Saving Electricity in Mexican Homes: Potential and Accomplishments to Date

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An end-use analysis of Mexican homes shows lighting, refrigeration, air conditioning, and television accounting for about 90% of 1992 residential electricity use. These four end-uses also may have comprised 43% of Mexican peak electric demand.

Current projections of residential electrical demand estimate growth at 6% per year to the year 2000 from 1992's 24 TWh. This growth could be reduced with the dissemination of more efficient appliances. Up to 10 TWh of electricity and 6.7 GW peak electric demand could be saved in these four end-uses, (or 82% and 160%, respectively, of the expected increase with current appliances). These savings would be obtained through the introduction of 2 compact fluorescent lamps per home, ensuring that refrigerators and air conditioners sold in the remainder of this decade comply with 1993 refrigerator and 1990 air conditioner U.S. minimum efficiency standards, as well as increasing by 50% the share of evaporative coolers and improving building shell characteristics and planting trees, and ensuring that televisions sold are as efficient as typical current U.S. models.

Significant efforts will be required by the public and private sectors to obtain the savings identified. Projects already carried out in Mexico for the promotion of electricity conservation and efficiency in the homes are noted. The nine compact fluorescent projects carried out by the Comision Federal de Electricidad—CFE, are summarized. Refrigerator efficiency labels and current efforts to establish minimum efficiency standards are briefly described. Finally, attempts at reducing the air conditioning load in the northern border areas through insulation of homes and minimum efficiency standards for air conditioners are summarized.

Introduction

Mexico's development is becoming more difficult due to the rapid rate of demand increase (5.9% annually in the 1980-1991 period) (CFE 1993b). Garnering sufficient financial, material, and institutional resources, and allaying the growing awareness of the environmental impacts of the power sector will further make difficult the expansion of generation capacity. Electric generating capacity is expected to grow to 42 GW in the year 2000, up from the 27.1 GW of 1992 (CFE 1992a). This expansion will require 40.1 billion US$ (8.4 billion US$ from private sector) between 1992 and 2000 for generation, transmission, distribution, global investments, and maintenance (CFE 1992a). [1] Sales of electricity are expected to grow at a 6.8% yearly rate from 1992's 97.6 TWh (CFE 1993a).

An alternate approach for assuring the development of Mexico without having to invest huge sums of capital, human and financial resources, is to decrease the amount of energy required for providing the services one wants. This can be obtained through programs for maximizing the use of technologies that will increase the efficiency with which energy is used.

The residential sector is an important component of the electric sector due to its size, growth, and highly subsidized rates. In 1992, the residential sector used 24 TWh (24.6% of total national consumption). Growth of electricity demand by households (9.4% in 1992) has been greater than that of the whole electric sector (3% in 1992) (CFE 1993b). Growth in residential electric demand probably will continue at similar rates in the future, partly as a result of increased electrification (about 91% of homes are electrified) and increased intensity of household electricity use (1.52 MWh/hh-yr in 1992). In the past, growth of residential electricity demand has been due to the increase in the number of electrified homes and the saturation of electric appliances. During the decade of the eighties, the number of residential users increased from nine million in 1980 (INEGI 1990), to 15.8 million in 1992 (CFE 1993b). There still are 88,683 villages

(7.5 million people) without electric service (CFE 1993b). The saturation of electric appliances is low compared to industrialized countries and varies widely between urban and rural areas; with a large potential for growth (Masera et al. 1992). Residential demand is a principal determinant of peak demand (19.8 GW in 1992) that occurs nationally between 19:00 and 22:00 hours.[2] To supply electricity to the household sector requires significant investments in the distribution grid (that represent 20 percent of the total power sector investments) (World Bank 1989). Residential tariffs are highly subsidized (40%, or about 832 million US$ in 1992).[3] Residential tariffs declined from 8.8 /kWh in 1970 to 4.3 ¢/kWh in 1989 (both figures in 1989 U.S. cents) due to the socio-political considerations which still difficult raising tariffs in real terms (Masera et al. 1992). In 1991, CFE significantly increased residential tariffs to 5.3 ¢/kWh by introducing a fixed charge (SEMIP 1993). There was widespread discontent among residential users to this fixed charge. Since 1992, residential tariffs are being increased every month at a yearly rate of 5.7% (for low to medium consumption users) to 7.9% (for high consumption users) (CFE 1993c). General inflation since 1992 has been about double these rate increases.

Residential electric use is also influenced by household income, and geographic and climatic aspects (Gutiérrez E. 1992; Masera et al. 1992; Willars 1990). In the northwestern part of the country, one observes household electric use two times larger than the national average. This is due to the more extreme climate of this area (very hot and dry summers) and its proximity to the U.S.A., which has influenced lifestyles and permitted the acquisition of electric appliances (particularly air conditioning units) in the U.S.A. (De Buen 1993). In other hot areas of the country (the South and the coasts, where very hot and humid conditions prevail), residential electric use is much lower than that observed in the Northwest. This is because these areas are less urbanized (difficult access to modern fuels), have lower levels of income, and less accessibility to used, cheap appliances.

Programs for saving electricity in Mexican households can significantly reduce the need for new electric generation capacity, reduce the revenue losses from the large tariff subsidy, and permit the utility to move toward marginal cost pricing while avoiding bill and rate shocks to users.

Objectives

The main purpose of this paper is to estimate the electric savings potential achievable by the year 2000 in Mexican homes. Additionally, the paper briefly describes actions taken to increase efficiency of household electricity use, and provides guidance of where to focus actions on promoting efficiency in Mexican homes.

Main Electric End-Uses in Mexican Homes in 1992 and 2000

The main electric end-uses in Mexican homes are lighting, refrigeration, air conditioning, and television. Together, these four accounted for about 90% of household electricity use and over 43% of peak national electric demand in 1992. Below, the assumptions and methods used to estimate these end-uses contribution in 1992 and 2000 are given. The main results are summarized in Table 1.

Future residential demand will depend on number of users and intensity of use (Masera et al. 1992). CFE expects to have 22 million households (100% electrification) by 2000. Intensity of use is expected to increase by 1.6% to 2.3% annually. Residential demand could reach between 38.1 and 46.5 TWh by 2000 (CFE 1992a).

Lighting in Mexican Homes

Lighting is the main use of electricity in Mexican homes. In low income, single room homes, lighting can easily account for 3/4 of total electric use. Lighting's share of total electricity diminishes with increasing income as other electric appliances are bought and used. Almost all lighting is with incandescent lamps. For example, a survey of Guadalajara and Monterrey homes done in August of 1992, showed respectively 8.7 and 9.5 lamps per home of which only 2% and 9% were fluorescent lamps (CEE 1992). Yearly incandescent lamp sales attributed to Mexican homes (about 70% of the total sales) were 107 million lamps with an average power of 74.8 Watts.[4] There is a growing market for compact fluorescent larnps—CFLs; sales reached about 1 million in 1993 (or 1/6 of Mexican production). Most CFL sales are probably in the commercial and institutional sectors.

Assuming useful life of 1000 hours per incandescent lamp, lighting represents about 8 TWh/year (505 kWh/hh-yr or 33% of the residential electric consumption). Residential lighting is also an important component of total system peak electric demand. Assuming 2 incandescent bulbs are on during the daily peak (the Guadalajara and Monterrey survey found up to 3.3 lights), then residential lighting would amount to 3 GW at the power plant (assuming 22% T&D losses), or 15% of 1992 peak load.

If residential lighting demand will grow apace with the number of electrified homes (4.2% per year) for the rest of the decade, then in the year 2000, residential lighting will be 11.1 TWh/year. Residential lighting peak demand could reach 4.2 GW at the power plant, an increase of 1.2 GW. This requires almost 3.2 billion US$ of investment (at US$ 2691/kW).

Refrigeration in Mexican Homes

Refrigeration is the second largest end-use of household electricity. According to a 1988 national household survey, 57.9 percent of households had a refrigerator (Sepulveda 1989). Average size (capacity) of household refrigerator sales in the 1980's was 243 liters (8.6 ft^3) (ANFAD 1990). About 90% of sales were 1 door units, with manual defrost, compressors of EER of 2.3 to 3.1, and under 340 liters (12 ft^3) of capacity. The remaining 10% of sales were mostly 2 door, semi-automatic defrost units of under 400 liters (14 ft^3) in size (ANFAD 1990 & 1992). Assuming that 85% of the sales since 1989 were to homes without refrigerators (ANFAD 1990), results in a total of 10 million refrigerators at the end of 1992, for a 63% saturation. Sales in 1992 were 1.02 million and are expected to increase to 1.3 million by 2000 (Cuevas 1993). Sales of 2 door and over 300 liters in size units are expected to increase from 29% of the market in 1992 to 42% by 2000 (Cuevas, 1993). About 25% of national production is exported to the U.S. and a similar number of units is imported mostly from the U.S. (large, 2 door units) and South Korea (small bar-type units).

Values for yearly electric consumption of Mexican refrigerators used were based on the results of analyses to set minimum efficiency standards. The work is being done by the Instituto de Investigaciones E1éctricas-IIE (Mexico's equivalent of EPRI), under the patronage of the Energy Ministry. The calculations assumed 716 kWh/year for the 1 door manual defrost units, 967 kWh/year for the 2 door semiautomatic defrost units, and 796 kWh/year for the 2 door automatic defrost refrigerators. Unit consumption values were combined with manufacturers estimates of their future market shares.

Household refrigeration's electric use is estimated at 7.3 TWh in 1992; approximately 30% of residential demand. Assuming refrigerators operate 50% of the time, results in a peak demand of 1.1 GW in 1992 (5% of national peak demand). [5]

Using the manufacturers estimates for future sales and considering 15% replacement of old units, gives a total of 17.9 million refrigerators (81% saturation) in 2000 and 13.5 TWh/year of electric use. Residential refrigeration peak demand could represent 2.0 GW at the power plant, an increase of 0.9 GW from 1992, or 2.4 billion US$ of investment.

Air Conditioning

The limited data available makes estimating air conditioning's contribution to residential demand difficult. No saturation values are known, and sales of imported units are unknown. Air conditioning is most prevalent along the northern border and the coastal regions. Many air conditioners are old, inefficient, used units bought across the border from the U.S.A. that use double the energy of new, same capacity units (De Buen 1993). A survey in Mexicali showed air conditioning exists in almost all homes, with about 2/3 of the units being evaporator coolers and the remainder compression driven AC units (Morales 1992). As part of its work on the technical analysis for setting a minimum efficiency standard for window AC units, IIE reports that 15% of 1992's residential demand was for air conditioning and a 10% annual increase expected (Landa 1993).6 If the IIE data are accurate, air conditioning accounted for 3.6 TWh and 3.2 GW in 1992 (assuming 8 hours per day for 6 months). IIE now expects air conditioning demand to grow only at 5% per year, resulting in 5.3 TWh and 4.7 GW by the year 2000.

Television in Mexican Homes

Televisions are widespread in Mexican homes. A national survey conducted in 1988 found televisions in 76.6% of the homes (Sepulveda 1989). Surveys conducted in various cities have shown at least one or more televisions in all homes using over 100 kWh/month (CEE 1992, CFE 1989 & 1992b; CLFC 1989). Television sales were 600 to 700 thousand units per year during the 1980's except 1983 and 1984 when 400 thousand units were sold annually, and increased dramatically to 1.3 million in 1992. Until 1986, most sales were black and white units; color sets now dominate the market, accounting for 92% of the units sold in 1992 (CANIECE 1993). Sales of large color sets (more than 26" size) reached 12% of the market in 1992, up from 1% in 1986. Between 1989 and 1992, 3.4 million televisions were sold in Mexico.

Average power requirements of Mexican televisions have been reported to be 200 Watts (Gutiérrez Vera 1992). This value seems too high (Shepard et al. 1990; USDOE 1993), and a more conservative value of 100 Watts is used here. The Guadalajara and Monterrey survey shows that televisions are turned on about 8.2 and 9.5 hours every day respectively, and 88% peak coincidence factor (CEE 1992). For a national average, assume a more conservative value of 6 hours of use per day and 80% peak coincidence factor. If only 1/2 of the television sales between 1989 and 1992 replaced old televisions, then there were about 12.4 million televisions in Mexican homes at the end of 1992 (78% saturation). Residential television in 1992 thus accounts for 2.7 TWh/year and 1.3 GW peak electrical demand, or 6% of total peak demand.

If sales are assumed to continue at 1.3 million units per year, and 50% replacing old sets, then in the year 2000 there will be 17.6 million televisions (80% saturation).

Television will use 3.9 TWh and account for 1.8 GW peak power. This is an increase of 537 MW, about 1.4 billion US$ in investment.

Other Electric Appliances in Mexican Homes

If the above calculations are accurate, all other electric appliances represent about 10% of total residential demand for electricity. The lack of national data on saturation levels and quality of these appliances makes a determination of their individual contributions impossible at this time. A qualitative description of the most important appliances is given next.

Significant differences in end-use distribution occur depending on income and geographical location (Masera et al. 1992). In low income households in rural areas, radios and stereos are probably the most important end-uses after lighting and televisions. Fans also become important along the hot and humid coastal regions. In low and medium income homes in urban areas, recreational appliances, clothes washing, and ironing are probably the other main end-uses. In high income homes in urban and rural areas, end-use patterns are very similar to those found in industrialized nation homes.

Geographically, the main differences in electric end-use distribution are climate related. In Mexico City's mild climate, major end-uses are water pumping to tanks on the roofs of homes and ironing clothes.[7] In the hot and humid coastal regions, fans or air conditioning (among the wealthy) become important. In the northern hot and dry areas, air conditioning is the major and fastest growing end-use.

Potential for Electricity Savings in the Year 2000

This section shows the cost-effective electricity savings believed achievable both, technically and socio-politically in the major end-uses of residential electricity demand by the year 2000. The results of this section are summarized in Table 1.

Savings in Lighting

From survey results it seems plausible to assume that two incandescent lamps per home, used 4 hours per day on average, can be replaced with CFLs (Friedmann 1993). Assuming 2/3 savings for each 74.8 Watt incandescent replaced with a CFL results in 3.2 TWh lighting savings in the year 2000. Assuming 2 CFLs per home, peak load is reduced as well by 2.8 GW. This would result in a gross savings of 7.6 billion US$ in investment. A CFL program of this magnitude could cost about US$ 12 per CFL (including program implementation), or a total of 528 million US$ (IIEC 1992). A nationwide CFL program has been estimated to have net present value of benefits to society of US$ 880 million to US$ 2.3 billion (Sathaye et al. 1994).

Savings in Refrigeration

A review of Mexican minimum efficiency standard's documents shows that USDOE 1993 standard is achievable by Mexican manufacturers (Landa et al. 1993). This implies that 1 door units could use 425 kWh/year (41% savings), 2 door semiautomatic defrost units could use 527 kWh/year (46% savings), and 2 door automatic units could use 594 kWh/year (25% savings). If USDOE 1993 standard is applied from 1995 to 2000, the use of improved refrigerators would save 2.1 TWh and 0.3 GW. This would imply a gross saving of 0.8 billion US$ in investment. Net savings cannot be determined at this time. However, IIE estimated that the electric consumption of a typical Mexican refrigerator of 272 liters (9.7 ft^3) could be reduced from 747 kWh to 296 kWh per year with an increase in retail price from the current 417 US$ to 500 US$ (Flores et al. 1993). This gives a cost of conserved energy of about 2.5 ¢/kWh, significantly lower than the 8.6 ¢/kWh it costs to serve residential customers (Friedmann 1993).[8]

Savings in Air Conditioning

Mexico makes window air conditioners of 10,000 to 36,000 Btu/hour with EERs of 6.6 to 9.7 (in contrast with EERs of 8 to 12 in the U.S.). In many dry areas, consumers could use evaporative coolers whose consumption is about 1/5 that of compressor driven AC units. Many AC units are second-hand discards from the U.S. and typically use twice the energy of a new AC unit (De Buen 1993). IIE estimates possible savings of 1.4 TWh by improving the EER of window air conditioners to the 1990 USDOE standard of 8 to 9 (Landa et al. 1993), This estimate is very conservative. It does not include building shell improvements that in Mexicali (only roof insulation) led to a 35% reduction in household consumption (Morales 1992). Insulating walls, using low-U value windows, using passive solar architecture, painting roofs and walls with high reflectivity finishes, and planting trees can all result in further savings. IIE's value also does not include the potential savings from ensuring that evaporative coolers are used whenever climate permits.

Three savings scenarios are examined and potential savings estimated. The simplest scenario considers only applying USDOE 1990 standards to compressor-driven window air conditioners. From IIE's initial results (which assumed 10% instead of 5% annual growth assumed

here), I interpolate a potential for 965 GWh and 846 MW peak power savings. The intermediate scenario considers the above standards and building shell improvements (insulating ceilings, using high reflectivity finishes, and planting trees for an overall savings of 40%). Under the intermediate scenario conditions, savings of 2.1 TWh and 1.9 GW peak power are obtained. In the most aggressive scenario, besides the standards and building shell improvements, incentives are introduced to reduce by half the market share of compressor driven AC units and a similar increase in market share by evaporative coolers. Under this last scenario, savings could reach 3.5 TWh and 3.1 GW peak power in the year 2000. Gross investment savings could therefore lie between US$ 2.6 billion and US$ 8.3 billion.

Savings in Television

Assuming 50% reposition means that 10.5 million of the 17.7 million televisions in the year 2000 will be of the more efficient type. Assuming that these efficient televisions use 50 Watts (instead of the 100 Watts of current models) and 80% peak coincidence factor, results in a savings of 1.1 TWh and 537 MW in the year 2000. This value is probably optimistic in that current televisions being sold in the USA typically use 77 Watts (USDOE 1993). It is not clear to what degree the televisions being sold in Mexico (a good portion of which are assembled there), incorporate top-of-the-line technology. Another complicating factor is the widespread use of voltage regulators with televisions in Mexico. Efficient televisions would need to have safeguards against the irregular quality of electric supply.

Summary of Savings Achievable by 2000

It has been estimated that by the year 2000 it would be possible to save between 7.4 TWh to 10 TWh and 4.5 GW to 6.7 GW peak load (see Table 1). This implies a gross savings of 12.1 to 18 billion US$ in investment. The most significant savings occur in lighting (3.2 TWh and 2.8 GW) and air conditioning (1 to 3.5 TWh and 0.8 to 3.1 GW). The introduction of USDOE 1993 refrigerator standards beginning in 1995 results in 2.1 TWh and 0.3 GW saved. Savings in televisions are at most 1.1 TWh and 0.5 GW.

Barriers to Increased Efficiency

Many barriers exist that will make difficult attainment of the technical electric savings potential identified above for Mexico's residential sector. Most of the major barriers identified in the literature (Kempton 1987; Lovins and Shepard 1988a & 1988b; Masera et al. 1992; Reddy 1991) exist in Mexico. Below, the most important political, institutional, and financial constraints are discussed. Solutions to these barriers are not proposed here because of space limitations and a personal belief that the specific actions to be taken should be decided by the Mexicans themselves.

Most Mexican energy policy makers agree on the benefits of imposing real cost-of-service residential tariffs, but are constrained by socio-political considerations. The electric utilities are still used by the government to address social equity concerns and bolster political hegemony. About 50 to 60 percent of households earn less than 200 US$ per month. Lower-income households cannot invest in the more capital intensive efficient appliances. Increases in electric rates without increases in efficiency would have significant impacts on household income, with a potential for serious social unrest. Programs will need to allow lower income households to get the more efficient appliances and facilitate a reduction in the residential subsidy.

Due to low household income levels, Mexican appliance manufacturers face a limited internal market for efficient and more expensive appliances. Most of their production is in cheaper, less efficient appliances made in old and highly depreciated facilities. There is little incentive to modernize both their factories and their products. Since 1986 (when import tariffs were significantly reduced to under 30%), imported goods captured the more lucrative "luxury" appliances market. This loss of market share reduced Mexican investment capital available for plant modernization. As a survival mechanism, Mexican manufacturers have established joint-ventures with foreign firms and/or become sales representatives. Mexican manufacturers have thus lost their autonomy on what products are made. Mechanisms must be found to promote the manufacturing and importation of efficient appliances.

Institutionally, the two Mexican utilities are not recompensed for pursuing electric efficiency. Instead, any reduction in the rate of growth of electric demand probably will result in a reduction of their budgets by the Finance Ministry since fewer power plants will need to be built and operated. Also, a change in the utility's mission paradigm from a provider of more supply to a service oriented institution is required. Operationally, this implies that within CFE, both a clearer authority for the group in charge of improving customer efficiency (Programa de Ahorro de Energía en el Sector E1éctrico-PAESE), and linkage with the planning, technical, and distribution groups is required. The unresolved status of Compañía de Luz y Fuerza del Centro-CLFC (the utility serving Mexico City and its surroundings) as an independent utility or a subsidiary of CFE must be resolved to enable CLFC to initiate its own customer electric savings programs.

Table 1. Lighting, Refrigeration, Air Conditioning and Television in Mexican Homes

Year->	1992		2000		2000		2000	
End-Use	Base TWh	Case GWpeak	Base TWh	Case GWpeak	Savings TWh	Case GWpeak	Net TWh	Savings GWpeak
Lights	8.0	3.0	11.1	4.2	7.9	1.4	3.2	2.8
Refrig.	7.3	1.1	13.5	2.0	11.4	1.7	2.1	0.3
AC	3.6	3.2	5.3	4.7	1.8-4.4	1.6-3.8	1.0-3.5	0.8-3.1
TV	2.7	1.3	3.9	1.8	2.7	1.3	1.1	0.5
Total	21.6	8.5	33.8	12.7	23.8-26.4	5.9-8.1	7.4-10	4.5-6.7

Note: 1. All GW values include a 22% T&D loss factor.

Financing for efficiency programs is very difficult to obtain. Mexico has begun to resolve this by setting up a fund (Fideicomiso de apoyo al PAESE-FIDE) that receives a fixed proportion (0.7%) of every utility contract. FIDE is funding electric efficiency pilot projects proposed by PAESE. Banking institutions are not familiar with efficiency projects and shy away from them or impose premiums or other conditions in their lending terms. International aid institutions are beginning to fund efficiency and as experience increases and successes are documented, one can expect funding to increase.

Programs and Policies for Increasing Residential Efficiency

Mexico's main electric utility, CFE, has implemented 3 pilot-scale and 6 larger residential programs to promote the use of CFLs instead of incandescent lamps for the past 4 years (see Blanc et al. 1992; Blanc & De Buen 1994). Over 120,000 CFLs have been introduced. Current plans call for a project of 40,000 CFLs in Aguascalientes (to begin in April). These projects are providing the know-how to carry out Ilumex, a project whose aim is the introduction during a two-year period, of 1.5 to 2 million CFLs in the homes of Guadalajara and Monterrey. Ilumex is funded by a 10 million US$ grant of the Global Environment Facility, a 3 million US$ grant from the Norwegian government, and a 10 million US$ loan of the World Bank to CFE. Ilumex expects to introduce 900,000 CFLs in it's first year and is slated to begin in June, 1994. The 10 million US$ of the World Bank will be recuperated from Ilumex participants to establish a revolving fund. If justified by the market, Ilumex's revolving fund will be used to promote CFLs elsewhere in Mexico (IIEC 1992).

In 1992, IIE was contracted by the Secretarial de Energía, Minas e Industria Paraestatal-SEMIP, (Mexico's energy ministry), to set the ground work for the establishment of refrigerator and air conditioner efficiency standards. It is hoped that both standards will be enacted in late 1994. The refrigerator standard will be applied in two phases, the first to reduce consumption by around 25% in 1994, and the second to reduce consumption to USDOE 1993 levels by 1997. As a side-product of this work, Mexican refrigerators were required to be sold with energy consumption labels (very similar to the ones used in the U.S.) between 1991 and October, 1993. Labels are now voluntary until the new refrigerator standard is approved. A major critique of the labels is that the highlighted annual consumption bill is calculated using a value of 3 ¢/kWh; usually half to one-fifth the true cost to the customer. IIE has set up testing facilities for refrigerator energy consumption verification and is in the process of setting up a facility for testing air conditioners. The air conditioning standard will require USDOE 1990 levels in 1994. Future work is being considered for minimum efficiency standards for clothes washers, televisions, irons, water heaters, and pumps. Preliminary work is being initiated on building efficiency standards by IIE for SEMIP. It is not clear at this time if residential buildings will be included. The preferred action is that residential buildings in air conditioning prone areas have a special efficiency related addendum in their building codes.

Since 1991, CFE has been promoting insulation of the roofs of homes in northern Mexico by providing financing to users of more than 1 MWh/month in the summer. CFE provides a loan of about 1,200 US$ to be paid back without interest in 3 years. About 40,000 homes have had their roofs insulated for an average savings of 20% of their residential electric consumption. Homes participating

in the insulation program also can opt for interruptible power rates. These customers agree to allow CFE to turn off their air conditioning units for 15 minutes during afternoon peak hours if necessary. In the first summer the program had 2,500 participants, resulting in 17 MW of load that CFE could shed if necessary. The interruptible rate program has not been as successful as hoped for due to fear from both customers and CFE on whom will be liable if the old, second-hand air conditioner units fail due to more frequent switching (De Buen 1993).

Conclusions

In 1992, lighting, refrigeration, air conditioning, and televisions accounted for about 90% of residential electricity consumption and 43% of national peak power demand. By the year 2000, programs to promote the acquisition of the most efficient appliances could reduce future growth in residential electricity end-use by 7.4 to 10 TWh and peak load by 4.5 to 6.7 GW. If these savings are attained, total residential electricity energy demand in these four end-uses would only increase at the most 22% over its 1992 value. More importantly, the promotion of efficient technologies in these four end-uses could result in gross savings of 12.1 to 18.2 billion dollars of investment for peak capacity. These savings are obtainable by introducing 2 CFLs per home; ensuring refrigerators sold meet USDOE 1993 efficiency standards; combining building shell improvements with increased use of evaporative coolers and ensuring compressor driven air conditioners comply with USDOE 1990 standards; and ensuring televisions use half the power supposed for current models.

The large savings potential identified above show the importance of accelerating and expanding programs to promote the use of the most efficient appliances in Mexican homes. Evaluation must be stressed to allow learning on the go and ensure that each projects insights are used in future programs. In this way it will be possible to avoid spending years planning projects (Ilumex will be implemented after four years of analysis and planning). Particularly important will be the promotion of efficiency in lighting and air conditioning and to a lesser degree, refrigeration. The replication of Ilumex throughout Mexico must proceed as quickly as possible. The implementation of appliance standards must be advanced. DSM programs must be expanded and savings obtained be returned to the utility to be used to further expand DSM activities instead of reducing utility budgets. Government and multilateral banks must improve the availability and amount of financing available to private enterprise and manufacturers. "Golden Tacos" (akin to Golden Carrot programs in the USA) should be set up to promote more efficient products. Collaborative can be used to quicken the identification and resolution of barriers among affected parties and tap into the marketing expertise of manufacturers. Tariffs can be increased in real terms with improvements in efficiency.

Within the electric sector two main changes are required to promote efficiency. Electricity must be seen as a service not a commodity. A planning framework must then be designed where both supply and demand side interventions are on a level playing field.

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Endnotes

1. This is equivalent to 2691 US$/kW. CFE estimates 42 GW capacity by 2000 (CFE 1992a). This CFE forecast value is probably too high since it is based in part on econometric models using GDP growth projections. CFE is forced to use GDP determined by the Finance Ministry and Central Bank of Mexico, whose values tend to be high for political reasons.

2. Mexico has a national integrated grid and a separate grid serving the Baja California Peninsula. The value of 19.8 GW for peak power used here is the sum of the peak power demand of each of these two independent grids.

3. The residential subsidy has been reported to be 40% to 50%. Here I use the lower value of 40% (CFE 1993a). The value of 50% has been given to me by knowledgeable CFE officials. The value of 832 million US$ of subsidy is based on residential sales of 1.247 billion US$ in 1992 (CFE 1993b). Thus, the true cost of supply of the residential sector for 1992 was 2.08 billion US$.

4. A higher value of 140 million incandescent lamps for 1992 residential sales has been reported (Ramirez 1993). The more conservative value of 107 million used here is based on personal conversations with several Mexican lighting manufacturers.

5. The value of 50% on time for refrigerators lies between 40% reported to me by the CEO of Mexico's main refrigerator manufacturer, and 60% reported in the refrigerator standards documents.

6. IIE's value seems appropriate since as an upper bound one can estimate a total of 4.7 TWh of air conditioning (assuming all the 6.2 M users in hot climate area residential tariffs average excess of 63 kWh/month over the average of temperate, non-air conditioned areas, is due to air conditioning). Thus IIE's estimate for air conditioning in 1992 is about 75% of this upper bound. The remainder can be attributed to higher electric use by refrigerators, lights, and higher saturation of electric appliances.

7. A 500 Watt water pump operated 1 hour/day would use 186 kWh/year, 12% of the average Mexico City household's annual consumption of about 1.5 MWh. Similarly, a 1000 Watt iron used at a medium setting drawing 500 Watt, and 2 hours/week would require 52 kWh every year.

8. The cost of conserved energy assumed 20 year useful life for the refrigerators and a 12% discount rate. The cost of supply is obtained by dividing the 1992 cost of supply to the residential sector of 2.08 billion US$ (see note 2 above) by the sales of 24.05 TWh.

References

ANFAD (Asociación National de Fabricates de Aparatos Domésticos). 1990. *Memoria ANFAD 1989.* ANFAD, Mexico City.

ANFAD. 1992. *Memoria ANFAD 1991.* ANFAD, Mexico City.

Blanc, A., J. Sada Gámiz, and A. Valera. 1992. "Proyecto Piloto de Sustitución de Focos por Lámparas Fluorescences Compactas en Servicios Domésticos." *Reunión International: Energía* y *Medio Ambiente en el Sector Residential Mexicano,* pp. 179-184. UNAM, Mexico City.

Blanc, A., and O. De Buen. 1994. "Mexican Experiences in Projects to Substitute Incandescent Lighting With Compact Fluorescent" to be presented at ACEEE 1994 Summer Study.

CANIECE (Cámara National de la Industria Electrónica y de Comunicaciones E1éctricas). 1993. *Informe Anual 1992.* CANIECE. Mexico City.

CEE (Centro de Estudios Energéticos AC). 1992. *Encuesta para el Análisis de Iluminación Guadalajara y Monterrey.* CEE, Mexico City.

CFE (Comisión Federal de Electricidad). 1989. *Resumen de la encuesta en unidades habitacionales.* CFE, Mexico City.

CFE. 1992a. *Programa de Obras e Inversions del Sector Eléctrico.* CFE, Mexico City.

CFE. 1992b. *Encuesta a clientes residenciales para estudio tarifario 1990-1991.* CFE, Mexico City.

CFE. 1993a. *Informe Annual 1992.* CFE, Mexico City.

CFE. 1993b. *Información Básica 1992.* CFE, Mexico City.

CFE. 1993c. *Tarifas Electrical.* CFE, Mexico City.

CLFC (Compañía de Luz y Fuerza del Centro). 1989. *Encuesta Unidades Habitacionales.* CLFC, Mexico City.

Cuevas, S. 1993. Presentation at meeting on saving energy in refrigerators, Monterrey, Mexico.

De Buen, O. 1993. *Residential Air-Conditioning in Northern Mexico: Impacts and Alternatives.* M.Sc. Thesis, Energy & Resources Group, University of California, Berkeley, California.

Flores Puebla, H., R. Covarrubias, R. Landa, I. Sánchez, and E. Campero. 1993. "Análisis de Impactos del Estudio Para la Formulación y Aplicación de Normas de Consumo de Energía en Refrigeradores Domésticos." *Document No. 3227EERF. 080,* IIE, Mexico City.

Friedmann, R. 1993. "Ahorro de Energía o Privatización? El Caso del Sector E1éctrico Residential de México." *Memoria XIV Seminario National Sobre el Uso Rational de la Energía y Ekposición de Equipos y Servicios,* pp. 161-170. ATPAE, Mexico City.

Guttiérez Elizararás, G. 1992. "Análisis de la Relación Ingreso Familiar-Gasto en Energia frente al Consumo Energéico Familiar." *Reunión International: Energía y Medio Ambiente en el Sector Residential Mexicano,* pp. 107-113. UNAM, Mexico City.

Guttiérez Vera, J. 1992. "Option para la Electrification de Pequeñas Comunidades Rurales en México." *Reunión International: Energía y Medio Ambiente en el Sector Residential Mexicano,* pp. 205-214. UNAM, Mexico City.

INEGI (Instituto National de Estadísticas Geográficas e Informática). 1990. *Anuario Estadístico de los Estados Unidos Mexicanos 1988-1989,* pp. 210. INEGI, Mexico City.

IIEC (International Institute for Energy Conservation). 1992. *Feasibility Study Ilumex.* IIEC, Washington D.C.

Kempton, W., and M. Neiman (eds). 1987. *Energy Efficiency: Perspectives on Individual Behavior*. ACEEE, Washington D.C., 333 pages.

Landa, R., I. Sanchez, and M. Malacara. 1993. "Potenciales de Ahorro de Energía en Refrigeradores Domésticos y Equipos de Aire Acondicionado." *XIII Seminario National Sobre el Uso Rational de la Energía,* pp. 511-517. ATPAE, Mexico City.

Lovins, A., and M. Shepard. 1988a. "Financing Electric End-Use Efficiency." *Implementation Paper #1, COMPETITEK*[SM], Rocky Mountain Institute, Snowmass, Colorado.

Lovins, A., and M. Shepard. 1988b. "Customer Behavior and Information Programs." *Implementation Paper #2, COMPETITEK*[SM], Rocky Mountain Institute, Snowmass, Colorado.

Masera, O., O. De Buen, and R. Friedmann. 1992. "Consumo Residential de Energía en México: Estructura, Potential de Ahorro e Impactos Ambientales." Reunión International: Energía y Medio Ambiente en el Sector Residential Mexicano, pp. 73-96. UNAM, Mexico City.

Morales, L. 1992. "Acondicionamiento de Vivienda en Zona Cálida Seca: Caso Mexicali, Baja California." *Reunión International: Energía y Medio Ambiente en el Sector Residential Mexicano,* pp. 185-190. UNAM, Mexico City.

Ramirez, A. 1993. "Ahorro de Energía en Iluminación en México." Presented at *XIV Seminario National Sobre el Uso Rational de la Energía y Exposición de Equipos y Servicios.* ATPAE, Mexico City.

Reddy, A. 1991. *Barriers to Improvements in Energy Efficiency*. LBL-31439, Lawrence Berkeley Laboratory, Berkeley, California.

Sathaye, J., R. Friedmann, S. Meyers, O. de Buen, A. Gadgil, E. Vargas, and R. Saucedo. 1994. "Economic Analysis of Ilumex. A Project to Promote Energy-Efficient Residential Lighting in Mexico." *Energy Policy* 22(2):163-171.

SEMIP (Secretarial de Energía, Minas e Industria Paraestatal). 1993. *Reporte Estadístico del Sector Energetic.* SEMIP, Mexico City.

Sepúlveda, J. 1989. "Estado Nutritional de los Preescolares y las Mujeres en México." Academia National de Medicina, Mexico City.

Shepard, M., A. Lovins, J. Neymark, D. Houghton, and R. Heede. 1990. *The State of the Art: Appliances.* COMPETITEK[SM], Rocky Mountain Institute, Snowmass, Colorado.

USDOE (U.S. Department of Energy). 1993. *Technical Support Document: Energy Efficiency Standards for Consumer Products.* Vol. 2. DOE/EE-0009, U.S. Department of Energy, Washington, D.C.

Willars, J., y A. Heredia. 1990. "Caracterización Energética del Sector Doméstico Mexicano." *Cuadernos Sobre Energía No. 1,* Facultad de Ingeniería, UNAM, Mexico City.

The World Bank. 1989. *Staff Appraisal Report México Hydroelectric Development Project.* Report No. 7391-ME, The World Bank, Washington D.C.