Mexico's Residential Sector: Main Electric End-Uses and Savings Potential

Rafael A Friedmann, Energy & Resources Group, University of California

1. SYNOPSIS

Main electric end-uses of Mexican homes are quantified. Estimate the potential electric savings in the year 2000 of using the currently most efficient technologies.

2. ABSTRACT

The two purposes of this paper were to identify the major electric end-uses of Mexican homes and to quantify the potential savings in electric demand and energy in the year 2000, from the introduction of the currently most efficient and cost-effective technologies. Historical sales data on electric appliances in Mexico were combined with household survey data and appliance efficiency data to determine the main electric end-uses. Extrapolation of historical data to the year 2000 was used to determine the expected electric demand and energy use by Mexican homes with current appliances. A similar extrapolation, but with the most efficient appliances available today was used to estimate the savings potential to the year 2000. In 1991, lighting, refrigeration, and television accounted for about 3/4 of residential electric use and 1/3 of peak electric demand in Mexico. By the year 2000, efficient technologies could reduce peak electric demand by about 3,2 GW and electricity end-use by about 6,8 TWh; obviating 4,3 billion ECU in electric capacity expansion. These household electric savings would also permit the public utility to increase residential tariffs and reduce the residential subsidy of about 50 percent (about 651 million ECU in 1991). To achieve these savings will require a strengthening and expansion of the current small-scale projects being done collaboratively by the utility, consumers, manufacturers, retailers, and government.

3. INTRODUCTION

Assuring the future increases in electric supply to fuel Mexico's development is becoming more difficult due to the rapid rate of demand increase (5,9% annually in the 1980-1991 period) and the difficulty of having sufficient financial, material, and institutional resources (CFE 1991b; CFE 1992b). It is now expected that electric generating capacity will grow to 42 GW in the year 2000, almost 15 GW more than the 26,8 GW the system had in 1991 (CFE 1992a). This expansion will require almost 21 billion ECU in generation and transmission and distribution investment (assuming 1.364 ECU/kW as reported in World Bank 1990). Sales of electricity are expected to grow at a 6,8% yearly rate from 1991's 94,8 TWh (CFE 1992a). Also increasing in importance is the growing awareness of the environmental impacts of the power sector, further difficulting the continued expansion of the generation capacity.

An alternative method of 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 it's size, growth, and highly subsidized rates. In 1991, the residential sector used 22 TWh (23,2 percent of total national consumption). Growth of electricity demand by households (7,8% in 1991) has been significantly greater than that of the whole electric sector (2,9% in 1991) (CFE 1992b). This growth in residential demand will probably continue at similar rates in the future, partly as a result of increased electrification (about 90% of the towns are electrified) and increased intensity of household electricity use. Residential demand is also the principal cause of peak demand (18,7 GW in 1991) which is observed nationally between 19 and 22 hours. To

supply electricity to the household sector requires significant investments in the distribution grid (which were 20 percent of the total power sector investments) (World Bank 1989). Residential tariffs are highly subsidized (50 percent, or about 651 million ECU in 1990).[1] Residential tariffs declined from 217 pesos/kWh in 1970 to 106 pesos/kWh in 1989 (both figures in 1989 pesos) due to the socio-political considerations which still difficult raising tariffs in real terms. Since 1989 Comisión Federal de Electricidad - CFE (Mexico's main electric utility) has tried to increase residential tariffs in real terms (as part of an agreement with the World Bank); only managing to keep the tariffs about the level they were in 1989. 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 rate shocks to users.

The growth of residential electricity demand is 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 15.1 million in 1991 (CFE 1992b). Nevertheless, there are still at least 86.000 rural towns and villages without electric service (Gutiérrez Vera 1992). 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 electric use is also influenced by the household income, and geographic and climatic aspects (Fernández 1992; Gutierrez 1992; Masera et al 1992; Mendoza & Macías 1991; Willars 1990). In the Northeastern 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 also permitted the acquisition of electric appliances (particularly air conditioning units) in the U.S.A. (CFE 1991a; De Buen 1990, De Buen & Woychik 1992). 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 Northeast. This is due to the fact that these areas are less urbanized (difficulting access to modern fuels), have lower levels of income, and face more dificulties for acquiring cheap appliances.

4. OBJECTIVES

The purpose of this paper is to estimate the electric savings potential achievable by the year 2000 in Mexican homes. An identification of the main electric end-uses in Mexican homes is followed by estimates of potential peak power and energy savings achievable in those end-uses by the year 2000. The values of electrical energy and power demanded are given at the point-of-use. The values of equivalent generation capacity are estimated at the point-of-generation, including a correction factor for transmission and distribution (T&D) loses of 12.6 percent.[2]

5. MAIN ELECTRIC END-USES IN MEXICAN HOMES

In this section we identify and quantify the three main end-uses of electricity in Mexican homes. The methodology used is generally based on appliance saturation data and unit annual consumption values. The results are for the entire nation. Regional data will vary significantly from the national average, particularly in the Northern areas of the country where air conditioning is a major end-use of residential electricity. Peak power is estimated based on manufacturer or sales data. The results of this section are summarized in Table 1. (This table appears at the rear of the paper)

5.1. Lighting in Mexican homes

The major use of electricity in Mexican homes is for lighting. 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.

Mexican homes use almost exclusively incandescent lamps for lighting. 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).[3] Yearly incandescent lamp sales attributed to Mexican homes (about 70% of the total sales) are about 107 million lamps (about 7 lamps per home) with an average power of 77,5 Watts. There is a growing market for compact fluorescent lamps - CFLs; over 760.000 units were sold during 1992 according to Mr. Villaseñor, a Marketing Manager for Philips Mexico.[4] It is unknown how many CFLs are used in the residential sector; most sales are probably still in the commercial sector.

Assuming an useful life of 1.000 hours for each incandescent lamp, we have that lighting represents about 8,3 TWh/year of electricity (38% of the residential electric consumption). Residential lighting electric consumption is equivalent to 2,2 GW of capacity or 8% of national installed capacity (using the 50% average Mexican capacity factor and 12,6% loses in transmission and distribution) (CFE 1992b).[2] In 1991, CFE spent 476 million ECU to supply household lighting needs (assuming 0.057 ECU/kWh).

Household lighting is an important component of total system peak electric demand. Assuming only 2 incandescent bulbs are on during the daily peak (the Guadalajara and Monterrey survey found up to 3,3 replaceable lights), then residential lighting would amount to 2,3 GW (2 lamps * 15,1 million homes * 77,5 Watts/lamp) at the home and 2,6 GW at the power plant. This represents 14% of the 1991 peak demand of 18,7 GW.

Lighting will continue to be an important component of residential demand during the rest of this decade. If assume that residential lighting demand will grow at 2% per year for the rest of the decade (significantly less than the 5,5% growth rate in number of electrified homes between 1989 and 1991, yet recognizing that since 90% of homes are electrified, future growth in demand will most likely be in non-lighting uses), then by the year 2000, residential lighting will be 9,9 TWh/year. This implies a growth of 1,6 TWh/year; necessitating the construction of a 418 MW power plant at a cost of 570 million ECU. Residential lighting peak demand could reach 2,8 GW at the homes and 3,2 GW at the power plant (again assuming 2% yearly growth), an increase of 520 MW; requiring 710 million ECU of investment.

5.2 Refrigeration in Mexican homes

Refrigeration is the second largest end-use of electricity in Mexican homes. According to a 1988 national household survey, 57,9 percent of households had a refrigerator (Sepúlveda 1989). Average size (capacity) of household refrigerator sales in the 1980's was 243 liters (according to Mr. Dupuis, President of Mexico's largest refrigerator manufacturer). About 90% of sales were 1 door units, with manual defrost, compressors of EER of 2.3 to 3.1, and under 340 liters of capacity. The remaining 10% of sales were mostly 2 door, semi-automatic defrost units of under 400 liters in size (ANFAD 1990 & 1992). Assuming that 85% of the sales since 1989 were by homes without refrigerators (ANFAD 1990), results in a total of 9,1 million refrigerators at the end of 1991, for a 60.4% saturation. Sales in 1991 were 15% higher than in 1980, reaching 788.845 units. It is almost certain that once the data is in, 1992 sales will surpass the 1991 value.

Values for yearly electric consumption of Mexican refrigerators are being determined. A 1992 study based on ANSI laboratory tests showed the average yearly energy consumption of the 255 liter (average size) refrigerator to be 618 kWh/year (Sánchez 1992). Previous studies using both laboratory and household measurements by other researchers gave values of 1.1 to 5.4 kWh/liter-year and 1.7 to 4.2 kWh/liter-year, respectively (or between 280 and 1375 kWh/year, with averages of 828 and 751 kWh/year, respectively) (Campero 1990 & 1992, Fernández 1992).

Household refrigeration thus accounted for about 5,6 TWh (9,1 million refrigerators * 618 kWh/year) in 1991; approximately 26% of residential demand. Residential refrigeration electric consumption is equivalent to 1,5 GW of capacity or 6% of national installed capacity (using the 50% average Mexican capacity factor and 12,6% loses in transmission and distribution). In 1991, CFE spent 321 million ECU to supply household refrigeration needs (assuming 0.056 ECU/kWh).

Household refrigeration is an important component of total system peak electric demand. Mr. Dupuis indicated refrigerators work only 40% of the time, which implies that in 1991, household refrigerators contribution to peak demand was 2,3 GW (618 kWh/y * 1/3506 h/y * 9.1 million refrigerators * 1/0.876 T&D loss). This represents 12% of the 1991 peak demand.

Refrigeration will continue to be an important component of residential demand during the rest of this decade; probably growing faster than lighting. During the 1980's, a decade in which Mexico suffered a severe economic depression, about 6 million refrigerators were bought. If sales during the next 9 years are similar to those of 1991, one can easily assume that 7 million refrigerators will be bought by Mexican residences in that time. This would imply a total of 15.1 million refrigerators by the year 2000 (if 85% are by non-refrigerated homes, or an 83.5% saturation at 2% growth in the number of homes). Residential refrigeration could reach 9,3 TWh/year at the homes and 10,7 TWh at the power plant in the year 2000. This growth implies construction of a 958 MW power plant at a cost of 1,307 billion ECU. Residential refrigeration peak demand could reach 2,7 GW at the homes and 3,03 GW at the power plant, an increase of 1.049 MW; requiring 1,431 billion ECU of investment.

The above results are conservative, since with the North American Free Trade Agreement one can expect an acceleration in Mexican emulation of U.S. living standards, resulting in the acquisition of much larger and more electricity using refrigerators. Counteracting this trend will be a push to make Mexican products more efficient to maintain their market share.

5.3 Television in Mexican homes

Televisions are widespread in Mexican homes. A national survey conducted in 1988 found televisions in 76.6% of the homes (Sepúlveda 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 & 1992c; CLFC 1989). Television sales hovered around 600 to 700 thousand units per year during the 1980's with the exception of 1983 and 1984 when about 400 thousand units were sold per year. Until 1986, most sales were black and white units. Since then, color sets have dominated the market, accounting for about 85% of the 765.000 units sold in 1991 (CANIECE 1992). Sales of large color sets (more than 26" size) reached 12.2% of the market in 1991, up from 1% in 1986. Between 1989 and 1991, about 2.1 million televisions were sold in Mexico.

Estimating the electrical energy and demand attributable to residential television is difficult due to the lack of data. What follows is a conservative estimate. If only 1/2 of the television sales between 1989 and 1991 replaced old televisions, then there were about 11.75 million televisions in Mexican homes at the end of 1991 (77.7% saturation). Average power requirements of Mexican televisions have been reported to be 200 Watts (Gutiérrez Vera 1992; Mendoza 1991). This value seems too high (Shepard 1990), 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 that almost 88% of all televisions are turned on during the 19 to 22 hours evening peak electric demand period. For the national average, assume a more conservative value of 6 hours of use per day and 80% peak coincidence. Residential television thus accounts for 2,6 TWh/year at the home and 2,9 TWh/year at the power plant (11,75 million TVs * 100 W/TV * 6 h/d * 365.25 d/y * 1/0.876 T&D loses). This is equivalent to 672 MW capacity (2.5% of national total) and implies a annual supply cost to CFE of 149 million ECU. Peak electrical demand from these televisions is 1.3 GW (11.75 million TVs * 0.88 on at peak * 100 W/TV * 1/0.876 T&D loses), which represents 7% of total peak demand.

If we assume that between 1991 and 2000, another 7 million TVs will be bought, of which 50% will replace old sets, then in the year 2000 there will be 15.25 million televisions (85% saturation). This growth will imply another 0,9 TWh per year (3.5 million TVs * 100 W/TV * 6 h/d * 365.25 d/y * 1/0.876 T&D loss) of television demand equivalent to 200 MW of capacity or 272 million ECU investment. Peak electrical demand by televisions (assuming that the larger models that will be bought will also be more efficient than today's) will increase by another 320 MW (3.5 million TVs * 100 W/TV * 0.8 TV on peak * 1/0.876 T*D loss) , or 436 million ECU.

5.4 Other electric appliances in Mexican homes

If the above calculations are accurate, then all other electric appliances represent about 24% 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, have to do with climate. In Mexico City's relatively mild climate, major end-uses are water pumping to tanks located in the roofs of homes and ironing clothes.[5] Along 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 definitely the major and rapidly growing end-use. Many of the air conditioning units are old, very inefficient, used units bought across the border in the U.S.A. (De Buen & Woychik 1992). Estimates of air conditioners demand vary between 2% to 20% of total residential demand (Mendoza 1991, Sánchez 1992).

6. POTENTIAL FOR ELECTRICITY SAVINGS

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

6.1. Savings in lighting

Technically, by replacing incandescent lights with CFLs, one could save 75% of lighting demand. More realistically, such a replacement can only be obtained in a small percentage of lamps due to physical and economic constraints. Here it is assumed that only two incandescent lamps per home can be replaced. One of these lamps is on 8 hours per day, the other only 4 hours per day. Both are on during peak hours. Savings amount to 58 Watts per lamp (75% of 77.5 Watts).

With these assumptions, it is possible to save 4,6 TWh at the home and 5,2 TWh at the power plants (18 million homes * 2 CFL/home * 58 W/CFL * 6 h/d * 365.25 d/y * 1/0.876 T&D loss) in the year 2000. This is equivalent to saving 1,2 GW of generating capacity and 1,626 billion ECU.

Peak lighting load demand would be reduced by 2,1 GW at the homes and 2,4 GW at the power station (36 million CFLs * 58 W/CFL * 1/0.876 T&D loss); saving 3,259 billion ECU in capacity investments.

Mexico's electric utility, the Comisión Federal de Electricidad - CFE, has been implementing 7 pilot-scale, residential lighting programs to promote the use of CFLs instead of incandescent lamps for the past 3 years (Blanc 1992). It is hoped that in 1993 funding will be available from the World Bank to begin a project whose aim is to introduce during a two-year period, 1,5 to 2 million CFLs in the homes of Guadalajara and Monterrey. If required by the market, such a project would be replicated elsewhere in Mexico (CFE 1991c, IIEC 1992).

6.2 Savings in refrigeration

The large uncertainty in Mexican refrigerators power and energy use difficults the estimation of savings potential. Here assume that on average, the 7 million units sold between 1991 and 2000 will comply with

the 1993 U.S.A. efficiency standard of 420.5 kWh/year for a 255 liter refrigerator.[6] The savings in refrigeration could be 1,4 TWh at the homes and 1,6 TWh at the power plants (7 million refrigerators * 197.5 kWh/ref.-year * 1/0.876 T&D loss), or 360 MW and 491 million ECU. Peak demand savings are 394 MW at the homes and 450 MW at the power stations (7 million refrigerators * 197.5 kWh/ref.-year * 1 y/8766 h / 0.4 on at peak / 0.876 T&D loss), or 614 million ECU.

During 1992, the Instituto de Investigaciones Eléctricas - IIE (Mexico's EPRI), was contracted by SEMIP, Mexico's energy ministry, to conduct a study on the efficiency of the Mexican refrigerators and the establishment of an refrigerator efficiency standard. It is hoped that the standard will be enacted this year. As a side-product of this work, Mexican refrigerators now are required to be sold with energy consumption labels. IIE is also conducting standard tests to verify manufacturer's energy consumption claims. Preliminary results have shown manufacturer's efficiency claims to be significantly lower than IIE test results.

6.3 Savings in television

Due to the uncertain nature of the unit consumption values of current televisions, the following savings estimates are very preliminary. The large savings estimated will hopefully serve to prompt more research in this area.

Assuming 7 million televisions are sold between 1991 and 2000, and that they require on average only 50 Watts (characteristic of most U.S.A. TVs), would imply an annual savings potential of 0,9 TWh at the power plants (7 million TVs * 50 Watt saved/TV * 6 h/d * 365.25 d/y * 1/0.876 T&D loss), equivalent to 200 MW of capacity or 272 million ECU investment. Peak electrical demand savings at the power plant will be 320 MW (7 million TVs * 50 W/TV * 0.8 TV on peak * 1/0.876 T*D loss), or 436 million ECU.

SEMIP has asked IIE in 1993 to study the potential for saving electricity in televisions. They hope to finish this work in 1993.

6.4 Savings in other appliances

From the international experience (Koomey 1991; Shepard 1990; Turiel 1991; and Wilson & Merrill 1992), it is probably possible to save 50% of electric consumption in other appliances. For example, air conditioners being installed in Mexico have EER's of 5 to 9 instead of EER's of 12 to 15 found in the more efficient models (Masera et al 1992). Projects sponsored by CFE and SEMIP have begun to quantify better the energy use and potential for savings in air conditioning, water pumping, and clothes washing and ironing. For example, a CFE program for insulating the roofs of homes in Mexicali (a very hot area) resulted in 35% reduction in electric use (Morales 1992). Savings of 50% or more could be easily achieved if these insulated homes also used very efficient air conditioners.

6.5 Barriers difficulting increased efficiency

Many barriers exist that will difficult attaining the technical electric savings potential identified above for Mexico's residential sector. Most of the major barriers identified in the literature (Kempton 1987; Lovins 1988a & 1988b; Masera et al 1992; Nadel 1991; Reddy 1991) exist in Mexico. Below, a description of 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 any actions taken should be a consensus result of discussions amongst 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 140 ECU's per month. Lower-income households usually 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 be

designed to permit lower income households to acquire the more efficient appliances and facilitate a reduction in the residential subsidy.

Due to the relatively low household income levels, Mexican appliance manufacturers faced a very limited internal market for efficient and more expensive appliances. Most of their production was in cheaper, less efficient appliances made in old and highly depreciated facilities. There was little incentive to modernize both their factories and their products. Since 1986 (when import tariffs were significantly reduced to under 30%), imported goods snatched the more lucrative "luxury" appliances market. This loss of market share reduced the Mexican capital available for plant modernization. As a survival mechanism, Mexican manufacturers have entered into 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 will probably only result in a reduction of their budgets by the Finance Ministry since less power plants will need to be built and operated. Furthermore, a change in the utility's purpose 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 (PAESE), and linkage with the planning, technical, and distribution groups is required. CFLC's (the utility serving Mexico City and its sorroundings) status as an independent utility or a subsidiary of CFE must be resolved to enable it to initiate its own customer electric savings programs.

Financially, it is very difficult to obtain money for carrying out efficiency programs. Mexico has resolved this issue to a small degree by setting up a fund which recieves a fix proportion (0.7 percent) of every utility contract. This fund (FIDE) is being used for demonstration electric efficiency pilot projects proposed by PAESE. Banking institutions are not familiar with efficiency projects and tend to shy away from them or impose interest premiums or other conditions in their lending terms. International aid institutions are begining to fund efficiency projects and as experience increases and successes become more documented, one can expect this to increase. Currently, Mexican authorities are waiting for a decision from the Global Environment Facility of the World Bank to finance a multi-million CFL project in the homes of Guadalajara and Monterrey.

7. CONCLUSIONS

Lighting, refrigeration, and televisions account for almost 3/4 of residential electricity consumption and 1/3 of national peak power demand. Technologies exist to significantly reduce the electric energy needed to cover these three residential electricity end-uses.

By the year 2000, programs to promote the acquisition of the most efficient appliances could reduce future growth in residential electricity end-use by 6,8 TWh/year, equivalent to 1,8 GW of capacity or 2,9 GW of peak demand, for a savings of 4,3 billion ECU. These savings would reduce annual residential electrical energy demand in these three end-uses from their 1991 value. The 6,8 TWh/year of savings are obtained by the strong promotion of CFLs in lighting; reducing lighting demand from 8,3 TWh currently to only 5,3 TWh instead of the expected 9,9 TWh in the year 2000. Refrigeration grows from 5,6 TWh in 1991 to 7,9 TWh instead of 9,3 TWh in the year 2000. Finally, television remains at 2,6 TWh, as a result of growth in the number of televisions being offset by the reduction in their energy consumption. The costs associated with achieving these savings are (if the international experience holds), significantly smaller than the alternative of supply expansion.

The above results show the importance of pursuing programs to promote the use of the most efficient appliances in Mexican homes. A first task will be gathering more detailed data on residential end-use by region and income level. Appliance characteristics and improvement costs need to be determined. It may be necessary to facilitate industrial retrofitting. Also important will be a determination of where the electrical system is facing its most acute demand problems and then promote cost-effective efficiency in

those end-uses that will give the required reductions in demand growth to obviate the need for more expensive supply investments.

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.

ACKNOWLEDGEMENTS

The author would like to acknowledge the support of The John D. and Catherine T. MacArthur Foundation as well as Mexican colleagues: A. Blanc, E. Campero, R. Covarrubias, G. Fernández, L. Fernández, R. Landa, Y. Mendoza, G. Rodríguez, R. Saucedo, E. Vargas, and J. Villaseñor.

ENDNOTES

1. This value is approximate. It is based on a tariff study completed in 1992 for CFE that showed marginal costs to be about 0.056 ECU/kWh at the transmission level (EDFI & ENDESA 1992). From CFE revenue and sales data, the average residential tariff was only 0.028 ECU/kWh using an exchange rate of 4285 pesos/ECU (CFE 1992b).

2. Higher values of 18 and 22% for T&D loses have been claimed by utility functionaires. The value used here of 12.6% was preferred due to questionable practices in estimating the higher T&D loss figures. It was given by E. Campero who worked in the T&D utility losses study.

3. Guadalajara and Monterrey are the second and third largest urban centers in Mexico (Mexico City being the largest). Guadalajara can be used to represent the electric consumption patterns of almost 10 million Mexican homes where the climate is mild all year long. Monterrey homes are a good representative for about 5 million Mexican homes in the North where the Summers are very warm and the Winters are cold.

4. It is unknown how many of these CFLs are used by the residential sector. According to Mr. Villaseñor, in 1992, 760.000 CFLs were sold in Mexico, 50% more than in 1991. About 410.000 of these were only lamps (for replacing old CFLs), the other 310.000 being lamp and ballast packages (not necessarily integral units). Of the lamp and ballast sales, about 50% are circular 22 Watt units, 20% are 9 Watt units, 17% are 13 Watt units, and the rest are 15 and 18 Watt units. Electronically ballasted CFLs are less than one percent of sales due to their initial retail price of about 21 ECU/CFL which is about three times that of magnetically ballasted CFLs.

5. For example, a 500 Watt water pump operated 2 hours/day would use 365 kWh/year, 24% of the average Mexico City household's annual consumption of about 1,5 MWh. Similarly, a 400 Watt iron used 2.5 hours/week would require 52 kWh every year. Unfortunately, saturation, sizes, and hours-of-use data do not exist to permit a more accurate estimate of these appliances total residential demand.

6. Obviously most refrigerators being sold in Mexico do not meet this standard, but it is expected that after 1994 with the Golden Carrot program there will be units that will use 50% of the 1993 standard, a level already attained by the best U.S.A. refrigerators and some Danish models as well (Sunelco 1992; Lebot & Szabo 1991). The continued opening of the Mexican market to imported goods will continue to pressure Mexican manufacturers to improve their refrigerators. There also are units in the market that use about 132 kWh/year.

REFERENCES

ANFAD (Asociación Nacional de Fabricantes de Aparatos Domésticos). 1990. *Memoria ANFAD 89'*. ANFAD, Mexico City, Mexico.

ANFAD. 1992. *Memoria ANFAD 91'*. ANFAD, Mexico City, Mexico.

Blanc, A., J. Sada Gamiz, and A. Valera. 1992. "Proyecto Piloto de Sustitución de Focos por Lámparas Fluorescentes Compactas en Servicios Domésticos". *Reunión Internacional: Energía y Medio Ambiente en el Sector Residencial Mexicano*. Mexico City, Mexico. Dec. 2 & 3, 1991. pp. 179-184.

Campero, E., G. Monroy, y L. Sosa. 1990. "Medición del Consumo de Energía de Refrigeradores Domésticos". *Proceedings of XI Seminario Nacional Sobre el Uso Racional de la Energía y Exposición de Equipos y Servicios*, ATPAE, Mexico City, Mexico. (November).

Campero, E. 1992. "Impacto de los Refrigeradores Domésticos en el Consumo de Energía del Sector Residencial Mexicano". *Reunión Internacional: Energía y Medio Ambiente en el Sector Residencial Mexicano*. Mexico City, Mexico. Dec. 2 & 3, 1991. pp. 151-156.

CANIECE (Cámara Nacional de la Industria Electrónica y de Comunicaciones Eléctricas). 1992. Informe Anual 1991. CANIECE. Mexico City, Mexico. (February).

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

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

CFE. 1991a. *Estadísticas por Entidad Federativa 1990*. CFE, Mexico City, Mexico. 43 pp.

CFE. 1991b. *Estadísticas del Sector Eléctrico Nacional 1978-1990*. CFE, Mexico City, Mexico. 45 pp.

CFE. 1991c. *Anteproyecto de Ahorro de Energía por Sustitución de Lámparas Incandescentes por Fluorescentes Compactas en Servicio Residencial*. CFE, Mexico City, Mexico. (October).

CFE. 1992a. *Programa de Obras e Inversiones del Sector Eléctrico*. CFE, Mexico City, Mexico. (May)

CFE. 1992b. *Información Básica 1991*. CFE, Mexico City, Mexico.

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

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

De Buen, O. 1990. "Air Conditioning in Northern Mexico: An Energy Conservation Approach". *Proceedings ACEEE 1990 Summer Study on Energy Efficiency in Buildings*, Vol. 8, Asilomar, California. (August), pp. 8.25-8.26.

De Buen, O.. and E. Woychik. 1992. "Northern Mexico's Rapid Growth from Air Conditioning: What Impacts from Appliance Dumping, What Solutions?" *Proceedings 1992 International Energy Efficiency and DSM Conference*, Toronto, Canada. (October 21).

EDFI (Electricité de France International), and ENDESA. 1992. *Estudio de Tarifa*. Mexico City, Mexico. (September) 84 pages.

Fernández, L. 1992. "Usos Finales de la Energía en la Ciudad de México". *Reunión Internacional: Energía y Medio Ambiente en el Sector Residencial Mexicano*. Mexico City, Mexico. Dec. 2 & 3, 1991. pp. 141-144.

Guttierez Elizararás, G. 1992. "Análisis de la Relación Ingreso Familiar-Gasto en Energía frente al Consumo Energético Familiar." *Reunión Internacional: Energía y Medio Ambiente en el Sector Residencial Mexicano*. Mexico City, Mexico. Dec. 2 & 3, 1991. pp. 107-113.

Guttierez Vera, J. 1991. "Opción para la Electrificación de Pequeñas Comunidades Rurales en México." *Reunión Internacional: Energía y Medio Ambiente en el Sector Residencial Mexicano*. Mexico City, Mexico. Dec. 2 & 3, 1991. pp. 205-214.

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

IIEC (International Institute for Energy Conservation). 1992. *Feasibility Study Ilumex*. Washington D.C., (December). 124 pages.

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

Koomey, J., C. Atkinson, A. Meier, J. McMahon, S. Boghosian, B. Atkinson, I. Turiel, M. Levine, B. Nordman, y P. Chan. 1991. *The Potential for Electricity Efficiency Improvements in the U.S. Residential Sector*. LBL-30477, Lawrence Berkeley Laboratory, CA. (July).

Lebot, B., and A. Szabo. 1991. "Dometechnica 1991: Steady Progress, No Revolutions." *Home Energy*. Vol. 8, No. 5, (Sep./Oct.). pp. 23-25.

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

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

Masera, O., O. De Buen, and R. Friedmann. 1992. "Consumo Residencial de Energía en México: Estructura, Potencial de Ahorro e Impactos Ambientales". *Reunión Internacional: Energía y Medio Ambiente en el Sector Residencial Mexicano*. Mexico City, Mexico. Dec. 2 & 3, 1991. pp. 73-96.

Mendoza, Y., y P. Macías. 1991. *Consumo de Energía del Sector Doméstico Mexicano*. SEMIP. Mexico.

Morales, L. 1992. "Acondicionamiento de Vivienda en Zona Cálida Seca: Caso Mexicali, Baja California". *Reunión Internacional: Energía y Medio Ambiente en el Sector Residencial Mexicano*. Mexico City, Mexico. Dec. 2 & 3, 1991. pp. 185-190.

Nadel, S. 1991. "A Review of Electricity Conservation Programs for Developing Countries". ACEEE. Washington D.C. (unpublished)

Reddy, A. 1991. *Barriers to Improvements in Energy Efficiency*. LBL-31439, Lawrence Berkeley Labroratory, Berkeley, CA (October).

Sánchez, I. 1992. *Análisis de la Tecnología de Ahorro de Energía en Refrigeradores*. B.Sc. Thesis, UNAM, Mexico. (August). 142 pp.

Sepúlveda, J. 1989. "Estado Nutricional de los Preescolares y las Mujeres en México". Academia Nacional de Medicina, Mexico.

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

SUNELCO. 1992. "Electricity from the Sun". Catalog, SUNELCO, Montana.

Turiel, I., D. Berman, P. Chan, T. Chan, J. Koomey, B. Lebot, M. Levine, J. McMahon, G. Rosenquist, y S. Stoft. 1991. "U.S. Residential Appliance Energy Efficiency: Present Status and Future Policy Directions." Chap. 7 in *State of the Art of Energy Efficiency: Future Directions.* ACEEE, Washington D.C., pp. 199-227.

Villaseñor, J. 1993. Personal communication.

Willars, J., y A. Heredia. 1990. "Caracterización Energética del Sector Doméstico Mexicano". *Cuadernos Sobre Energía No.1*, Facultad de Ingeniería, UNAM, Mexico City, Mexico. (March), 69 pp.

Wilson, A., and J. Morrill. 1992. *Consumer Guide to Home Energy Savings.* ACEEE & Home Energy Magazine, Washington D.C., 252 pp.

The World Bank. 1989. *Staff Appraisal Report México Hydroelectric Development Project.* Report No. 7391-ME, The World Bank, Washington D.C., (May 16), 91 pp.

The World Bank. 1990. "Capital Expenditures for Electric Power in the Developing Countries in the 1990s". *Energy Series Paper # 21.* The World Bank, Washington D.C., (Feb.), 108 pp.

Table 1. ***Lighting, refrigeration, and television energy and power demand***

Year & Quantity	Lighting	Refrigeration	Television	Total
1991 Values:				
- Electric Energy Use[1] (TWh)	8,3	5,6	2,6	16,5
- % of Total Energy Use[2] (%)	38	26	12	76
- Electric Power Demand (GW)	2,2	1,5	0,7	4,4
- % of Total Power Demand[3] (%)	8	6	2	16
- Peak Power Demand (GW)	2,6	2,3	1,3	6,2
- % Peak Power Demand (%)[4]	14	12	7	33
Estimation of Increment in the period 1991 - 2000[5]				
- Electric Energy Use (TWh)	1,6	3,7	0,8	6,1
- Electric Power Demand (MW)	418	958	200	1.576
- Electric Power Demand (MECU)	570	1.307	279	2.155
- Peak Power Demand (MW)	520	1.049	320	1.889
- Peak Power Demand (MECU)	710	1.431	436	2.577
Savings Potential in the year 2000[6]				
- Electric Energy Use (TWh)	4,6	1,4	0,8	6,8
- Electric Power Demand (MW)	1.192	360	200	1.752
- Electric Power Demand (MECU)	1.626	491	272	2.390
- Peak Power Demand (MW)	2.389	450	320	3.159
- Peak Power Demand (MECU)	3.259	614	436	4.309

Notes:
[1] All the values of electric energy use (TWh) are at the point of end-use (i.e., at the homes). All other values (i.e., for power demand, peak power demand, and associated investment costs), are referred to the power plant (i.e., include the 50% average system capacity factor and the 12.6% T&D loss factor)
[2] As a percent of total 1991 residential electric energy use of 21,983 TWh
[3] As a percent of total 1991 installed electric capacity of 26,799 GW
[4] As a percent of total 1991 peak electric demand of 18,699 GW
[5] The values presented are the increase expected by the year 2000 beyond the value in 1991
[6] The values presented are the total savings that could be achieved by the year 2000