tariff class account for around 35% of total four-hour-per-day retrofit opportunities in Monterrey, but for only around 15-20% in Guadalajara.

CFE still benefits even if it sells CFLs to lower-tariff customers at a discount greater than 50%. Because of the multi-block nature of the residential tariff structure, the economic incentive to purchase CFLs varies considerably among customers. In theory, the customers in each group could be allowed to purchase CFLs at a discount that "buys down" the payback period to roughly the same length (perhaps shorter for the poorest households). Charging a different price for each of the six customer groups might be impractical, however. For the lowest-income households, for whom the incentive for CFL use is most at odds with that for CFE, door-to-door canvassing with free or low-cost installation may be worth considering. This approach has been very successful in the U.S.

The analysis indicates that societal benefits are 20% higher in the case of replacing two-hour per day incandescent lamps with CFLs than in the four-hour per day situation. For customers, however, the benefits are less with two-hour per day lamps, and the payback period is long for most households. Thus, maximizing societal gains will require an appropriate way of sharing the societal gains with customers.

V. Expanding to a Mexico-Wide Program

In analyzing the impacts of a Mexico-wide CFL program, we make the simplifying assumption that the Guadalajara and Monterrey survey results are applicable for all electrified households in Mexico (which account for nearly 90% of all households). Based on geographical characteristics, we assume that the Guadalajara survey results would apply to 74% of Mexico's approximately 15.1 million residential customers, and the Monterrey results would apply to the rest.[21]

We use the same marginal avoided capacity and energy costs in analyzing the Mexico-wide program as in the Ilumex analysis. A strategic plan for implementing a major CFL program would initially target those regions where the avoided costs are greatest (i.e., higher than the system-wide averages used in our calculations). The impact of a Mexico-wide CFL program would be sufficiently large that it would probably result in somewhat lower average avoided costs over time.

The analysis indicates that the deferred peak capacity from a Mexico-wide CFL program would total 1.2 GW if all appropriate lamps used at least four hours per day were replaced with CFLs, and 2.6 GW if all lamps used at least two hours per day were replaced (Table 7). A nation-wide program for replacing incandescent illumination with CFLs could thus make a significant contribution towards reducing the planned capacity expansion of 15 GW between 1991 and 2000.[22] The economic benefits to be derived from such a program are large. The society (nation) would receive a NPV of benefit of 2.6 billion N$ (US$ 880 million) by replacing all four hour per day lamps and 7 billion N$ (US$ 2300 million) if two hour per day lamps were also included. Environmental benefits would include reduced emissions of 23 ktons/year of SO_2, 2.7 ktons/year of NO_x, and 420 kton/year of CO_2 (carbon).

VI. Conclusion

In view of the results of the economic feasibility study, particularly in regards to small customers, CFE decided to share the costs of the project with customers. CFE will offer the CFLs with an 18 N$ (about US$6) discount per bulb to all its customers, which means that CFE will cover about half of the costs of the program. A differentiated discount according to consumption level was deemed to be too difficult to implement. The discount ensures that all users will have net benefits. The discount is expected to enhance CFL adoption by customers and may reduce the amount of outreach efforts required.

If it meets its goal of 1.5 million lamps installed, the Ilumex project will allow the deferral of 78 MW of new peak generating capacity and will yield 135 GWh/yr in electricity savings. Our analysis indicates that the project will bring substantial net economic benefits to Mexico, CFE, and customers and also deliver carbon, SO_2, and NO_x savings. The analysis shows that CFE can absorb a significant part of the CFL and program costs to reduce the payback period for households and still obtain substantial economic benefits.

Expanding the Ilumex project to a Mexico-wide program could make a significant contribution towards meeting CFE's planned addition of generation capacity by the year 2000. The net present value of benefits for a Mexico-wide program could reach between 2.6 and 7 billion N$ (US$ 880 to 2300 million).

End notes

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2. A. Gadgil & G. Jannuzzi, "Conservation potential of compact fluorescent lamps in India and Brazil", *Energy Policy*, Vol 19, No 5, June 1991, pp 449-463.

3. For further discussion of the project, see: International Institute for Energy Conservation and Lawrence Berkeley Laboratory, "Ilumex: Proyecto del Uso Racional de Iluminacion en Mexico, Feasibility Study", Washington, D.C., December 1992.

4. O. Masera, O. de Buen, and R. Friedmann, "Consumo Residencial de Energia en Mexico: Estructura, Impactos Ambientales y Potencial de Ahorro," in Primera Reunion International Sobre Energia y Medio Ambiente en el Sector Residencial Mexicano, UNAM, Mexico City, Dec. 2-3, 1991. Also in English as: Lawrence Berkeley Laboratory Report LBL-34174, "Residential Energy Use in Mexico: Structure, Environmental Impacts, and Savings Potential." Also see: R. Friedmann, "Mexico's Residential Sector: Main Electric End-Uses and Savings Potential", Proceedings of the 1993 ECEEE Summer Study: The Energy Efficient Challenge for Europe, R. Ling and H. Wilhite (eds.). The European Council for an Energy Efficient Economy. Oslo, Norway. Vol. 1. pp. 311-322.

5. CFE, "Estadisticas del Sector Electrico National 1978-1990", Mexico DF, 1991. Compañía de Luz y Fuerza del Centro, a subsidiary of CFE serves the Mexico City metropolitan area. Guadalajara and Monterrey are the second and third largest cities in Mexico after Mexico City.

6. A. Blanc and O. De Buen, "Experiencias Mexicanas en Proyectos Piloto Sustitucion de Focos Incandescentes por Lamparas Fluorescentes Compactas en Servicios Domesticos", Mexico, D.F., March 1992.

7. Centro de Estudios Energeticos A.C., "Encuesta Para el Analisis de Iluminacion Guadalajara y Monterrey", Mexico D.F., October 1992.

8. Less than 2% of households had at least 1 CFL in Guadalajara; in Monterrey, less than 6%.

9. At the end of 1990, the total number of residential customers in both cities was 1.117 million: 0.568 million in Guadalajara and 0.549 million in Monterrey. The number of residential users increased at about 3.9% during 1990 in both cities. If growth continues at that rate, one could expect to have 1.161 million residential users by September 1993 and 1.176 million by December 1995.

10. The actual situation for CFE with respect to financial costs and benefits is more complicated than the model presented here because the utility, like most owned utilities in the developing world, is not financially independent from the federal government. The tariffs that CFE is allowed to charge are not sufficient to cover its full revenue requirements, a situation that requires transfers from the state treasury or assumption of debt (the amount has varied greatly from year to year). Thus, some of the cost savings from electricity conservation programs (such as from deferral of new capacity) may be retained by the treasury, benefitting the nation and not CFE directly.

11. Centro de Estudios Energeticos A.C., *op.cit.*

12. Imported CFLs face a tariff of 20.3% and all products pay a 15% value added tax. Imported CFLs will have to match the price of Mexican CFLs.

13. This figure is for a program in which 1.2 million CFLs are sold at CFE agencies (with implementation costs of 3.2 $N per CFL) and 0.3 million CFLs are sold in the neighborhoods (at an implementation cost of 4.7 $N per CFL). An additional cost of 1.4 $N per CFL is for program evaluation.

14. A typical CFL light source lasts about 9000 hours, but the ballast has a life of 30,000 to 50,000 hours. With modular CFLs, when the light source fails, it can be replaced with a similar component, which costs only around 1/2 of a CFL with ballast in Mexico. With a program to encourage such replacement, the benefits could be extended at a low cost. We conservatively assumed no replacement after 9000 hours.

15. Electricite de France/ENDESA, Tariff Study, December 1991.

16. CFE, "Programa de Obras e Inversiones del Sector Electrico-Preliminar", Mexico D.F., May 1992; Personal communications with CFE Distribution on Tariffs, CFL market prices and sales in Mexico, and deferred investments; US Department of Energy, "Energy Technology Characterization Handbook: Environmental Pollution and Control Factors", DOE/EP-0093, Washington, D.C., March 1983.

17. CFE, "Costos y Parametros de Referencia para la Formulacion de Proyectos de Inversion in el Sector Electrico", Mexico D.F., July 1991; World Bank, "Staff Appraisal Report, Mexico Transmission and Distribution Project", Washington, D.C., March 1990.

18. Mexico has 5 residential tariffs (1, 1a, 1b, 1c, and 1d). Tariff 1 is applied to all customers during the six "winter" months and some customers during the six "summer" months. Tariffs 1a through 1d are applied to select areas during the summer months; the areas determined according to average maximum ambient temperature.

19. In Guadalajara the same six-tier tariff is applied all year long. In Monterrey different tariffs are applied in the summer and in winter. Because of Monterrey's warmer summers, households pay less for their electricity during the summer months than Guadalajarans. During the winter, customers in both cities pay the same rates.

20. One can also use a distribution according to sales instead of customers. By using customer distribution instead of consumption level we are more closely approximating the situation of 1 CFL per customer. By using the kWh distribution one could perhaps approximate more closely the situation of a different number of CFLs per household (i.e., more in the richer homes).

21. Guadalajara falls under tariff 1 while Monterrey is in 1b. In extrapolating the Guadalajara and Monterrey results to get Mexico-wide results, we assumed that all tariff 1 and 1a customers could be represented by Guadalajara results, while tariff 1b through 1d customers could be represented by Monterrey results.

22. CFE, "Programa de Obras e Inversiones del Sector Electrico-Preliminar", Mexico D.F., May 1992.

Table 1
Survey Results for Replaceable Incandescent Lamps

GUADALAJARA:

Elec. Use kWh/month	Number of households	Lamps per household	Replaceable lamps per household[a] Total	4 hr/day	2 hr/day	Total CFL possible ('000) 4 hr/day	2 hr/day
0-->150	221	7.9	5.34	1.28	3.05	549	1307
151-->300	106	10.2	6.21[c]	1.48[c]	3.46[c]	160	372
301-->	18	9.9[b]	6.21[c]	1.48[c]	3.46[c]	47	110
Total	345	8.7	5.60	1.34	3.16	756	1788

MONTERREY:

Elec. Use kWh/month	Number of households	Lamps per household	Replaceable lamps per household Total	4 hr/day	2 hr/day	Total CFL possible ('000) 4 hr/day	2 hr/day
0-->175	181	7.7	5.24	1.43	2.93	486	999
176-->350	116	13.1	6.67	1.80	3.66	268	544
351-->	51	18.8	10.20	2.98	5.92	176	350
Total	348	11.1	6.16	1.78	3.61	931	1894

a. Replaceable incandescent lamps were those of at least 40 watts, located in fixtures that permitted their replacement with compact fluorescent lamps.

b. We believe that this value is low and a result of under-reporting by surveyed homes.

c. These values are actually an average of the results obtained for both consumption levels. The original survey results showed less replaceable lamps in the highest consumption level, but this result is not credible.

Table 2
Assumptions and Data for the Economic Analysis

	Perspectives		
	Societal	CFE	Avg. Customer
Real Discount Rate	10%	12%	18%
CFL Life (Hrs.)	9000	9000	9000
Costs:			
Investment (N$/unit)			
CFL Lamp Price[a]	30	0 or 15	30 or 15
Program Costs per CFL	4.9	0 or 2.5	4.9 or 2.5
Recurrent (N$/kWh)			
Revenue Loss to CFE		0.15[c]	
Benefits:			
Avoided Investment			
Long-Run Marginal Capacity Cost at Customer Level (US $/kW/year)[b]	132.5	132.5	
Avoided Recurrent Expenses			
Long-Run Marginal Energy Cost at Customer Level (US cents/kWh)[b]	6.2	6.2	
Avoided Elec. Price (N$/kWh)			0.15[c]
Avoided Inc. Bulbs (N$)[d]	1.42		1.42

a. Assumed CFLs carry no taxes and same price to society and customers. Exchange rate is 3 new pesos (N$) per US$. CFE either passes all CFL and program costs to the customer or shares in half of these costs.

b. EDF/Endesa Electric tariff study.

c. Weighted average of the marginal electricity prices for residential customers in Guadalajara and Monterrey. The values for each city were 0.16 and 0.14 new pesos/kWh respectively.

d. Incandescent bulb purchase is avoided at the beginning and again every 750 hours, which is the assumed life of the bulb. The bulb price is fixed by the government. The subsidy, if any, was not available to the authors.

Table 3
Impacts on Electricity Generation System[a]

Capacity Savings (MW)[b]	78
Avoided Generation (GWh/year)[c]	135
Fuel Savings (thous.bbl/year)[d]	265
Carbon Savings (thous.tons/year)[e]	27.5
SO_2 Savings (thous.tons/year)[f]	1.5
NO_x Savings (tons/year)[f]	175

a. CFL use of 4 hours per day. 1.5 million lamps.
b. 1.5 million lamps * 50.4 watts/CFL /(1-.22) * 0.8
   # CFLs * Wsaved/CFL /(1-T&D Loss) * peak coincidence factor
c. 1.5 M. CFLs * 50.4 watts/CFL/(1-.10) * 4 hrs/day * 365
   # CFLs * Wsaved/CFL/(1-T&D loss) * Lamp hrs/day * 365 days/year
d. Based on power plant efficiency of 27.53%.
e. Carbon content: 0.82 kg per kg of fuel oil or 0.204 kg carbon per kWh.
f. Emissions coefficients for fuel oil are 0.011 kg/kWh for SO_2 and 0.0013 kg/kWh for NO_x. These values are from US DOE, Energy Technology Characterization Handbook: Environmental Pollution and Control Factors, DOE/EP-0093, March 1993.

Table 4
Economic Indicators from Customer Perspectives[a]

	Tariff Class[b]		
	Lowest	Average	Highest
Customer Pays All Costs			
NPV per CFL (New Pesos)	- 5.9	20	99
Payback Period (Years)	8.2	3.2	1.1
Customer Pays 50%			
NPV per CFL (New Pesos)	10.7	37	117
Payback Period (Years)	3.2	1.5	0.6

a. CFL use of 4 hours/day; 18% discount rate.
b. Marginal price (Pesos/kWh): Lowest–0.057; Average–0.15; Highest–0.43

Table 5
Economic Indicators from CFE Perspective[a]

	Tariff Class[b]		
	Lowest	Average	Highest
Customer Pays All Costs			
NPV per CFL (New Pesos)	111	81	- 9
Total NPV (Million New Pesos)		122	
Customer Pays 50%			
NPV per CFL (New Pesos)	95	65	- 27
Total NPV (Million New Pesos)		98	

a. CFL use of 4 hours/day; 12% discount rate.
b. Marginal price (New Pesos/kWh): Lowest–0.057; Average–0.15; Highest–0.43

Table 6
Expanding Ilumex to a Mexico-wide Program

	Minimum Lamp Use per Day	
	4 hours per day	2 hours per day
Number of Customers (millions)[a]	15.1	15.1
Number of CFLs (millions)[b]	23	50
Deferred Peak Capacity (GW)[c]	1.19	2.58
Avoided Generation (TWh/Year)[d]	2.07	2.25
Fuel Saved (Million Bbls/Year)[e]	4.05	4.40
Carbon Savings (kTons/Year)[f]	421	458
SO_2 Savings (kTons/Year)[f]	22.7	24.7
NO_x Savings (kTons/Year)[f]	2.7	2.9
Net Present Value (10^6 Pesos)[g]		
Societal	2645	6982
Utility Company	1866	6106
Customer	469	189

a. This was the number of customers in December 1990. During 1990 the number of customers increased by 3% and similar growth is expected in the future.

b. These figures were obtained by combining the survey results of Guadalajara and Monterrey on number of lamps replaceable at 4 and 2 hours of daily use.

c. Avoided Capacity = # CFLs * 50.4 W saved/CFL * 0.8 (peak coincidence factor) * 1/0.78 (T&D loss).

d. Avoided Energy = # CFLs * 50.4 W saved/CFL * # hours used/year * 1/0.82 (T&D loss for energy).

e. Fuel saved = # kWh saved/y * 1 barrel oil/1852 kWh thermal * 1/0.2753 (oil plant efficiency).

f. CO_2, SO_2, and No_x savings are annual, not over the 9000 hour life of the CFL. Carbon content: 0.82 kg per kg of fuel oil or 0.204 kg carbon per kWh. Emissions coefficients: 0.011 kg SO_2/kWh, 0.0013 kg NO_x/kWh.

g. Discount rates of 10%, 12%, and 18%.