RESIDENTIAL AIR-CONDITIONING IN NORTHERN MEXICO: IMPACTS AND ALTERNATIVES

by

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To my father,
who taught me about being amazed.
To my mother,
who has taught me about justice and the wise use of resources.

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INTRODUCTION

In the last decade northern Mexico has played an important part in growth of the power sector in Mexico. In this paper the nature of its role will be examined, paying particular attention to the residential electricity demand. The environmental and economic impacts of air conditioning use will also be defined and the alternative approaches available for facing the growing demand for electricity will be discused. This work is the result of several years of research that I first began as a staff member of Mexico's national utility and later as as Masters student at the University of California at Berkeley. It is intended for scholars, planners and policy makers studying and analyzing the on-going changes occurring at the Mexico-U.S. border.

Based primarily on electricity consumption data that the Comisión Federal de Electricidad (CFE) publishes periodically, the paper concentrates on an analysis of the period of 1982 to 1990. Data on electricity supply (evolution, costs, and future plans) was also obtained from CFE documents. Other sources, such as census reports, were consulted to develop longitudinal perspectives of important factors such as population, income, and climate. This information is presented in the form of longitudinal profiles in a series of charts that I developed and organized. The source from which the raw data was drawn is noted below each chart. I also made two site visits in the summer of 1991 and in the winter of 1993 to the border town of Mexicali. During these visits data I collected data on appliance characteristics and prices and I interviewed several local experts. Documents published by the Universidad Autónoma de Baja California, (particularly the results of a survey on electricity consumption) were also an important source of data.

The paper starts with a description of the national context. I then discuss the current situation of the power sector, define the importance of northern Mexico's residential power demand, and then present a case study based on an analysis of Mexicali, Baja California.

The first two chapters are mainly descriptive and don't include any new contributions. The first chapter examines the importance of northern Mexico and the problems it is facing. The second chapter describes the role that CFE, the national utility, has played in the modernization of México and its present situation in terms of demand, supply, and finances.

The principal contributions of this paper start in the third chapter. In that chapter I show the importance of the northern border states and of the residential sector in the growth of electricity demand. In the fourth chapter I show the higher economic impact that electricity use has on residential consumers in northern Mexico. My main contribution comes in the fifth chapter, where I present the case study of the city of Mexicali and show how the economic impacts of electricity consumption are greater for the middle class than for the other social groups. The sixth chapter analyzes policy options. The conclusions are presented in the seventh and final chapter.

1. BACKGROUND

1.1. The Maquiladora Program

The year of 1982 marks the beginning of an era for Mexico. After close to forty years of following an economic development strategy based on Import Substitution Industrialization (ISI), the country economy finally succumbed to the new realities of the international economy.[1] Mexico depended on oil both as its main source of foreign currency and as the collateral required to secure the large international loans need to extend the life of the old strategy. But in 1982, when to price of oil fell, Mexico had to redefine its economic policies.

Due in large part to the conditions imposed by the international banks and to its own population pressures[2], the new economic policy has focused on international competition and integration to the world markets. Based on "competitive advantages" such as a relatively adequate and extensive infrastructure, a high percentage of the population with a basic education, proximity to the U.S. markets, and cheap labor (especially following the devaluation of the peso in 1982), the new economic strategy has had several effects on the country. One of the most important of these has been the redefinition of the economic geography of México, with the northern border states becoming the new frontier of Mexico's industrialization.

Northern Mexico's role can be traced to the early 1960s with the creation of the

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[1]ISI is based on the notion that a nation will develop through import substitution--the replacement of imports with home-produced goods. Under this strategy industries are protected with import tariffs and quotas that make foreign products a lot more expensive than national ones.

[2] Mexico has a population of more than 81 million people (with a population growth rate of 2.0% from 1980 to 1990) (Masera *et al.*, 1991).

"Maquiladora"program, which intended to retain on Mexico's northern border all of those Mexican citizens returning to the country at the end of the "Bracero" program. The "Bracero" program was part of a 1942 U.S-Mexican treaty providing for the importation of an unlimited number of temporary workers (called Braceros) in response to war-induced labor shortages in the agricultural industry of the U.S.. By the end of the Bracero program in 1965, more than 4.5 million Mexicans had gone to work temporally in the U.S. (Vernez and Ronfeldt, 1991).

The "Maquiladora" program promoted the creation of twin plants in neighboring cities along the México-U.S. border with the labor intensive part of the production on the Mexican side. These Mexican plants were (and are) allowed to assemble imported products, tax-free, for immediate, duty-free (except on the value added in México) re-export. The program was relatively successful until the changes of 1982--the year it took off as an economic sucess.

By 1990 the maquiladora program was the second largest foreign-exchange earner for México, behind oil and just ahead of tourism (Nelson , 1990). By the end of 1992 there were more than 1,700 maquiladoras employing more than half a million Mexicans (The Mexican-American, 1992) and providing about 5 billion $US a year in foreign currency (Secofi: Generaron, 1992).

Since 1982, after taking a strong blow from several devaluations of the peso, cities along Mexico's side of the 2,000 mile-long México-U.S. border have been growing at a rate greater than the rest of the country. While nationally the 1980-1990 urban population growth rate was 2.7% p.a., border cities like Tijuana, Ciudad Juárez, and Nogales have had growth rates greater than 3.5% p.a..

1.2. Environmental Impacts of Northern Mexico's Growth

Besides economic growth, the process has also had serious environmental effects. For example, water pollution in the Rio Grande has been considered a factor in a cluster of babies with grave birth defects in both U.S. and Mexican border towns. Non-treated sewage coming from Tijuana and Mexicali is another serious problem in California, where water going into California from Tijuana has to be treated before being deposited in the Pacific Ocean. In Ciudad Juárez, Chihuahua and El Paso, Texas air quality standards for lead, carbon monoxide, ozone, and total suspended particulates (PM-10) are not met, most of this resulting from emissions originated in Ciudad Juárez (Applegate *et. al.*,1989).

Lack of planning and infrastructure have played an important role in environmental degradation in northern Mexico. Lack of planning has given rise to chaotic growth that has allowed, for example, situating housing and industry in places that are not appropriate for those purposes. Lack of infrastructure is prevalent in water and sewage treatment (about 50 percent of the border inhabitants have no municipal sewage system), but also in telecommunications, transportation, water, energy, and housing. Altogether this lack of infrastructure represents one of the biggest problem for the future development of the region.

Two main factors have led to the current situation. First, the local tax policy associated with the Maquiladora program, under which no corporate taxes are levied by the cities (The Mexican-American, 1992). And second, the restriction on foreign loans due to the austerity programs imposed on the federal government since 1982.

These financial constraints have resulted in serious limitations to make the investments necessary for developing needed services.

One attempt to fill this financial gap is the Environmental Plan for the Mexican-U.S. Border Area. Under this plan, "Mexico has committed to investing at least $460 (US) million over three years in environmental projects in Mexican border cities." Also, President Bush's 1993 fiscal year budget request for the Environmental Protection Agency (EPA) includes $179 million for border-area environmental protection". The funds "will be dedicated to sewer systems and wastewater treatment facilities, solid waste collection and disposal, transportation and road improvements, land acquisition, and contingency funds" (EPA, 1992).

Also trying to fill the gap, are several groups in the U.S. Some of them view the growth of the border region as a problem affecting them while others see it as a business opportunity. Organizations on both sides of the border have called for the creation of a binational authority that would seek financing to either augment infrastructure projects or fully fund new ones along the border (Nelson, 1992).

1.3.The Power Sector and the Role of Air Conditioning

One very important component of infrastructure are power plants. Power plants, in order to be installed and operated, require large investments and a process of design and construction that takes several years. In Mexico, as will be shown in the next chapter, the same economic changes that brought economic growth to northern Mexico also brought with them the end of a period of relatively easy access to the international loans that made possible much of the fast growth of Mexico's power sector.

Besides requiring large investments, power plants also represent an important source of environmental problems. In northern Mexico, where power generation is predominantly based on fossil fuels, power plants consume significant amounts of water and emit air pollutants. The amounts of water consumed and of air pollution emitted depend, however, on the amount of electricity demanded. In northern Mexico where there is a high demand for energy in the residential sector for operating air conditioners, electricity seems to be used inefficiently thus generating more pollution and consuming more water than necessary to provide this service.

Northern Mexico is a region predominantly hot and arid (the Mexico-U.S. border area has an annual average rainfall of only 11 inches per year), making cool air a basic necessity. Cool air is mostly provided by devices that require electricity. In northern Mexico the acquisition and use of oversized, second-hand appliances imported from the U.S. at very low prices is widespread[3], resulting in the highest levels of electricity consumption in all of Mexico's residential sector.

1.4. The Importance of Construction Practices

Inefficient cooling devices are not the only cause of greater-than- necessary electricity consumption. Housing design and materials also determine a good portion of the electricity consumption for air conditioning. A house built with materials that have high insulation values, with walls and windows that are not overly exposed to the sun's radiation, painted with light colors, and surrounded by vegetation to reduce

[3] The economy of discards plays an important role in survival strategies in the border region. The poor of Tijuana, for example, have access to second-hand durable goods that are normally within reach of the poor living in the interior of the country, at least not as cheaply and easy as at the border (Anderson and De la Rosa, 1991)

exposure and cool the surrounding air, gains a lot less heat, thus reducing the size of the device needed for cooling. Smaller electrical devices demand less electricity.

Standard practice for construction in Northern Mexico, however, has been determined by the materials in the market and by the training of designers and builders. Both the materials and the architectural training are foreign to the region, and they basically reproduce what is done in Mexico City, a place with different climatic conditions.

There are signs that construction practices may be changing. Driven by the interest in new energy alternatives in the 1970s, a number of professionals who started working on solar energy applications have moved into architecture and are influencing new designs. Furthermore, rapid increases in residential electricity tariffs have motivated them to establish several companies to sell construction materials and methods that are justified by their thermal characteristics. Influence coming from the U.S., where energy conservation has become an activity with a large market, has also been important.

2. ELECTRICITY IN MEXICO AND THE SITUATION OF THE POWER SECTOR

2.1. Historical Overview of Mexico's Power Sector

In 1937, in order to provide electricity to areas found outside those served by the private utilities that at that time generated all of the electricity in Mexico, the federal government created the Comisión Federal de Electricidad (CFE)[4]. CFE was "to organize and direct a national system of generation, transmission and distribution of electricity, based on economic and technical principles, without purpose of profit, and with the objective of obtaining, with a minimum cost, the greatest possible yield in the benefit of the general interests" (USDOE and SEMIP, 1991). In 1949 CFE was legally defined as a "decentralized public organization, with legal personality, and patrimony of its own" (USDOE and SEMIP, 1991).

The great expansion of CFE did not start until the mid 1940s when the Import Substitution Industrialization strategy became the national industrialization policy and CFE started operating large power plants that generated electricity for the new industrial centers. This industrialization process brought with it massive migration from the rural areas into the cities, particularly to Mexico City, incorporating an increasing number of households to a market economy and to the electrical grid.

Reflecting the importance of Mexico City in the ISI strategy, a large part of the new capacity was built to supply the needs of the explosive growth of the city, where large peripheral settlements of migrants arriving from the rural areas were an

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[4] Since 1879, when the first electricity generation plant in Mexico was installed at a textile factory , and until President Cardenas decree in 1937, all electricity in Mexico was generated by private companies (De Buen Lozano O.,1975)

increasingly important component of the electrical demand. This situation prompted the government to organize large scale electrification of these (sometimes very large) settlements in the city and its periphery[5].

By 1960 CFE was generating 40% of the electricity in Mexico. The generation and distribution of electricity for the central region was controlled by the foreign owned Mexican Light and Power Co. which produced 20% of the country's electricity (Tamayo J., 1972). This situation, characterized by the growth of electrical demand coupled with the great economic importance of Mexico City, made the federal government decide to the nationalize of the electric sector in 1960. Under president Adolfo Lopez Mateos, the Mexican government bought most of the stock of the foreign owned utilities and changed Article 27 of the Mexican Constitution to establish that "the supply of electricity for public service is to be performed by the nation" (Viqueira J., 1989). The nationalization "creates a platform to integrate a national electric system capable of satisfying the needs of industry, human settlements, and agriculture" (Monteforte R., 1991).

Following the nationalization came a process of integration of seven regional systems--that had been developed independently--into a single interconnected national system. Due to the different origins of the technology used in the different regions (with two different frequencies) the process involved a large effort to convert both the plants and the customer's equipment to operate with 60 Hertz. The frequency change was completed successfully in three years from 1973 to 1976 and permitted

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[5] In 1963, when México City's population was growing at 6% p.a. (2.5% above population growth of the whole country). There were at least 158 "colonias" (neighborhoods) that were not connected formally to the grid. Many of these households, whose residents had acquired some basic electric devices, had illegal connections, creating a set of technical and political problems that required some large scale effort to resolve. The largest of this was that of Ciudad Netzahualcoyotl which, at the time of its electrification in the early seventies, had about a million inhabitants (De Buen Lozano O., 1965).

the integration of what is called the National Interconnected System (Viqueira J., 1989).

2.2. CFE's Functions

The activities of CFE include the planning and the operation of generation, transmission, and distribution systems. CFE is also responsible for "entering into contracts necessary for the fulfillment of its functions, promoting scientific and technological research and development in electricity, and for regulating the export and import of electric energy" (USDOE and SEMIP, 1991)

CFE is part of the second level of the Mexican Federal Government --within the Paraestate Public Administration-- and its operations are regulated by the Secretaria de Energia, Minas e Industria Paraestatal (SEMIP). CFE’s investments and rates must be approved by SEMIP, the Secretaria de Programación y Presupuesto (Secretary of Programming and Budget), and the Secretaria de Hacienda y Credito Publico (Secretary of the Treasury and Finance).

CFE is the only organization responsible for the planning of electrical systems in Mexico. Expansion of the system is based on an integrated scheme in geography and time. This integrated planning is supported by a hierarchical structure of generation-transmission-sub transmission-distribution. Due to the complexity of the problem, it is solved by decomposition in a time hierarchy (long-, mid-, and short term) and by spatial hierarchy (generation, bulk transmission, and distribution networks), complemented by global and marginal analysis (USDOE and SEMIP, 1991).

According to SEMIP (1991b) "CFE's national network is divided into eight regions for administration of generation, 13 for transmission, and thirteen for distribution, in addition to Compania de Luz y Fuerza del Centro (CLFC) which serves the Central Area and Mexico City[6]." Also according to USDOE and SEMIP (1991) "CFE's national network is a single synchronized system, with the exception of the Baja California Systems...the 400 kV bulk transmission system almost links the nation."

2.3. CFE's Installed Capacity and Generation in 1991

Supported by large foreign loans, the power sector has grown at a fast pace. From 1960 until 1989, Mexico's installed capacity grew by a factor of 10, which represents a rate of growth of 8.3% per year and was greater than that of the GDP (Fig. 1). Between 1971 and 1989 electricity service coverage increased from 50% to 86% of Mexico's households, the total number of customers increased nearly three times, and per capita consumption went from 428 kWh to 1,035 (OLADE, 1991).

By the end of 1991 CFE's installed capacity had reached 26.8 GW. It was composed of 61% thermal (fuel oil, gas, and diesel), 29% hydro, 5% coal, 3% geothermal, and 2% nuclear. Of the 118,412 GWh that were generated by CFE's plants in 1991, 66% were generated by thermal plants, 18% by hydro plants, 7% by coal plants, 5% by geothermal plants, and 4% by the Laguna Verde nuclear plant (Fig. 2).

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[6] Created in 1990, CLFC is one of the oldest utilities in Mexico. It was nationalized in 1960 and put in a process of liquidation that lasted close to 30 years. Currently CLFC is an independent utility but its activities are mostly limited to the distribution of electricity.

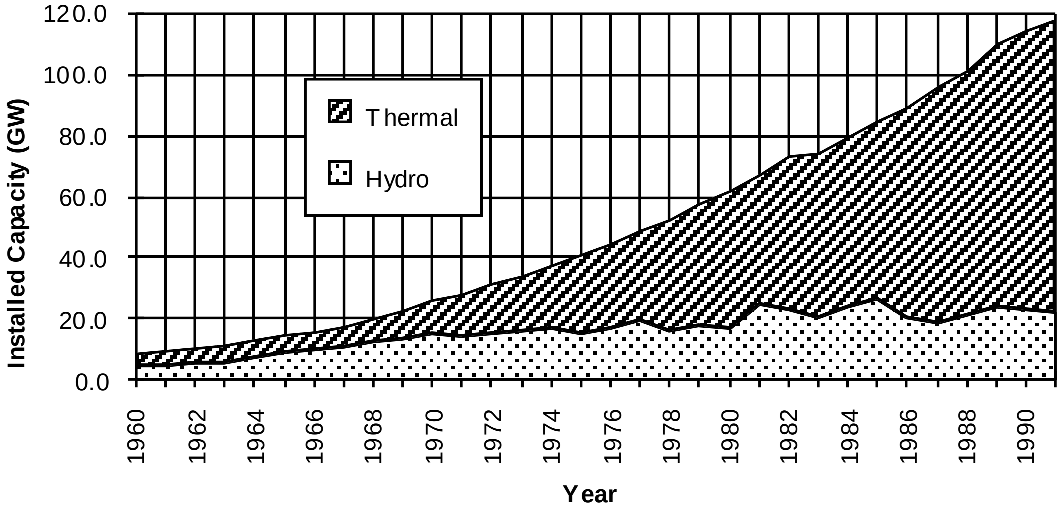

Figure 1. Evolution of Mexico's Electric Sector's Installed Capacity, 1960-1991. Raw Data Source (RDS): De Buen Lozano 0. (1975), INEGI (1990)

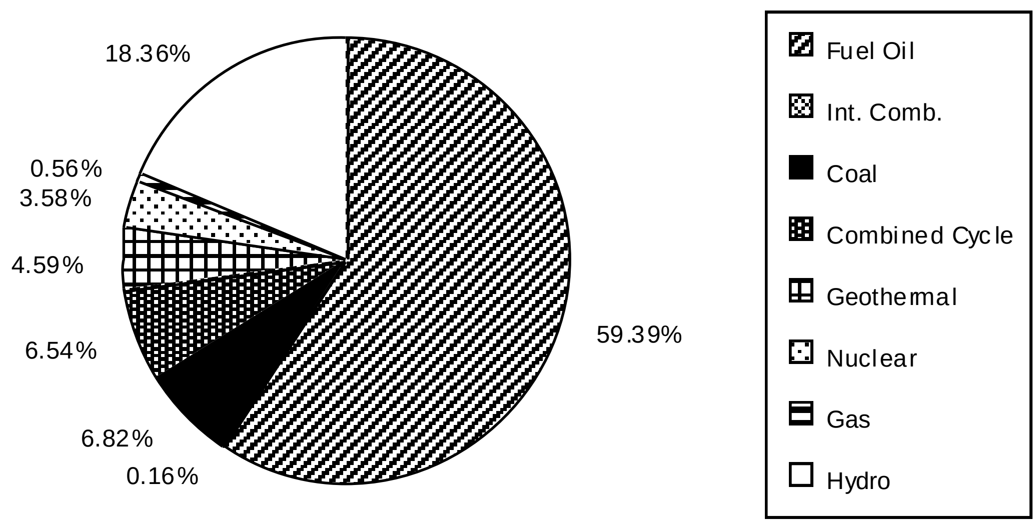

Figure 2. CFE's Generation by Type of Plant, 1991 RDS: CFE (1991a)

2.4. CFE's Financial Situation after 1982

CFE's situation changed drastically in 1982, when the government, as a result of the collapse of the oil prices, had to stop borrowing, introduce an economic adjustment program, and reconsider its traditional industrial policy. This had a great impact on the power sector. Among other things, it had to reduce the use of debt to pay for new investments. Figure 3 shows how, from 1982 to 1983, the use of loans was drastically reduced, with the debt acquired in 1983 less than a fourth of that acquired in 1982.

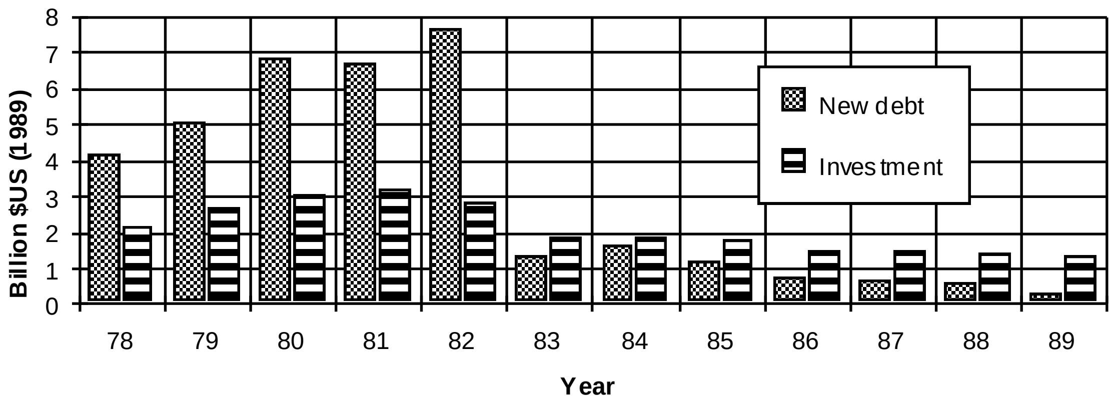

Figure 3. CFE's Debt and Investment, 1978-1989. RDS: CFE (1990a)

The problems presented in 1982 did not have an immediate effect on the utility, mainly because the economy slowed down and new plants coming into operation in the early 1980s were those planned before 1982 when demand expectations were high. In 1983 the reserve margin was at 54%, its highest level ever (OLADE, 1991).

But the lack of investment has reduced the growth of the installed capacity. While from 1960 to 1980 the rate of growth of the installed capacity was more than 9.0 % p.a., the average growth rate during the eighties was lower, at 5.6% p.a. As a result, the reserve margin went from 54% in 1983 to less than 30% in 1989. Another indication of the strains on the system is the percentage of electricity losses, which increased from 12% in 1980 to 14% in 1989[7] (OLADE, 1991).

In 1983 the small fraction of CFE's income coming from its revenues became an obvious problem. From 1978 to 1982 less than 25% of CFE's income came from its revenues, while more than 50% came from loans (Fig 4). As a result (but also as part of the economic adjustment plans of the federal government to phase out all subsidies) electricity tariffs were increased in 1983.

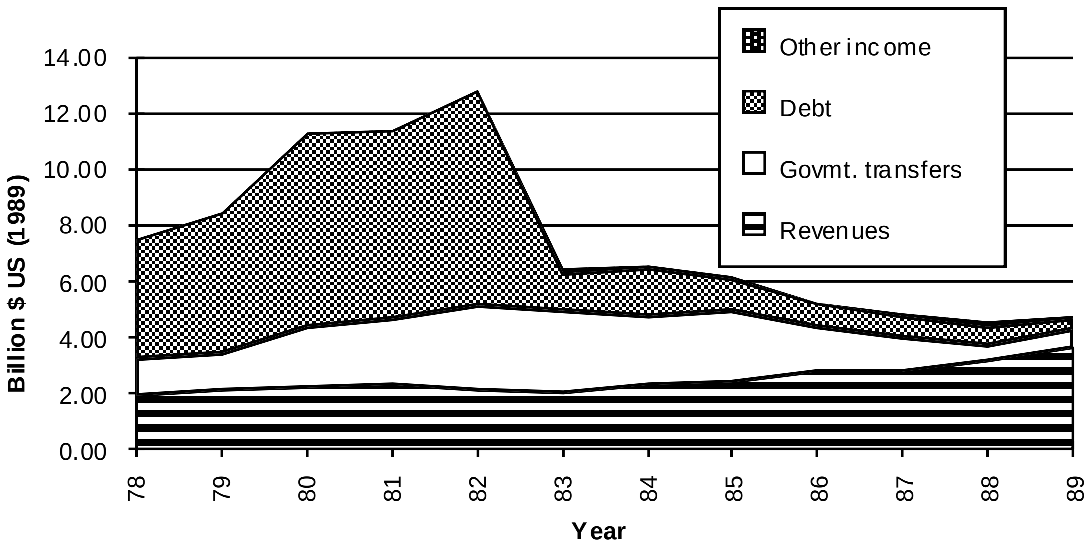

Figure 4. Evolution of CFE's Income, 1978-1989.<u>RDS</u>: CFE (1990a)

Tariff increases were only partially successful in increasing CFE's revenues, mainly because high inflation (with inflation rates above 100% for 1986 and 1987) was prevalent through 1988. The real price of the different electricity tariffs fell drastically from 1981 to 1983, remained more or less constant through 1987, and has had a notorious increase after 1988 (Fig. 5).

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[7]About 70% of the losses are estimated to be technical losses and 30% unaccounted losses (billing errors, thefts, etc.) (OLADE, 1991).

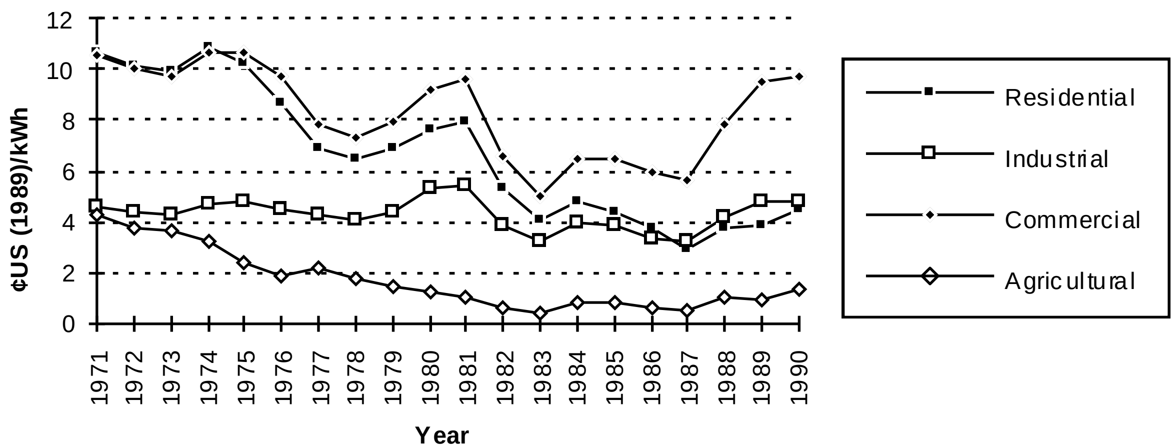

Figure 5. Evolution of Electricity Tariffs, 1971-1990 RDS: CFE (1990a)

The poor financial situation of the electric sector prompted the federal government in 1986 to assume US$8.6 billion of CFE's debt. In an agreement signed between the federal government and CFE, Mexico's national utility was left with a debt of US$1.7 billion.

In 1987, once CFE's debt had been reduced, the tariff increases had an impact on CFE's income and on the subsidies that were transfered to the customers. By 1989 revenues were already more than 75% of CFE's income, while subsidies (government transfers) had gone down from a peak of 1.8 billion $US in 1983 to 0.9 billion $US in 1989 (Fig. 4) (CFE, 1990a).

2.5. Financial Options for Future Expansion of the Power Sector

Despite of Mexico's and CFE's economic situation, electrification of the country has continued. From 1982 to 1990, while the installed capacity only grew at 4.1% p.a., Mexico's total electricity consumption grew at a rate of 6.98% p.a. At the same time, final customers kept increasing the proportion of electricity use in relation to other types of energy. Electricity consumption reached 9.7% of the total energy consumed in Mexico in 1990 (Fig. 6).

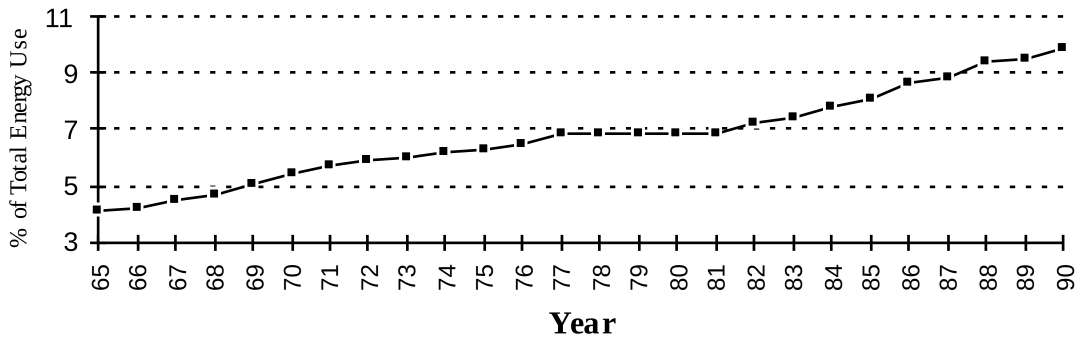

Figure 6. Evolution of Electricity's Share of Total Energy Use by Final Users, Mexico, 1965-90. RDS: SEMIP (1986), (1987), (1988), (1989), (1990), and (1991)

CFE's expansion plans call for the installation of 17,176 GW of new capacity from 1992 to 2001. A large fraction of the planned new capacity is based on fossil fuels. The largest fraction is to be taken by dual (gas and fuel oil) plants, with 6,700 GW, followed by fuel-oil plants with 6,700 GW , hydro with 3,378 GW, coal with 1,400 GW, nuclear with 675 GW, and geothermal with 310 GW.

It is estimated that the sector will require about US$36.1 billion (US$3.6 billion p.a.) between 1992 and 2001 to fund its investment program (Fig. 7). Just to cover debt service requirements between 1990 and 1996 CFE will need US$8.1 billion that will come from internal funding (OLADE, 1991).

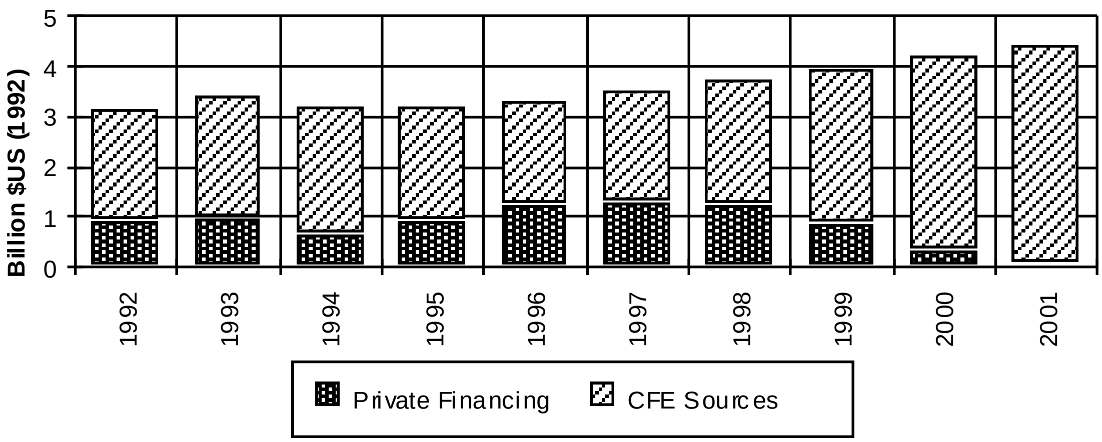

Figure 7. CFE's Investment Plan, 1992-2001. RDS: CFE (1992d)

According to CFE plans, between 1992 and 2001, 23.3% of the total resources needed ($US 8.4 billion) will come from private sources (CFE, 1991). This will increase the pressure for a greater rate of return from CFE operations, which currently is very poor. In 1989 the estimated return on investment of CFE's operations was 2.1% (OLADE, 1991).

3. ELECTRICITY DEMAND IN THE EIGHTIES, THE ROLE OF THE NORTHERN STATES, AND THE IMPORTANCE OF THE RESIDENTIAL SECTOR

3.1. Distribution of Electricity Consumption by Types of Customers

Electricity in Mexico is sold under 17 different rates (Table 1). More than half of the electricity consumed in Mexico is used by the industrial customers. In 1990 59% of the 92,127 GWh of electricity consumed in Mexico by 16,285,502 customers went to industrial customers--31% to 279 customers in rates 12 and 12-A (Table 1). With 78% of the customers, the residential sector used 22% of the total consumption (rates 1, 1-A, 1-B, 1-C , and 1-D) . The commercial sector (rates 2 and 3) consumed 9% of the total.

Rate	Type of Service	Customers	Consumption (GWh)	Revenues (1e6 $US)	Avg. Cons. (MWh/Cust.)	Avg. Price ($US/kWh)
1	Residential	8681174	9808	357	1.13	0.036
1-A	Resid./hot climate	1879461	2626	105	1.40	0.040
1-B	Resid./hot climate	2263705	4024	176	1.78	0.044
1-C	Resid./hot climate	1283844	3265	149	2.54	0.046
1-D	Resid./hot climate	208705	679	38	3.25	0.056
2	Commercial	1698727	6052	578	3.56	0.096
3	Large Commercial	18870	1946	174	103.13	0.090
4	Tortilla production	45049	266	12	5.90	0.046
5	Street lighting	3051	733	74	240.25	0.101
5-A	Street lighting	41290	1516	118	36.72	0.078
6	Muni. water pumping	18552	2279	119	122.84	0.052
7	Seasonal	8476	19	4	2.24	0.190
8	Medium Industrial	52062	24400	1286	468.67	0.053
8-A	Medium Industrial	5012	3926	194	783.32	0.049
9	Agricultural	77245	6707	76	86.83	0.011
12	Large Industrial	177	13846	514	78225.99	0.037
12-A	Large Industrial	102	10035	356	98382.35	0.035
	SUB-TOTAL	16285502	92127	4330	5.66	0.047
	Export		1946	86		0.044
	TOTAL		94073	4416		0.047

Table 1. Distribution of Consumption, No. of Customers, Revenues, and Unit Price of Electricity by Rates, México, 1990. RDS: CFE (1991c)

Average electricity prices ranged, in 1991, from a low of 0.01 $US/kWh for agricultural customers (rate 9) to a high of 0.19 $US/kWh for those customers who used electricity under a seasonal contract (rate 7) with CFE.

3.2. Regional Distribution of Electricity Consumption

The Mexico City area includes the Federal District (DF) and part of the state of Mexico. It has traditionally had the largest portion of energy used in the country. In 1990 the DF and the State of Mexico had the two largest percentages of consumption (11% and 10.4% respectively) and of customers (13.2% and 10.7%) (Table 2). Only four other states had consumption shares larger than 5% (Veracruz, Nuevo Leon, Jalisco, and Sonora).

From 1982 to 1990, however, there has been an important shift in electricity consumption in Mexico. Driven by the important economic changes in 1982, the share of electrical consumption in different regions of Mexico[8] changed noticeably from 1982 to 1990 (Fig. 9). While in 1982 a set of states located in the geographic center of Mexico was still the largest national consumer of electricity, by 1990 it had become second to the six northern border states (Fig. 9).

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[8] The regions that are defined in this paper are somewhat arbitrary because they were established as clusters of states that are located in certain parts of the country. Under this scheme the "Bajio" region includes the states of Aguascalientes, Guanajuato, Jalisco, Michoacán, Querétaro, San Luis Potosi, and Zacatecas; the "Central" region includes the Federal District (Mexico City) and the states of Hidalgo, México, Morelos, Puebla, and Tlaxcala; the "Gulf" region includes Tabasco, Veracruz, and Yucatán; the "Northern" region that includes all the states that have borders with the US (Baja California Norte, Chihuahua, Coahuila, Nuevo León, Sonora, and Tamaulipas) and Durango; the "Pacific" region includes Baja California Sur, Colima, Guerrero, Nayarit, and Sinaloa; and the "Southern" region includes Campeche, Chiapas, Oaxaca, and Quintana Roo.

State	Consumption	Customers	Cons/Cust	% Cons.	% Cust.
	(GWh)		(MWh/yr)		
Aguascalientes	899	155409	**5.78**	1.0	1.0
Baja California Norte	3538	435986	**8.11**	3.8	2.7
Baja California Sur	676	71870	**9.41**	0.7	0.4
Campeche	349	108290	**3.22**	0.4	0.7
Coahuila	4310	444887	**9.69**	4.7	2.7
Colima	728	106499	**6.84**	0.8	0.7
Chiapas	832	450208	**1.85**	0.9	2.8
Chihuahua	4112	557161	**7.38**	4.5	3.4
Distrito Federal	10146	2153455	**4.71**	11.0	13.2
Durango	1429	256318	**5.58**	1.6	1.6
Guanajuato	4076	722477	**5.64**	4.4	4.4
Guerrero	1255	410562	**3.06**	1.4	2.5
Hidalgo	1721	316540	**5.44**	1.9	1.9
Jalisco	5516	1182877	**4.66**	6.0	7.3
Mexico	9576	1740543	**5.50**	10.4	10.7
Michoacán	2769	723517	**3.83**	3.0	4.4
Morelos	912	278136	**3.28**	1.0	1.7
Nayarit	399	187449	**2.13**	0.4	1.2
Nuevo León	6976	737031	**9.47**	7.6	4.5
Oaxaca	1235	539529	**2.29**	1.3	3.3
Puebla	3474	677610	**5.13**	3.8	4.2
Querétaro	1488	188023	**7.91**	1.6	1.2
Quintana Roo	830	110198	**7.53**	0.9	0.7
San Luis Potosí	2348	340467	**6.90**	2.5	2.1
Sinaloa	2098	449936	**4.66**	2.3	2.8
Sonora	5436	428352	**12.69**	5.9	2.6
Tabasco	1171	284934	**4.11**	1.3	1.7
Tamaulipas	3433	490877	**6.99**	3.7	3.0
Tlaxcala	574	147030	**3.90**	0.6	0.9
Veracruz	7606	1010962	**7.52**	8.3	6.2
Yucatán	1129	318725	**3.54**	1.2	2.0
Zacatecas	1082	259644	**4.17**	1.2	1.6
Total	92123	16285502	**5.66**	100	100

Table 2. Distribution of Total Electricity Consumption, by States, México, 1990.
RDS: CFE (1991c)

Map of Mexico

Fig 8. Map of Mexico. RDS: Tamayo (1976)

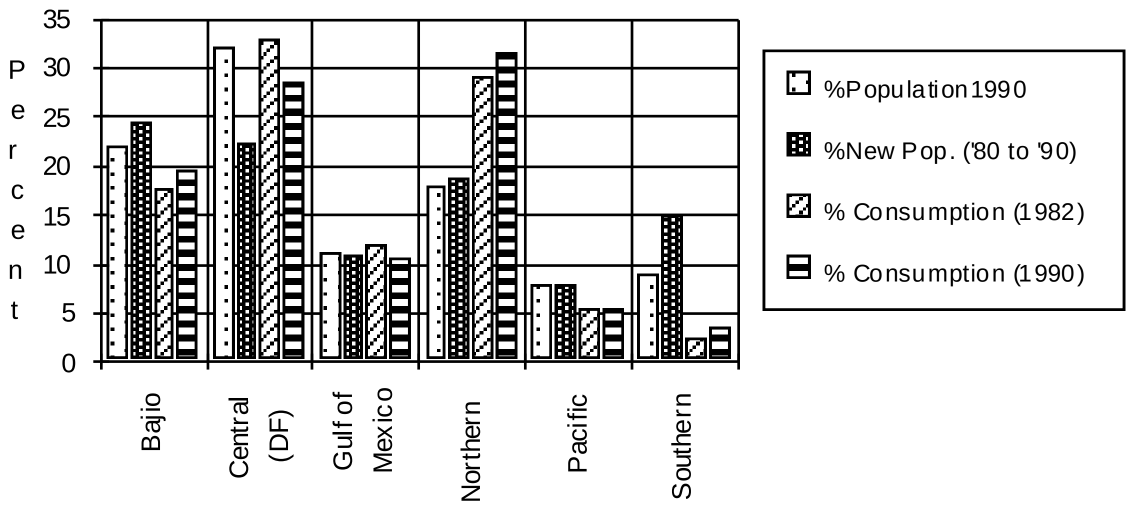

Figure 9. Percentage of 1990 Population, New Population (1980-90), and Electricity Consumption (1982 and 1990), Mexico, by Regions. RDS: CFE and INEGI.

This redistribution of electricity consumption in Mexico is not due to population growth in the region. It is mainly the result the important process of industrial expansion that has been occurring in that part of Mexico. The percentage of new population in the northern border states from 1980-1990 was almost the same as the fraction of Mexico's population living in the region in 1990 (Fig. 9).

The northern states electricity consumption has grown faster than that of the rest of the country, but even faster for consumption by industrial customers under rate 8 (Fig. 10). Rate 8 applies to customers in high voltage, which are generally medium size industries. On the other hand, residential consumption has almost the same growth rate in the northern states as it does nationally.

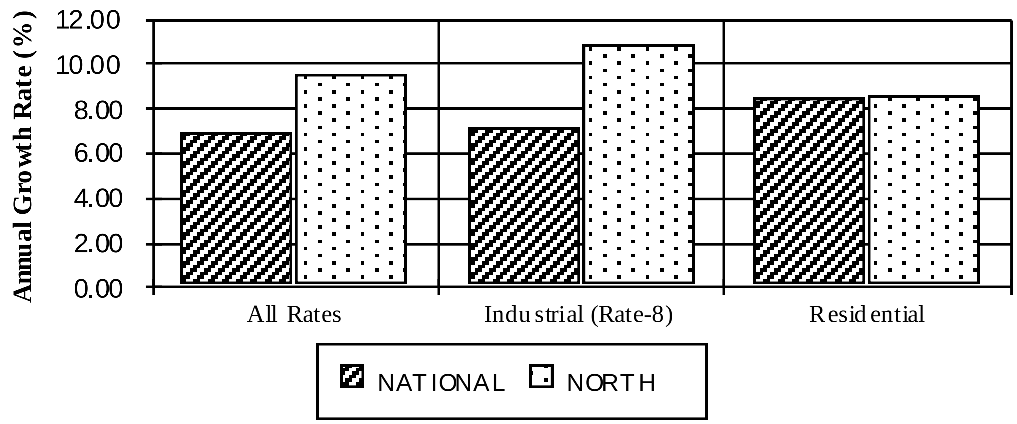

Figure 10. Average Growth Rates of Electricity Consumption, per-year, 1982-1990.
RDS: CFE (1983) and (1991c)

Using electricity as their main energy source (for lights, motors and miscellaneous assembly tools), the maquiladora plants have driven up electricity demand in northern Mexico. The Rate-8 customers in the states of Baja California and Chihuahua have grown the most, with growth rates of 15.6% p.a. and 16.7% p.a., respectively (Fig. 11). Approximately 56% of the maquiladoras on the border are located in Ciudad Juarez, Chihuahua and Tijuana, Baja California. The maquiladoras in these two cities employ just over half of the border area maquiladora workforce (EPA, 1992).

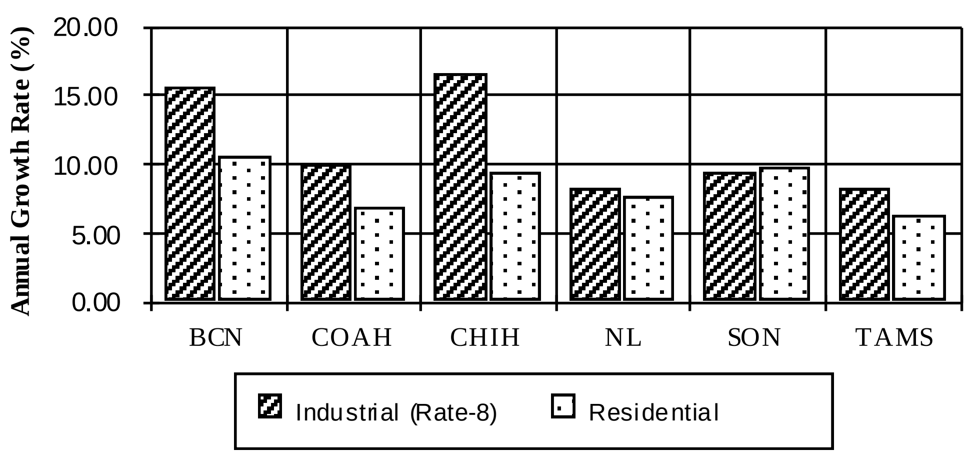

Figure 11. Average Growth Rates of Electricity Consumption, Rate-8 Industrial and

All Residential Customers, Northern States, per-year, 1982-1990. RDS: CFE (1983) and (1991c)

3.3.The Residential Sector

Residential customers are organized under four different rates, one for temperate climate (Rate 1) and four for hot climates (Rates 1A, 1B, 1C, and 1D). Residential rates for hot-climate regions are defined by the average outdoor temperature of two or more consecutive summer months as measured by the Secretaria de Recursos Hidraulicos (SARH). Rate 1A is thus applied to residential customers located in places where the outdoor temperature is equal to or greater than 25°C but less than 28°C; rate 1B applies to locations with temperatures equal or greater than 28°C but less than 30°C; rate 1C applies to locations with temperatures equal or greater than 30°C but less than 31°C; rate 1D applies to locations with temperatures equal or greater than 31°C.

The residential sector has been, at a national level and from 1982 to 1990, the fastest growing of the customer groups, increasing its share of the national total electricity consumption from 20.0% in 1982 to 22.1% in 1990 (Fig. 12). Yet this has not been a continuous process. From 1982 to 1987 it was approximately 20.5% of the national total, and after 1987 it went up almost two percentage points to reach 22.1% in 1990.

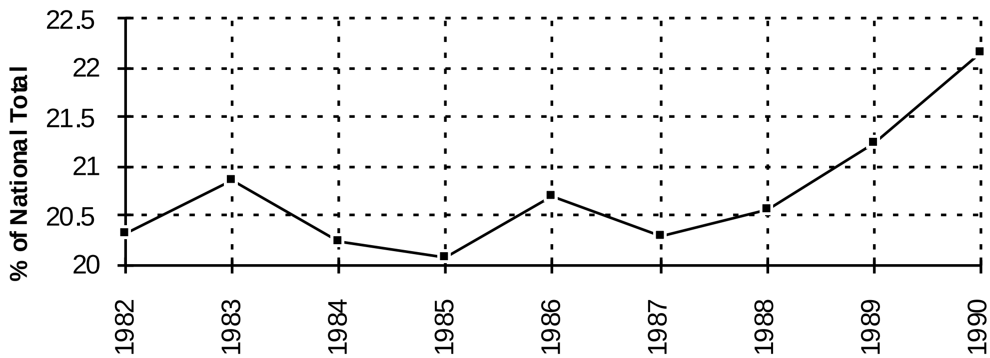

Figure 12. Evolution of the Residential Electricity Consumption as a Percentage of National Total Electricity Use, 1982-1990. RDS: CFE (1983), (1984), (1985), (1986), (1987), (1988), (1989a), (1990b) and (1991c)

Nationwide, average electricity consumption of the residential customers is 1.42 MWh/yr. By state (Table 3), the lowest average is that of the residential customers under the temperate-climate rate in the state of Oaxaca (0.59 MWh/yr), while the highest average consumption is that of the residential customers under the hot-climate rate in the state of Baja California Norte (5.25 MWh/yr). By rate (Table 1), the lowest average consumption corresponds to the customers under rate-1 with 1.13 MWh/yr and the highest to rate-1D with 3.25 MWh/yr.

Electricity use by residential customers located in hot-climate regions is higher than that of those located where climate is temperate. Higher intensity of use, however, seems to be more a result of economic development than of climate. This difference is demonstrated by the fact that temperate-climate residential customers in the poor southern state of Chiapas (CHA in Table 3) have average consumptions that are less than a third that what residential customers under the same rate consume in the wealthier state of Baja California (BCN in Table 3).

3.3.1. Residential power demand and peak load

Residential demand is an important component of peak demand, making the growth of the residential sector a driving factor in for the expansion of the installed capacity. Two coincidental demand patterns, that are typical in the country, show the role of residential power demand. One, like that of the central region (Fig. 13)[9], has its peak demand in the early evening, reflecting the important role of residential lighting. The other one, typical of the country's northwestern region, has its peak demand in the early summer-afternoons, which is the time of the day when residential air-conditioning devices are operated (Fig. 14).

[9] It should be noted that the percent of peak load for the peak load figures is based on the monthly peak load and not to the yearly peak load.

STATE	Unit Consumption by Rate (MWh/yr)		
	Temperate	**Hot**	**ALL**
Aguascalientes	1.18	-	1.18
Baja California Norte	2.17	5.25	3.40
Baja California Sur	1.54	2.74	2.71
Campeche	-	1.56	1.56
Coahuila	1.31	1.90	1.75
Colima	0.98	1.31	1.30
Chiapas	0.62	1.08	0.96
Chihuahua	0.97	1.84	1.65
Distrito Federal	1.33	-	1.33
Durango	0.92	1.34	1.07
Guanajuato	1.19	1.52	1.20
Guerrero	0.76	1.16	1.07
Hidalgo	0.85	0.61	0.83
Jalisco	1.31	1.49	1.33
Mexico	1.12	1.51	1.12
Michoacán	0.77	1.48	0.87
Morelos	1.47	1.04	1.17
Nayarit	0.29	1.18	1.16
Nuevo León	0.59	2.21	2.17
Oaxaca	0.59	0.95	0.73
Puebla	0.91	4.04	0.92
Querétaro	1.12	0.48	1.10
Quintana Roo	-	2.02	2.02
San Luis Potosí	1.06	1.18	1.09
Sinaloa	-	2.46	2.46
Sonora	-	3.13	3.13
Tabasco	-	1.54	1.54
Tamaulipas	0.53	2.39	2.38
Tlaxcala	0.77	-	0.77
Veracruz	1.03	1.36	1.26
Yucatán	-	1.37	1.37
Zacatecas	0.83	-	0.83
TOTAL	**1.13**	**1.88**	**1.42**

Table 3. Average per-Customer Residential Consumption, by Rate Categories, México, 1990. RDS: CFE (1991c)

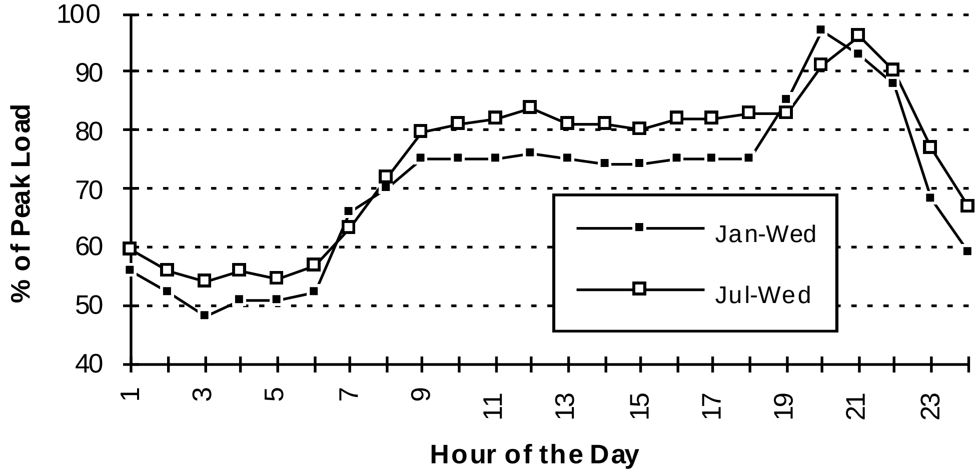

Figure 13. Typical Load Curves, CFE's Central Area (1987) RDS: CFE (1988b)

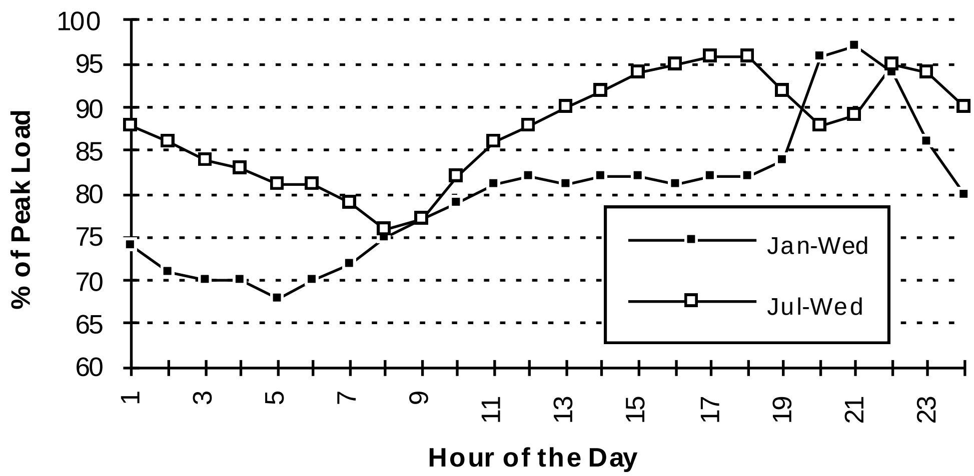

Figure 14. Typical Load Curves, CFE's Northwestern Area (1987) RDS: CFE (1988b)

There may be shifts in the patterns of peak demand in the regions with hot climates due to the growth of the importance of the hot-climate customers from 1982 to 1990. While in 1982 the hot-climate customers represented 36% of the number of residential customers, by 1990 they were 39% of the total. This growth in the number of hot-climate residential customers has meant for them a growing share of the total national consumption from 10% in 1982 to 11.5% in 1990 (Fig. 15).

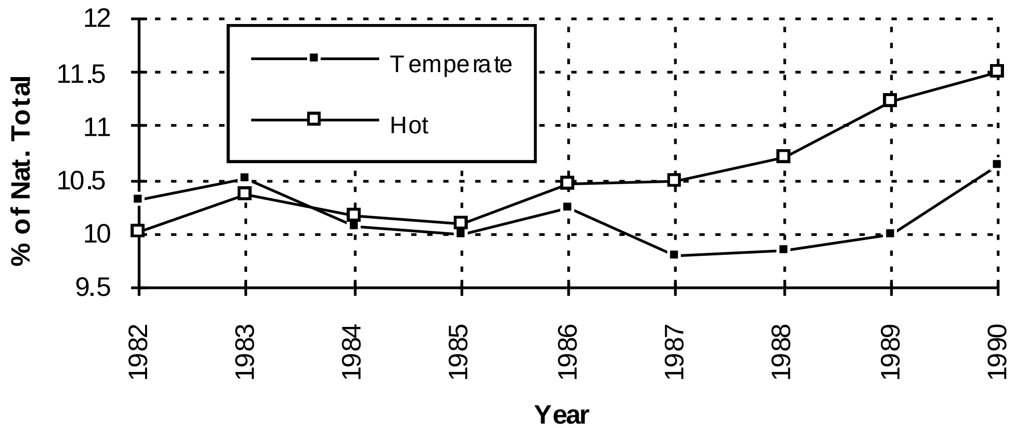

Figure 15. Evolution of Residential Consumption as a Percentage of National Total Consumption, by Rate Type, 1982-90. RDS: CFE (1983), (1984), (1985), (1986), (1987), (1988), (1989a), (1990b) and (1991c)

Probably as a result of greater appliance saturation in their households, consumption of hot-climate customers grew at a faster rate than that of the number of customers in the 1982-90 period (9.4% vs. 8.5% p.a.) increasing their average consumption to 1.9 MWh/yr in 1990.

3.3.2. Residential electricity tariffs

As stated above, residential electricity tariffs are organized under four different rates, one for temperate climate (Rate 1) and four for hot climates (rates 1A, 1B, 1C, and 1D). The tariffs are structured with a fixed charge per hookup and an energy charge that varies by levels of consumption, with cheaper lower kilowatt-hours and more expensive higher kilowatt-hours. The tariff for hot-climate customers works only during a period that goes from May first to September thirtieth; the rest of the year all of Mexico's residential customers are under rate 1.

Table 4 shows the residential tariffs that came into effect on November of 1990. Price per kWh ranges from 0.015 $US for the first 25 kWh/month of the hot-climate customers to 0.143 $US for the kWhs above 1,000 kWh/month of all the residential customers. The main difference between rates is the level of consumption where the 0.143 $US/kWh applies. For rate 1, this price is applied to monthly electricity consumption beyond 200 kWh/month, while for the hot-climate rates the limit ranges from 250 kWh/month for rate 1A to 1000 kWh/month for rate 1D. The fixed charge does not vary by rate but only by levels of monthly consumption.

Ranges	**Rates**	($US/kWh)				
(kWh/month)	**1**	**1A**	**1B**	**1C**	**1D**	Fixed Charge
0-25	0.019	0.015	0.015	0.015	0.015	1.202
26-50	0.027	0.021	0.021	0.021	0.021	1.402
51-75	0.035	0.028	0.028	0.028	0.028	1.603
76-100	0.041	0.033	0.033	0.033	0.033	1.603
101-200	0.045	0.036	0.036	0.036	0.036	2.003
201-250	0.143	0.050	0.040	0.040	0.040	3.005
251-300	0.143	0.143	0.040	0.040	0.040	3.005
301-400	0.143	0.143	0.143	0.040	0.040	3.005
401-500	0.143	0.143	0.143	0.040	0.040	3.005
501-750	0.143	0.143	0.143	0.050	0.050	3.005
751-1000	0.143	0.143	0.143	0.143	0.095	3.005
1001-more	0.143	0.143	0.143	0.143	0.143	3.005

Table 4. Residential Electricity Tariffs as of November 1991. RDS: Acuerdo (1991)

The present tariff structure clearly subsidizes the electric use of the low-consumption residential customers; it also subsidizes its use by hot-climate customers at higher consumption levels than those of temperate climate customers. Overall, residential customers paid, in 1991, an average price of 0.05 $US for each kWh they used.

As mentioned in the previous chapter, the average price paid per kWh by residential customers has undergone several changes. The average price per kWh (in 1989 dollars) declined from a high of 0.11 $US/kWh in 1974 to a low of 0.03 $US/kWh in 1987 (Fig. 16). A growth tendency that begins after the 1987 low has brought the average price up to 0.05 $US/kWh in 1991.

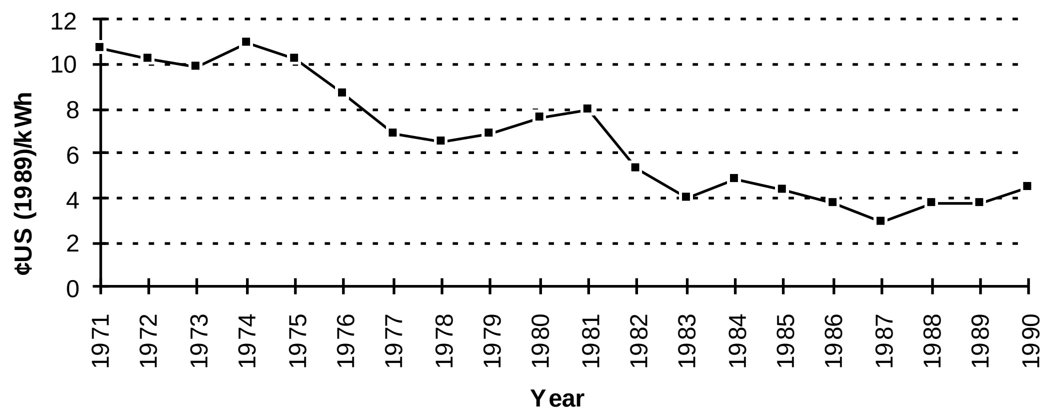

Figure 16. Average Residential Rates, 1971-1990. RDS: CFE (1990a)

Though not openly stated, CFE and Mexico's federal government have a policy of subsidy elimination. This policy makes economic sense from the perspective of CFE as an independent economic entity and it also makes sense from the point of view of a government that is in the process of privatizing this service and seeks to secure a rate of return for the private investors. However, the subsidies have existed for a series of important reasons. They have been socially necessary in order to make a basic service available to everyone. From an economic point of view, they have played an important role in the creation of a market for industrial products such as household appliances, televisions, radios and so on. Politically, they have served the purpose of maintaining the loyalty of the low-income population to the governing party.

These reasons for keeping the subsidies may no longer be valid. But, at a time when the buying power of the majority of the population has reached its lowest levels in more than a decade, it makes social and political sense to promote alternatives that mitigate the effects of higher electricity tariffs.

4. RESIDENTIAL ELECTRICITY DEMAND IN THE NORTHERN BORDER STATES

4.1. Population in the Northern Border States

With a population of more than 13.2 million people in 1990 (16.3% of the national total), Mexico's northern border states occupy two fifths of its territory. Of this population total, about one quarter live in the state of Nuevo Leon, while the other states have from 12.4 to 17% of the region's total (Fig. 17).

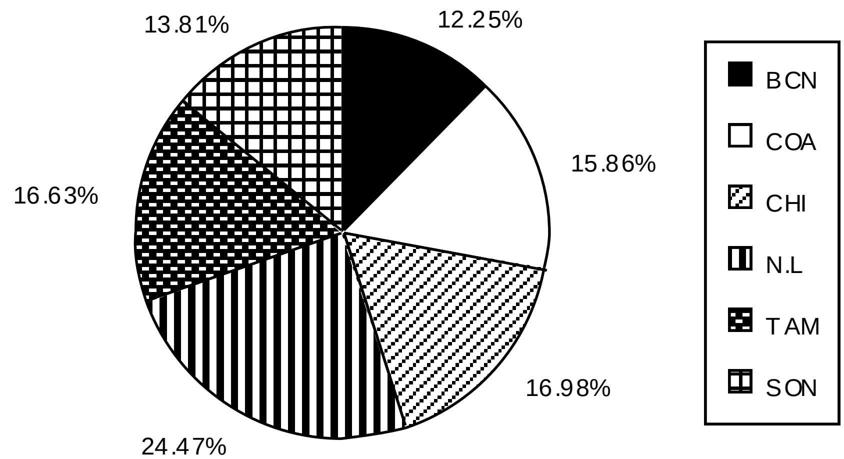

Figure 17. Distribution of Population by State, Mexico's Northern States, 1990. RDS: INEGI (1991)

About 68% of the population of the northern border states live in urbanized counties with more than 100,000 inhabitants (Table 5). The largest metropolitan area in the region is Monterrey, which includes all of Nuevo Leon's counties listed in Table 4. This metropolitan area of more than 3 million people is the second largest industrial city in Mexico (after Mexico City).

State	County	Population 1980	Population 1990	Growth Rate 90/80
BCN	Tijuana	461257	742686	4.9
BCN	Mexicali	510664	602390	1.7
COA	Torreon	363886	459809	2.4
COA	Saltillo	321758	440845	3.2
COA	Monclova	119609	178023	4.1
CHI	Cd. Juarez	567365	797679	3.5
CHI	Chihuahua	406830	530487	2.7
N.L	Monterrey	1090009	1064197	-0.2
N.L	Apodaca	37181	102886	10.7
N.L	Garza Garcia	81974	112394	3.2
N.L	Guadalupe	370908	534782	3.7
N.L	S. N. de los Garza	280696	446457	4.8
N.L	Santa Catarina	89488	162795	6.2
SON	Hermosillo	340779	449472	2.8
SON	Cajeme	255845	311078	2.0
SON	Guaymas	97962	128960	2.8
SON	Navojoa	106221	122390	1.4
SON	Nogales	68076	107119	4.6
SON	S. L. Rio Colorado	92790	111508	1.9
TAM	Matamoros	238840	303392	2.4
TAM	Ciudad Madero	132444	159644	1.9
TAM	Mante	106426	116267	0.9
TAM	Nuevo Laredo	203286	217912	0.7
TAM	Reynosa	211412	281618	2.9
TAM	Tampico	267957	271636	0.1
TAM	Victoria	153206	207830	3.1

Table 5. Population of Counties with more than 100,000 Inhabitants, Northern Border States, México, 1990. RDS: SPP (1981) and INEGI (1991)

Second and third in population to Monterrey's metropolitan area are two border cities, Ciudad Juarez, Chihauhua and Tijuana, Baja California. These two cities, that together are home to close to two million people, are two of the fastest growing cities in northern as well as in the nation of a whole. Located just across from two important U.S. metropolitan areas, Ciudad Juarez and Tijuana (across the border from

El Paso, Texas and San Diego, California respectively) are the two cities that have concentrated much of demand growth in their states. This rapid growth has been a result of maquiladora plants being created and expanded in those cities.

Figure 18. Map of the Mexican-U.S. Border.

4.2. Residential Electricity Consumption in Mexico's Northern Border States

With 16% of the national population, the northern border states consumed 32% of the national total for the residential sector in 1991, 54% of the national total for the hot-climate subset, and had an average unit consumption of 2.5 MWh/yr in 1990--66% greater than the national average. For the hot-climate households in the six northern border states, the average consumption was 2.64 MWh/yr.

The relative importance of residential electricity consumption varies widely from state to state, ranging from a low of 16% in Coahuila to a high of 37% in Baja California. For Nuevo Leon, the most industrialized state with the highest per-state total electricity consumption of the northern border states, the fraction of residential consumption is 20.5% (Fig. 19).

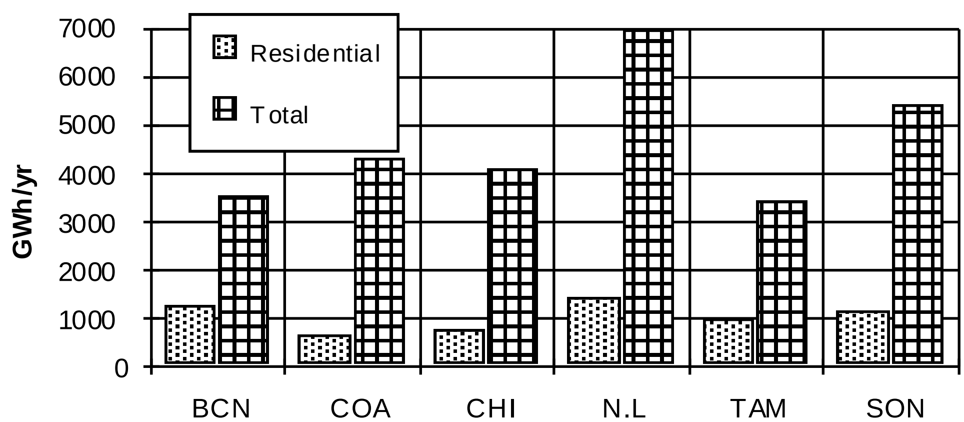

Fig 19. Total and Residential Electricity Consumption, Northern Border Sates, México, 1990. RDS: CFE (1991c)

Even though industrial power demand has grown faster than residential demand in northern Mexico, previous developments (like that of Mexico City) suggest that residential demand will continue to grow steadily even after industrial power demand growth slows down.

It is precisely the growth potential of the residential sector that calls for a closer look at the factors that determine residential electricity consumption. In the particular case of northern Mexico, where air conditioning is a major end use, it is very important to understand what drives the demand for air conditioning.

4.2.1 Distribution of customers

A large fracion of the residential customers in the northern border states are under hot-climate rates during the summer months. Of about 2.7 million residential customers in the region, 83% were located in areas under hot-climate rates while only 17% were in areas under rate 1 (Fig. 20).

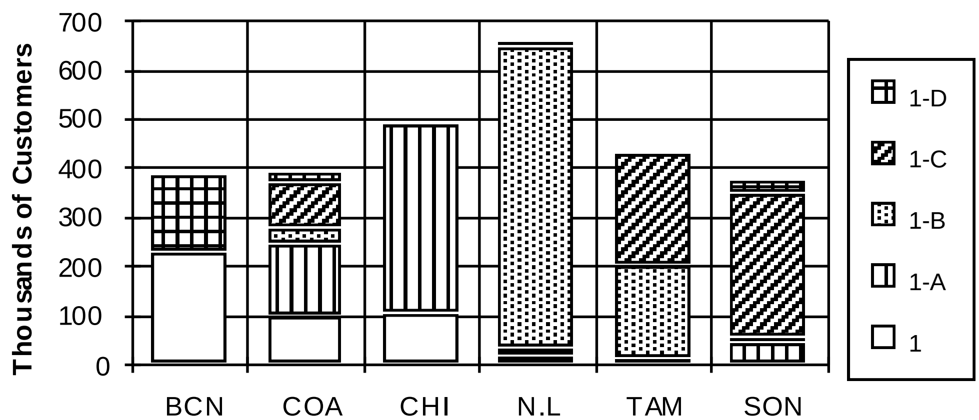

Fig 20. Distribution of Residential Customers by Rate, Northern Border States, Mexico, 1990. RDS: CFE (1991c)

The largest group of residential hot-climate customers--31%--is under rate-1-B (Fig. 20); most of these customers are in Nuevo Leon, and particularly in the city of Monterrey. Rate 1-C customers are the second largest group--23.1%--and are located in Sonora, Tamaulipas, and Coahuila. Third are the rate 1-A customers --21.8%-- located predominantly in Chihuahua and Coahuila. Residential customers under rate 1 are in fourth place and about half of them are located in Baja California Norte, Chihuahua, and Coahuila. Finally, the residential customers under rate 1-D--7.6%--are predominantly located in Baja California Norte.

4.2.2. Levels and distribution of residential consumption

Mexicali, Baja California Norte has the highest average per-customer residential electricity consumption in the northern border states. It is a location under rate 1-D and the average use is 5.3 MWh/yr (Fig. 21). It is followed by Sonora's rate 1-C customers (Hermosillo), with 3.2 MWh/yr, and by Coahuila's 1-B customers, with 3.0 MWh/yr.

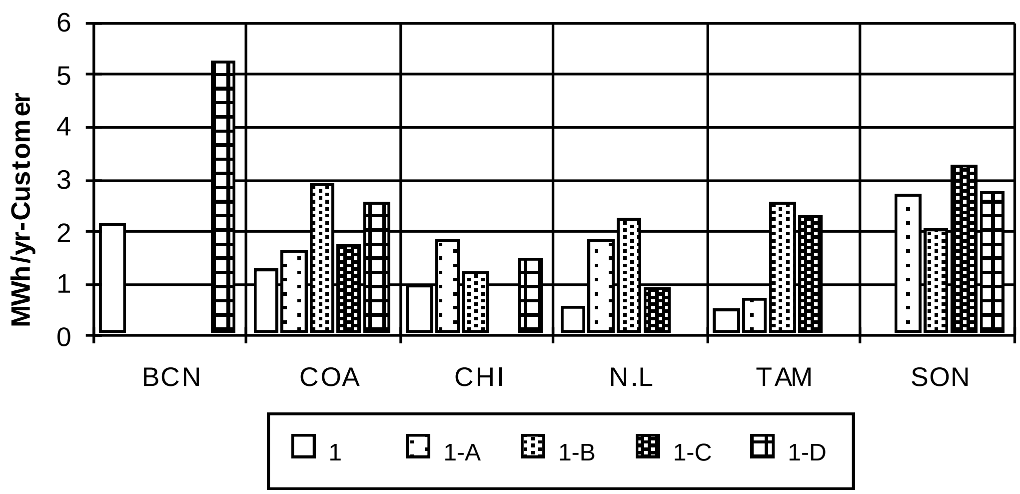

Fig 21. Average Electricity Consumption by Rate, Residential Customers, Northern Border Sates, Mexico, 1990. RDS: CFE (1991c)

As a comparison, average yearly electricity consumption in the U.S. in 1987 was 8.9 GWh/yr (EIA, 1988). For California, where the climate makes heating not as important an end use as in other parts of the country, the average in 1990 was 6.6 GWh/yr, a value not much greater than that of Mexicali's (CEC, 1991).

4.2.3. Economic impacts of electricity consumption on residential customers

The impact that electricity consumption has on residential customers in northern Mexico varies widely. Impacts range from as low as about 10 $US/year for rate 1 customers in Nuevo Leon to as much as 300 $US/year for rate 1-D in Baja California Norte (Fig. 22). These differences are a function of climate, income, availability and price of appliances, lifestyle, and the way the residential tariffs are structured.

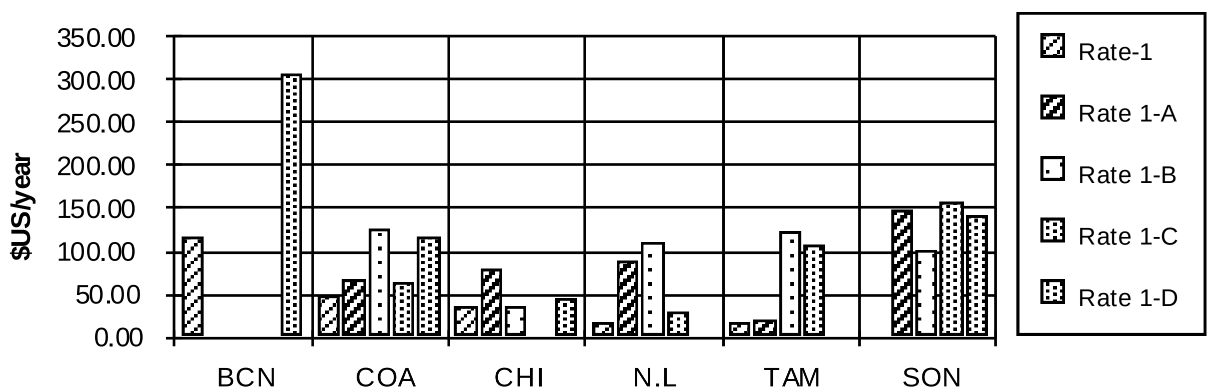

Figure 22. Average Yearly Expenditure, Residential Customers, Northern Border States, Mexico,1990. RDS: CFE (1991c)

The economic impact of electricity consumption on household economies of northern Mexico's population has been increased noticeably in recent years as a result of decreasing buying power and higher electricity tariffs. An important indicator of buying power, Mexico's legally specified minimum monthly wage has declined (in U.S. dollars) since 1981 more than 50%, reaching a value of around 100 $US/month in 1990 (Fig. 23). Just in the case of Mexicali, Baja California,where 60% of the households earn less than 350 $US , the average residential electricity bill is 25 $US.

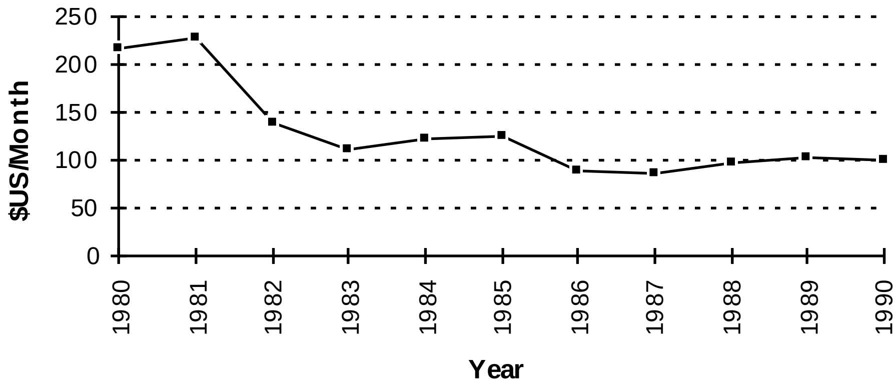

Figure 23. Evolution of Monthly Minimum Wage Mexico, 1980-90. RDS: CFE (1990c)

At the same time that purchasing power (in $U.S.) has decreased, electricity tariffs have been increased (in $U.S.), thus having a greater economic impact on the population. The average yearly expenditure on electricity (in $US) for all rates at all locations increased 50% from 1988 to 1990 (Fig. 24). Just for Mexicali's households, yearly expendituers has reached an average of 300 $US. As a comparison, average electricity expenditures in California were 660 $US in 1991 (CEC, 1991).

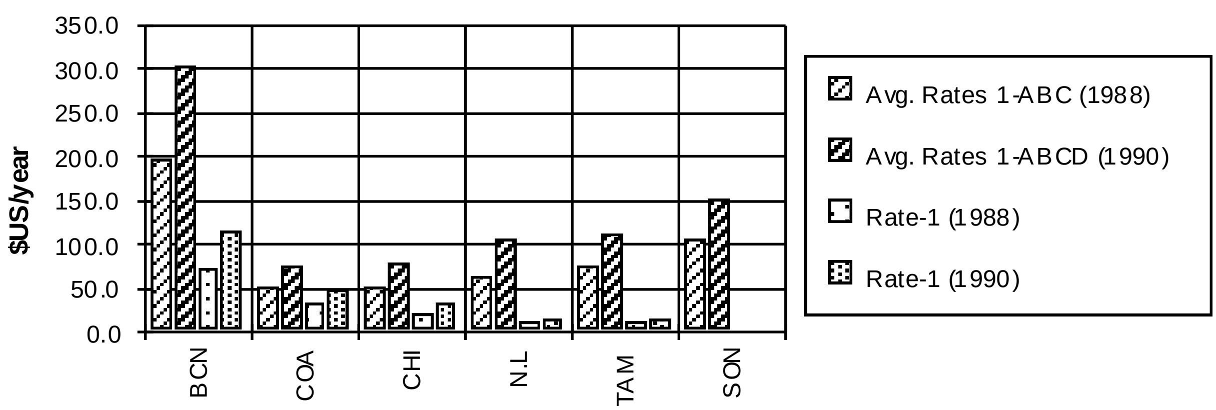

Figure 24. Average Yearly Expenditure per-Household by Rates, México and Baja California Norte, 1987-90. RDS: CFE (1989a) and (1991c)

The average price of residential electricity in Mexico ranges from less than 0.03

$US/kWh to nearly 0.06 $US/kWh (Fig. 25). As a comparison average residential rates in California at the same time were 0.105 $US/kWh (CEC, 1991).

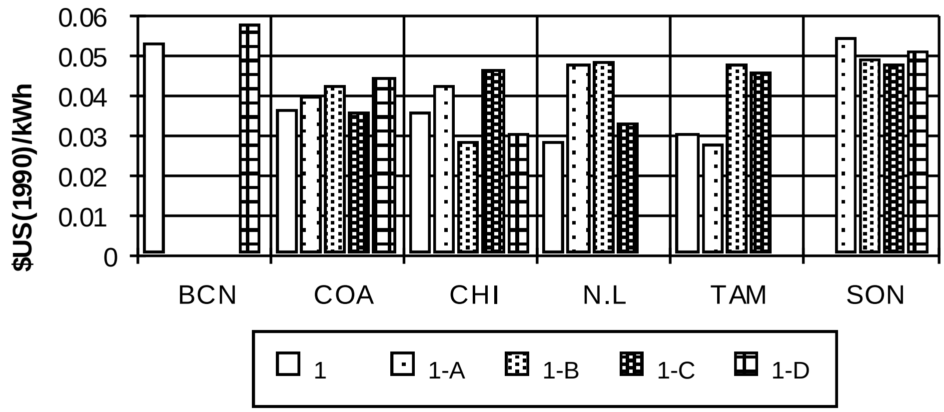

Figure 25. Average Price per kWh for Residential Customers, by Rate, Northern Border Sates, México, 1990. RDS: CFE (1991a)

4.2.4. Political impacts of electricity prices

Because residential customers are still subsidized and one of CFE's current policies is to eliminate subsidies, the cost of electricity will keep going up for this group of customers. This development may fuel social actions against CFE and the federal government.

Social actions against CFE are not new in northern Mexico (Ponce and Silva, 1989). Driven many times by the desire of local groups for autonomy from a very centralized federal regime, many of CFE's actions (particularly rate increases) are strongly criticized. Manifested through strong editorials in local newspapers, demonstrations, consumer take-overs of CFE installations, and "pay strikes", social actions have generally resulted, when successful, in changes in the tariff structures.

Mexicali and Hermosillo are two good examples of a successful process of social actions against tariff increases. Rate 1D, which was created in 1991, works solely for these two cities, which are the two cities where the citizen's actions have been more intense. Coincidentally, both these cities have elected mayors from the Partido Acción Nacional (PAN), a political party that opposes the governing Partido Revolucionario Institucional (PRI). The PAN has used the electricity tariffs issue as part of its platform against the PRI's candidates, the party that has dominated Mexico's politics in the last 65 years and is widely identified with the central government.

5. BAJA CALIFORNIA NORTE AND THE CASE OF MEXICALI

The state of Baja California Norte plays an important role in the expansion of the power sector in northern Mexico. With the greatest electricity demand growth rate of all the northern states (12.1% from 1982 to 1990), it also has the highest average unit consumption per residential customer for both temperate and climate regions (2.17 MWh/yr for rate 1 and 5.25 MWh/yr for rate 1-D).

Baja California Norte's residential customers also have high levels of growth from 1982 to 1990, having increased their consumption 10.7% p.a. (12.4% for rate 1 and 9.7% for rate 1-D), which is the highest value for all of the northern border states.

5.1. Baja California's Power System

Baja California Norte is served by an electrical grid separated from the national interconnected system. The installed capacity of the state system was 1,240 MW at the end of 1991: 49% geothermal plants, 37% fuel-oil based thermal plants, and 14% gas turbines. Baseload power generation in the Baja California System is done with geothermal plants that operate at a load factor of more than 80%. This results in more than 70% of the electricity generated in the Baja California system coming from these plants (Fig. 26). Geothermal plants (Cerro Prieto I and II) are located in the southwest section of the Municipio de Mexicali. Peak load generation is provided by the fuel-oil plants, which have load factors of around 50%, and are located in Rosarito, south of Tijuana.

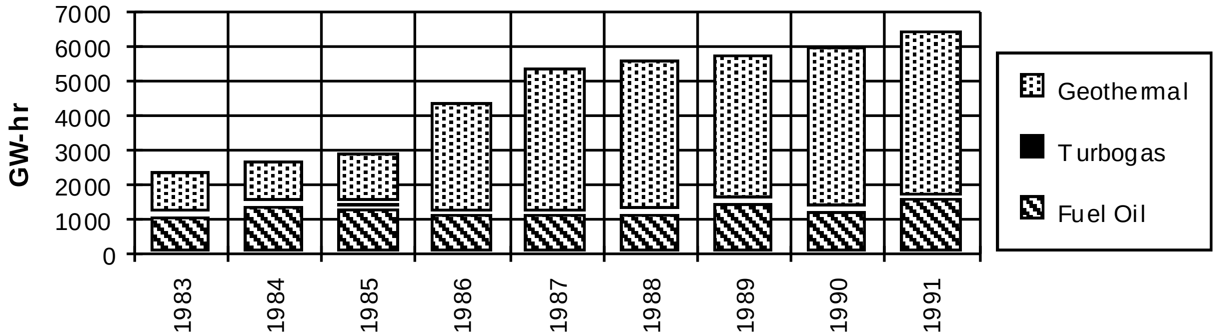

Figure 27. Evolution of Power Generation by Type of Plant, 1983-91, Baja California System. RDS: CFE

Not all of the energy generated in the Baja California system is used in the state. About 2,000 GWh of the electricity generated by the geothermal plants is sold to the U.S., mainly to San Diego Gas and Electric (SDGE) and to Southern California Edison (SCE) under a contract to provide SDGE and SCE 150 and 70 MW, respectively, of firm capacity. The contract expires in August of 1996 (USDOE and SEMIP, 1991).

Baja California system peak demand occurs in the early afternoon of summer weekdays (Figs. 27 and 28), coinciding with the highest outdoor temperatures, the main factor driving the demand for air-conditioning.The winter hourly peak demand in Baja California, which is a very similar pattern to that of Mexico's Central area (Fig, 28).

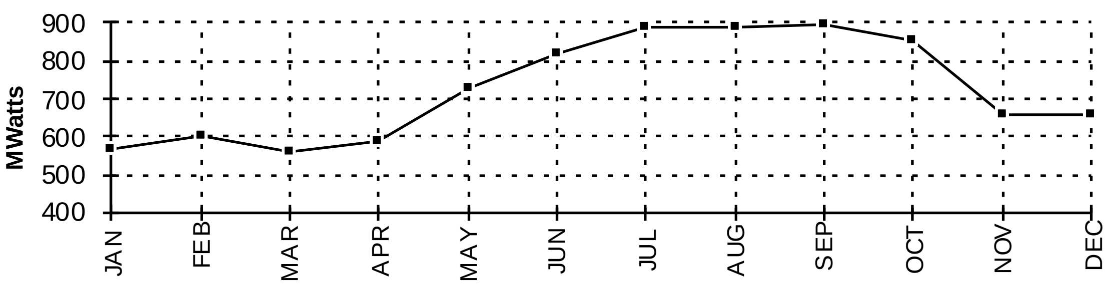

Figure 27. Monthly Peak Demand, Baja California System, 1991. RDS: CFE, (1992a)

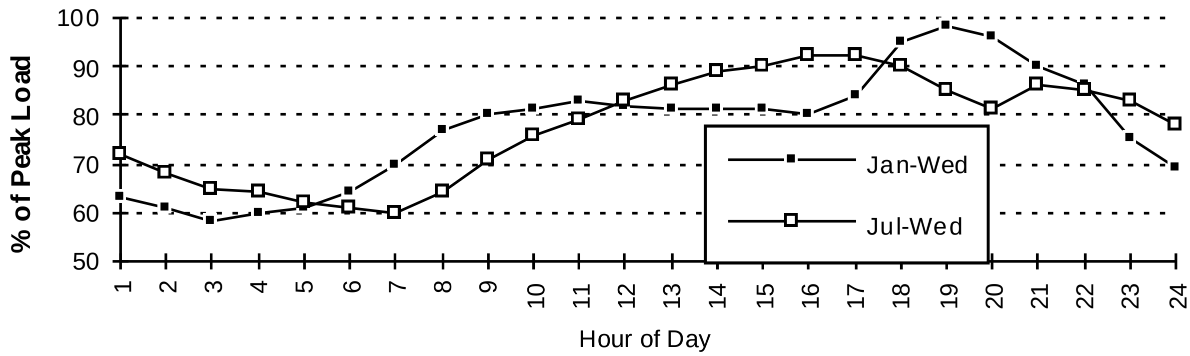

Figure 28. Peak Demand, by Time of Day, Summer and Winter Weekdays, Baja California System, 1991. RDS: CFE (1988a)

Baja California's system has been under increasing pressure as a result of the state's growth. While in 1985 it had a reserve margin of about 50%, by 1990 the margin was reduced to about 20% (Fig. 29). In 1991, however, a flattening in the growth of the coincidental demand (which may have been partially a result of a new industrial hourly-rate) and the beginning of operations of the Rosarito II unit increased the reserve margin to close to 40%.

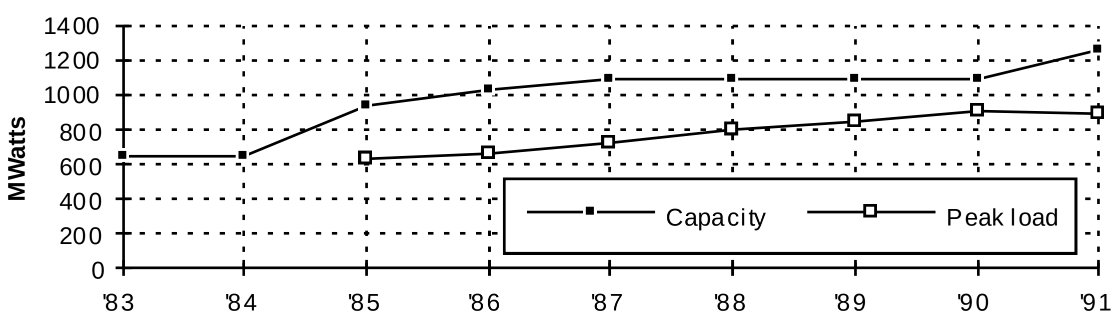

Figure 30. Installed Capacity and Peak Load, 1983-91, Baja California System. RDS: INEGI (1990) and CFE (1990d), and CFE (1991b)

5.2. Electricity Demand in the Baja California System

In 1991 3,530 GWh of electricity were consumed in the state of Baja California

Norte (Table 6). Of this total 41% went to industrial customers (rates 8, 8-A, 12, and 12-A), 37% to the residential customers, 15% to commercial customers (rates 2 and 3), 5% to agricultural customers (rate 9), and 4% to municipal customers.

About 30% of the 272.9 M$US (@ 3,000 pesos/$US) revenues collected by CFE in Baja California during 1991 came from its exports to SDGE and SCE (Table 6). Of the sale of electricity inside the state (192.2 M$US), CFE collected 36% from the residential customers (@0.053 $US/kWh), 35% from the industrial (@0.048 $US/kWh), and 23% from the commercial (@0.091 $US/kWh).

Rate	Type of Service	Customers	Consumption	Revenues
			(GWh)	(1e6 US dlls)
1	Residential	231350	501	25.29
1-D	Residential in hot climate	153611	806	44.02
2	Small Commercial	43673	345	31.65
3	Large Commercial	1824	160	13.95
4	Tortilla production	345	6	0.31
5-A	Street lighting	1307	50	3.78
6	Municipal water pumping	434	61	2.95
8	Medium Industrial	1595	761	40.28
8-A	Medium Industrial	298	297	14.12
9	Agricultural water pumping	1523	155	1.79
12	Large Industrial	10	281	10.31
12-A	Large Industrial	6	107	3.74
	Sub-total	435986	3531	192.20
	Export		1946	80.71
	TOTAL		5477	272.91

Table 6. Distribution of Consumption, No. of Customers, and Revenues, by Rates, Baja California Norte, 1991. RDS: CFE (1992c)

5.3. Mexicali

With more than 600,000 inhabitants, Mexicali is the third largest city along the México-U.S. border and has a relatively important agricultural and industrial base. It is located in the southern part of the Imperial Valley, a very arid region. The Imperial Valley receives less than three inches of water annually, and is considered an arid desert (Snyder, 1983). Mexicali is where some of the highest summer temperatures in Mexico occur--daily average outdoor temperatures are well above 90 F in July and August (Fig. 30).

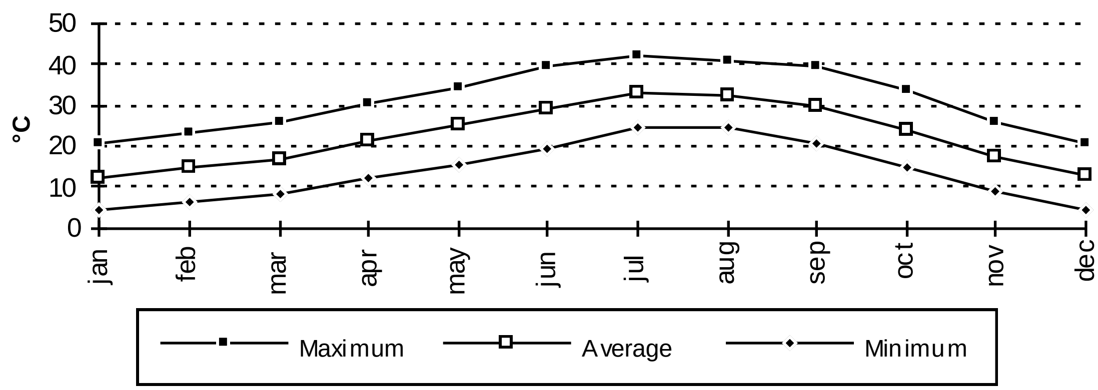

Figure 30. Average Outdoor Dry-Bulb Temperatures, Mexicali, BCN. RDS: SARH (1976)

5.4. Mexicali's residential electricity consumption

All of Baja California's rate 1D customers reside in the Municipio of Mexicali. There were more than 153,000 customers under this rate in the state in 1991, and they consumed 806 GWh (about 23% of the state's total) (Table 6).

Average residential electricity consumption in the Municipio de Mexicali is 450 kWh/month and changes through the seasons, going from 175 kWh/month in the winter to 700 kWh/month in the summer.

Electricity consumption reflects the social stratification of Mexicali's population. About 30% of the residential customers in Mexicali consume more than 2,000 kWh/month in the summer. At the same time 30% consume less than 350 kWh/month in the same period, resulting in the top 30% of the customers using 60% of the electricity while the bottom 30% of the customers use only 10% of the total.

5.5. Determining Factors of Electricity Use for Air Conditioning in Mexicali

Electricity use for air conditioning is determined, among other factors, by the characteristics of the dwelling and the system providing cool air. In Mexicali, as will be shown, these two factors play a very important role.

5.5.1. Characteristics of Mexicali's housing stock

Houses in Mexicali have characteristics that reflect different historical moments of the region's development. However, they also reflect the social differences that are present in the local society. The traditional construction materials used in housing are adobe walls and wooden roofs. Around the 1920s and 1930s, bricks were substituted for the adobe although the roofs continued to be made out of wood. Apparently because of lower cost, concrete started replacing bricks as the material of choice for walls and concrete took the place of wood on roofs during the 1960s. These were the materials used in the construction of large housing projects built in the region over the last 20 years (UABC, 1990).

A survey conducted in 1989 for CFE (UABC, 1990) showed that Mexicali's houses have characteristics that favor large cooling loads [10]. The survey was done on a sample of 1,200 customers with a range of summer monthly consumption from 200 to 2,000 kWh. The survey did not include aspects of the dwellings that affect the levels of air infiltration and that I think are important.

Among the most important results of the survey were the following:

• only 40% of the houses have concrete roofs, while 60% have wooden roofs with A-frames;

• houses with concrete roofs have the higher levels of electricity consumption (which, more than a result of the fact that the house has a concrete roof, is a result of the income levels of those who live in houses with this type of roof);

• concrete roofs have thicknesses of 4 to 8 inches;

• 40% of the houses have brick walls, 30% concrete block, 20% adobe, and the rest wood;

• only 15% of the houses have some kind of insulation;

• most of Mexicali's houses have masonry walls with fine finishes;

• only 30% of the houses are painted with light colors, while more than 50% of are painted with medium colors and the rest have dark colors;

• there is less than one tree per house (trees have the effect of shading the houses, and also work as air coolers through evapo-transpiration); and

• most of the houses have exterior concrete floors with no thermal breaks (the absence of thermal breaks allows for the heat collected on the horizontal surrounding surfaces to be conducted into the house through the walls).

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[10] Outside weather conditions and the sun combine to produce a cooling or heating load through a building's envelope. The load depends on: (a) the thermal characteristics of the walls, roof, fenestration, floor, interior building furnishings, and construction, and (b) the driving force resulting from the inside and outside conditions (including solar) and the inside conditions (McQuinston and Spliter, 1992.)

5.5.2. Characteristics of the air-conditioning devices

The second main factor that affects the intensity of electricity consumption in Mexicali is the characteristics of the air-conditioning devices.

Most of the residential customers in Mexicali make use of evaporative coolers[11]. According to the survey by UABC in Mexicali (UABC, 1990), an estimated two thirds of the residential customers have evaporative coolers while one third have compressor-based units.

In order to establish the cost of air conditioning in Mexicali I visited the city in the summer of 1990. Based on Yellow Pages of Mexicali's phone directory, I either phoned or visited 22 different businesses (out of about 40 listed) that either sold or repaired systems used for air conditioning. I asked for the model, price, Energy Efficiency Ratio (EER)[12], warranties, and installation cost for units of a specific capacity (which I radmonly chose). At places where the units are repaired, I asked for the price of maintenance and for a description and cost of repair of the most common failures.

In the survey I also asked about used air-conditioning units. These units are not sold by the established merchants but are sold at flea markets. Unfortunately I was

[11]There are two basic types of cooling devices that are used for cooling air. One is the evaporative cooler, which operates with electricity and water and that cools non-saturated air by extracting heat from the air to increase its relative humidity. The second is the compressor-based AC-unit that operates with electricity. It cools the air that goes through a heat exchanger (condenser) containing a refrigerant fluid that goes through a compression stage allowing it to cool. The evaporative coolers require less power than the compressor-based devices, but can only work well where the relative humidity of the air is low.

[12] The EER is equal to the heat extraction capacity of the compresor-based air-conditioning unit (in BTU/h) divided by the power of the motor of the compressor (in Watts).

not able to visit any of these markets. There was, however, a consensus among those who I asked that a very high fraction of the market of compressor-based air-conditioning units are used units.

According to my survey, in Mexicali the cheapest first-cost option for residential air-cooling is the most energy-inefficient. A used compressor-based unit is up to five times cheaper than a new one and also cheaper than an evaporative cooler (Table 7). This is also the option with the highest operating cost per unit of heat removed: the cost per year of operating a used air conditioners can be more than twice the price paid for the device.

Equipment	Description				Cons./Year(1)		Price	Electricity costs	
	Type	Size	EER	Power (kW)	Elect. (kWh)	Water (m3)	(w/o inst.) (US dlls)	Price(2) ($US/kWh)	Cost ($US/yr)
AC unit	Used	1 ton	5.0	2.40	5184	-	120.00	0.045	233
	New	1 ton	9.0	1.30	2808	-	550.00	0.035	98
	New	1 ton	12.0	1.00	2160	-	N.A.	0.035	76
	Used	3 ton	5.0	7.20	15552	-	300.00	0.090	1400
	New	3 ton	9.0	3.90	8424	-	1300.00	0.075	632
	New	3 ton	12.0	3.00	6480	-	3600.00	0.060	389
	Used	5 ton	5.0	12.00	25920	-	500.00	0.100	2592
	New	5 ton	9.0	6.70	14472	-	1900.00	0.090	1302
	New	5 ton	12.0	5.00	10800	-	N.A.	0.090	972
Cooler	New	40 m3	-	0.33	713	35.6	260.00	0.035	25
	New	80m3	-	0.55	1188	69.1	400.00	0.035	42
	New	120m3	-	0.84	1814	95.0	520.00	0.035	64

Table 7. Characteristics of Air-Cooling Devices on Sale in Mexicali, 1991. (Based on survey done by the author)
(1) Consumption per year calculated assuming 12 hrs/day for 180 days.
(2) Price of electricity based on average price for level of consumption.

While no information is available on the different characteristics of the compressor based units installed in Mexicali (size, age, brands, new or used, window or central, etc.), many of the people I interviewed in Mexicali and Calexico told me that a large percentage of the stock of the AC units installed in the city is bought used through a well established market that brings discarded equipment (including refrigerators) from the U.S. According to the same sources, truckloads of used appliances are brought into Calexico, California and sold there. In the case of AC units, and according to a former distributor of used equipment, the only test performed on the equipment is to demonstrate its ability to provide cool air.

The quality of installation and operation of the AC units also has important effects on electricity consumption. Poor installations are characterized by non-insulated ducts, lack of sealing around the AC units (where it connects with the wall), and sun-exposed units; these are conditions that can be detected with a visual inspection. During my visit to Mexicali in the summer of 1991 I walked through several city blocks of middle-class neighborghoods and looked at many units. These observations indicate a large number of poorly installed and poorly operated units.

5.6. Air-conditioning electricity consumption of Mexicali's residential customers

My estimate of the amount of electricity used for cooling by Mexicali's residential customers in 1991 is 480 GWh. To get to this estimate I made some simple assumptions. I assumed that the per-customer consumption without air conditioning in Mexicali is the same as the total for Tijuana's customers (2.2 MWh/yr)[13]. I then subtracted that consumption from Mexicali's average (5.3 MWh/yr) to obtain 3.08 MWh/yr per customer, which I then multiplied by the number of customers in Mexicali (154,000), which results in an estimated use of electricity for cooling by Mexicali's residential customers in 1991 of 480 GWh. For CFE this 480 GWh/yr represent an annual revenue of 38.4 M$ (@ 0.08 $/kWh)[14], which 20% of CFE's revenues in the state.

For the average power demand of Mexicali's residential customers I estimated 1.43 kW per customer. To calculate this value I assumed that the cooling devices operate 12 hours/day during a six month cooling season (180 days/season), which results in 2,160 hours of operation per yearly cooling season. I then divided the

[13] Tijuana is a good baseline for comparison with Mexicali. Located 200 km. to the west of Mexicali, it has temperate climate and it is also at the Baja California (Mexico)-California (U.S.) border--which I assume indicates similar lifestyles and appliance saturation levels.

[14] 0.08 $US/kWh was used assuming that the kilowatt-hours used for cooling are "on-top" of the rest the consumption, thus costing more than the average price.

average 3.08 MWh/yr by the 2,160 hrs/yr , resulting in the 1.43 kW. The coincidental power demand of Mexicali's residential customers cooling-devices would therefore be (assuming that all of them are on at the same time) 220 MW, which is 16% of BCN's installed capacity and 22% of maximum coincidental demand.

5.7. Economic impacts of air-conditioning electricity consumption in Mexicali

The economic impact that electricity consumption has on Mexicali's household incomes and on CFE's finances is a very important issue, which is reflected in the social activity in Mexicali on the issue and on the special attention that CFE has payed to the city.

5.7.1. Estimate based on surveys

Analyzing a survey of 1,200 households, Sandez (UABC, 1990 and Sandez 1991) estimated that the economic impacts were inversely proportional to household income. According to Sandez (1990), those households with incomes of less than 100 $US/month (one minimum monthly wage) used 17.7% of their income to pay for electricity, while those households with incomes above 350 $US/month (eight minimum monthly wages) used 4.1% or less of their household income in electricity.

Although the numbers show impacts greater than the national averages (which is expected for a city that has a large end-use like air conditioning), the social distribution of economic impact may not be correctly represented in the survey used by Sandez to reach his conclusions.

First, anecdotal evidence that I have collected from people that live or that have lived in Mexicali gives me the impression that the impacts on middle class households are greater than what Sandez estimates. Second, the survey is limited to customers with summer monthly average consumptions above 200 kWh/month and below 2,000 kWh/month. The problem with the use of this range is that more than 30% of the residential customer-population of Mexicali consumes more than 2,000 kWh/month (Fig. 31).

A simple calculation also shows the limited scope of the survey used by Sandez. A household with a 5 ton unit (the type of unit that is common on the roofs of many middle class dwellings) with an EER of 5.0 (which would have a power of 12 kW) would have to operate less than 5 hours/day in the summer months to have been considered in the survey (assuming that the household uses only 200 kWh/month for the other electric devices).

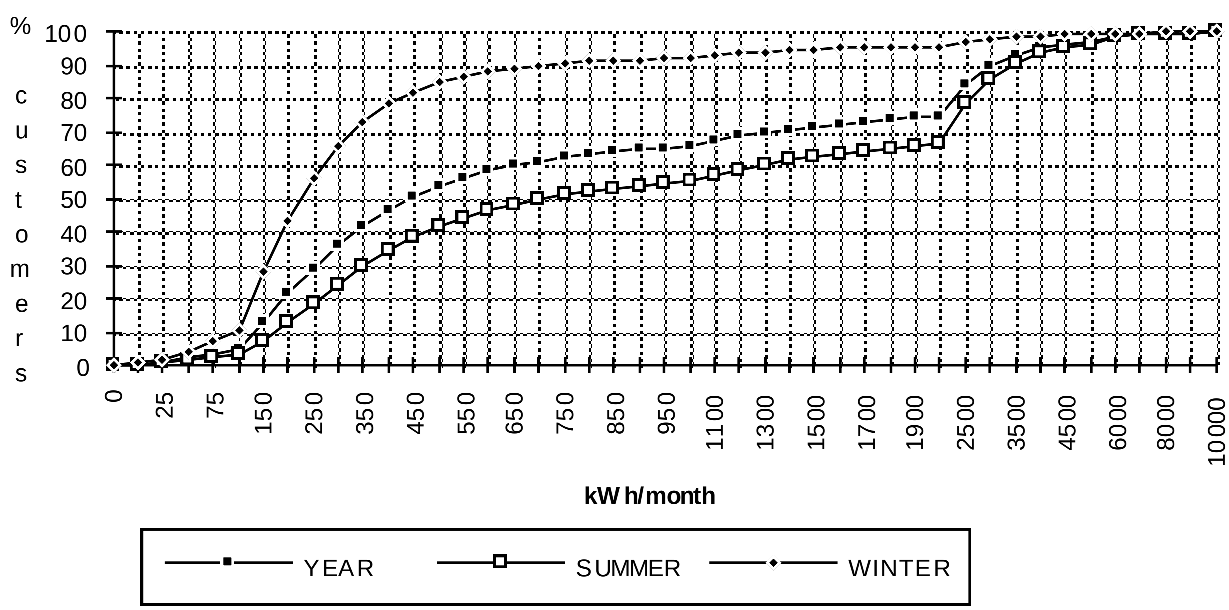

Figure 31. Distribution of Monthly Electricity Consumption by Residential

Customers, Mexicali, Baja California System, 1989. RDS: CFE (1990c)

5.7.2. Estimate based on utility and income distribution data

Using a different approach, based on aggregate electricity-consumption and income-distribution data, I arrived at a different estimate of the economic impacts of electricity consumption on the customers.

My basic assumption in this approach was that there is a correlation between income and electricity consumption. This assumption allowed me to match the cumulated percentage of customers (Fig. 31) with the cumulated percentages of the ten levels of income-per-household levels that were obtained in the UABC survey (UABC, 1991). Using Figure 31, I was able to obtain graphically the average monthly summer, winter, and annual consumption for these groups[15]. Expenditures were then calculated using the average kWh price for that consumption level (Fig. 32).

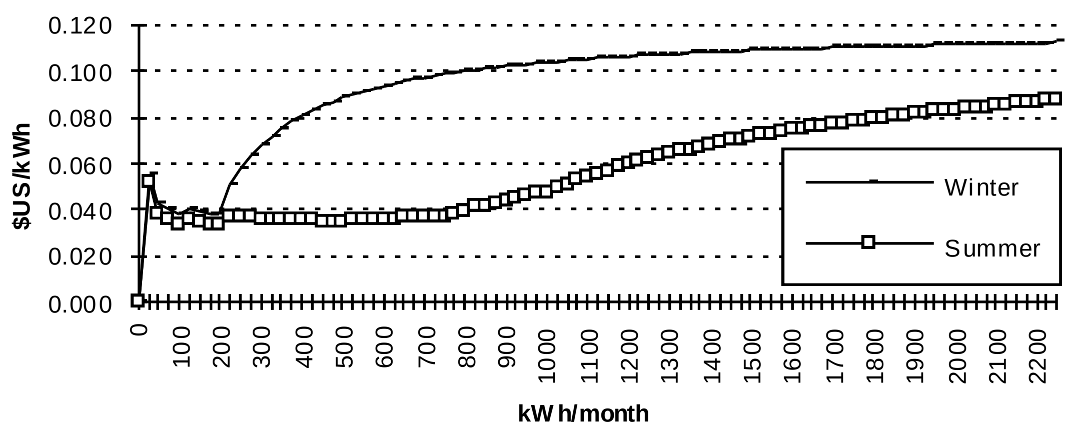

Figure 32. Average Price of Electricity for Residential Customers, Mexicali, Baja California System, 1989. RDS: (Acuerdo, 1989).

[15]To calculate consumption, the middle point between the two values that defined the cumulative percentage of customers in a given income range was used.

The results obtained with this approach are different from the results obtained by Sandez. My calculations indicate that the greater economic impacts of electricity consumption are for households in the income ranges that go from 500 to 1,100 $US/month. These households, which can be considered middle-class households, represent 28% of Mexicali's households. For this set of customers the impact of electricity consumption ranges from 12.1 to 21.3% of the total income of the household in one year. In the summer the impact is greater, going from 21.4 to 32.5% of the monthly income.

Coincidentally, the set of households most impacted by electricity use seems to be the one that uses compressor-based devices, which are those that have power greater than 1 kW (Table 8). I calculated this electric power by dividing the cooling consumption estimate by 6 months (per cooling season), 30 days (per month), and by 12 hours (per day). The estimated fraction of households that have compressor-based cooling units is about 30% of the population, a value that coincides with the survey results mentioned above.

% of House-holds	**Per-Household Income Range** (min. wages)	**Consumption (kWh)**			**Cooling Consumption** (kWh/yr)	**Power** (kW)	**% of income**	
		Monthly		**Yearly**				
		Summer	Winter				summer	year
2.7	0-1	25	10	210	90	0.04	1.25	0.88
4.6	1-1.5	75	35	660	240	0.11	2.00	1.47
12.0	1.5-2	160	75	1410	510	0.24	2.96	2.14
24.6	2-3.5	310	125	2610	1110	0.51	3.10	2.18
23.0	3.5-5	700	190	5340	3060	1.42	7.00	4.45
10.7	5-6.5	1600	275	11250	7950	3.68	21.42	12.19
9.8	6.5-8	2350	410	16560	11640	5.39	26.44	15.53
4.6	8-9.5	2900	650	21300	13500	6.25	28.08	17.46
2.9	9.5-11	3650	1000	27900	15900	7.36	32.52	21.26
5.1	11 or more	5000	1600	39600	20400	9.44	16.67	11.27
-	Average	700	225	5550	2850	1.32	4.29	2.84

Table 8. Estimated Economic Impacts of Electricity Consumption on Residential

Customers, Mexicali, 1991.

It should be noted that my approach may underestimate the impact of electricity-use among low-income population, in particular those households with an income of less than 150 $U.S./month. One consideration is that the consumption of this group is below a realistic consumption level (a 100 Watt bulb operating 12 hrs./day consumes 35 kWh/month which is greater than the consumption estimates for the lowest income group). The effect on this group is not so much economic but reduced comfort. One of the conclusions from the survey done by the Autonomous University of Baja California (UABC, 1990) was that households with lower incomes and electricity consumption had lower levels of comfort than those with higher incomes and electricity consumption.

5.8. Environmental impacts of residential air conditioning in Mexicali

The most significant environmental effect of electricity use for residential air conditioning in Mexicali is air pollution. Most of that pollution comes from fuel-oil based power plants, which are used for peak load; geothermal ones are used for baseload. It is important to note that electricity used for air conditioning is demanded at peak load. Assuming that all of the energy generated for air conditioning comes from fuel-oil plants, the fuel used to generate the 470 Gwh needed for air conditioning will be about 130,000 tons of fuel-oil per year. This amount of fuel-oil represents an emission of 5.9e3 tons of SO_2, 870 tons of NOx, 820 tons of hydrocarbons, 420 tons of particulates, 4.5e5 tons of CO_2, and 80 tons of CO into the atmosphere during the summer months[16].

[16] Emission factors were obtained from "*Environmental Costs of Electricity*" Pace University, Center for Environmental Studies,, Oceana Publications Inc., New York, 1991.

The fossil fuel plants that generate peak load electricity in BCN are not located in Mexicali but south of Tijuana, resulting in air pollution far away from where the electricity is used. So far no air quality monitoring has been done in Tijuana. The neighboring city of San Diego, however, has the second highest rate of ozone non-attainment days in the U.S..

The cooling system for the Rosarito plants operates by exchanging heat with Pacific Ocean water, which receives about 930 GWh (8.0e11 Kcal) of heat rejected during the generation of the electricity used for residential air-conditioning in Mexicali.

5.9. Energy efficiency potentials

Because of the large thermal loads and the inefficient air conditioning devices used in housing in Mexicali, there is a large potential for energy conservation.

Potential electricity savings could result from replacing low-efficiency compressor-based air conditioning units. Assuming that the average AC unit used by 30% of the customers (50,000 customers) is a 1.5 Ton, EER=6 unit (2 kW/ton), and that the levels of comfort remain constant, the savings potential of increasing the average EER of all the units from 6 to 12 is 150 GWh/yr; the estimate for demand reduction is about 1.5 kW per customer, or about 75 MW.

Assuming that CFE pays for the replacement of 50,000, 1.5 ton (average), EER=6 units (2.0 kW/ton) with an equal number of new, EER=12 (1 kW/ton) at a cost of 500 $US/ton (500 $US/kW), CFE could avoid the installation of 75 MW capacity for less than the cost of building a plant of that capacity (2*37.5 MW conventional thermal @ 1.3 M$US/kW). Furthermore, CFE would also avoid all of the effects on the environment that generating 150 GWh/yr represents.

5.10. CFE's energy conservation programs in Mexicali

Starting in 1991 CFE created a fund to give loans for the installation of insulation on roofs and walls of customers with consumptions of more than 1,000 kWh/month in the summer (who, according to my estimates, are those who are the most effected by their energy bills.) The program consisted of a loan of about $1,200 US for the customers to use to contract the installation of either wall and/or roof insulation. The loan is to be paid back in 36 months with no interest, by installments of 35.0 $US/month charged directly on the electrical bill. The program, that is extensively advertised with the claim that it can save up to 30% of the customer's electrical bill, had 4,625 participants by the end of the first summer it was operational (Gutierrez, 1991). For a customer who uses 1,000 kWh/month in the summer, 30% savings represents, at 0.095 $US/kWh, 28.5 $US/month. The cost of the insulation in Mexicali ranges from 10 to 13 $/m2 (which allows insulation of up to 100 m2).

The insulation program also includes an "interruptible" rate-option that allows CFE to turn off AC units for 15 minute intervals from 2 to 6 PM in the afternoon. This is an additional option for those who insulate their homes and offers them a reduction on their electrical bill by a fixed amount. By the summer of 1991, the program had 2,500 participants, most of whom have 5-ton units, resulting in 17 MW of controllable load. According to a CFE official in Mexicali, there has not been, however, the expected rate of participation in the "interruptable" part of the program. The official believed that customers feared that their old equipment would fail as a result of the forced cycling of the devices.

6. POLICY OPTIONS

There is a wide range of approaches that can be applied to meeting the electrical demand in northern México. These options, however, fall into two basic categories: those that require increasing the installed capacity for power generation (supply side), and those that involve measures that reduce the need for new power plants (demand side).

6.1. Supply Approaches

The supply alternatives are the traditional ones and are those most likely to be followed by CFE. CFE (1992d) has defined under the present Mexican legal structure, six ways to cover the energy and power demands of Mexico's electric sector.

Projects done by CFE. Most of the projects considered in the short run by CFE fall into this category, but CFE has serious financial restrictions that limit its ability a to cover fully the projected expansion of the power demand with its own income.

Energy and firm capacity imported from the U.S.. While Mexico has already imported electricity and firm capacity from the U.S. as a partial solution, CFE's plans do not include this as a major option. According to CFE's 1992 construction and investment program (CFE, 1992d), less than 1% of the total energy requirements of the power sector[17] will be met with imports, and the imports are only needed until 1996.

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[17] The POISE estimates a maximum of 1,005 GWh/yr being imported from the U.S. (out of more than 120 GWh that are estimated as the national total.)

This option faces serious technical limitations due to northern Mexico's limited electrical interconnections with the U.S. The most important power interconnections (230 kV) only allow for the transfer of 408 MW, and are already being used to send electricity to the U.S. (CFE to SDGE and SCE) Others include three 138 kV interconnections between the CFE's Northeast system and Texas and two interconnections (115 and 69 kV) between CFE's substations in Ciudad Juarez, Chihuahua and El Paso Electric in El Paso, Texas. These connections are relatively small and are not used for regular transfers but for emergency situations (USDOE and SEMIP, 1992).

Construction of self-generation installations, with excess generation and capacity to be sold to CFE. The construction of self-generating power plants seems to be the option that represents the largest part of the new capacity built by private investors in northern Mexico. One large project of this type in northern México is currently being assembled. The project is the Carbon II plant, a 1,400 MW coal- and oil-fired power plant in Piedras Negras, Coahuila. In this project, a foreign investor, Mission Energy, has acquired the right to build, lease and transfer 49% of the plant, while Grupo ACERERO (a Mexican conglomerate) will hold the other 51%. CFE will hold operate the plant and buy any excess capacity.

A second scheme of this type is being negotiated with investors from Monterrey who own large industrial installations that require new capacity and would share it with CFE (Fin a subsidios, 1992.) The project will be co-developed by Electricité de France International, an affiliate of the national French utility, and by Southern Electric International, an affiliate of an Atlanta, Ga. utility. The project totals 1,125 MW in two gas-fired plants and will be located in the city of Monterrey.

Construction of co-generation plants by private investors in Mexican territory. Co-generation (producing process heat and electricity at the same time) is an alternative actively promoted by the Mexican government all around the country. In the border areas, however, it may have limited possibilities because the predominant industrial installations in the area (maquiladoras) are not the type that require large amounts of heat (thus producing ecxess heat for co-generation.)

Leasing schemes for projects identified by CFE. This alternative is being used mainly for transmission projects, in particular to obtain resources for the construction of new substations.

Co-investments by CFE and other beneficieries in multiple-purpose projects. No projects were identified under this scheme.

6.2. Costs of the Supply--Side Alternatives

According to CFE all of the supply alternatives have to comply with the cost estimates defined by the utility in the "Costos y Parámetros de Referencia para la Formulación de Proyectos de Inversión en el Sector Eléctrico" (COPAR) (CFE,1990c) (Table 9). Capacity costs (calculated for start of operations) range from as high as 1,848.5 $US/kW for a 2*32.5 MW diesel plant to as low as 385.5 $US/kW for a gas-fired 30 MW turbogas plant; generation costs range from a low of 0.046 $US/kWh for a 2*350 MW dual-coal plant without a desulfurator to 0.13 $US/kWh for a diesel-fueled 30 MW turbogas plant. These costs do not include transmission and distribution costs.

Type of Plant	Size (MW)	Fuel	Eff. (%)	Plant Factor	COSTS Capacity ($US/kW)	Generation ($US/kWh)
Conventional thermal	2 * 350	Fuel oil	33.89	0.650	829.5	0.053
	2 * 160	Fuel oil	33.89	0.650	999.4	0.061
	2 * 84	Fuel oil	31.88	0.650	1164.1	0.067
	2 * 37.5	Fuel oil	29.38	0.650	1375.5	0.077
Turbogas	1 * 30	Gas	23.62	0.125	385.5	0.108
	1 * 30	Diesel	23.06	0.125	396.3	0.130
Combined Cycle	1 * 250	Gas	38.41	0.550	897.3	0.064
	1 * 250	Diesel	37.67	0.550	914.1	0.077
Diesel	2 * 32.5	Diesel	45.70	0.650	1848.5	0.073
Coal	2 * 350	Coal	36.35	0.650	1294.3	0.050
Dual-Coal wo/desulfurator	2 * 350	Coal	39.96	0.650	1359.1	0.046
Dual-Coal w/desulfurator	2 * 350	Coal	39.96	0.650	1750.9	0.058
Geothermal (Cerro Prieto)	2 * 110	-	-	0.800	936.9	0.054
Hydro	3 * 320	-	-	0.250	1348.7	0.067
	2 * 120	-	-	0.210	984.3	0.063

Table 9. CFE's Capacity and Generation Costs, 1990. RDS: CFE (1990c)

6.3 Environmental Implications of the Supply Alternatives

Water availability and air pollution are serious problems in the Mexican northern border states. Power plants in the region are important contributors to these problems.

6.3.1. Air pollution

In 1990 more than 82% of the 35,875 GWh generated in the northern states came from fossil-fuel plants (Fig. 33). Table 10 shows estimated emissions of selected air pollutants by the power sector at a national and regional (northern border states) level. The table shows a larger than proportional (to the fraction of electricity generated in the region) contribution of the northern states in the emission of nitrogen oxides (NOx)[18] and carbon dioxide (CO_2). Also important, but with a contribution slightly smaller than their fraction of electricity generation, are the sulfur dioxide and methane emissions.

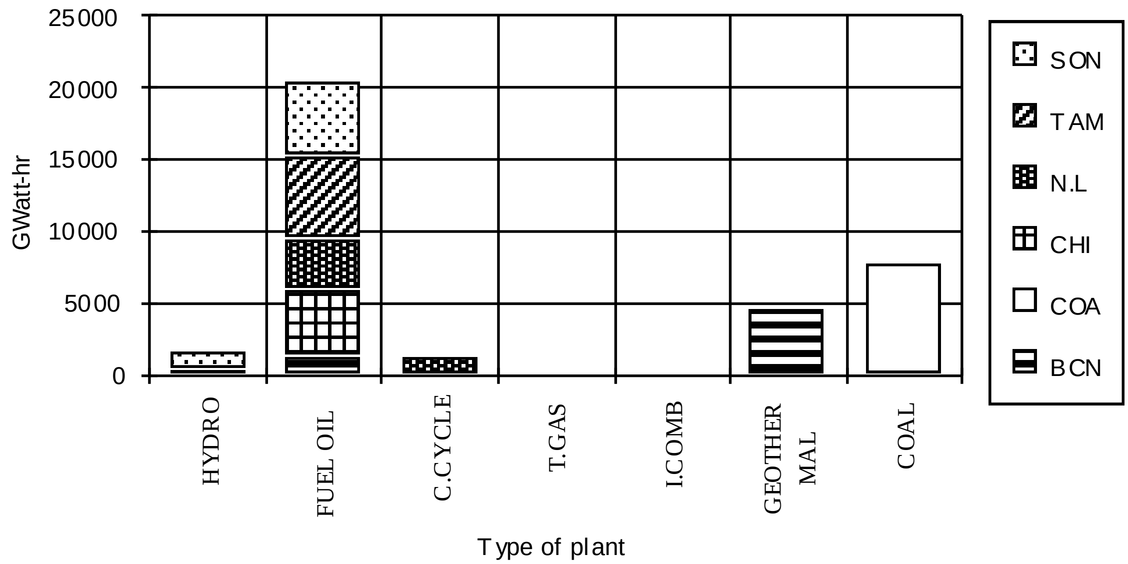

Figure 33. Generation by Type of Plant, Northern Border Sates, México, 1990. RDS: CFE (1991a)

	National (MTons)	**Northern Sates** (MTons)	**% North**
SO2	660	205	*31.03*
NOx	123	54	*44.04*
CO2	55,733	23,474	*42.12*
HCs(methane)	98	33	*33.92*

Table 10. Power-Generation Air-Pollutant Emissions of Selected Pollutants by Power Plants, National and Northern Border States, Mexico, 1990.

[18] Nitrogen oxides are, together with hydrocarbons in the air, precursors of ozone.

The two fastest growing cities on the northern border with major power plants have air quality problems. In Ciudad Juárez, Chihuahua and El Paso, Texas U.S. National Ambient Air Quality Standards for lead, carbon monoxide, ozone, and total suspended particulates (PM-10) are not met, most of this is a result of emissions originated in Ciudad Juárez (Applegate *et al*.,1989). In San Diego, California (which shares an air basin with Tijuana) the number of days exceeding the National Ambient Air Quality Standards for ozone was 26 (REF). This made San Diego the city with the second highest number of non-attainment days in the U.S..

6.3.2. Water Consumption

Fossil-fuel plants are also large water consumers. To generate one kWh of electricity a fossil fuel plant requires from 1.0 to 3.8 liters of water, most of which is evaporated into the atmosphere through cooling towers. Assuming that 82% of the 35,875 GWh generated in the region came from fossil-fuel plants, that all of the cooling was done with cooling towers, and that 2.5 liters are needed per kWh, about 74 million cubic meters are consumed every year by northern Mexico's power plants. This is about 2 cubic meters per inhabitant of the northern border states.

On the border, the most critical water shortage occurs at El Paso-Ciudad Juarez. Each city obtains more than 90% of its drinking water from the Bolson del Hueco and is pumping water at a such a rate that the aquifer is expected to last no more than 10 years (Sanchez R., 1991). Mexicali gets 1.5 million acre-feet (1.85 billion cubic meters) of water from the Colorado River. The local government estimates that the local acquifier is already being overdrawn at a rate 50% greater than the average 700 million cubic meters of water it gets every year (Ayuntamiento de Mexicali, 1989).

According to CFE's plans the fossil-fuel share of total electricity sources is forecasted to increase from 67% in 1989 to 79% in 1997. Most of this fossil-fuel based new capacity will be installed in northern México (OLADE, 1991).

6.4. Demand-Side Alternatives

Addressing the problem of intensive use of electricity for air-conditioning in the existing stock of dwellings and devices is not simple but may be more cost effective than building new power plants. The main problem is, however, that each dwelling is a particular case and the cost effectiveness of energy conservation does not just depend on the efficiency of a single device, but on how the house was built, on how it is used, and how the device is operated.

6.4.1. Existing dwellings.

Many alternative measures can be applied to a dwellings to save electricity. These can be classified as related to the shell or related to the air conditioning unit. Although the measures can be applied in any order, it will be most cost effective, for dwellings that were not designed and built according to the local climate, to install energy conservation measures in the shell before something is done to the electric device that provides the cool air (particularly if the device is going to be replaced).

Shell measures. One of the most cost-effective energy conservation measures for a poorly designed and constructed house in a Mexican dry-hot-climate location is roof insulation with a reflecting surface. The reason for this is simple and has to do with the fact that the roof is the area most exposed to solar radiation. In the case of houses with non-insulated concrete roofs, the roof is also an important mass that collects heat during the day and releases it into the house during the night.

Other measures that involve shell modifications may also have an important effect. Conductive gains can be reduced by insulating the walls, particularly the ones to the east and to the west; they can also be reduced by de-coupling the walls from the surrounding horizontal masonry surfaces. Solar gains can be reduced using internal or external shades or polarizing the windows. Infiltration gains can be reduced by weatherizing windows and doors to reduce the exchange of air between the inside and the outside.

Similar or greater cost-effectiveness may be obtained with other and simpler measures in other parts of the dwellings. Solar gains can be reduced by installing overheads that shade the windows, using light colors on exteriors (increasing the surface's reflectivity), changing the textures of the walls (to increase heat transfer by convection to the surrounding air), and by planting shade trees on the sunniest sides (to reduce solar gains but also to cool the surrounding air.)

Air conditioning system measures. The most radical measure on the air conditioning system is to replace the present device with a more efficient one. In the case of compressor-based air conditioner, the replacement can either be a more efficient compressor-based air conditioner or an evaporative cooler. The cost-effectiveness of this replacement will depend on the efficiency of the device being replaced. Determining the efficiency of the installed system may not, however, be simple and may involve a relatively expensive procedure.

Other, less radical, measures involve better maintenance and operation of the cooling equipment. A yearly checkup in which heat exchangers are cleaned, air filters replaced, fans are oiled, and coolant volume revised (and repaired if a leak is found) will help increase comfort and reduce energy use. Also important is to check the quality of the installation, which may have air leaks around the units and that may be gaining heat through the ducts (that may not even be insulated.) Also important are the thermostats, which should be calibrated to allow for a proper adjustment of the delivery of cool air.

The cost effectiveness of all these measures will depend on the conditions of the dwellings and of the cooling devices. Also important is the economic impact that air-conditioning has on a specific household, which is what may finally determine the decision to reduce energy use by investing in conservation.

Higher electricity tariffs will probably drive many households into action. The problem here is what alternative paths are followed. One path may be to act politicaly and participate in social actions to get, as in the past, special tariff treatment. The other one, however, may be to invest to reduce electricity use by using it more efficiently. The extent to which this path is followed will depend on how the energy conservation alternatives are perceived by those who make the decisions in the household. Some type of financial support to implement the measures and good information about all the implications of the alternatives thus become very important public policy. The way in which the utility and the different authorities (local, state, and federal) present the alternatives may be just as important as the availability of the alternatives themselves.

Also important, however, is the availability of all the materials, the equipment, and the trained personnel necessary to apply these measures in the houses. As the Mexicali experience seems to demonstrate, there has been no problem in making available in the market all kinds of insulating materials. The problem seems to be more on the avaliability of equipment and trained personnel. As an example, while in the U.S. (and California in particular) the market for efficient air conditioners has expanded greatly, no high efficiency compressor-based devices were available in the market in Mexicali during my 1991 visit.

The problem of lack of trained personnel does not relate to lack of technicians to install insulation or to install and repair air-conditioning devices. The problem has to do with a lack of professionals that can play the role of what has been called "house doctors". A "house doctor" is a specialist that can audit a house using a set of monitoring and analytical tools (manual and computerized) that allow for a better identification of the best conservation options for both shell and equipment.

6.4.2 New housing.

The most important policy in the long run is the creation of building standards that mandate certain shell and equipment characteristics for new construction. These standards, that are not to be enforced by CFE but by local authorities, should minimize the heat gains of the dwellings and maximize the efficiency of the cooling units.

There are, however, some structural problems that cannot be addressed by standards alone. The first of these problems has to do with construction materials, which are generally poorly characterized in terms of their thermal characteristics. The second problem is that it seems that the most common materials in the market (cement blocks) are not the best in terms of thermal performance. To thermally enhace the houses built with these materials requires the use of materials that make the overall insulating cost higher than other new, cheaper construction methods and materials coming into the market. A third problem is precisely the quality and performance of these new construction methods and materials, which should be tested carefully before being used widely in the market.

A second type of problem relates to the avalialabilty and the price of the most efficient air-conditioning devices. Regarding availability, eliminating import tariffs would reduce price and increase the demand. A measure of this type may, however, face the opposition of national manufacturers, but this opposition may either come too late (the market is already dominated by the foreign manufacturers), or may result in governmental support that helps them transform their products and production to compete in the market.

Regarding the problem of price (with high prices making it difficult for the customers to buy the more efficient devices) there could be some help from the utility, which could offer rebates for efficiencies above a threshold.

The most serious problem for the implementation of energy-conservation construction-standards is, however, the large fraction of the housing stock being constructed without permits (also known as self-construction). Just in Mexicali an estimated 65% of the housing stock was designed and built by its owners. This non-regulated sector of the housing market, which is that of the low-income population, may not be, as the case of Mexicali shows, the one that has the higher intensities of electricity use. The sector is, however, important. As families get established and get more affluent they will tend to buy cooling equipment that will be operated in houses that were built with greater regard to cost than to thermal efficiency.

7. CONCLUSIONS

The historical period covered in the previous chapters was marked by substantial changes in Mexico's economy. At the same time that the role of the goverment as the driving force of the economy has diminished, integration to the world markets has brought rapid growth to the northern border states. These two processes have resulted in insufficient infrastructure for several of Mexico's northern border cities, a situation that may complicate the future economic growth of the cities, the region, and Mexico.

Based mainly on assembly lines where electricity is the most common form of energy, the economic development of northern Mexico has meant high industrial electricity growth rates, which has accelerated the need for new generation capacity in the region. This has represented an important challenge for CFE, which in the same period has had to stop using debt as its main source of income and redefine its sources of funds for new investements.

Higher electricity tariffs and greater private investment are two of the main effects that the new circumstances have had on CFE. Residential electricity tariffs, however, are still subsidized and require to go up, at the least, 40% from their present average price. Private investment, on the other side, requires a rate of return that is competitive with other investment opportunities. If residential electricity tariffs are not priced at their real cost, other sectors will have to pay the difference.

Although industrial electricity consumption has grown faster than residential consumption in northern Mexico, previous developments show how, as population settles in new industrial cities, the residential demand keeps growing at a steady rate. This development is very important because the power demand of the residential sector represents a high fraction of peak demand.

The intensity of residential electricity consumption is higher in northern Mexico than in any other region of the country. This higher intensity is a result of the region's climate, but also of very inefficient use. Inefficient use is a product of both the widespread use of low-efficiency devices and of poorly designed houses.

Higher intensity results in greater economic impacts on the population's income, which is not growing (and probably will not grow) as fast as the electricity tariffs. Higher economic impacts have resulted in greater awareness and criticism of CFE's actions in northern Mexico than in other parts of the country. Tariff increases to residential rates may face strong opposition of groups already organized in political parties opposed to Mexico's governing party.

At the same time, the environmental impacts of greater power demand in northern Mexico are another important issue that has to be taken into account. Primarily based on fossil fuel plants, electricity use in northern Mexico has great impacts on air pollution and water consumption in the region.

The situation calls for new approaches to power demand, particularly to residential power demand. Installing new power plants is something that may not be avoided if the region is to fully develop. But, in a region where residential electricity use is highly inefficient, other options are cheaper in the short and medium run than new capacity, which would reduce the economic impact on households and the pressure to finance and build new power plants.

New approaches, however, have to go beyond the jurisdiction of CFE. Policies to stop the flow of inefficient-second-hand air-conditioning devices into the region fall into the category of fiscal and trade policies. New construction standards fall into housing policies. Training personnel to play the role of "house doctors" requires the creation of new programs of technical training and fall into education policies.

The electricity demand of northern Mexico's residential-sector thus represents a serious technical and political challenge for decison makers in the power sector in particular and in Mexico's federal government in general. Acting on power demand in the region rather than increasing its supply is an alternative that requires serious consideration. Demand side management is a strategy that has proven economically and technically feasible in many electric utilities in the U.S.. In the case of Mexico's air-conditioned residential sector, however, demand-side alternatives may be promoted more as a result of political necessity than from its proven economic logic.

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