First Edition

Guide to Electric Power in Mexico

September 2006

Center for Energy Economics
Bureau of Economic Geology, The University of Texas at Austin
and
Instituto Tecnológico y de Estudios Superiores de Monterrey

PREFACE

This First Edition of Guide to Electric Power in Mexico was prepared to provide a comprehensive and balanced educational resource for a wide range of electricity customer groups, from interested residential consumers to large commercial and industrial organizations. It is modeled on the Guide to Electric Power in Texas, conceived of and prepared in 1997 by the Houston Advanced Research Center (HARC) and the Center for Energy Economics (CEE) now based in the Bureau of Economic Geology at the Jackson School of Geosciences, the University of Texas at Austin (then at the University of Houston).

The Mexico guide stems largely from work undertaken since 1991 by Dr. Francisco García independently and jointly with Dr. Michelle Michot Foss of CEE to explore issues in Mexico's energy sector. Dr. García, an emeritus professor at the Instituto Tecnológico y de Estudios Superiores de Monterrey (ITESM), has been teaching and conducting research on energy and resource economics for more than 15 years. The ITESM is one of the most prominent universities in Mexico and an international partner with the University of Texas-Austin. Also, the ITESM is a campus-wide higher education system that is spread all over México. Inside the Monterrey Campus, operates the Center for Energy Studies that is based in the Engineering Division and the former Center for Strategic Studies that now is part of the Graduate School of Public Policy. Dr García has been doing research on the Mexican Economic Policy, Regional Development and Econometric Modeling. Dr. Garcia and Dr. Foss published joint research on the Mexican Markets of Natural Gas, LPG and Electricity. More information about ITESM and its programs and Dr. García's research can be obtained from www.mty.itesm.mx/profesores/

The CEE is a university-based research, education, and outreach center of excellence. Our main focus is on the investment frameworks that support sustainable, commercially successful energy resource and infrastructure investments worldwide. The CEE team specializes in interdisciplinary approaches (economic, business, technology and policy/regulatory) that best optimize energy value chains, from energy resource exploration and production, to transportation and distribution, and conversion and delivery for end use. Research, training and outreach undertaken by the CEE team encompass the North American continental marketplace, South America, West Africa, Turkey, Eurasia and Russia. The CEE helps to facilitate energy sector problem solving through an international education program, New Era in Oil, Gas and Power Value Creation held each May in Houston. CEE researchers involved in preparation of this guide are Miranda Ferrell Wainberg, senior researcher and project leader; Dr. Michelle Michot Foss, chief energy economist and head of CEE; Dmitry Volkov, energy analyst; Ruzanna Makaryan, senior energy analyst; Dr. Gürcan Gülen, senior energy economist; and Dr. Mariano Gurfinkel, project manager and associate head of CEE. The CEE is supported by both private and public sector donors. More information about the CEE can be obtained from www.beg.utexas.edu/energyecon.

For free downloads of Guide to Electric Power in Mexico or to make inquiries, please contact:

Center for Energy Economics

Bureau of Economic Geology

Jackson School of Geosciences

The University of Texas at Austin

Telephone 281-313-9753

Fax 281-340-3482

Email: energyecon@beg.utexas.edu

Web: www.beg.utexas.edu/energyecon

The Instituto Tecnológico y de Estudios Superiores de Monterrey http://daf.mty.itesm.mx/investigacion

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Mexico's Secretaría de Energía (SENER) reports internal Mexican electricity consumption as follows:

- SEN (Sistema Eléctrico Nacional) electricity sales which consist of sales made by the two large state owned electric companies, Comisión Federal de Electricidad (CFE) and Luz y Fuerza del Centro (LFC). SEN sales *include* electricity sales made by independent power producers (IPPs) to CFE which CFE then resells to final customers. SEN sales *exclude* electricity generated by end-users, largely industrial companies, for their own use.
- Total internal Mexican electricity consumption includes SEN electricity sales as well as electricity generated by self-suppliers.

Total Internal Electricity Consumption

During the period 1994-2004, total sales of electricity in Mexico grew at an average rate of 4.5 percent per year.[1] This growth has been driven by increases in residential and industrial electricity consumption, including sharp increases in electricity generated by end-users for their own use. (An example of the latter is an industrial facility that generates electricity for its own consumption, termed "self-generation" or "generation for self-consumption.")

The 1994-2004 increase is below the 5.7 percent annual growth rate experienced for the comparable period 1993 and 2003. Nevertheless, the increase between 1994 and 2004 is significantly higher than electricity consumption growth rates experienced in North America and Western Europe for the same period (2.0 percent and 2.3 percent, respectively).[17] Only Asia shows a higher growth rate (7.0 percent).[17]

SEN Electricity Sales

SEN sales of electricity in Mexico grew at an average rate of 4.1 percent during the period 1994-2004. Between 2003 and 2004 SEN electricity sales grew by 1.9 percent, largely due to increased electricity sales to industries. This stands in contrast to virtually no electricity sales growth between 2002 and 2003, the result of an economic slowdown in the country.[42] When generation for self-consumption is added to sales by CFE and LFC, total electricity sales increased 3.9 percent between 2003 and 2004.

CFE generates, transmits and distributes electricity across all of Mexico. LFC is mainly responsible for transmission and distribution of electricity in Mexico City (Distrito Federal, DF or Federal District). LFC buys approximately 95 percent of its electricity supply from CFE.[8] IPPs sell almost all of their output to CFE which then re-sells the electricity to its customers.[2] (IPPs, self-generation and cogeneration will be discussed in more detail in later sections of this chapter).

Most of Mexico's electricity sold by SEN is consumed by industrial and residential customers (59 percent and 25 percent, respectively, in 2004). Growth in these two important sectors has propelled the overall growth in national consumption over the period 1994-2004. Sales of electricity to industries flattened or decreased between 2000 and 2003 due to a slowing economy and declining energy intensity in the industrial sector. However, in 2004 SEN sales of electricity to industrial customers (both large and medium) grew 1.8 percent.[42]

Electricity consumption and economic growth (as measured by gross domestic product or GDP) are closely intertwined. Electricity use per person or per capita tends to be higher in more advanced economies and lower in countries with less developed economies. Despite the growth in electric consumption in Mexico over the period 1993-2003, per capita consumption (KWh/resident) remains low at 1,810 KWh/resident compared to about 8,000 KWh/resident on average for industrialized countries.

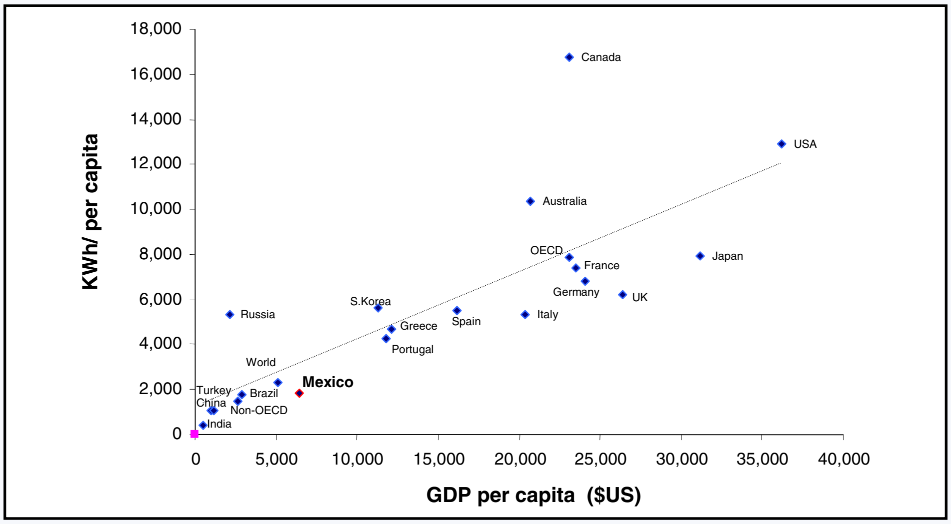

Figure 1. Electricity Consumption and GDP per Capita in Select Countries, 2001

Table 1. SEN Electricity Sales by Consumer Category (GWh)

Year	1994	%	2000	%	2003	%	2004	%
Residential	27,781	25	36,127	23	39,861	25	40,733	25
Commercial	9,844	9	11,674	8	12,808	8	12,908	8
Services	5,306	5	5,891	4	6,149	4	6,288	4
Agricultural	6,551	6	7,901	5	7,338	4	6,968	4
Industrial	60,051	55	93,755	60	94,228	59	96,613	59
TOTAL	**109,533**	**100**	**155,349**	**100**	**160,384**	**100**	**163,509**	**100**

Source: SENER

1 As this book went to press in September 2006, the most recent data available are for 2004.

2 Current electricity law dating from 1993 allows IPPs to operate in Mexico but also limits the amount of "surplus" electricity they can generate and sell to buyers other than CFE. The existing limitation on surplus is 5 percent of generation capacity.

Although richer countries consume more electricity per capita than poorer ones, the energy intensity of their economies is lower. Richer countries use less energy to generate an additional dollar of GDP. In Mexico, energy intensity remains relatively high in spite of marked improvements by certain industries, like steel, to modernize facilities and achieve greater energy efficiencies. Thus, Mexico has yet to demonstrate widespread, sustained, declining energy intensity observed in other industrial countries. If Mexico begins to manifest the declining energy intensity typical of other industrial countries in all electricity consuming sectors, the overall growth rate of total electric consumption could decrease.[23]

Who Uses Electricity in Mexico?

More than 28 million customers (representing over 100 million inhabitants) buy electricity from CFE and LFC. The two organizations provide electric service to approximately 95 percent of Mexico's population. About 88 percent of these customers are residential. There are three million commercial customers and about 166,000 industrial customers. CFE and LFC receive most of their revenue from industrial customers who spent over $7 billion on electricity in 2004. In this same year, residential customers spent $3 billion and commercial users $1.9 billion.[3]

In most countries, large volume industrial customers pay lower tariffs (the final price for delivered electricity)[4] than low volume commercial, residential and agricultural users. This lower tariff for large volume customers reflects lower delivery costs and more stable demand. (Low voltage, dense distribution systems required to serve residential and small commercial "load" or demand are relatively expensive to install and maintain, and in some locations, residential and commercial load can be highly seasonal.)

In Mexico, however, residential customers pay only slightly more than large industrial customers and agricultural customers pay the lowest price of all. In 2004, SEN's average rates for different customer classes were 9.2¢/kWh for residential customers; 7.2-9.7¢/kWh for large and medium size industrial customers respectively; 4.1¢/kWh for agricultural customers; and 14-19¢/kWh for public service and commercial customers respectively.

Mexico's tariff structure is due to electricity prices to residential and agricultural customers being set below the actual costs to serve these customers. All Mexican electricity customers receive discounted pricing. Official figures estimate a total net subsidy of US $6 billion per year. In 2000, residential consumers received 64.1 percent of the total subsidy; industrial customers 17.9 percent; the agriculture sector 11 percent; and the commercial sector 5.3 percent.[5] As a consequence of receiving the largest proportion of the total net subsidy, residential consumers in Mexico receive a tariff that is among the lowest in the world.

Regional Patterns of Electricity Consumption

Electricity consumption across the Mexican regions reflects varying patterns. These regional variations are related to differences in climate and urbanization as well as the different compositions of and concentrations of industrial activity. Over the period 1994-2004 the states with the largest electricity consumption were Sonora, Nuevo León, Jalisco, Distrito Federal, México and Veracruz.[42]

Prior to the North American Free Trade Agreement (NAFTA), maquiladoras (factories that were able to import intermediate goods duty-free and tariff-free for final assembly and export) were concentrated in the northern border states of Baja California, Sonora, Chihuahua, Coahuila, Nuevo León

Table 2. Facts on Mexico Electricity – 2004

Number of Central Stations	187
Number of Generation Units	598
Total Annual Generation[5]	235,600 GWh
Total Generating Capacity[6]	54 GW
Number of Residential Customers	25 million
Number of Commercial Customers	3 million
Number of Industrial Customers	166,000
Number of Agricultural Customers	105,000
Number of Public Sector Customers	152,000
Average Residential Rate	9.2¢/kWh
Average Commercial Rate	19.0¢/kWh
Average Industrial Rate	7.2-9.7¢/kWh
Average Agricultural Rate	4.1¢/kWh
Average Services Rate	14.3¢/kWh
Number of State Owned Companies	2 (CFE and LFC)
Percent Generation by State-Owned Cos.	69 percent
Percent Generation by Private Entities	31 percent

Source: CFE and SENER, 2004-2006

3 The average actual exchange rate between U.S. dollars and Mexican pesos for the year cited is used in this guide to convert Mexican pesos to US dollars and vice versa.

4 The tariff for electric power includes all costs associated with generating, transmitting, and distributing electricity, including operating and maintenance costs and depreciation of the electricity systems and including a rate of return that allows for reinvestment in the electricity systems. Costs for electric power are generally apportioned across classes or categories of customers that reflect amount of usage and the cost to serve particular customer classes. See section on Evolution of Electricity Prices in Mexico.

5 Includes generation by CFE, LFC, IPPS, self-suppliers, cogeneration and exports.

6 Includes generation capacity of CFE, LFC, IPPS, self-suppliers, cogeneration and exports.

Table 3. SEN Electricity Sales by Region (GWh)

Region[7]	1994	% Total, 1994	2000	% Total, 2000	2004	% Total, 2004
Northwest	13,470	12.3	19,949	12.8	22,311	13.6
Northeast	25,626	23.4	39,236	25.3	39,421	24.1
Central West	24,417	22.3	35,192	22.6	37,451	22.9
Central	31,366	28.6	40,733	26.2	41,006	25.1
Southeast	14,600	13.4	20,160	12.9	23,227	14.3
Small Systems	54	--	80	--	93	--
Total	**109,533**	**100**	**155,349**	**100**	**163,509**	**100**

Source: SENER 2006.

Table 4. SEN Regional Electricity Sales Growth Rates (percent over previous year)

Region	1994/93	2000/99	2002/01	2003/02	2004/03	2004/94
Northwest	8.7%	7.8%	-.6%	4.5%	4.9%	5.2%
Northeast	9.9	7.8	2.2	-4.0	0.5	4.4
Central West	9.9	7.3	1.9	1.9	3.3	4.4
Central	5.5	6.5	0.7	-0.8	0.1	2.7
Southeast	7.7	6.3	6.3	2.4	2.9	4.8
Total	**8.2**	**7.1**	**1.9**	**0.1**	**1.9**	**4.1**

Source: SENER 2006.

and Tamaulipas. As a result, electricity sales in the Northwest and Northeast regions grew faster than those in the rest of the country between 1994 and 2000. Following the implementation of NAFTA, the benefits of maquiladora production were extended to other Mexican industries. In addition, the growth rate in the Northeast slowed markedly after 2000 due to a slowdown in economic growth.[23] The Northeast region's electricity consumption rebounded slightly in 2004 but has not reached the levels observed in 2000 or 2001. Since 2000, the Northeast has been surpassed by the Central West region in terms of increased industrial consumption of electricity.

In the Central West region electricity consumption growth in recent years has been greater than 7 percent in the states of Nayarit, Michoacán and San Luis Potosi. This growth has been driven by companies like SERSIINSA, Industrial Minera México, Cementos Apasco, Celanese, Las Encinas and the development of industrial parks like Silao, Apaseo and Buenavista.[42]

Electricity consumption in the Northwest region had the highest growth rate in Mexico over the period 1994-2004 (5.2 percent) followed by the Southeast region (4.8 percent). High temperatures and large industrial consumption drove demand for electricity in the Northwest. In the Southeast, the negative growth rate of Veracruz (which accounts for 37.5 percent of the region's electricity consumption) in 2004 was offset by increased growth in the region's other states, especially Tabasco and Quintana Roo both of which had growth rates in excess of 7 percent.[42]

Evolution of Electricity Prices in Mexico

The price of electricity in Mexico is a function of volume demanded, voltage, user type, and service (interruptible versus firm or guaranteed deliveries). There are currently over 30 tariff categories. The tariff structure is gradually being adapted to reflect the variety of services desired and consumer preferences. The relationship between costs of production and electricity prices and tariffs continues to be debated in Mexico.

Electric tariffs in Mexico are set by the Secretaría de Hacienda (Ministry of Finance) and are thus linked to the government's economic and development strategy for the country as a whole. Unlike practices in most industrially advanced countries, Mexico's independent electric sector regulator, the Comisión Reguladora de Energía (CRE) is not responsible for setting electric tariffs. As a result, electric tariffs frequently have not been compatible with the needs of a financially self-sustaining power sector. Tariffs have tended to lag production costs but the exact relationship between tariffs and costs is difficult to measure due to a lack of credible statistics on the true cost of electricity production in Mexico.[5] In 2004 the average price of electricity in Mexico was 9.9¢/kwh compared to an average production cost of 15¢/kwh, a price/cost ratio of 66 percent.[8] Although real prices of electricity have been increasing since 1999,[23] most observers believe that the more politically sensitive residential and agricultural sector tariffs do not cover costs of production. On the assumption that industry could pay a stiffer rate, there continues to be a cross-subsidy from industrial and commercial users to residential and agricultural users. Industries complain that their electricity rates hamper their ability to compete in global markets. And with artificially low tariffs, residential and agricultural customers have little price incentive to moderate demand.

Table 5. Average Electricity Prices by Consumer Category in US $/KWh

Category/Year	1995	2000	2004
Residential	0.0407	0.0591	0.092
Commercial	0.0971	0.1332	0.187
Services	0.0670	0.1106	0.143
Agriculture	0.0217	0.0303	0.041
Medium Size Industry	0.0391	0.0647	0.097
Large Industry	0.0248	0.0458	0.072
Total	**0.0412**	**0.0636**	**0.099**

Source: www.sener.gob.mx

[7] Northwest includes Baja California, Baja California Sur, Sinaloa and Sonora. Northeast includes Chihuahua, Durango, Coahuila, Nuevo León, Tamaulipas. Central includes Distrito Federal, Hidalgo, México, Morelos, Puebla, Tlaxcala. Central West includes Aguascalientes, Colima, Guanajuato, Jalisco, Michoacán, Nayarit, Querétero, San Luis Potosi, Zacatacas. Southeast includes Campeche, Chiapas, Guerrero, Oaxaca, Quintana Roo, Tabasco, Veracruz, Yucatán.

[8] www.sener.gob.mx

Making and Moving Electricity

The main function of an electrical power system is to transmit all electricity demanded reliably, and in the exact amount, where it is needed. In addition, it should provide for unforeseen contingencies arising from larger than expected demand or system outages. The industry structure has three main segments – generation, transmission and distribution.

Generation involves the process of producing electric energy by utilizing other, primary forms of energy such as fossil fuels (coal, natural gas or oil), uranium (nuclear), or renewable energy sources (solar, wind) into electricity. Transmission is the movement or transfer of electric energy over an interconnected group of high voltage lines between points of supply and points at which it is transformed to lower voltage for delivery to final consumers such as factories or across low voltage local distribution systems to smaller end users such as homes or businesses.

In Mexico, electric generation is provided by the state-owned companies CFE and LFC, independent power producers and industries for their own consumption. Transmission and distribution service are provided exclusively by state-owned CFE and LFC.

Generation

Electric power plants use coal, lignite, natural gas, fuel oil, and uranium to make electricity. Renewable fuels such as moving water, solar, wind, geothermal sources and biomass are also used.

The type of fuel, its cost, and generating plant efficiency can determine the way a generator is used. For example, a natural gas generator with steam turbines has a high marginal cost but can be brought on line quickly, making it useful for peak periods of demand. Coal, lignite, and nuclear units have lower marginal costs but cannot be brought on line quickly. They are used primarily to provide the base load of electricity (e.g. the constant requirement of the power system which is demanded continuously).

Costs for fuel, construction and operations and maintenance vary greatly among types of power plants. For example, renewable generation plants, such as solar or wind, have virtually no fuel costs but are expensive to manufacture and install and can be expensive to maintain. Nuclear and coal-fueled plants have low fuel costs but are more expensive to build and maintain. Coal units also incur additional costs for meeting air quality standards. Natural gas plants have higher fuel costs than coal or nuclear, but have lower initial construction costs.

Generation Providers

Mexicans view energy, including electricity, as a sovereign activity and as such it is the exclusive responsibility of the federal government. By constitutional law, electricity for public service consumption must be provided by state owned CFE and LFC. CFE and LFC are large public enterprises with total assets at year end 2004 of about $63 billion and $9 billion respectively.[8,10] LFC serves Mexico City and the surrounding areas and CFE serves the rest of the country. LFC buys approximately 95 percent of its marketed electricity from CFE.

Reforms to the Law of Public Service of Electricity (Ley del Servicio Público de Energía Eléctrica) passed in 1992 and implemented in 1993 permits cogeneration[9] and generation for self-consumption by private entities (principally industries) as well as generation by IPPs with the requirement that essentially all IPP output is sold to CFE. In 2004, CFE and LFC accounted for 73 percent of effective installed generation capacity in Mexico and private generators accounted for 27 percent of capacity.

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[9] Cogeneration refers to a generating facility that produces electricity and another form of useful thermal energy (such as heat or steam) that is used for industrial, commercial, heating or cooling purposes.

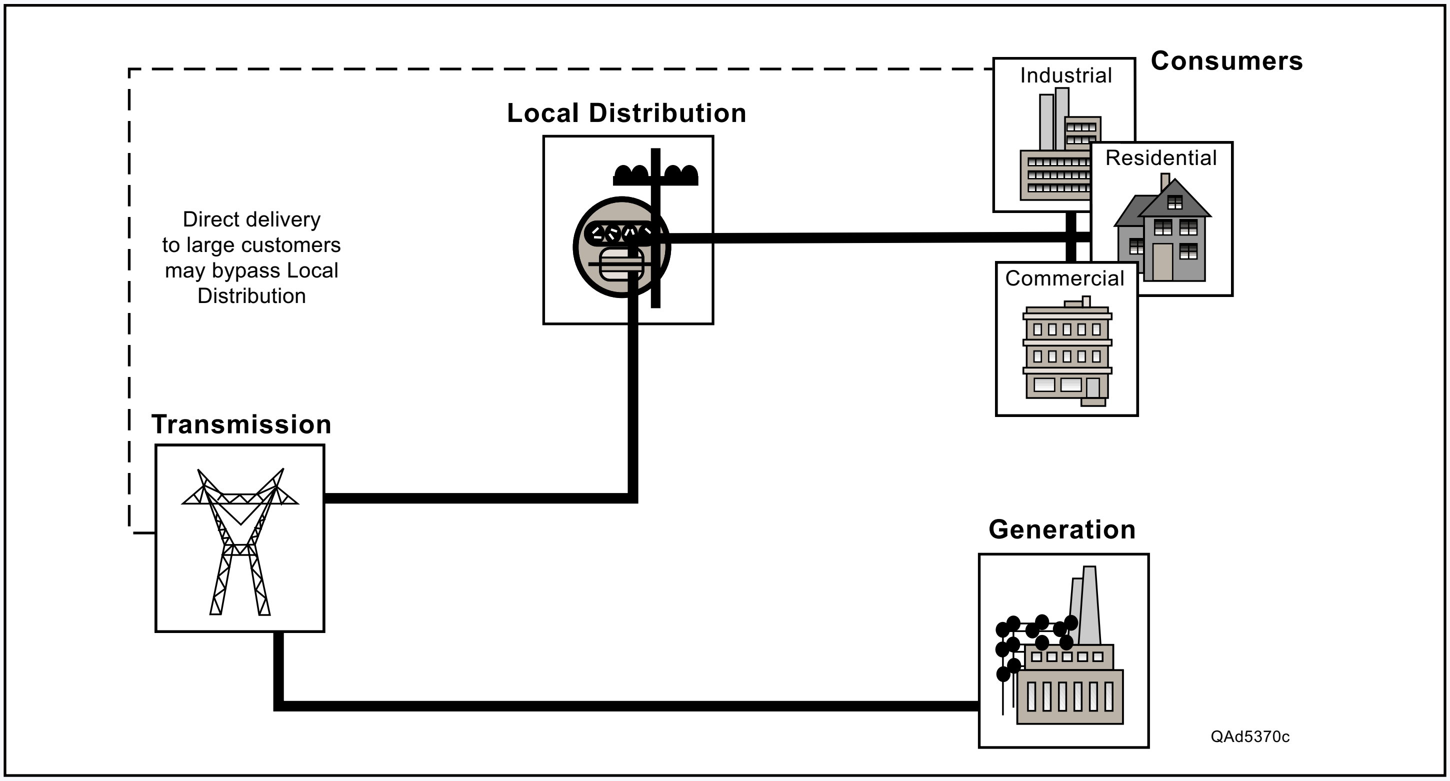

Figure 2. Basic Electric Power System

Installed Generation Capacity

At the end of 2004, Mexico had installed generation capacity of 53,561 MW, an increase of 5 percent over 2003. Most of this capacity increase is due to the completion of IPP projects.[10] About 73 percent of this capacity is controlled by CFE and LFC; 14 percent is controlled by IPPs; 3 percent by cogenerators; and the remaining 8 percent by self-suppliers.[42]

The installed generation capacity of SEN at the end of 2004 was 46,552 MW or 87 percent of total installed capacity. The SEN capacity consists of CFE and LFC capacity and the IPP capacity under contract to CFE. SEN installed generation capacity between 1994 and 2004 has grown at an average annual rate of four percent compared to average annual sales growth of 4.1 percent over the same period. The regional distribution of SEN generation capacity can be seen in Table 6.

The Northeast and Southeast regions account for 61 percent of SEN's installed generation capacity. The Southeast region has the most hydroelectric generation of any region and also has the sole nuclear generation facility (Laguna Verde near Veracruz). The Northeast region has registered the most growth in its generation capacity due to the economic factors discussed previously and attractiveness of the region for IPP investments. The Northeast also has the greatest amount of natural gas combined cycle generation capacity (4,955 MW) followed by the Southeast region (2,886 MW). In the Northeast 60 percent of the combined cycle capacity is IPP-owned; in the Southeast 77 percent of the combined cycle capacity is IPP-owned.

Of the 46,552 MW of SEN installed generation capacity, approximately 23 percent is hydroelectric; 3 percent is nuclear; 2 percent is geothermal and wind; and 72 percent requires the fossil fuels of oil, natural gas and coal.

Total Actual Generation

In 2004 total generation (SEN and generation for self-use) was 235,600 GWh, an increase of 4.7 percent over 2003. Non-CFE and LFC generators provided 32 percent of total generation.

Table 6. SEN Generation Capacity By Region (MW)

Region/Year	1994	% Total	2004	% Total
Northwest	4,258	13.5	6,923	14.9
Northeast	5,783	18.3	11,854	25.5
Central West	5,753	18.1	6,728	14.4
Central	4,176	13.2	4,608	9.9
Southeast	11,619	36.9	16,439	35.3
Total	**31,649**	**100**	**46,552**	**100**

Source: SENER 2006.

Table 7. Total Mexico Generation 2004 (GWh)

Generation Provider	Generation (GWh)	% Total Generation
CFE and LFC	162,300	68
IPPs	46,334	20
SEN (Sub-Total)	208,634	88
Self-supply/Cogeneration	22,544	10
Export	4,422	2
TOTAL	**235,600**	**100**

Source: SENER 2006.

Actual Generation SEN

In 2004 SEN electric generation was 208,634 GWh, an increase of 2.4 percent over 2003 and 52 percent over 1994. The amount of SEN generation provided by IPPs increased almost 50 percent from 2003 to 46,334 GWh in 2004. Generation provided by gas-fired combined cycle generating plants increased 31.3 percent from 2003 to 62,376 GWh or 30 percent of the SEN total generation. All of the IPP generation is from natural gas-fired combined cycle generating plants. Gross SEN generation by type of fossil fuel can be seen in Table 8.

Table 8. Fossil Fuel SEN Generation By Fuel Type (percent)

Year/Fuel	1994 Total	2004 Total
Fuel Oil	68	**35**
Natural Gas	16	**46**
Coal	14	**17**
Diesel	2	**2**
All Fossil Fuels	**100**	**100**

Source: SENER 2006.

Between 1994 and 2004, fuel oil has lost almost 50 percent of its market share as a result of environmental restrictions and the adoption of natural gas-fired combined cycle technology (combined cycle gas turbine or CCGT).[11] In contrast, natural gas has more than doubled its market share over the same time period. State-owned oil and gas company Petróleos Mexicanos (PEMEX) supplies the oil and natural gas for this capacity.

The majority of Mexico's coal reserves, which are low quality due to their high ash content, are located in Coahuila. The major coal producers are Mission Energy, a U.S. company, and Minerales Monclova, a subsidiary of Mexican steel company Grupo Acerero del Norte. Small volumes of coal are imported from the United States, Canada and Colombia.

Actual Generation Private: Figure 3 shows the rapid growth in electricity produced by private entities (IPPs, self-generation, cogeneration etc.) since 1999, primarily driven by the large increase in IPP generation after 2001. When generation from self-suppliers, cogenerators and exporters is added to SEN generation of 203,555 GWh, total generation in Mexico in 2003 was 224,881 GWh.

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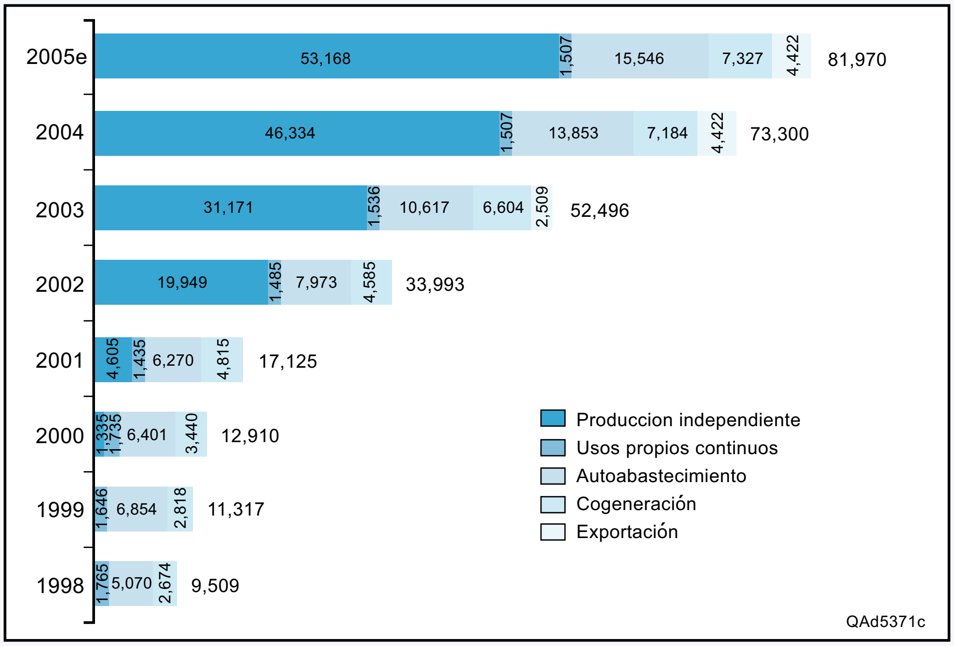
[10] IPP generation capacity increased 7.5 percent in 2004.[42]

[11] Combined cycle is an electric generating technology in which electricity is produced from waste heat that would otherwise be lost as it exits from one or more natural gas combustion turbines. The exiting heat is routed to a conventional boiler or to a heat recovery steam generator for utilization by a steam turbine in the production of electricity. This process increases the efficiency of the electric generating plant. Combined cycle plants can achieve efficiencies ranging from 50 to 80 percent as opposed to efficiencies of 35 to 40 percent for conventional thermal plants. Construction time is shorter and operating costs are lower. Natural gas-fired combined cycle plants produce no sulfur dioxide and only half as much carbon dioxide as conventional coal-fired thermal plants for the same energy output.



Source: SENER 2006.

Figure 3. Generation of Electricity by Type, GWH

Storing Electricity

Unlike water and natural gas, electricity cannot be easily stored. This presents a fundamental challenge to the electric power system. There is no container or large "battery" that can store electricity for indefinite periods. Energy is stored in the fuel itself before it is converted to electricity. Once converted, it has to go out on the power lines.

Worldwide, research and development on possible electricity storage technologies have been underway for some time. Compressed air, pumped hydroelectric, advanced batteries and superconducting magnetic energy storage are the four main technologies being studied for possible electricity storage.

Transmission and Distribution Systems

In general, power plants are located at points which allow access to the fuel source. The most desirable fuel sources are generally far away from population centers, and electricity must be moved from the point at which it is generated to consumers. The transmission system accomplishes much of this task with an interconnected system of lines, distribution centers, and control systems. Electricity is transported at high voltages (69 KV or greater) over a multi-path powerline network that provides alternative ways for electricity to flow.

Most homes and businesses in most countries use low voltage electric power while industries can often use higher voltages. Some large commercial and industrial customers may receive electricity at high voltages directly from the transmission system.

Substations on the transmission system receive power at higher voltages and lower them to feed local distribution systems. The local distribution system consists of the poles and wires commonly seen in neighborhoods and can also include below ground lines. At key locations, voltage is again lowered or "stepped down" by transformers to meet customer needs.

Customers on the local distribution system are categorized as industrial, commercial/public sector, and residential/agricultural. Industrial use is fairly constant, both during the day and across seasons. Commercial/public sector and agricultural use is less constant and can vary across seasons. Residential and commercial use may change rapidly during the day in response to customer needs, appliance use and weather events.

Mexico's national electric grid, SEN, is owned and operated by CFE and LFC and serves 95 percent of the population. The transmission and distribution systems of Baja California are not connected with the national interconnected system and neither are some small systems in the Northeast.

In Mexico, transmission lines are those lines of high tension (150-400 kV) that transport electricity over large distances. These transmission lines supply the networks of subtransmission (69-138kV) which cover much shorter distances. These subtransmission lines supply distribution lines (2.4-34.5 kV) which cover small geographic zones. Finally, low tension lines (220-240 volts) are used to supply low volume consumers.

Over the same period 1994 to 2004, LFC's transmission and distribution lines grew from 25,862 km to 70,221 km in 2004. Much of the large increase occurred in 2003 as a result of including low tension lines (38,515 km) in LFC's data for the first time.

Overall, a major effort has been made to increase long distance transmission capacity as well as distribution capacity in Mexico. Over the last ten years, the most substantial expansions of the transmission system have taken place in the north and the center of Mexico.[42]

As mentioned above, the transmission and distribution network is complemented by transmission substations, distribution

Table 9. CFE Transmission, Subtransmission and Distribution Lines (Kilometers)

Year	Transmission	Subtransmission	Distribution	Low Tension[12]	Total
1994	29,267	35,867	271,398	196,290	558,684
2004	44,203	44,919	357,304	242,707	746,911
Percent Increase	**51**	**25**	**32**	**24**	**34**

Source: SENER 2006.

Table 10. 2004 Substation Capacities in Mexico (millions of volts ampere) [13]

Transmission-CFE	128,841 MVA
Distribution-CFE	69,667 MVA
Total-LFC:	27,107 MVA
Total SEN	**225,615 MVA (3.6 percent increase from 2003)**

Source: SENER 2006.

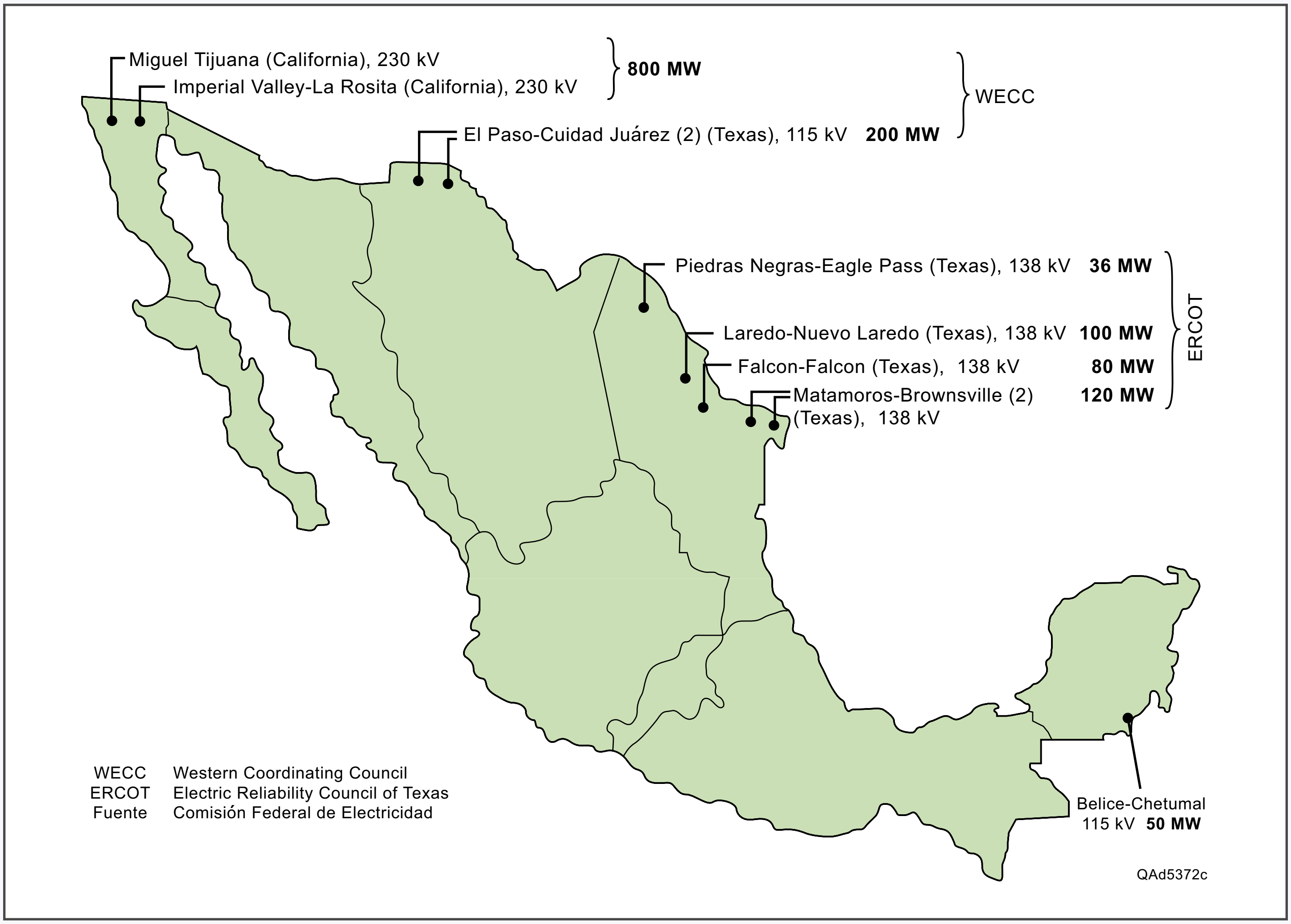
[12] Includes subterranean lines.

[13] Ampere is a unit of measurement, amps, of electrical current or flow.

Table 11. System Losses of CFE

Year	1996	1997	1998	1999	2000	2001	2002*
Losses (percent of net generation)	11.1	10.6	10.67	10.97	10.6	10.76	10.6

Source: Garcia, Foss, and Elizalde, 2001. *January-August 2002.



Source: SENER 2006.

Figure 4. Existing Electrical Interconnections in Mexico, 2004

substations and distribution transformers. In 2004, substation capacities can be seen in Table 10.

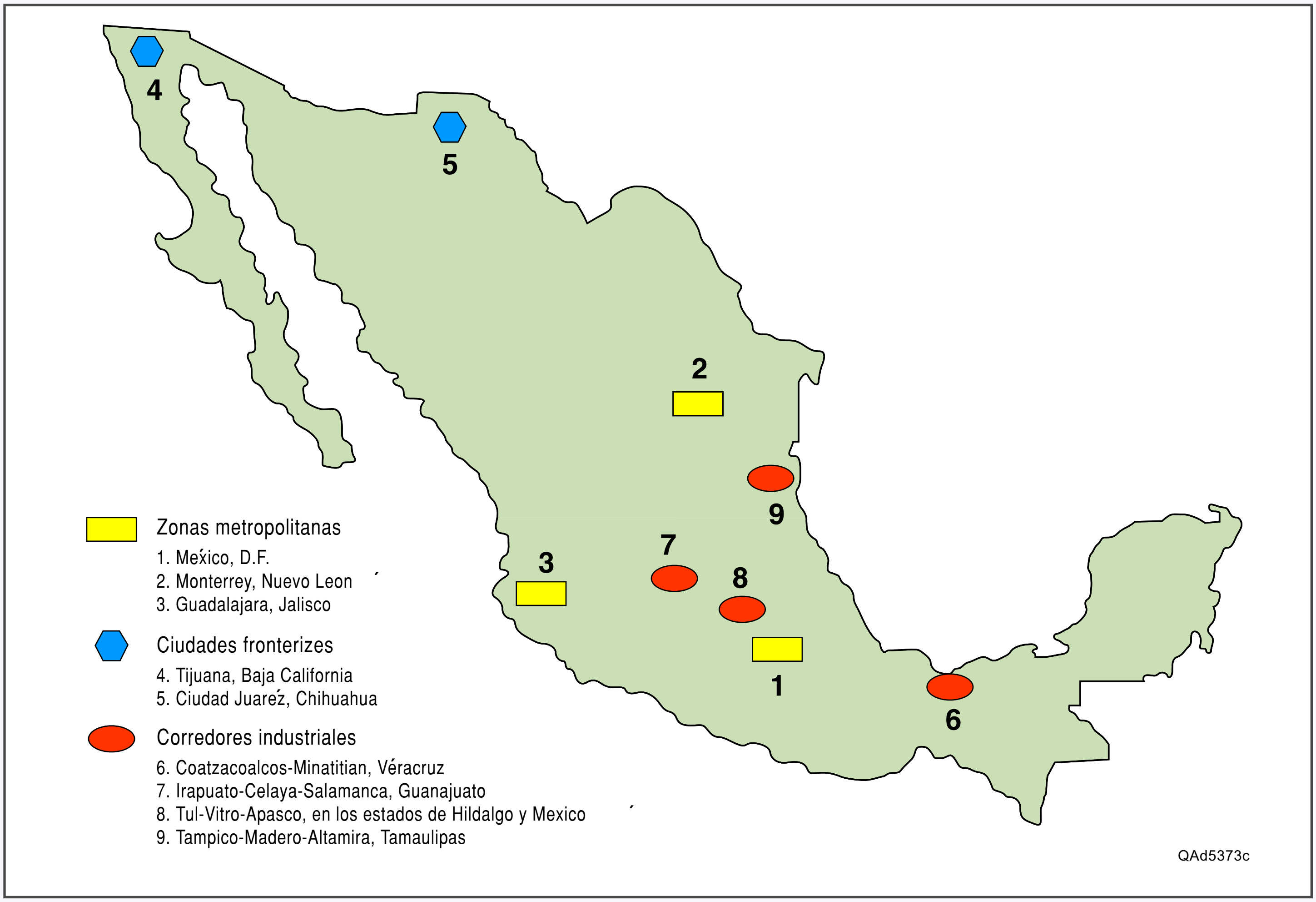
Transmission and Distribution System Losses

Two types of losses are typically experienced by electricity systems: technical or line losses and non-technical losses. These losses are calculated as a percentage of net generation. Technical or line losses occur because electricity dissipates in the form of heat to the atmosphere along transmission and distribution lines. Excessive line losses are due to inefficient and/or non-optimal operation of the system and as such are the responsibility of the system operator, CFE. Non-technical losses, on the other hand, usually occur as illegal taps along a local distribution network. Non-technical losses impose costs to electricity systems that are not recovered in payments. Theft degrades system reliability and presents serious hazards both to those making the illegal taps as well as to people and property in the vicinity of illegal taps. In Mexico, technical and non-technical losses are aggregated; losses are higher in some parts of the country than others. These losses are not insignificant as can be seen in Table 11.

According to CFE's annual report for 2001-2002, the reduction in system losses for 2002 was due to a decrease in non-technical losses resulting from the implementation of a program to reduce electricity theft. To further identify and reduce system losses, it would be useful to distinguish between technical and non-technical losses.

Imports/Exports

Mexico has 1,336 MW of electrical interconnections with the United States,



Source: SENER 2006.

Figure 5. Critical Zones Defined by NOMs

50 MW with Belize and 200 MW under construction with Guatemala. The interconnections between Mexico and the US are relatively weak, with only 12 high voltage operating interconnections.[36] The interconnections between Baja California and the US and between Mexico and Belize operate as "permanent" connections which are used for normal system operations. The Baja California interconnection has been a consistent exporter of electricity to the US during the period 1994-2004. With the exception of the Eagle Pass-Piedras Negras interconnection, the Texas-Mexico interconnections are for emergency support only due to technical constraints and the potential for system instability. The Eagle Pass-Piedras Negras interconnection uses new technology which allows it to be operated in a "permanent" manner for normal operations.[42]

Since 1996, Mexico has been a net importer of electricity from the United States. This trend was reversed in 2003 when Mexico became a net exporter of electricity. This reversal is due to increased generation capacity in Baja California North and other northern states. In 2004 Mexico exported 1,006 GWh and imported 47 GWh.[42]

Energy Savings and Efficiency

Energy savings and efficiency plans are implemented mainly by government agencies such as the Comisión Nacional para el Ahorro de Energia (CONAE), the Fidecomiso para el Ahorro de Energia Eléctrica (FIDE), the Programa de Ahorro de Energía del Sector Eléctrico (CFE-PAESE) and the Programa de Ahorro Sistemático Integral (ASI) with the goal of postponing new electric generation capacity creation. CONAE has published 16 Normas Oficiales Mexicanas (NOMs) requiring implementation of various energy efficiency/conservation measures. SENER estimates that these measures saved 9 percent of total electricity sales by CFE in 2005, deferring new CFE generation capacity of about 4,900 MW.

Environmental Regulations

Three NOMs regulate emission of air and water pollutants by electric generators and the environmental impacts of electricity transmission systems. These regulations vary by geographical zone and type and amount of generation capacity. Nine areas have been defined as "critical zones" in terms of air and water pollution levels.

THE BASICS OF ELECTRIC POWER

Electricity travels fast, cannot be stored easily or cheaply, and cannot be switched from one route to another. These three principles are basic to the operation of an electric power system.

Electricity is almost instantaneous. When a light is turned on, electricity must be readily available. Since it is not stored anywhere on the power grid, electricity must somehow be dispatched immediately. A generator is not simply started up to provide this power. Electric power must be managed so that electricity is always available for all of the lights, appliances, computers and other uses that are required at any particular moment.

Electricity traveling from one point to another follows the path of least resistance[14] rather than the shortest distance. With thousands of kilometers of interconnected wires throughout Mexico, electricity may travel miles out of any direct path to get where it is needed.

As a result of these three principles, designing and operating an electrical system is complex and requires constant management.

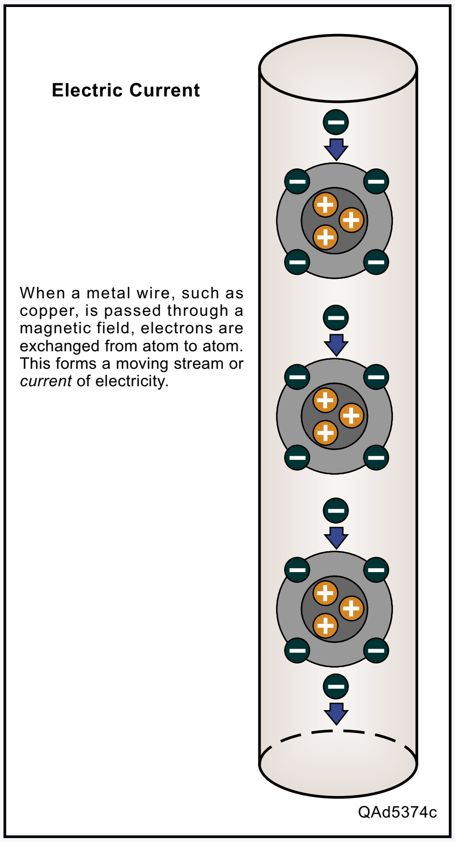


Figure 6. Electric Current

Defining and Measuring Electricity

Electricity is simply the flow or exchange of electrons between atoms. This exchange of electrons forms a moving stream or current of electricity. The atoms of some metals, such as copper and aluminum, have electrons that move easily. That makes these metals good electrical conductors.

Electricity is created when a coil of metal wire is turned near a magnet as shown in the diagram above. Thus, an electric generator is simply a coil of wire spinning around a magnet. This phenomenon enables us to build generators that produce electricity in power plants.

The push, or pressure, forcing electricity from a generator is expressed as **volts**. The flow of electricity is called **current.** Current is measured in **amperes (amps)**.

Watts are a measure of the amount of work done by electricity. Watts are calculated by multiplying amps times volts. Electrical appliances, light bulbs and motors have certain wattage requirements that depend on the tasks they are expected to perform. One kilowatt (1,000 watts) equals 1.34 horsepower. One megawatt is equal to 1,000,000 watts.

Kilowatts are used in measuring electrical use. Electricity is sold in units of kilowatt-hours (kWh). A 100-watt light bulb left on for ten hours uses one kilowatt-hour of electricity (100 watts x 10 hours=1,000 watt hours=1 kWh).

Electricity is generated and usually transmitted as alternating current (AC). The direction of current flow is reversed 60 times per second, called 60 hertz (Hz). Operators want the same frequency throughout the interconnected power grid and strive to maintain it 60 Hz.

Higher voltages in many instances can be transmitted more easily by direct current (DC). High voltage direct current (HVDC) lines are used to move electricity long distances.

Generating Electricity

There are many fuels and technologies that can generate electricity. Usually a fuel like coal, natural gas, or fuel oil is ignited in the furnace section of a boiler. Water piped through the boiler in large tubes is superheated to produce heat and steam. The steam turns turbine blades which are connected by a shaft to a generator. Nuclear power plants use nuclear reactions to produce heat while wind turbines use the wind to turn the generator.

A generator is a huge electromagnet surrounded by coils of wire which produces electricity when the shaft is rotated. Electricity generation ranges from 13,000 to 24,000 volts. Transformers increase the voltage to hundreds of thousand of volts for transmission. High voltages provide an economical way of moving large amounts of electricity over the transmission system.

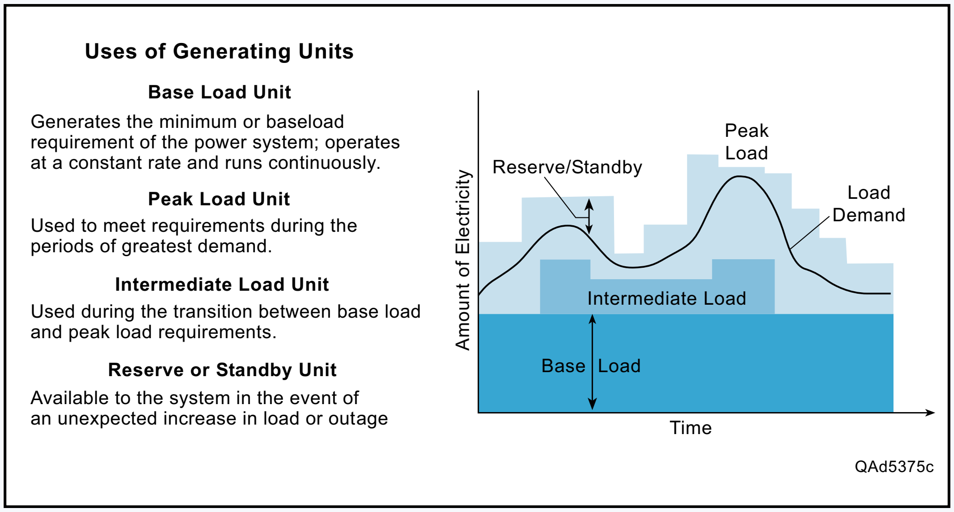


Figure 7. Types and Uses of Generating Units

[14] Resistance is measured in ohms of how much force it takes to move electric current through a conductor. Resistance in conductors causes power to be consumed as electricity flows through.

Types of Generators

Steam turbines use either fossil fuel or nuclear fuel to generate heat to produce steam that passes through a turbine to drive the generator. These generators are used primarily for base loads but some gas-fired plants are also used for peak loads. Sizes range from 1 to 1,250 megawatts.

In **combustion turbines** hot gases are produced by combustion of natural gas or fuel oil in a high pressure combustion chamber. These gases pass directly through a turbine which spins the generator. These generators are used primarily for peak loads but combined cycle combustion turbines are used for base loads. Simple combustion turbines are generally less than 100 megawatts and allow quick startup suitable for peaking, emergency and reserve power.

In **hydroelectric generating units** flowing water is used to spin a turbine connected to a generator. Sizes range from 1 to 700 megawatts. These units can start quickly and respond to rapid changes in power output. They are used for base loads, peak loads and spinning reserve.[15]

Internal combustion engines are usually diesel engines connected to the shaft of a generator and are usually 5 megawatts or less. There is no startup time and these units are typically operated in periods of high demand.

Other types of generators include **geothermal, solar, wind** and **biomass** which utilize many different technologies and range widely in size and capabilities. These are discussed in more detail in the Fuels for Electric Generation chapter.

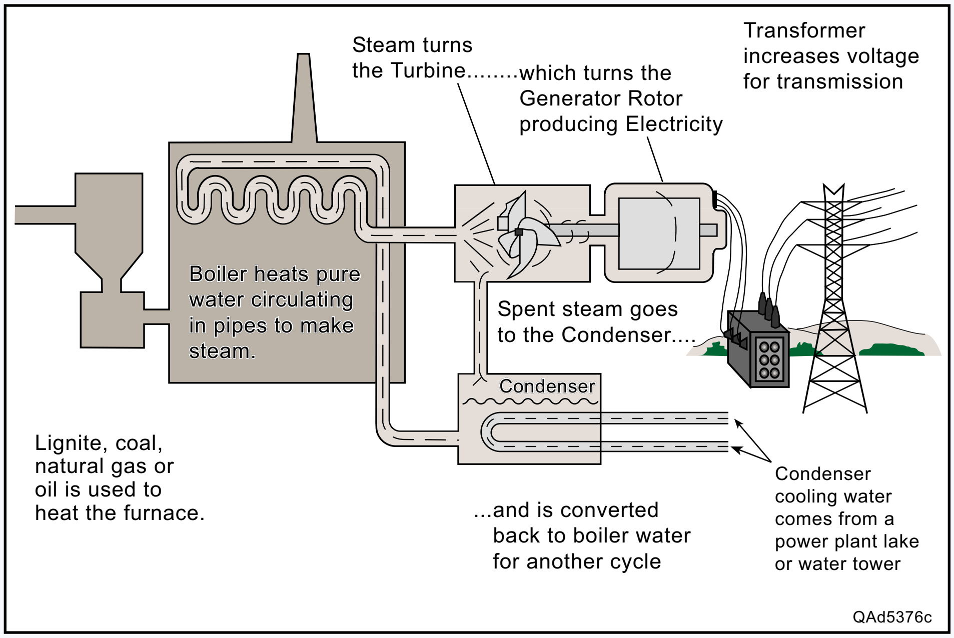


Figure 8. Steam Turbine Electric Power Plant

Transmission and Distribution

Once electricity is given enough push (voltage) to travel long distances, it can be moved onto the wires or cables of the transmission system. Electricity is stepped up from lower voltages to higher voltages for transmission. The transmission system moves large quantities of electricity from the power plant through an interconnected network of transmission lines to many distribution centers called **substations**. These substations are generally located long distances from the power plant.

High voltage transmission lines are interconnected to form an extensive and multi-path network. Redundancy means that electricity can travel over various different lines to get where it needs to go. If one line fails, another will take over the load. Most transmission systems use overhead lines that carry alternating current (AC). There are also overhead direct current (DC) lines, underground lines and underwater lines.

All AC transmission lines carry three-phase current—three separate streams of electricity traveling along three separate conductors. Lines are designated by the voltage that they can carry. Power lines operated at 60 kilovolt (kV) or above are considered transmission and subtransmission lines.

Even though higher voltages help push along the current, electricity dissipates in the form of heat to the atmosphere along transmission and distribution lines. This loss of electricity is called **line loss**.

Switching stations and **substations** are used to (1) change the voltage, (2) transfer from one line to another, and (3) redirect power when a fault occurs on a transmission line or other equipment. **Circuit breakers** are used to disconnect power to prevent damage from overloads.

Control centers coordinate the operation of all power system components. To do its job, the control center receives continuous information on power plant output, transmission lines, interconnections and other system conditions.

Transmission Constraints

There are some important constraints that affect the transmission system. These include thermal limits, voltage limits, and system operation factors.

Thermal/Current limits refer to the maximum amount of electrical current that a transmission line or electricity facility can conduct over a specified time period before it sustains permanent damage by overheating or violating public safety requirements. Electrical lines resist the flow of electricity and this produces heat. If the current flow is too high for too long, the line can heat up and lose strength. Over time the line can expand and sag between supporting towers. This can lead to power disruptions. Transmission lines are rated according to thermal limits as are transformers and other equipment.

Voltage limits refer to the maximum voltage that can be handled without causing damage to the electric system or customer facilities. Voltage tends to drop from the sending to the receiving end of a transmission

[15] Spinning reserve is that reserve generating capacity running at zero load and synchronized to the electric system.

line. System voltages and voltage changes must be maintained within the range of acceptable minimum and maximum limits. To achieve this, equipment (**capacitors and inductive reactors**) is installed to help control voltage drop. If voltage is too low, customer equipment and motors can be damaged. A widespread collapse of system voltage can result in a blackout of portions or all of the interconnected network.

System operation constraints refer to those operating constraints that must be observed to assure power system security and reliability. These constraints apply to power flows, preventive operations and system stability.

Power flows: Electricity flows over the path of least resistance. Consequently, power flows into other systems' networks when transmission systems are interconnected. This creates what are known as loop flows. Power also flows over parallel lines rather than the lines directly connecting two points—called parallel flows. Both of these flows can limit the ability to make other transmissions or cause too much electricity to flow along transmission lines, thus affecting reliability.

Preventive operations refer to standards and procedures designed to prevent service failures. These operating requirements include (1) having a sufficient amount of generating capacity available to provide reserves for unanticipated demand and (2) limiting the power transfers on the transmission system. Operations should be able to handle any single contingency and to provide for multiple contingencies when practical. Contingencies are identified in the design and analysis of the power system.

Stability limits: An interconnected system must be capable of surviving disturbances through time periods varying from milliseconds to several minutes. With an electrical disturbance, generators can begin to spin at slightly differing speeds causing differences in frequency, current and system voltages. These oscillations must diminish as the electric system attains a new stable operating point. If a new point is not quickly established, generators can lose synchronism and all or a portion of the interconnected system may become unstable, causing damage to equipment and, left unchecked, widespread service interruption.

The two types of stability problems are maintaining the synchronization of generators and preventing voltage collapse. Generators operate in unison at a constant frequency of 60 Hz. When this is disturbed by a fault in the transmission system, a generator may accelerate or slow down. Unless returned to normal conditions, the system can become unstable and fail.

Voltage instability occurs when the transmission system is not adequate to handle **reactive power flows**.[16] "Reactive power" is needed to sustain the electric and magnetic fields in equipment such as motors and transformers, and for voltage control on the transmission network.

Distribution

The distribution system is made up of poles and wire seen in neighborhoods and underground circuits. Distribution substations monitor and adjust circuits within the system. The distribution substations lower the transmission line voltages.

Substations are fenced yards with switches, transformers and other electrical equipment. Once the voltage has been lowered at the substation, the electricity flows to homes and businesses through the distribution system.

Conductors called feeders reach out from the substation to carry electricity to customers. At key locations along the distribution system, voltage is lowered by distribution transformers to the voltage needed by customers.

Customers at the End of the Line

The ultimate customers who consume electricity are generally divided into three categories: industrial, commercial, and residential. The cost to serve customers depends upon a number of factors including the type of service (for example, high or low voltage) and the customer's location with respect to generating and delivery facilities.

Industrial customers generally use electricity in amounts that are relatively constant throughout the day. They often consume many times more electricity than residential consumers and most industrial demand is considered base load (e.g. the load remains within certain limits over time with relatively little variation). As such it is the least expensive load to serve. Major industrial customers may receive electricity directly from the transmission system rather than from the distribution network. Some industrial plants have their own generators. Their excess electricity can be sold to CFE.

Commercial loads are similar to industrial loads in that they remain with certain levels over intermediate periods of time. Examples of commercial customers are office buildings, warehouses, and shopping centers.

Residential electric use is the most difficult to provide because households use much of their electricity in the morning and evening and less at other times of the day. This is less efficient to provide and is therefore a more expensive use of generating facilities. Over time, as homeowners buy new appliances and change life-styles, their electricity loads also change. Examples of residential loads are individual households.

[16] Reactive power is the product of voltage and the out-of-phase component of alternating current. Usually measured in megavolt-amperes reactive, reactive power is produced by capacitors, overexcited generators and capacitive devices and is absorbed by reactors, underexcited generators and other inductive devices.

HISTORY OF ELECTRIC POWER IN MEXICO

The history of Mexico's electric industry can be divided into five phases as follows:

- **1879-1910:** Mexican-owned companies dominated the landscape with foreign capital as an adjunct;
- **1910-1934:** Domination of the electric industry by foreign capital, primarily from the US, Canada and Germany;
- **1934-1960:** The creation and growth of CFE;
- **1960-1992:** Nationalization of the electric industry and expansion of the CFE system, and
- **1992-Present:** Initiation of reforms to permit private sector participation in the electric industry.

1879-1910: Mexican Companies Dominant

In the last quarter of the nineteenth century Mexicans were beginning to use electric-powered engines in industry, especially mining, and to a lesser extent for public lighting. The first electric generation plant (coal-fired) was installed in 1879 in León, Guanajuato for the use of the textile factory "La Americana." In 1889, the first hydroelectric plant began operation in Batopilas, Chihuahua for the mining industry. At the same time, the Mexican government sold lucrative concessions for electrification of cities; the first of these, in 1881, was sold to Mexicana de Gas y Luz Eléctrica for electric service in Mexico City.[5] Surplus power not needed by industry was sold in surrounding areas for commercial and residential use. By 1899, Mexico had generation capacity of 31 MW which was 39 percent hydroelectric and 61 percent thermoelectric.[11]

In the beginning, electric generation, transmission and distribution were controlled entirely by vertically integrated private companies. From 1890 to 1905, almost all electric companies were Mexican-owned.[3] At first, these companies were very small and highly dispersed and were drawn to the wealthiest and most industrialized areas, leaving rural areas unserved.[11] Between 1887 and 1910, more than one hundred Mexican light and power companies were established, almost all in central Mexico.[3]

1910-1934: Foreign Companies Dominant

Despite the Mexican revolution, the years from 1910 on saw a gradual and sustained influx of foreign capital, primarily from Canada, the US and Germany, which would almost completely displace Mexican capital by the 1930s. By 1935, Canadian capital represented more than 50 percent of total investment in the sector (about $175 million), followed by the US with $90 million while German investment focused on electrical equipment.[3]

By 1910, Mexico's generation capacity was 50 MW and 80 percent of that capacity was owned by Mexican Light and Power Company (MLP), headquartered in Toronto, Canada. This growth in generation capacity was primarily due to MLP's construction of Mexico's first major hydroelectric project – the Necaxa plant in the state of Puebla.[11]

From 1902 until 1933, Mexican generation, transmission and distribution were dominated by three large foreign companies with a "strong tendency to monopoly": MLP, Impulsora de Empresas Eléctricas (Impulsora), and the Compañía Eléctrica de Chapala (CEC) headquartered in Guadalajara.[17] MLP had practically an absolute monopoly on electric generation in the central zone of the country around Mexico City; Impulsora controlled three interconnected electric systems in the north, and CEC controlled the western electric system. These three companies acquired the assets of the small, dispersed private companies and extended their transmission and distribution networks into the most economically attractive markets in the cities in which they operated.

The Constitution of 1917, promulgated at the end of the Mexican Revolution, opened the possibility of state intervention in and regulation of the economy, including the electric sector. However, state regulation of the electric sector grew very slowly. The period 1920-1938 was characterized by the consolidation of the monopolies (e.g., the most important firms became holding companies by absorbing the many small retail companies) and increases in tariffs to consumers.

The first effort at regulating the electric industry was the creation in 1922 of the Comisión Nacional para el Fomento y Control de la Industria de Generación. This first regulatory attempt was in response to consumer pressure protesting the arbitrary monopoly tariffs of the companies. In 1926 this commission was restructured as the Comisión Nacional de Fuerza Motriz which tried to prevent the worst monopolistic abuses while continuing to attract private investment.[11]

Also in 1926, the enactment of the Código Nacional Eléctrico declared electricity to be a public service and conferred to Congress the rights to legislate in related matters. Initially, this code had little impact due to the weakness of the federal government whereas regulation of local electrical monopolies was controlled by local governments and large industrial electricity consumers.[11] Local governance of the monopolies was unpredictable. In some areas such as Mexico City, arbitrary tariff rules set the stage for perpetual under-investment in the electric sector.[5] In other areas, local arbitrariness and corruption resulted in practices that favored the monopolies.[11]

1934-1960: The Creation and Growth of CFE

By the early 1930's, MLP, CEC and Impulsora supplied power to only 38 percent of the population; the rural areas, where 67 percent of the population resided, were largely neglected. *"Supply did not fulfill demand, power outages were constant and rates were too high; these conditions hindered the country's economic development,"* according to CFE (www.cfe.gob.mx).

As a result, the Mexican government assumed the function of supplying electricity itself through the creation of the CFE in 1934-1937. The nascent CFE had two main objectives: (1) to operate as a regulatory agency and liaison between the foreign private companies and the government, and (2) to supply electric service to those areas considered unprofitable by the foreign private companies.[11] CFE's pioneer generation projects were in the states of Guerreo, Michoacán, Oaxaca and Sonora; the power generated was sold to the private companies for resale.

At the same time, President Lázaro Cárdenas consolidated power around his party, the Partido Revolucionario Institucional (PRI). One of the key supports for the PRI came

[17] Impulsora was a subsidiary of the US group, Bond and Share Co.[3]

from the labor unions, and the best organized ones were those in the largest industries – mining and electricity.[5] The oldest and strongest labor union in Mexico, the Sindicato Mexicano de Electricistas (SME) founded in 1914, was a critical piece in Cárdenas' "corporatist" political structure, e.g. strong central government in collaboration with other important sectors such as organized labor.

In 1936, the SME struck Impulsora and its seven subsidiaries. Labor unrest coupled with low mandated tariffs in key areas led the foreign private companies to reduce new investment in Mexico. From 1937 to 1943 private investment grew less than 1 percent due to the uncertainty surrounding the role of CFE and the vitality of the trade unions.

In 1938, the Congress enacted the Electricity Public Service Act which required strong federal regulation of the electric sector.

In response to underinvestment in the electric sector, a "rolling process of nationalization" was begun: CFE was instructed to buy (at depressed prices) existing electric assets and to construct new generation, transmission and distribution assets funded by public resources. In 1944, CFE acquired CEC, the third largest of the foreign private companies and built its first large-scale generating plant Ixtapantongo. During the 1940's and 1950's, CFE acquired and consolidated hundreds of regional electricity monopolies into a single firm with common technical standards. From 1939 to 1950, 82 percent of the total investment in the electric power system came from public resources and was dedicated to expanding the CFE system; only 18 percent of the total investment came from private firms during this same period.[5]

1960-1992: Nationalization and Development of the CFE System

In 1960, Mexico's rated capacity was 2,308 MW: 54 percent owned by CFE, 25 percent by MLP, 12 percent by Impulsora and 9 percent by remaining private companies. The consolidation of the electric sector continued in that year when the Mexican government acquired a majority stake in MLP and 95 percent of the common shares of Impulsora. At the same time, a new state-owned enterprise, Compañia de Luz y Fuerza del Centro (LFC), was created out of the remnants of MLP which would provide electric service to the central states of Mexico, Morelos, Puebla, Hidalgo and Distrito Federal.

Having completed the nationalization of the electric sector in fact, the government made the arrangement official in 1960 by amending the Mexican constitution (Article 27, paragraph 6) to state: *"It is the exclusive responsibility of the Nation to generate, transmit, transform, distribute and supply electricity that is intended for public service use. Therefore, concessions will not be given to private individuals and the Nation shall utilize its natural resources and assets required for such purposes"*.

During the 1960's, more than 50 percent of total public investment was dedicated to infrastructure projects. Major generating plants were built from these proceeds, including Infiernillo and Temascal. Installed generation capacity reached 17,360 MW by 1980 and 26,797 MW by 1991.

In addition to greatly expanding the country's generation capacity, the CFE standardized technical and economic criteria for the power system. It standardized operating voltages and interconnected the separated transmission systems. During the 1970's all the transmission systems were interconnected except the electric systems of Baja California and the Yucatan peninsula. In 1990, the Yucatan was incorporated into the Sistema Eléctrico Nacional (SEN).

In 1976 the 60 hertz electrical frequency was unified throughout the country. This was done despite technical, social and labor union obstacles that opposed the conversion of existing electric equipment operating at 50 hertz.

During this period, the CFE adhered to two basic principles: (1) satisfy the growing demand for electricity, and (2) keep electricity prices low to promote competitiveness.[3] The remarkable success of the CFE in connecting millions of people to the electric grid, achieving nearly universal coverage, is one of the reasons why many people in Mexico support state control of electric utilities. In addition, the idea of social justice was expanded to include a wide array of electricity price subsidies for residential and agricultural consumers which ultimately led to a system characterized by mounting financial losses.[5]

In 1975 this process of nationalization and consolidation of state control of the electric industry was formalized legally with the Ley del Servicio Público de Energía Eléctrica (LSPEE) which declared CFE and LFC as public suppliers of electricity. *"State-controlled monopoly, it was thought, was essential for ensuring the real-time management of electric power. Only a state enterprise could be trusted with a technology that had large economies of scale and thus natural tendencies to monopoly. Furthermore, private generators sought only profitable markets, leaving a large part of the population without electricity, and it was assumed that only a state-owned enterprise could deliver electric service more equitably."*[18]

This system performed well throughout the 1970's. Demand grew rapidly, but so did installed capacity. In fact, over-building of generation capacity was commonplace with reserve margins greater than 30 percent throughout the period.[3]

During the 1970's and 1980's, fuel oil became the primary generation fuel. Water resources in the north are scarce and the load factors on hydroelectric plants were fairly low. As Mexico became one of the world's top ten oil producers, oil-fired generation facilities, constructed mainly with local equipment in contrast to coal and gas plants, made sense for an oil-rich nation. Importantly, however, PEMEX sold fuel oil to the power sector at 30 percent of its opportunity cost during the 1970's and 1980's. This under-pricing of fuel oil amounted to a massive implicit subsidy to the power sector that averaged about $1.5 billion dollars per year for the period 1974-1989 at 2001 constant dollars.[5]

Artificially low fuel oil prices for electric generation permitted electric tariffs that did not fully cover costs. Overall, the Mexican power sector's tariff policy seems to have been broadly reflecting costs until 1973. After that time, tariffs were lowered with the help of oil revenues.[5]

Beginning in the early 1980's, Mexico entered into an economic period characterized by financial crises, increasing public debt and hyperinflation. The price for fuel oil for electric

[18] Nationalism has always been invoked by both the government and the unions as a motivation for the consolidation of the electricity sector. Mexican society as a whole has a positive impression of CFE and its accomplishments although specific operational and management criticisms exist.[5,3]

generation was increased as well as the electric tariffs for commercial and industrial users. However, the tariffs for the more politically sensitive residential and agricultural consumers were kept flat. On the assumption that industry could pay a higher price for electricity, the cross-subsidy from industrial and consumer users to the other customer classes grew over the following years.[5]

Importantly each financial crisis since 1982 has brought strict limits on public debt. In fact, the financial crisis of 1994-1995 resulted in a negotiated settlement with Mexico's creditors that included a prohibition against state-owned enterprises incurring additional debt. These financial crises and their consequences limited the ability of CFE to raise the capital needed to build new plants to keep pace with rising demand. In contrast with the 1970's, from 1982 to the present, the growth in electricity supply and demand was more unpredictable and reserve margins varied widely because of lack of investment in capacity as demand was growing. In addition, the NAFTA treaty fueled economic growth in Mexico and led to power demand that rose at a much higher rate than expected.

1992-Present: Reforms to Permit Private Participation in the Electric Sector

As a result of these factors, reforms to the LSPEE were undertaken in 1992 to permit limited private participation in the electric generation sector in order to alleviate the looming crisis in power supply caused by CFE's inability to fund the required investment. Under current conditions, private entities can only participate in the sector as a generator; the resulting power can only be used for its own consumption, for export, or for sale to a single buyer, the CFE.[3] This reform of 1992 and attempted further reforms in 1999 and post-2000 are discussed in more detail in the chapter Regulations and Policies.

In addition, measures were taken to raise tariffs and reduce CFE operating costs with the aim of restoring some sustainability to the sector.[5] However, it has proved to be politically very difficult to raise residential and agricultural tariffs. Similarly, it is politically difficult to reduce CFE's costs because it requires confronting the powerful labor unions embedded in both CFE and LFC. These labor unions have led a broad coalition to block private investment in the sector and tariff reforms. If both consumers and labor unions oppose meaningful reforms, it becomes politically very risky to support further electric sector reforms.

FUELS FOR MEXICO ELECTRIC GENERATION

Table 12 below shows that the SEN's installed generation capacity of 46,552 MW is fueled primarily by water (23 percent) and the fossil fuels[19] oil and natural gas (67 percent). Other fuels such as geothermal, wind, uranium for nuclear and coal play a relatively small role at present.

The use of natural gas as a fuel for electric generation has grown dramatically increasing from 7.1 percent of the total to 36 percent of the total. Oil-fueled electric generation has dropped significantly in both absolute and percentage terms.

Hydroelectric

Electricity can be created as turbine generators are driven by moving water. While hydroelectricity is considered a renewable fuel[20] management of flowing rivers and cycles of rain and drought can impact hydroelectric capacity greatly as well as contribute to other environmental effects.

There are no major river systems in Mexico. The Sierra Madre mountains separate the country into Pacific and Atlantic watersheds resulting in short-length rivers that flow west to the Pacific Ocean or east to the Gulf of Mexico.[48]

The longest river in Mexico is the Rio Grande (called Rio Bravo in Mexico) which forms part of Mexico's northern border with the United States. The longest river within Mexico is the Lerma-Santiago in south-central Mexico which flows northward and westward to the Pacific.

Historically Mexico has derived much of its power from hydroelectric facilities some of which date back to the 1920's in remote areas. Although expensive to construct, hydroelectric facilities typically generate the least cost electricity on an operating basis. If water resources are abundant, countries

Figure 9. Rivers of Mexico

Table 12. 2004 SEN Installed Capacity by Fuel (MW and percent)

Type	Hydro	Thermo*	Geothermal	Wind	Nuclear	Coal	Total
MW	10,530	31,099	960	2	1,365	2,600	46,552
Percent of Installed Capacity	23	67	2	N/S	3	5	100

Source: SENER, 2006. *Oil and Natural Gas

Table 13. SEN Gross Generation by Fuel (GWh)

Year/Type	1994	% of Total	2004	% of Total
Hydro	20,047	14.6	25,076	12.0
Oil	77,023	56.0	66,334	31.8
Natural Gas	9,822	7.1	75,649	36.3
Wind & Geothermal	5,602	4.0	6,583	3.1
Coal	13,036	9.5	17,883	8.6
Dual (Oil/Gas)	7,770	5.6	7,915	3.8
Nuclear	4,239	3.2	9,194	4.4
Total	**137,539**	**100**	**208,634**	**100**

Source: SENER 2006

[19] Fossil fuels are derived from decaying vegetation over many thousands or millions of years. Coal, lignite, oil (petroleum) and natural gas are all fossil fuels. Fossil fuels are non-renewable, meaning that we extract and use them faster than they can be replaced. A concern is that fossil fuels, when combusted, may emit gases into the atmosphere that contribute to climate change. Considerable effort is underway to devise clean technologies that will allow fossil fuel use with few or no emissions.

[20] Renewable fuels are those that are not depleted as they are consumed.

will typically develop extensive hydroelectric capacity. Hydroelectric power is produced as water moves from a higher to lower level and pushes a turbine. Most of Mexico's hydroelectric facilities are located in the south south-east part of the country. Recent droughts in the northeast and northwest (where much of the growth in electricity consumption is occurring) have led to curtailments affecting about 20 percent of the area's generation.[48] As a result, hydroelectric generation declined in both absolute numbers and percent of total generation from 2000 to 2003. It increased 27 percent from 2003 to 2004 due to new hydroelectric capacity added in the Southeast region (Chiapas state).

CFE owns and operates all of Mexico's hydroelectric generation except for one small 6 MW facility. CFE estimates that the country's total hydroelectric potential is about 42,000 MW compared with 10,530 MW currently. However, because of the arid conditions over much of the northern part of the country, there are relatively few sites for new hydroelectric facilities. Environmental concerns and the need to relocate rural communities also hinder the development of new hydroelectric facilities.

Fuel Oil

Fuel oils are the heavier oils in a barrel of crude oil, comprised of complex hydrocarbon molecules that remain after the lighter oils have been distilled off during the refining process. Fuel oils are classified according to specific gravity and the amount of sulfur and other substances they contain. Virtually all petroleum used in steam electric plants is heavy fuel oil.

In 2004 fuel oil fired the second- largest percentage (32 percent) of Mexico's SEN generation. It comes primarily from heavy high sulfur crude oil (Maya-22) and PEMEX is the sole supplier. Historically, years of neglected capital investment in refining meant that PEMEX had large volumes of this high sulfur fuel oil for which CFE was a steady customer. On the positive side, Mexico had abundant reserves of Maya-22; on the negative side, fuel oil-fired electric generation contributed to extensive air quality degradation in the major metropolitan areas. As a result of stricter environmental regulations and the increase in the construction of gas-fired power plants, fuel oil's percentage of total SEN generation has declined 24 percent over the decade 1994 to 2004.

Mexico contains an estimated 17,600 miles of crude oil pipelines, 6,300 miles of petroleum products pipelines, and 875 miles of petrochemical pipelines. Significant expansion of this system to transport oil to electric generators is not contemplated at present.

Natural Gas

Natural gas is a mixture of hydrocarbons (principally methane, a molecule of one carbon and four hydrogen atoms) and small quantities of various non-hydrocarbons in a gaseous phase or in solution with crude oil in underground reservoirs.

Natural gas consumption for electric generation in Mexico grew dramatically over the decade 1994 to 2004. This growth is due to the increased construction of combined cycle gas-fired generation plants, most of which was undertaken by IPPs, cogenerators and self-suppliers.

Because natural gas has been such an important fuel for electric power capacity additions in Mexico, additional detail is provided on natural gas supply and disposition.

Who Uses Natural Gas in Mexico?

Consumption of natural gas in Mexico is heavily concentrated in the oil, industrial and electric sectors representing 97 percent and 98 percent of gas consumption in 1994 and 2004, respectively. This has been the pattern of consumption historically in Mexico with dropping percentage shares in the industrial and oil sectors being offset by growing consumption in the electric sector. The residential and commercial sectors are relatively small in part due to underdevelopment of the distribution network until recent years.[43]

The oil sector uses natural gas for gas lift in oil fields, for nitrogen injection in the Cantarell oil field offshore, for fuel in refineries and to generate electric power. In the industrial sector in 2004, PEMEX Petroquímica (PPQ) accounted for 24 percent of total industrial consumption, down from 47 percent in 1994. PPQ uses natural gas both as a fuel and as a raw material in the production of secondary petrochemicals. The decrease in gas consumption by PPQ reflects its reduced petrochemical output. PPQ's output has been displaced by cheaper imported petrochemicals since the mid-1990's.

The remaining industrial consumption is concentrated in the industries highlighted in Table 15. Basic metals and chemicals accounted for 43.9 percent of total industrial gas consumption with food and glass at 20 percent of the total.

Electric sector consumption of natural gas represented 17 percent of total gas consumption in 1994, increasing to 36 percent in 2004. The most striking change is the growth in natural gas consumption by private generators. In 1994, gas demand by CFE and LFC accounted for 85 percent of total gas consumption for electric generation; this dropped to 40 percent in 2004. On the other hand, gas consumed by private generators was 15 percent of total gas consumption for electric generation in 1994 and now represents 60 percent of the total consumed in the sector. This is due

Table 14. Natural Gas Demand by Sector (million cubic feet per day, or MMcf/day)

Year	1994	2000	2004	AAGR, %
PEMEX	1,194	1,843	2,312	7.4
Industrial, of which:	1,404	1,392	1,246	-1.2
PPQ	658	373	295	-7.7
Others	746	1,019	951	2.5
Electric, of which:	547	1,011	2,056	14.2
CFE & LFC	466	870	843	6.4
IPPs	--	27	896	--
Self-generation	81	115	229	10.9
Export	--	--	89	--
Residential	58	60	86	3.9
Services	18	20	20	1.0
Transport	0	1	2	--
Export	19	24	--	--
TOTAL	**3,240**	**4,350**	**5,722**	**5.8**

Source: SENER, 2005. AAGR is annual average growth rate.

Table 15. Natural Gas Consumption by Industry Type 2004[21]

Industry Type	MMcf/Day	Total
Basic Metals	297	31.2
Chemicals	121	12.7
Food, Drink, Tobacco	96	10.1
Glass	94	9.9
Non-Metal Mineral Products	64	6.7
Pulp and Paper	49	5.1
Cement	17	1.8
Other	214	22.5
TOTAL	**951**	**100**

Source: SENER 2005

Table 16. Electric Sector Natural Gas Consumption (MMcf/day)

Year	1994	Percent	2004	Percent
CFE	437	80	814	39
LFC	28	5	29	1
Sub-Total	*465*	*85*	*843*	*40*
IPPs	0	--	896	44
Self-generation	81	15	229	11
Export	0	--	89	5
Sub-Total Private Generation	*81*	*15*	*1,214*	*60*
TOTAL	**547**	**100**	**2,056**	**100**

Source: SENER 2006.

to the fact that all the IPP projects are gas-fired combined cycle generation plants.

Who Supplies Natural Gas in Mexico?

There are two primary sources of natural gas supply in Mexico: PEMEX and imports. In recent years, PEMEX's gas production has not kept up with the growth in demand and as a result imports increased to 20 percent of total natural gas supply in 2004 (see Table 17).

PEMEX

In 1938, Mexico's President Lázaro Cárdenas del Rio nationalized the foreign-owned oil companies then operating in Mexico and consolidated their assets under the control of state-owned PEMEX. It is a decentralized public entity, 100 percent owned by the Mexican government, and is responsible for the central planning and strategic management of Mexico's hydrocarbon industry. The hydrocarbon reserves themselves are owned by the Mexican nation and not by PEMEX. In 1992, the operational management was split into four subsidiaries: PEMEX-Refinación (PEMEX Refining), PEMEX-Gas y Petroquímica Basica (PEMEX Gas and Basic Petrochemicals or PGBP), PEMEX-Petroquímica (PPQ) and PEMEX-Exploración y Producción (PEMEX Exploration and Production or PEP). Each subsidiary operates as a separate entity of the Mexican government and has the legal authority to own assets and operate its businesses under its own name.[22]

With respect to production of natural gas, PEP is responsible for the exploration, development, production and first hand sales of oil and natural gas. These activities are reserved exclusively to PEMEX by the Mexican Constitution. Natural gas processing, transportation and distribution are done by PGBP. In 1995, the Mexican Congress amended the law to allow domestic and foreign private companies to participate, with the Mexican government's approval, in the storage, distribution and transportation of natural gas.

Imports

To date, all natural gas imports have come from the United States and are delivered via natural gas pipeline. Natural gas infrastructure capacity between Mexico and the US amounts to 3.4 billion cubic feet per day (or Bcf/day) across 15 cross-

Punto de internación en México	Cepecided máxima (mmpcd)
Total	3,419
1. Tijuana, B.C.	300
2. Mexicali, B.C.	29
3. Los Algodones, B.C.	500
4. Naco, Son.	130
5. Neco-Agua Priete, Son.	215
6. Agua Prieta, Son.	85
7. Cd. Juárez, Chih.	80
8. San Agustin Valdivia, Chih.	312
9. Piedras Negras, Coah.	38
10. Ciudad Mier, Tamps.	425
11. Argûellos (Gulf Terra), Tamps.	35
12. Argûellos (Kinder Morgan), Tamps	340
13. Reynosa (Tetco), Tamps.	250
14. Reynosa (Tennessee), Tamps.	350
15. Reynosa (Río Bravo), Tamps.	330

Source: SENER 2006

Figure 10. Mexico-United States Gas Pipeline Interconnections

[21] Does not include gas consumption by PPQ.

[22] LatinPetroleum.com, PEMEX: Taming the Untamable, June 8, 2004. Also see Michelle Michot Foss and William A. Johnson, "Natural Gas in Mexico, " Proceedings of the IAEE 13th Annual North American Conference, November 1991, and Foss, Johnson, and García, "The Economics of Natural Gas in Mexico -- Revisited," The Energy Journal special edition, North American Energy After Free Trade, September 1993. Contact iaee@iaee.org or energyecon@beg.utexas.edu.

Table 17. Sources of Natural Gas Supplies (MMcf/day)

Year	1994	Percent	2000	Percent	2004	Percent	AAGR
PEMEX	3,131	96	4,091	94	4,626	80	4.0
Imports	125	4	281	6	1,124	20	24.6
TOTAL	**3,256**	**100**	**4,372**	**100**	**5,750**	**100**	**5.9**

Source: SENER 2006.

Table 18. Coal Production and Consumption in Mexico (millions of short tons)

Year	1990	1995	2001
Production-Bituminous	8.59	10.26	12.81
Consumption	8.59	12.30	14.81
Imports	--	2.04	2.00

Source: USEIA, 2004.

border interconnections.[43] The pipeline interconnections between Mexico and the United States can be seen in Figure 10.

In 2004 gas imports increased 13 percent over import volumes in 2003. The 2004 imports were received in the following states [43]:

- Tamaulipas – 53.9
- Baja California – 20.2
- Chihuahua – 17.8
- Sonora & Coahuila – 8.1

Liquefied Natural Gas (LNG) Imports

LNG is natural gas that has been cooled to the point that it condenses to a liquid, which occurs at a temperature of approximately -256 degrees F (-161 degrees C) and at atmospheric pressure. Liquefaction reduces the volume by approximately 600 times thus making it more economical to transport between continents in specially designed ocean vessels, whereas traditional pipeline transportation systems would be less economically attractive and could be technically or politically infeasible. Thus, LNG technology makes natural gas available throughout the world.[6]

During 2003, the CRE granted four LNG regasification permits; however, only two are currently being developed. One project is the construction of a 500 MMcf/d regasification terminal on the east coast at Altamira by Shell Oil Co. It is expected to begin operations in the fourth quarter of 2006 increasing output to 500 MMcf/d annually in 2007. CFE has signed a gas purchase contract with the Shell/Total joint venture for the full plant output to supply planned combined cycle power plants Altamira V, Tuxpan V, and Tamazunchale. These gas-fired generation plants will serve the states of Tamaulipas, Veracruz and San Luis Potosí. Possible gas supply sources include Nigeria, Trinidad and Tobago, Algeria and Qatar.

The second project in development is the Sempra Energy regasification terminal in Ensenada Baja California. The Ensenada plant's output will be 211 MMcf/d beginning 2008 and will increase to its maximum of 500 MMcf/d by 2010. SENER expects that Mexico may need additional regasification terminals in the future both to boost natural gas supplies and to provide supply diversification.

Table 19. Geothermal Installed Generation Capacity (MW)

Year	1994	2000	2004
Geothermal Capacity	753	855	960
Total SEN Generation Capacity	31,649	36,697	46,552
Geothermal Percent Total	2.4	2.3	2.1

Source: SENER, 2006

Nuclear (Uranium, Plutonium)

Nuclear energy is a non-renewable, non-fossil fuel form of energy derived from atomic fission. The heat from splitting atoms in fissionable material, such as uranium or plutonium, is used to generate steam to drive turbines connected to an electric generator. Nuclear plants have been by far the most expensive to construct, although uranium is the least expensive fuel to use (apart from questions about disposal costs). In recent years, nuclear facilities have proved to be reliable generators. Nuclear generation produces no greenhouse gas emissions.

Mexico has one nuclear power plant (1,365 MW) located in Veracruz state which was built 1990-1995 by Ebasco Services Inc.

Coal

Coal is a black or brownish black solid combustible fossil fuel typically obtained from surface or underground mines. Coal is classified according to carbon content, volatile matter and heating value. Lignite coal generally contains 9 to 17 million Btus[23] per ton. Sub-bituminous coals range from 16 to 24 million Btu per ton; bituminous coals range from 19 to 30 million Btu per ton; and anthracite, the hardest type of coal, from 22 to 28 million Btu per ton.

Coal fired generation facilities represent about 6 percent of Mexico's total installed generation capacity in 2003. Most of the country's coal reserves and all of its coal fired generation are in the northeastern state of Coahuila. The coal is low quality due to its high ash content.[16] Mission Energy, a US company, is the largest coal producer followed by Mexican company Minerales Monclova, a subsidiary of steel company Grupo Acecero del Norte. Due to an explosion at the Pasta de Conchos coal mine in February, 2006, the Mexican Congress passed a measure permitting non-PEMEX entities to develop and produce coalbed methane gas for self-use or sale to PEMEX.[30]

Domestic coal supplies are supplemented by imports from the United States, Canada and Colombia. Hard coal and brown coal are consumed in Mexico: hard coal is used by coke ovens in industrial operations and brown coal is used for electric generation.

Geothermal

Electricity can be created when steam produced deep in the earth is used to

[23] Btu or British thermal unit is a standard unit for measuring the quantity of heat energy equal to the quantity of heat required to raise the temperature of one pound of water by one degree Fahrenheit.

run turbines in a generator. Geothermal steam can be a renewable fuel if the associated geology and subsurface heat conditions are favorable.

Mexico's geothermal electricity potential is estimated at 8,000 MW, second in the world only to Indonesia.[16] The majority of this potential is located in a band of geothermal fields across the middle of Mexico in the volcano region. Potential geothermal energy sites are in close proximity to volcanos.

Currently most of Mexico's geothermal fired generation is in Baja California with very small amounts in the center regions. Currently CFE has five geothermal projects undergoing feasibility and prefeasibility studies.

Wind and Solar Energy

Electricity can be created when the kinetic energy of wind is converted into mechanical energy by wind turbines (blades rotating from a hub), that drive generators. Wind energy technology (advanced wind turbines) is available today at competitive prices. However, wind resources are fairly site specific and tend to be distant from major demand areas. As a result, the feasibility of wind energy is dependent on access to economic transmission which often is unavailable. In addition, wind energy is intermittent and thus is not always available to meet demand.

There is currently 3 MW of wind generation capacity in Mexico: 1 MW in the northwest and 2 MW in the southeast. Potential technically and economically feasible wind generation capacity in the country has been estimated at around 5,000 MW. CFE has four wind projects in feasibility studies and two wind projects ready to license.[42] To date, wind farms have been limited to smaller projects. Although several international companies have expressed interest in developing wind projects in Mexico, it is anticipated to remain a very small part of the country's total generation capacity, in keeping with worldwide trends.

Radiant energy from the sun can be converted to electricity by using thermal collecting equipment to concentrate heat, which is then used to convert water to steam to drive an electric generator (thermosolar) or can be converted to electricity directly through silica cells (photovoltaic). Solar energy depends on available sunlight and is reliant on storage or supplementary power sources.

Costs for solar energy applications have declined substantially and in some applications, solar electricity is economically competitive. Like wind resources, the best sites especially for large scale projects often are not near major populated areas and thus also are constrained by transmission access. Like wind, solar is intermittent, and backup power must be available for periods when radiant energy is too low or not available. In addition, solar panels and large solar arrays face environmental and community opposition similar to placement of other large electric power projects.

From 1993 to 2002 photovoltiac solar generation capacity has increased from 7 to 14 MW in Mexico. Mexico has a 10 MW experimental thermosolar plant operated by the Engineering Institute of UNAM and this technology has potential for expanded use in the northeast. Finally, Mexico's agriculture department has invested $6.2 million in solar-powered pumping systems for livestock and irrigation.

Biomass

Electricity can be created when various materials (like wood products, agricultural and urban waste) are combusted. Heat from combustion is used to convert water to steam for power generation. Biomass resources from urban waste are most available in heavily populated areas, while agricultural-based fuels are strongly associated with rainfall distribution as well as agricultural production.

The Institute of Electric Research (IIE) estimates that Mexico produces 90,000 tons of municipal waste annually which could support about 150 MW of generation capacity. At the beginning of 2004, CRE had granted three permits for biomass generation in Nuevo León. Currently there is 18 MW of capacity in operation. There are also 49 permits for hybrid generation using fuel oil and gas from sugar cane supporting 445 MW of potential generation.

ENVIRONMENTAL IMPACTS FROM ELECTRIC GENERATION

Providing electric power, in general, requires industrialization for provision of materials, equipment, and fuels; land and rights-of-way (corridors) for power plants, high voltage transmission grids, substations, and distribution networks; water resources for some power generation; and public acceptance of facilities and associated activity. Even the most seemingly benign types of electric power generation bear environmental consequences (factories and raw materials are required to manufacture solar panels) or may lack public support for development (recent opposition around the world to large wind power projects is clear evidence that public acceptance is a key consideration for electric power development). The environmental considerations must be weighed against the enormous benefits derived from electric power – for clean, indoor lighting and energy use; for the huge range of industrial, commercial, and household applications; for public safety associated with street and security lighting; and the endless host of benefits drawn from electricity that improve quality of life and standards of living across the globe.

Like most countries, Mexican electricity production is based on fossil fuels, primarily fuel oil and natural gas. Fossil fuels account for 67 percent of SEN generation and 100 percent of IPP generation in 2004. These fuels are expected to remain dominant in the foreseeable future. The main concerns resulting from the burning of fossil fuels for electric generation relate to air quality: greenhouse gases (and possible link to human induced climate change), urban ozone (smog), acid rain and particulate emissions.

Photo: American Petroleum Institute

Greenhouse Gas Emissions

Global warming, or the "greenhouse effect"' is an environmental issue that involves the potential for global climate change due to increased levels of atmospheric "greenhouse gases." Certain components in our atmosphere serve to regulate the amount of heat that is kept close to the Earth's surface. Scientists theorize that an increase in greenhouse gases from human activities could induce climate change, which could result in many environmental impacts, both positive and negative.

The principle greenhouse gases (GHG) include water vapor (the most abundant), carbon dioxide (the most prominent of human produced gases), methane (the most potent), nitrogen oxides, and some engineered chemicals such as choloroflourocarbons (which have been banned worldwide). While most of these gases occur in the atmosphere naturally, debate centers on the extent to which levels have been elevated due to a number of human activities ranging from agricultural practices and deforestation to the combustion of fossil fuels for energy production.

Among the GHG, carbon dioxide (CO_2) commands the greatest and most widespread attention. Although carbon dioxide does not trap heat as effectively as other greenhouse gases (making it a less potent greenhouse gas), and although the concentration of CO_2 in the atmosphere is very low relative to other time periods in the earth's history, measures of CO_2 associated with growing human populations and increased industrialization in recent decades suggest that concentrations have been rising rapidly. A number of policy and regulatory issues flow from the debate about CO_2. These include the potential for eliminating fossil fuel use altogether (an option that is widely regarded to be impractical because of trade offs associated with potential substitutes for electric power production, like nuclear power, and the lack of compelling and cost effective alternatives for fossil energy based vehicle transportation fuels); capturing CO_2 from power plant and other industrial flue gases and storing CO_2 long term in underground brine aquifers or through practical applications such as enhanced oil recovery (with CO_2 recaptured during oil conversion at refineries and petrochemical facilities); reducing CO_2 emissions through alternative technologies; and so on.

In addition to technology development, a number of policy and regulatory approaches are either under consideration or in experimental use to provide market and economic incentives for CO_2 reductions. The most common approach is creation of CO_2 credits, produced when measurable quantities of CO_2 emissions are reduced or eliminated, that can be traded and thus be used to transfer value of CO_2 emissions mitigation to those undertaking the cost of making the reductions. A variety of CO_2 emissions credit markets are operating around the world, including the European carbon credit market (the European Union Emissions Trading Scheme), the Chicago Climate Exchange in the US (a voluntary private market), and a variety of "over the counter" transactions in the US and Australia in which credits are derived and traded without formal trading schemes or market structures (exchanges).

Smog

Smog and poor air quality is a pressing environmental problem, particularly for large metropolitan areas. Smog, the primary constituent of which is ground level ozone, is formed by a chemical reaction of carbon monoxide, nitrogen oxides, volatile organic compounds, and heat from sunlight. As well as creating that familiar smoggy haze commonly found surrounding large cities, particularly in the summer time, smog and ground level ozone can contribute to respiratory problems ranging from temporary discomfort to long-lasting, permanent lung damage. Pollutants contributing to smog come from a variety of sources, including vehicle emissions, smokestack emissions like power plant flue gases, paints, and solvents. Because the reaction to create smog requires heat, smog problems are the worst in the summertime.

Acid Rain

Acid rain damages crops, forests, wildlife populations, and causes respiratory and other illnesses in humans. Acid rain is formed when sulfur dioxide and nitrogen oxides react with water vapor and other chemicals in the presence of sunlight to form various acidic compounds in the air. The principle source of acid rain causing pollutants, sulfur dioxide (SO_2) and nitrogen oxides (NO_x), are coal fired power plants. Particulate emissions also cause the degradation of air quality. These particulates can include soot, ash, metals, and other airborne particles.

Experimentation with tradable emissions credits was first undertaken with SO_2 in the US in response to concerns about acid rain deposition. SO_2 credits generated by power plants and other emitters are traded on the New York Mercantile Exchange (NYMEX). The success of that program in supporting SO_2 reductions is often cited as a main factor underlying development of tradable credit schemes for CO_2.

Fossil Fuels and Pollutants

Natural gas is the cleanest of all the fossil fuels. Composed primarily of methane, the main combustion products of natural gas are carbon dioxide and water vapor, the same compounds we exhale when we breathe. Coal and oil are composed of much more complex molecules, with a higher carbon ratio and higher nitrogen and sulfur contents. This means that when combusted, coal and oil release higher levels of harmful emissions, including a higher ratio of carbon emissions, NO_x, and SO_2. Coal and fuel oil also release ash particles into the environment, substances that do not burn but instead are carried into the atmosphere and contribute to pollution. The combustion of natural gas, on the other hand, releases very small amounts of sulfur dioxide and nitrogen oxides, virtually no ash or particulate matter, and lower levels of carbon dioxide, carbon monoxide, and other reactive hydrocarbons.

With respect to greenhouse gases, the combustion of natural gas emits almost 30 percent less carbon dioxide than oil, and just under 45 percent less carbon dioxide than coal. In addition, natural gas does not contribute significantly to smog formation, as it emits low levels of nitrogen oxides, and virtually no particulate matter.

In congested urban areas where NO_x and smog are specific problems, some natural gas power plants may be subjected to air quality rules that restrict the amount of emissions they can produce and thus the amount of time these plants can operate. During peak periods of demand, these rules can impact the amount of electric power available and limit the effective use of natural gas peaking units. In these cases, efforts are usually underway to balance NO_x emissions from natural gas electricity generators with emissions reductions from other sources in order to reduce production of ground level ozone and smog.

Since natural gas emits virtually no sulfur dioxide, and up to 80 percent less nitrogen oxides than the combustion of coal, it produces fewer acid rain causing emissions. Natural gas emits virtually no particulates into the atmosphere. In fact, emissions of particulates from natural gas combustion are 90 percent lower than from the combustion of oil, and 99 percent lower than burning coal.

Table 20. Fossil Fuel Emission Levels (pounds per billion Btu of energy input)

Pollutant	Natural Gas	Oil	Coal
Carbon Dioxide	117,000	164,000	208,000
Carbon Monoxide	40	33	208
Nitrogen Oxides	92	448	457
Sulfur Dioxide	1	1,122	2,591
Particulates	7	84	2,744
Mercury	0.000	0.007	0.016

Source: USEIA, Natural Gas Issues and Trends, 1998 (www.eia.doe.gov)

Environmental Mitigation Associated with Electric Power in Mexico

Mexico is the largest carbon dioxide emitter from fossil fuel burning in Latin America and may be relatively vulnerable to climate change.[24] As such, Mexico was the first country in the Western Hemisphere to sign the Kyoto accord.[26]

In addition, Mexico has implemented a fuel substitution policy that calls for reduced use of fuel oil and increased use of natural gas in electric generation. The Instituto Energia in Mexico City estimates that substitution of natural gas for other fossil fuels in electric generation decreased carbon dioxide emissions by 5.5 million tons between 1991 and 2002. It also appears that since 1998 carbon dioxide emissions growth has decoupled from GDP growth in Mexico; that is, carbon dioxide emissions have remained flat in spite of increased energy use and increased GDP. This is a result of the gradual improvements in energy efficiency and modernization referred to in FACTS ON MEXICO ELECTRIC POWER.

Of course, the use of renewable fuels such as water for hydroelectricity, solar, wind, geothermal and biomass fuels in place of fossil fuels for electric generation produces little or no direct emissions. However, generation from renewable fuels is generally more costly; still requires raw materials, land and water; and also has issues of availability, transmission access and reliability as discussed above. In 1996, CONAE[25] and ANES[26] established a consultative forum to identify actions necessary to promote the use of solar power. This forum was expanded into the COFER[27], composed of representatives from the industrial, commercial, academic, government and development bank sectors to promote the use of renewable fuels.

COFER identifies specific projects and develops programs and policies to support them. The current marginal generation cost, about 3.2 cents per KwH, in Mexico is based on gas-fired combined cycle units.[26] Generation costs using most renewable fuel sources are higher. Programs to promote renewable energy provide incentives to offset the higher marginal generation costs including green funds and carbon credits. According to CRE, at the beginning of 2004, it had granted 75 permits for generation with renewable fuels. Of these projects, 59 are in operation and 16 are in construction.[42]

[24] A three to five degree temperature increase without commensurate rainfall could cause drought in 50 percent of all arable land and significant damage to the inhabited Gulf of Mexico coasts.[26]

[25] Comisión Nacional para el Ahorro de Energia (National Commission for Energy Savings/Efficiency).

[26] Asociación Nacional de Energia Solar (National Association for Solar Energy).

[27] Consejo Consultivo para el Fomento de las Energias Renovables (Forum to Promote Renewable Fuels).

The legal framework for the Mexican electric sector is set out in the Mexican Constitution Articles 27 and 28 and the Public Electricity Utility Law (*Ley del Servicio Público de Energía Eléctrica).* This law makes providing energy for public service, e.g. selling electricity to consumers, the exclusive domain of the SEN companies CFE and LFC.

Prior to 1992, CFE and LFC controlled all electric generation, transmission, distribution and marketing activities with the exception of generation for self-use.[28]

In 1992 the government initiated changes to permit entry of private participants in electric power generation. Further attempts to modify the legal and regulatory structure of the industry were made in 1999 and during the Fox administration but were not successful.

Given the importance of fuel oil and natural gas supplies for electric generation, it is also necessary to address the legal and regulatory structure of the hydrocarbon sector in Mexico. As with the electric sector, the Mexican Constitution reserves oil and gas exploration and production, transportation, distribution and marketing to the state whose rights are exercised by PEMEX. In 1995 reforms were made to permit private participants in non-exploration and production related gas transmission, distribution and storage. In 2003, PEMEX implemented a contracting structure (Multiple Services Contracts) to attract private investment in designated non-associated natural gas areas in order to increase natural gas production.

The reform initiatives, successful and unsuccessful, as well as the current legal and regulatory structures of the energy industries are discussed below.

Energy Sector and Electricity Governance in Mexico

Secretaría de Energía (SENER, Ministry of Energy)

SENER is responsible for Mexico's energy policies (electricity and hydrocarbons) which should ensure competitive, sufficient, high quality, economically feasible and environmentally sustainable energy supplies as required by the nation.[33]

The Energy Minister is appointed by the President of Mexico. The Energy Minister is also the Chairman of the Boards of CFE, LFC and PEMEX. SENER also coordinates with and supports the CRE in its activities. The multiple roles of the Energy Minister which involve interaction with the regulatory body (CRE) and those it regulates (PEMEX, LFC and CFE) could lead to conflicts of interest. The Energy Minister is responsible for the financial and operating well-being of the state-owned companies while simultaneously promoting a fair and competitive business environment which policies may be to the detriment of the state-owned companies.

Comisión Reguladora de Energía (CRE, Energy Regulatory Commission)

The CRE was created in 1994 as a consultative body reporting to SENER, and its role as an advisor was limited to the electricity industry. The CRE Act (1995) transformed its role to that of an empowered, independent regulator with technical and operational autonomy with a legislative mandate to regulate the activities of both public and private operators in the electricity and natural gas industries. The CRE Act defines the following activities as subject to regulation:

- Supply and sale of electricity to public service customers;
- Private sector generation, import and export of electricity;
- Acquisition of electricity for public service;
- Electricity transmission and distribution;
- First hand sales of liquid petroleum gases or LPGs (mainly propane and butane) and natural gas (methane);
- Non-E&P (exploration and production) related natural gas transmission, distribution and storage;
- LPG transportation and distribution.

The main functions of the CRE are to grant permits, authorize transportation, transmission and distribution prices and rates, approve terms and conditions for the provision of services, issue directives, resolve disputes, request information and impose sanctions, among others. Although the CRE approves the methodologies for calculating payments for electricity and natural gas transmission and distribution, it does not have the authority to actually establish tariffs and end-use prices of electricity and natural gas. It "participates" in tariff setting with the Ministry of Finance.

The CRE also grants permits for the installation of regasification terminals in Mexico. These permits along with other guidelines regulate the operating, technical and safety standards of the facility. LNG storage and regasification facilities may be 100 percent privately owned and operated. Plant owners have a five year grace period from start-up before open access to the plant is required. The price of gas at the tail gate of the plant is set by market forces. Regasification tariff rates are regulated and approved by the CRE.

There does not appear to be a clear set of rules or procedures for appointment of CRE members. It appears that commissioners are selected by the Energy Minister (and presumably the President of Mexico) and approved by the President without public scrutiny or the approval of Congress.[19]

Secretaría de Hacienda (Ministry of Finance)

The Finance Ministry plays a critical role in both the electric and hydrocarbons sectors. It administers end-use electricity and hydrocarbons prices and is thus responsible for subsidy policies. By its ability to approve or disapprove financing for PEMEX-proposed projects, it also influences the supplies of hydrocarbons for electric generation.

The Finance Minister is a Presidential appointee.

Secretaría del Medio Ambiente y Recursos Naturales (Semarnat, Ministry of the Environment and Natural Resources)

All electric industry activities must obey the applicable legal provisions on environmental protection, chief among them the Ley General del Equilibrio Ecológico y la Protección al Ambiente-LGEEPA (General Law on Ecological Balance and Environmental Protection) and the Mexican official standards (NOM) on environmental protection. A summary of Mexico's NOMs is contained in SENER's annual *Prospectiva del Sector Eléctrico*, www.sener.gob.mx.

Mexican Congress

The Mexican Congress approves the annual operating and investment budgets of CFE, LFC and PEMEX. It also establishes the tax regimes for these companies. As a result, the Congress clearly influences

[28] Since 1975 the private sector has been allowed to generate power for its own use (autoabastecimiento).

the availability of capital for electric and hydrocarbons infrastructure and supplies.

Mexican Presidency

Substantial progress in political liberalization has been accomplished in Mexico including increased transparency in elections and voting in general, and for presidential elections in particular; a more open, free, and transparent press; increased public access to the political process; more competitive elections and greater transparency with respect to campaign finance. Mexico's president, with a six year term and life time ban on re-election, remains the nation's most important office for national policy making. The office of the president is also engaged in day-to-day energy sector operations through the process of establishing energy prices, as described earlier, as well as through key appointments to lead Mexico's energy companies and energy sector governance institutions.

Petróleos Mexicanos (PEMEX)

PEMEX is governed by an eleven member Board of Directors. The President of Mexico appoints six directors from various government ministries including the Chairman of the Board (the Energy Minister). The Petroleum Workers' Union selects the remaining five directors from amongst PEMEX employees. Board members are not appointed for a specific term. Board members, except for those selected by the Union, serve subject to the discretion of the President of Mexico.

The President also appoints the Director Generals of PEMEX and its subsidiaries. As a result, the PEMEX Director General has little authority over the actions of the operating company appointees.[13]

Each PEMEX subsidiary is governed by an eight member board consisting of the Director General of PEMEX, the Director Generals of the three other subsidiaries and four members appointed by the President of Mexico. These board members are not appointed for a specific term and serve subject to the discretion of the President of Mexico.

The CRE has no regulatory authority over PEMEX's oil and gas exploration and production activities. In this arena, critical to fuel supplies for electric generation, PEMEX is self-regulated.

Comisión Federal de Electricidad (CFE)

The CFE is governed by a government appointed Board of Directors as follows: the Energy Minister is the Chairman of the Board and other members include the Director General of PEMEX, the Secretaría de Hacienda y Crédito Público (Finance and Public Credit), the Secretaría de Desarrollo Social (Social Development), the Secretaría de Medio Ambiente y Recursos Naturales (Environment and Natural Resources) the Secretaría de Economía and three workers from the electrical workers' union. This board meets four times per year in regular session and also in extraordinary session when necessary. Decisions are taken by majority vote; in the case of a tie, the President of Mexico makes the decision. The mission and goals of the CFE are as follows.

Mission

- To ensure, within a technologically updated framework, supply of electricity with acceptable quality, quantity and price, with appropriate diversification of power sources;
- To optimize the use of physical, commercial and human resource infrastructures;
- To provide outstanding customer service, and
- To protect the environment, promote social development and respect the values of populations where electrical power is provided.

Goals

- To remain as the leading domestic electric power corporation;
- To operate according to international benchmarks in terms of productivity, competitiveness and technology;
- To be known to our customers as a corporation of excellence, concerned about the environment and customer service-oriented, and
- To promote high qualifications and professional development of CFE workers and managers.

Electric Power Reform Initiatives

1992 Electric Generation Reform

In an attempt to stimulate investment in Mexico's electric power industry, the Law of Public Service of Electricity was reformed during the Presidency of Carlos Salinas. This law is associated with Article 28 of the Mexican Constitution which addresses the sovereign control and public service responsibilities of the CFE. This reform allowed the private sector to participate in cogeneration and self-use production, in BLT (build, lease and transfer) and as independent power producers (IPPs). The main characteristics of each one of these categories can be described as follows:

- In the case of cogeneration and self-use production, any surplus production has to be sold to the CFE at a price fixed by an energy regulator.
- For BLT projects, building and financing are the responsibility of the private investor. The CFE supervises the project and sets the technical specifications. When construction is complete, the plant is operated by the CFE. Once in operation, the plant is leased to the CFE for a period of 20-25 years at the end of which ownership passes to the CFE. The project costs are registered as

Table 21. Generation Permits Through 2004

Type of Capacity	Permits Granted	Permits Operating	Capacity Permitted (MW)	Capacity Operating (MW)
Self-use pre-1992	59	58	594	574
Self-supply, or which:	184	162	4,682	3,678
• Cogeneration	34	30	2,117	1,427
• IPPs	21	15	12,557	8,212
• Export	5	4	1,630	1,330
• Import	27	27	184	184
• Total 1992-2004	271	238	21,170	14,831
TOTAL	**330**	**296**	**21,764**	**15,405**

Source: SENER, 2006

direct private investment (regardless of whether it is domestic or foreign), and after two years it is converted to public debt (again, regardless of whether the generator is domestic or foreign).

- In the case of IPPs, the project developer designs, finances, builds and operates the plant and delivers the electricity generated to the CFE for a period of 20-25 years. Through a bidding process the CFE guarantees the price and the market (total or partial) to the project developers.

In 1995, in conjunction with the natural gas reforms, a separate regulatory commission, CRE, was established to oversee natural gas and power activities. In addition to the duties outlined previously, the CRE also bids and licenses new IPP projects under the 1992 electricity law.

The results of the 1992 reform between can be seen in Table 21. Of the 21,170 MW of permitted capacity, 14,831 MW or 70 percent was operational by the end of 2004.

The 1992 reform was a stopgap measure that resulted in almost no change in the architecture of the sector. It is also complex in practice, due to the cumbersome bureaucracy it entails.[3,5] In addition, the level of electricity production engendered under the reform appears insufficient in light of projected electricity demand.

1995 Natural Gas Transportation, Storage and Distribution Reforms

In Mexico, the hydrocarbons (oil and natural gas) sector and the electricity sector are intertwined due to the importance of hydrocarbons as fuels for electric generation. Prior to 1995, oil and natural gas transportation, storage and distribution were controlled exclusively by PEMEX. In 1995, reforms were implemented to allow public and private companies, domestic and foreign, to own and operate natural gas transportation, storage and distribution systems subject to regulation by the CRE.[29] These natural gas reforms were related to the 1992 electric sector reforms: public and private natural gas-fired generators required access to an open and competitive market for natural gas, including transportation, distribution and storage. As natural gas production continued to be in the sole domain of PEMEX, these reforms partially "opened" the natural gas sector.

Both PEMEX and private companies are required to obtain permits. Transportation and storage permits are issued for 30 years and are renewable. There permits require the investor to assume the market risk for there is no exclusivity with respect to specific capacities or defined routes. Permits are assigned to technically sound proposals and the market decides which permitted project is finally carried out. For transportation promoted by the government, permits are issued through public bidding. For example, the CFE bid independent power projects together with the pipeline that connects the generation plant to the natural gas system.

Between 1996 and May 2005, the CRE issued 19 permits covering 11,316 kilometers of gas pipelines and requiring an investment of US $1.8 billion: about 20 percent of this investment is for private sector open access[30] pipeline projects and the other 80 percent is for PEMEX's expenditures on its own trunkline. Some 112 permits were also granted for "self use" pipelines for spur lines to connect large industrial users and electric generators to gas fields or to the main trunklines requiring an investment of US $230 million.[43]

Despite the introduction of competition into the gas transportation sector, PEMEX continues to control about 85 percent of installed capacity. It also controls all domestic natural gas production and the marketing of that production. In 2000, the CRE recognized that the vertical integration of PEMEX in natural gas production, transportation and marketing was hindering competition in gas marketing. The CRE issued a directive requiring PEMEX to "unbundle" or separate its production, transportation and marketing activities and to eliminate cross subsidies between marketing and first hand gas sales. Similarly, private transporters, distributors and storage operators can buy and sell natural gas but the services must be unbundled, with separate accounting systems for each service and without cross subsidies among services.

Also in 1995 private and public companies were permitted to own and operate gas distribution facilities in Mexico subject to government approval and regulation. PEMEX had to divest its distribution assets and provide open access to its transportation system for distributors. In 1997, the CRE granted 21 permits to nine private companies to operate gas distribution systems including Gas Natural, Tractebel (now Suez), Gaz de France, Sempra Energy, Kinder Morgan, TXU Energy, Grupo Diavaz and Grupo Imperial. Through May 2005, the distribution investment has totaled US $674 million.

One factor impeding growth in gas-fired generation is the continued dominance of PEMEX in gas production and transportation. This issue is discussed more fully in the Major Issues chapter.

Proposed 1999 Electric Sector Reforms

Concern began to grow that electric demand would continue to outstrip supply despite the 1992 electricity law reforms. Electric price subsidies continued to stimulate demand growth. As well, a number of factors discouraged potential IPP investors: the lack of flexibility for wholesale transactions outside of CFE; restrictions on how much surplus generation capacity could be developed for sale outside of CFE (no more than 5 percent); lack of clarity with regard to contracts for the purchase of natural gas from PEMEX for both new and existing facilities.[19]

As a result of these concerns, a second, broader phase of electric reform was contemplated by the government of President Ernesto Zedillo in 1999.

In late 1999, President Zedillo's energy minister, Luis Tellez, proposed a full restructuring of the electric power sector as follows.

- A wholesale market would be created with an independent system operator that would mimic the functions of similar organizations being created in the U.S.
- Generation would become fully competitive with generation companies or "Gencos" that could be privately owned.
- The sovereign electric companies would not be privatized, an important difference between Mexico's strategy and other nations. However, opinion hewed strongly to the notion that the Tellez proposals would pave the way for an eventual sale of CFE and LFC and it was clear that, privately, Tellez held out that possibility. Rather, CFE

[29] PEMEX continues to control oil and petroleum products transportation, storage and distribution.

[30] Open access is a regulatory mandate which allows third parties to use a transporter's transportation facilities to move gas from one point to another on a nondiscriminatory basis for a cost-based fee.

would maintain control and operation of transmission and local distribution (as would LFC). Mechanisms would be provided for private investment in new transmission facilities. A goal was to make Mexico's grid more compatible with that of the US in order to facilitate cross-border exchanges.[19]

Tellez's initiative was an unusual gambit to roll out a major policy change late in a presidential term. By summer 2000, Tellez's proposed reforms had failed in the Mexican Congress.

Proposed Fox Administration Electric Reforms

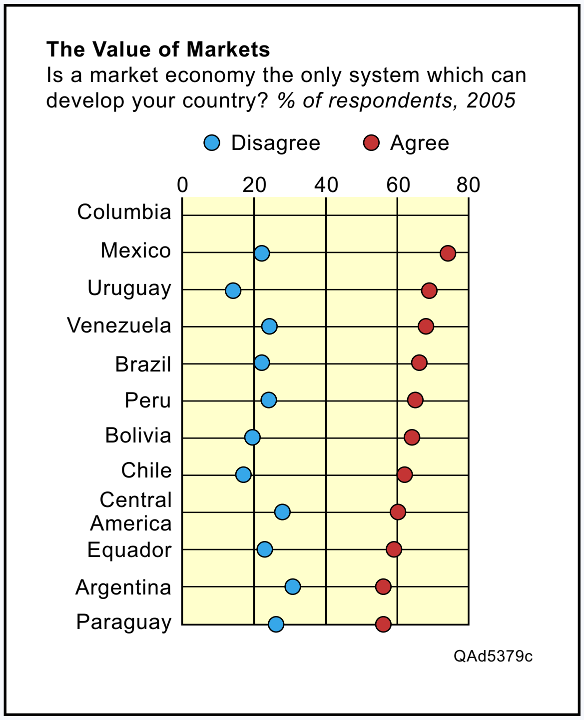
The government of President Vincente Fox attempted to amend the restriction on sales of surplus generation to non-CFE entities by increasing it from 5 percent to 10 percent but the attempt failed. A group of Congressmen filed a constitutional challenge before the Mexican Supreme Court, accusing Fox of exceeding his presidential authority. The Supreme Court, in an unprecedented decision, ruled that Fox's amendments were unconstitutional. Moreover, the Supreme Court, in its discussions and deliberations, considered that power generation by private parties could be against the Constitution, without making a final ruling on this issue since it was not the subject matter of the case.[34]

In 2003, Congressmen filed a complaint with Chamber of Deputies' auditing entity, the Auditoría Superior de la Federación (ASF), asking it to review the legality of the generation permits granted by the CRE to private parties. The ASF found that the generation permits granted by the CRE were illegal and contrary to the Constitution. SENER filed a constitutional challenge before the Supreme Court alleging that the ASF does not have the authority to decide on the legality of the generation permits granted to private parties by the CRE. The Supreme Court admitted SENER's constitutional challenge and a final resolution is pending. Legal experts expect the Supreme Court to rule in favor of SENER.[34] However, these legal challenges have cast a shadow over additional investments.

In 2001 President Fox introduced a recast version of the 1999 Tellez proposal to the Mexican Congress which also failed. It was opposed by an alliance made up of Senators and Deputies from the PRI, the Democratic Revolution Party (PRD), the National Workers Union (UNT), and the Mexican Trade Union, made up primarily of electric companies. Key components of the Fox proposal are listed below.

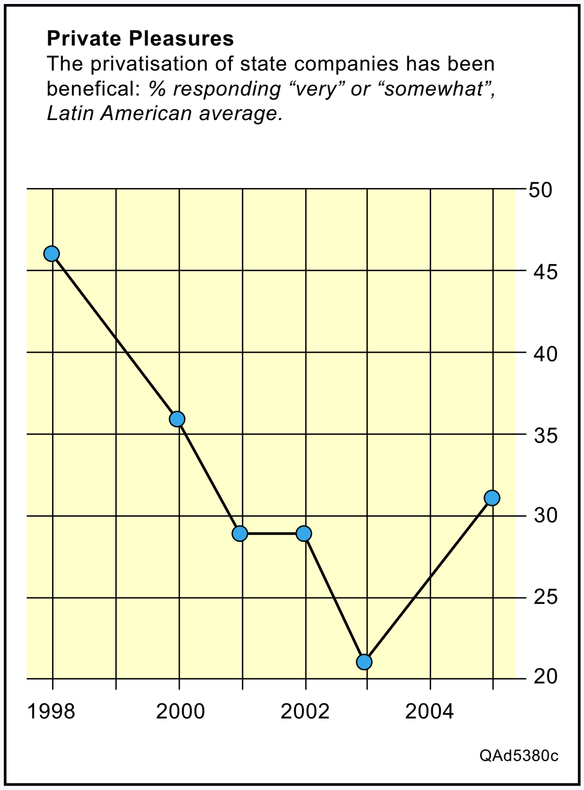
- Generation, transmission and distribution activities would be separated. Constitution articles 27 and 28 would be amended to permit private investment in generation and distribution. Transmission and nuclear generation would remain reserved to the state and regulated.
- CFE and LFC would not be privatized; they would be strengthened financially.
- The CRE would have new and increased responsibilities including the power to fix electricity prices, provide technical and economic regulation and deter anti-competitive behavior from market participants, including CFE and LFC.
- Redefinition of electricity price subsidies in a transparent way.[5]

Rather than implement the proposed reform, the alliance advocated granting technical, administrative and financial autonomy to the CFE and LFC so that they can expand capacity and leaving the system vertically integrated and organized much as it is today. Private generation (IPPs selling to CFE, self-supply and cogeneration) would be permitted as secondary and complementary activities to the public provision of electricity which would remain the responsibility of CFE and LFC. With respect to electricity prices, the PRI advocated that tariffs be set by the CRE with the input of the secretariats of Hacienda and



Source: Latinobarómetro Poll, as cited by The Economist, October 27, 2005

Figure 11. Latin American Public Opinion on Value of Markets



Source: Latinobarómetro Poll, as cited by The Economist, October 27, 2005

Figure 12. Latin American Public Opinion on Privatization

Economy. The PRD advocated that tariffs be proposed by CFE and approved by CRE.[4]

Outlook for Further Electric Sector Reform

It is the view of some analysts that no Mexican debate in recent memory has been so heated as was the debate over the proposed Zedillo and Fox electric sector reforms and that the subject of electricity reform has left the technical arena and has almost totally evolved into a political issue.[3,5] The fragmentation of politics in Mexico has also impeded reform: continual debate and the lack of control by any single party in the Congress has undercut continuity in reform strategy and has deterred investors. Finally, available data shows that Mexican public opinion opposes private investment in the energy sector (electricity and hydrocarbons) as well as privatization of the state-owned companies.[31] The public opinion results on private investment stand in marked contrast to preferences in Mexico for markets. Mexico has consistently been one of the strongest countries in Latin America with regard to value of markets for economic development. Public concerns regarding privatization are, however, widely shared across the Latin American region, a consequence of poorly devised and executed reforms in many instances as well as the perception that widespread benefits from privatization programs have not been achieved.

Creating a political coalition will be necessary for further reforms because of the large number of disparate and conflicting interest groups and opinions regarding how Mexico's electric power sector should be developed and operate. Finally, any further meaningful reform of the electric sector is contingent upon the influence of Mexico's president and effective use of the presidency to build consensus and support. As this publication was finalized, Felipe Calderón of the PAN party is the apparent president-elect following an extremely close election. Should Calderón assume the office of president as expected, it is likely that electricity and energy in general will be a prominent issue for engagement. The Calderón campaign organization articulated a number of potential electricity policies, as summarized below. Whether these remain the preferred approaches or priorities remain to be seen.

Felipe Calderón Electricity Policies (from May 2006 campaign document)

- Create a market system that allows large consumers to buy electricity at competitive prices;
- Implement best practices for management, governance and transparency in the state-owned energy companies;
- Strengthen the CRE to promote fair competition and regulate prices; and
- CFE will not be privatized. Opening the sector to private investment is the way to get competitive prices without damaging public finances.

[31] In a 2002 poll conducted by Coordinacion de Estudios de Opinion, 35 percent of the population opposed private investment in the electric sector and only 17 percent supported a strategy of attracting new private funds in the industry. Less than half (49 percent) of Mexicans feel that the country has electricity problems. 60 percent believe the electric sector reforms would harm worker rights and a majority believes that private investors will force higher tariffs. However, the poll shows that voters care much more about employment and public security than energy reforms.[5]

A number of key issues impact Mexico's electricity sector, now and into the future.

Political Fragmentation

Mexico is in the midst of both a political and an economic transition. The election of President Vincente Fox in 2000 marked an important shift towards democracy, increased political pluralism and resulted in more checks and balances to the power vested in the President. Seven decades of dominance by the Partido Revolucionario Institucional (PRI) resulted in an elite-driven policy-making process that was relatively straightforward. Today policy-making is much more complex, with the rise of a multi-party system, the decline of Presidentialism, and the rising importance of local governments for social and economic development. Mexico's Congress and legal system are Napoleanic in origin and administrative in practice, yielding few opportunities for and no experience with effective political coalition building.[19]

These increasingly complex political processes hampered the Fox administration's ambitious reform agenda, including further reforms in the energy (hydrocarbons and electricity) sector. According to the World Bank, further energy sector reform is needed to improve Mexico's economic competitiveness. Specifically, the Bank recommends further unbundling of energy activities, strengthening regulatory frameworks, increasing private investment, and enhancing corporate governance in the energy sectors.[52] However, because no party holds a majority in either house of Congress, the executive has had very limited success securing legislative approval on its reform proposals. There are at least ten electricity sector reform proposals that have been or are being discussed in Congress. However, inaction of further energy sector reforms appear to have stalled until a new government takes power in 2006.

Based on preliminary results from the 2006 national elections, no one party in the Congress will have the ability to pass laws or reform the Constitution. Thus, Mexico's incoming president will face a legislative situation similar to the one faced by President Fox. With increased pluralism, Mexico slowly is developing legislative practices that can foster coalition building. Considerable skill in coalition building will be required to implement new energy policies much less deal with other high priority policies for Mexico.

Table 22. Preliminary 2006 Mexican Congressional Election Results, Chamber of Deputies

- **251 votes required to enact new or change existing legislation**
- **334 votes required to reform Constitution**

Party	Seats	Percent Total Seats
PAN	206	41.2
PRD	124	24.8
PRI	103	20.6
Three Other Parties	67	13.4
Total	**500**	**100**

Source:CIDAC 2006 [7]

Table 23. Preliminary 2006 Mexican Congressional Election Results, Senate

- **65 votes required to enact/reform legislation**
- **86 votes required to reform Constitution**

Party	Seats	Percent Total Seats
PAN	52	34.4
PRI	33	21.8
PRD	29	19.2
Four Other Parties	37	24.6
Total	**151**	**100**

Source: CIDAC 2006 [7]

Regulatory Independence

The CRE is not completely independent of political control by SENER, although CRE commissioners have attempted to assert their independence on crucial decisions and controversial decisions on bids and licenses.[19] More problematic is the conflict of interest inherent in the position of the Secretary of Energy as chairman of the boards of PEMEX and CFE while also providing support for CRE's reforms when they threaten the competitive interests of the sovereign companies. Continuing issues range from implementation of an open access tariff on the PEMEX natural gas transportation system, to control of the wholesale power market, to the impact of high natural gas prices and the related question about whether Mexico can or should attempt to build a competitive natural gas market.[19]

In addition, other government entities, particularly the Secretariats of Hacienda and Economy, have significant input on electricity price regulation which, in most industrialized nations, is reserved to the independent regulator.

Infrastructure Investment

Investment in infrastructure, including energy infrastructure, has not kept pace with demand in Mexico. Infrastructure investment in Mexico collapsed from between 2-2.5 percent of GDP in most of the 1980's and the first half of the 1990's to between 0.8-1.3 percent of GDP in the second half of the 1990's. The Mexican Congress has not been able to implement the critical tax reforms necessary to regaining higher investment levels. Some 40 percent of CFE's installed generating capacity is over 35 years old and is due for replacement, not to mention incremental capacity to meet increased demand. SENER estimates that investments of approximately $58 billion will be required over the period 2005-2014 and the electric sector's ability to fund that investment remains questionable.

Of the expected investment of $58 billion, about 48 percent is expected to come from the private sector. This private sector investment is uncertain given the policy and regulatory concerns discussed previously. The $30 billion in investment to come from CFE and LFC is also problematic due to the financial condition of these companies which is discussed in more detail below. Concerns about future reliability of electricity

Table 24. Outlook for SEN Required Investment 2005-2014 (US$ Millions)

Investment Type	Total 2004-2013	Percent of Total Investment
Generation	*22,297*	*38*
IPP: Combined Cycle Gas-Fired & Wind	3,884[32]	7
Private Investment-OPF[33]	7,626	13
CFE & LFC	2,212	4
Private, to be defined	8,574	14
Transmission	*12,274*	*21*
Private-OPF	5,985	10
CFE & LFC	6,289	11
Distribution	*13,845*	*24*
Private-OPF	1,021	2
CFE & LFC	12,823	22
Maintenance	*8,268*	*14*
IPP Generation	1,374	2
CFE & LFC Generation	6,782	12
Other CFE & LFC	1,243	2
Total	**57,927**	**100**

Source: SENER 2006

supply are impacting foreign investment decisions in the industrial sectors.[53]

Subsidies of Electricity Prices

Mexico has long had "administered" prices for electric power: electricity prices have traditionally been established via a committee including the office of the president, Mexico's treasury ("Hacienda"), the energy ministry, the sovereign companies and the ministry of commerce.[19] As a result of this pricing scheme, the clearing of supply-demand imbalances is done through quantity. Thus, even during the worst of economic times, electric power consumption is resilient and even increases.

Concerns about the maintenance of social and political stability have led Mexican governments to subsidize the electricity consumption of a very large proportion of the population in an effort to maintain their purchasing power.[53] Tariffs have been held below the cost of service, preventing the sector from recovering costs of operations and investment. The average tariff charged to residential customers in 2000 covered just 43 percent of costs, and the average tariff for agricultural use covered 31 percent of costs. Industry and services paid almost 95 percent of costs.[53]

While the electric sector has been generally successful in providing electricity to meet current needs, its ability to make adequate provision for investment levels in the future could be impaired by the price subsidies. If subsidized electric prices continue to prevent cost recovery, the capacity of CFE and LFC to "pay their way" will continue to deteriorate, placing a growing burden on the public purse, as well as on PEMEX reinvestment. This is because PEMEX is the single largest generator of hard currency through petroleum exports and the single largest contributor to Hacienda finances. As a consequence, management of the electric power system in Mexico bears implications for the overall health and welfare of the energy sector in general.

In its *Prospectiva del Sector Eléctrico 2005-2014* SENER addresses the problem of electricity subsidies by assuming that almost half of the required electric sector investment will come from private investors. However, the market distortions resulting from subsidized electricity prices make it difficult to attract private investment and competition into the sector. If CFE and LFC buy power from private generators at market prices, they incur losses when they resell the power in the retail markets. These losses further erode the creditworthiness of the state-owned companies making it more difficult for private generators to obtain financing based on long-term sales contracts with the state-owned companies.

Even if allowed, private generators cannot compete directly with CFE and LFC in the retail markets because their prices are at a competitive disadvantage with respect to the subsidized prices. The lack of predictability and transparency in electric price setting is a major concern to current and potential private investors in the sector. The electricity business, like other subsectors that comprise the energy sector, is characterized by large sunk investments with long payback periods. As a result, financing for these investments requires a high degree of predictability with respect to future revenues.

Labor Unions

The electric sector hosts two of Mexico's strongest unions which historically have been key elements of the PRI's power base. The CFE-related union is the Sindicato Único de Trabajadores Eléctricos de la República Mexicana (SUTERM); the LFC-related union is the Sindicato Mexicano de Electricistas (SME). These unions have contributed to the debate surrounding the electric sector and electric tariffs reforms. The employment status of electric sector workers was an issue in Zedillo's proposed 1999 reforms. Although the SUTERM supported the 1999 initiatives, the sharpest protests against them were led by the SME which succeeded in rallying a large number of intellectuals, academics and opinion leaders, as well

[31] Gas-fired combined cycle plants represent 80 percent of the total.

[32] OPF is public works financed by private investment.

as a sizeable segment of the PRD, around the rejection of the proposal. The SME feared that electric sector restructuring would lead to massive layoffs as had occurred in other countries like Argentina. However, in July 2000, the government and SUTERM signed an employment security and stability agreement which asserted that if control of the CFE or LFC changed, labor rights would not be affected.[3]

With respect to electric tariff reform, especially increasing residential and agricultural tariffs, the SME and SUTERM created alliances with the PRD, the leftist wing of the PRI and some other social organizations to block modification of the electricity subsidy policies. Since the SME and SUTERM are well-organized groups with the capacity to mobilize votes, electric tariff reform remains politically risky.[5]

PEMEX Dominance in Natural Gas Transmission and Marketing

On February 23, 2000 the CRE issued the Directive on First Hand Sales of Natural Gas because the vertical integration of PEMEX in natural gas production, transmission and marketing was hindering competition in gas marketing.[55] Basically this directive posits that PEMEX retains a *de facto* monopoly in gas marketing and thus, this activity must be regulated.

The directive requires PEMEX to unbundle its production, transmission and marketing activities. PEMEX may negotiate long-term contracts at prices below the maximum allowed by regulation provided there are no cross-subsidies between marketing and first hand sales. However, regulation of PEMEX's discretionary discounts on domestic gas and transport services is easier said than done given the company's monopoly in gas production, its dominant position in gas transmission and asymmetry of information between PEMEX and CRE. This lack of clarity with regard to contracts for the purchase of natural gas from PEMEX is a concern of private investors developing natural gas-fired generation projects.

Future Natural Gas Supplies

As mentioned previously, natural gas consumption in Mexico grew by 77 percent between 1994 and 2004. Going forward, all expectations are that natural gas demand will continue to increase before eventually leveling out or decreasing with improved energy efficiencies (see later section on FUTURE TRENDS). The primary driver for this growth in natural gas consumption is consumption by the electric power sector.

From 1994 to 2004, PEMEX's natural gas production grew at an average annual rate of 4 percent compared to a 5.9 percent average annual rate of growth in natural gas demand.[43] The gap between demand and supply was made up by imports which grew at an average annual rate of 25 percent. However, dry gas proven reserves in Mexico have declined steadily in all production regions since 1998, decreasing from 31 trillion cubic feet (Tcf) in 1998 to 14.8 Tcf at year end 2005.

In its *Prospectiva del Mercado de Gas Natural 2004-2013* prepared in 2004, SENER estimated that PEMEX natural gas production would grow at an average annual rate of 2.5 percent compared to a 5.7 percent annual growth rate in demand. As a result, SENER projected that Mexico may need to increase its imports of natural gas (both pipeline gas from the US and LNG) over the period by an average annual rate of 14.4 percent.

However, in its *Prospectiva del Mercado de Gas Natural 2005-2014* prepared in 2005, SENER sharply revised upwards its estimate of PEMEX natural gas production which is now expected to grow at 5.2 percent annually. The demand forecast for 2013 is virtually unchanged: 9,303 MMcf/day (2004 publication) compared to 9,110 MMcf/day (2005publication).[34] As a result, gas imports are now projected to grow at a slower rate of 9.5 percent annually. Gas exports increase significantly over the forecast period compared with the 2004 estimates. Clearly, there are substantial differences of opinion regarding extent of use of natural gas in Mexico overall and in Mexico's electric power generation segment. These differences are due to recent trends with respect to higher natural gas prices in North America and attractiveness of competing fuels for power generation.

In order to meet the 2005 production forecast, PEMEX would have to see production from new fields as early as 2007. By 2014, 52 percent of forecast production will have to come from new fields to be discovered.[43] From 1975 until 2003 PEMEX had not made significant investments in exploration; future exploratory success is always uncertain.

Another issue associated with future natural gas supplies is PEMEX's ability to fund the estimated $104 billion of investment required to generate the gas production growth forecast by SENER for the period 2005-2014. An estimated $10 billion per year is the required investment in exploration and production (PEP); $4 billion over the projection period is the estimated investment requirement by PGBP for gas transmission and associated infrastructure.[43]

PEMEX's annual capital budget is part of the federal budget and as such must be approved by the Mexican Congress. As a result, PEMEX faces competition from other government programs for capital and the capital allocation is subject to politics. In other words, it is not certain that PEMEX will be able to obtain the capital it needs to implement the investment program embodied in these gas production forecasts.

In December 2001 PEMEX attempted to improve its investment dilemma by announcing the Multiple Services Contracts (MSC) scheme which was designed to attract private companies to develop non-associated natural gas fields pursuant to a contractual fee-based arrangement in which PEMEX retains the rights to all extracted hydrocarbons. SENER expects MSC production to contribute about 14 percent of total natural gas production by 2014.

In addition, the tax burden on PEMEX continues to be high with income taxed at approximately 63 percent. Taxes paid by PEMEX continue to represent the largest funding source for the federal government accounting for nearly 40 percent of federal fiscal tax revenues as a result of recent years of high oil prices. This high tax burden on PEMEX reduces the cash flow from operations that the company can retain for re-investment purposes.

In November 2005, the Mexican Congress approved a bill to reduce PEMEX's tax bill by about $2 billion per year beginning in 2006. Although the new tax regime is a positive step, it does not resolve PEMEX's capital dilemma. Credit ratings for PEMEX remained unchanged with credit rating agencies stating that "the bill will not make a significant impact on PEMEX's short-term financial and operating performance." [www.latinpetroleum.com, 7/6/05]

Also in the fall of 2005, in response to Hurricane Katrina's impact on North American natural gas supplies and prices, President Fox proposed to Congress a change in Mexico's Constitution to allow private

[34] Both the 2004 and 2005 forecasts discussed here are the base demand/medium supply cases.

companies to explore for and produce non-associated natural gas in Mexico. In addition, he also proposed changing laws to permit private investment in PEMEX's pipeline network which has suffered numerous leaks and deadly explosions. However, there has not been positive action on these proposals by Congress to date.

In the fall of 2005 in response to the same weather phenomenon, President Fox set temporary limits on the price of natural gas in Mexico (a cap of $7.65/mmBtu) in order to keep natural gas and electricity prices down for Mexican citizens. This price cap is expected to cost the government about $850 million by the end of 2005. As a result, demand for natural gas will not decrease as much as higher prices would predict, exacerbating the current natural gas import situation.

In Calderón campaign materials, the privatization of PEMEX is not advocated but support is expressed for private investment in refining, natural gas, and petrochemicals to supplement public sector investment. The materials also include a proposed change PEMEX's tax regime to increase its investment resources and support for PEMEX to form strategic alliances.

Natural Gas Imports

Imports of natural gas from the United States rose from 125 MMcf/d in 1994 to 1,124 MMcf/d in 2004. SENER expects natural gas imports to grow to fill the gap between domestic PEMEX gas production and domestic gas demand; LNG from non-US sources is expected to account for most imported natural gas. CFE is taking an active role in directly contracting for the natural gas imports needed for future generation including providing guarantees for LNG projects and potentially participating in natural gas projects directly, as is typical for integrated electric power companies in other countries.

Relying on imports of natural gas from the United States is problematic for Mexico for several reasons. First, natural gas demand in both the United States and Canada relative to available supply has contributed to a tight balance leading to concerns about reliability. Secondly, natural gas imports are a drain on Mexico's hard currency reserves, costing the country approximately $2 billion in 2003 and representing 35 percent of the country's balance of trade deficit.[35]

Natural Gas Vs. Fuel Oil

The issues surrounding future natural gas supplies for electric generation lead to the following question: Why not fuel future electric generation with fuel oil? Mexico has an abundant supply of this commodity. Historically, high sulfur fuel oil has fueled the largest percentage of Mexico's electric generation.

There are significant environmental problems associated with using high sulfur (>4 percent) fuel oil for electric generation. Upon combustion, this fuel oil releases relatively high quantities of sulfur dioxides, nitrogen oxides and carbon dioxides which contribute to air pollution, ozone formation, acid rain and global warming. Usage of natural gas for electric generation, on the other hand, results in substantially lower emissions of sulfur dioxides and nitrogen oxides. In addition, combined-cycle natural gas generation plants are much more thermally efficient (in terms of heat rate) than fuel oil fired generation plants.

As a result, the Mexican Congress enacted environmental norms 085 and 086 which began to be enforced in 2004 and should reach full enforcement in 2006. These norms mandate that natural gas be substituted for fuel oil in electric generation and industrial applications in environmentally sensitive areas. SENER believes that enforcement of these environmental norms accounts for about 6 percent of the growth in natural gas demand between 2002 and 2006.

However, as concerns about natural gas supplies and price levels have grown in North America, more attention is being devoted to improving the environmental impact of coal and fuel oil-fired generation. Technologies are being developed to "capture" carbon dioxide before it is emitted from electric generation plants and "sequester" or store it in safe receptacles below ground such as depleted oil and gas reservoirs. If cost competitive carbon dioxide capture technologies could be developed and cost effective "safe" sequestration is proved, the environmental impact of fuel oil and coal fired generation plants could be improved.

Renewable/ Alternative Fuels

As described earlier, alternatives for power generation include hydroelectric power, solar electricity, wind energy, biomass energy and geothermal power. The fuels for each of these are available at little or no cost; they are often renewable fuels; and they may produce little if any direct emissions. Proponents argue that the environmental costs of conventional electric power are not reflected in the cost of electricity produced. If these costs (externalities) were included, alternative fuel electricity could be very competitive.

While the benefits of cleaner, alternative energy sources for electricity are appealing, they do pose operational considerations for the management of electricity services. For one thing, they are "intermittent" power sources (the sun does not shine at night, the wind is variable), and peak availability of alternative energy sources does not always coincide with peak demand. Options like solar and wind cannot provide consistent power production, in contrast to the coal and nuclear facilities that are usually used for "base load" (the units operate continuously providing a consistent power base). Many solar technologies tend to be implemented in conjunction with natural gas turbines. In addition, both solar and wind require large amounts of acreage when deployed for large-scale power generation and extensive use of materials (steel and other products) that require considerable energy to produce.

Technological advances are such that some success in integrating wind-generated electricity has been achieved. Likewise, hydro facilities provide a readily available power reserve (interrupted only by periods of extreme drought). Solar poses more of a problem, because some form of storage is required. Scientists are experimenting with a variety of storage solutions, like letting daytime heat accumulate in fluids like molten salt so that turbines can continue to operate after sunset. However, it will be some time before the economics of utility-scale renewable technologies become favorable.

What many renewable technologies (and some small scale technologies like natural gas microturbines and fuel cells) do offer are options for users in remote locations or localized solutions for energy demand. An isolated community can distribute electricity to its residents "off-grid" (meaning that there does not have to be a connection to a transmission system). Or, excess power from location-specific generation, including cogeneration, can be distributed "on grid." Distributed and off-grid generation bear significant implications for the future, particularly for rural Mexican populations without reliable electricity service.

Cross-Border Electricity Trade

Cross-border electricity trade can offer a number of options for meeting both demand for electricity in North America and flexible and reliable management of North American electric power transmission grids. Mexico's electricity grid connects to the United States on its northern border in several places. There are two connections between Baja California and California which were used for exports from CFE to San Diego Gas and Electric and Southern California Edison in the 1980's. There are seven connections between Mexico and the Electric Reliability Council of Texas [ERCOT], six of which are used exclusively for emergency purposes.

Currently, ERCOT is working closely with CFE in an attempt to increase the interconnectedness of their grids, both for economic and reliability reasons. With the technology currently available, interconnections between the close geographic regions yet isolated transmission systems of CFE and ERCOT can uniquely and cost effectively displace inefficient units and provide economic reliability enhancements to meet local load growth needs. It is these border regions of Mexico that have experienced the most accelerated growth in electric demand in recent years. Asynchronous interconnections between CFE and ERCOT could reduce generation costs, provide mutual emergency support and allow for economic transactions.

In December, 2003 CFE and ERCOT released a midpoint report on their interconnection studies. With respect to short term alternatives that could leverage existing interconnections and infrastructure and do not require lengthy regulatory review, the study found that opportunities exist at the Matamoros/Brownsville, Reynosa/McAllen, Nuevo Laredo/Laredo, and Acuña/Del Rio areas to provide support between the electrical grids. Both CFE and ERCOT will follow through with proposals to facilitate these interconnections that, once reviewed by the appropriate government, regulatory, and stakeholder organizations, could be implemented over the next one to three years.[25]

The second phase of the study has begun and will evaluate opportunities for long-term interconnections that can support additional economic transactions and emergency assistance between CFE and ERCOT. Because of the broad policy and economic impacts that larger bulk transmission interconnections will have on the CFE and ERCOT power systems, the report recommends the involvement by the Public Utilities Commission of Texas and SENER in phase two.

The North American Free Trade Agreement (NAFTA) instituted specific concessions for electricity services as well as other energy services. However, it did not provide any resolution on government monopolies, formalize arrangements for energy regulatory harmonization or extend the energy crisis provisions from the Canada-US Free Trade Agreement to Mexico. As a result, the NAFTA provides only a weak framework for North American electricity integration.[22]

For a robust border electricity trade to take hold and flourish, harmonization of energy policies and regulatory frameworks between the United States and Mexico needs to take place. This is difficult to achieve because it requires resolution of fundamental differences of opinion between the two countries, and their sub-jurisdictions, regarding reliance on markets and the role of government. At any point in time, commitment to either philosophy can be influenced by economic, political and social conditions outside of the control of policy makers, regulators, firms or consumers, and long-term patterns can revert or become cyclical.[9]

In recognition of the need to harmonize energy policies and regulatory frameworks, the North American Energy Working Group (NAEWG) was established in the spring of 2001 by the Canadian Minister of Natural Resources, the Mexican Secretary of Energy and the US Secretary of Energy, to enhance North American energy cooperation.

The goals of the NAEWG are to foster communication and cooperation among the governments and energy sectors of the three countries on energy-related matters of common interest, and to enhance North American energy trade and interconnections consistent with the goal of sustainable development, for the benefit of all. This cooperative process fully respects the domestic policies, divisions of jurisdictional authority and existing trade obligations of each country.

In June, 2002, NAEWG released *North America-The Energy Picture.* This report presents a range of energy information for the three countries, including an economic overview, energy data, supply and demand trends, energy projections and descriptions of infrastructure, laws and regulations.[35] NAEWG also has issued two working papers: "Regulation of International Electricity Trade" (which deals with exports and imports as well as interconnection transmission lines) and "Energy Efficiency."

In addition to NAEWG, the regulatory commissions of the US, Canada and Mexico meet at least three times annually to review their regulatory agendas, strengthen relationships and exchange information. Some of the topics covered include: Electricity interconnection projects, LNG projects, possible natural gas interconnections, regional supply/demand topics and regulatory coordination.[36]

Since 1994, the Texas General Land Office has worked with a wide variety of partner agencies in the United States and Mexico, including representatives of local, state and federal governments, the private sector, universities and non-governmental organizations, to organize the annual Border Energy Forum. Composed of about 200 participants annually, the Forum is a conference designed to improve the exchange of information regarding energy, including electricity, and its relationship to the environment throughout the border region.

[35] The NAEWG report is available at http://www.eia.doe.gov/emeu/northamerica/index.htm.

Outlook for Electric System Growth

SENER projects demand for electricity to increase at an average annual rate of 5.2 percent, including self-generation, during the period 2005-2014. The main drivers of increased electricity demand are the medium and large industrial users. Forecasting energy demand in general is fraught with difficulty. For electricity, a great number of unknowns exist with respect to how electricity is used, how sensitive users are to price, costs of providing electricity, and underlying economics and other issues with respect to generation technologies and fuels for generation, among other things. Each generation fuel constitutes a discrete market with supply-demand balances, competing uses, potential for substitution, environmental considerations, and a host of other issues. Consequently, all forecasts are subject to considerable uncertainty and revision.

In order to meet this potential demand growth while accommodating planned generation capacity retirements of 5,108 MW, the SEN companies would have to add 22,574 MW in generation capacity over the period 2005-2014. The total investment (generation, transmission, distribution) required to meet this demand growth would total about $58 billion with 48 percent expected to come from the private sector.

The forecast growth rate in electricity demand of 5.2 percent per year is high by historical standards; by comparison, from 1994-2004 the annual average growth rate was 4.1 percent. The historical record includes two economic contractions in 1995 and 2001 when electricity demand actually declined. The future outlook for Mexico's economy is thus integral to forecasted demand for electricity.

Table 25. Electricity Demand-Projected Average Annual Growth Rates

Period/Sector	2005-2014
Self-Supply	2.0%
Residential	5.1%
Commercial	5.3%
Services	3.2%
Agriculture	3.1%
Medium Industry	5.7%
Large Industry	6.4%
Total Industry	6.0%
Total National	5.2%

Source: SENER, 2006.

Outlook for Electric Sector Natural Gas Consumption

Electric sector consumption of natural gas represented 36 percent of total gas consumption in 2004 and is expected to increase to 51 percent of total gas consumption in 2013. The most striking change is the expected shift between public and private gas consumption for generation. In 2004, gas demand by CFE and LFC accounted for 40 percent of total gas consumption for electric generation; this is expected to decrease to 18 percent by 2014. On the other hand, gas consumed by private generators was 60 percent of total gas consumption for electric generation in 2004 and is expected to increase to 82 percent by 2014. The vast majority of this growth is expected to occur in the IPP sector for electric generation.

The forecasted increase in natural gas consumption for electric generation is directly related to the forecasted 5.2 percent per year growth in electricity demand. The SENER outlook assumes that much of the new generation capacity added over the period is gas-fired for efficiency and environmental reasons; that fuel oil-fired generation capacity will continue to diminish, and that renewable/alternative fuels and other competing generation fuels like coal will play a fairly minor role in Mexico's generation profile.

New Generation Technologies

In addition to the advances in natural gas turbine design, there are new ways to achieve clean combustion of coal and fuel oil and improvements in alternative energy technologies. In Mexico, the Centro de Investigación en Energia (CIE) at the Universidad Nacional Autónoma de México (UNAM) is actively involved in researching and developing new generation technologies.

Integrated gasification combined cycle (IGCC) is a power generation process that integrates a gasification system with a conventional combustion turbine combined cycle power block. The gasification system converts coal (or other solid or liquid feedstocks such as petroleum coke, biomass or heavy oils) into a gaseous synthetic gas ("syngas") made predominantly of hydrogen and carbon monoxide. The syngas is used to fuel a combustion turbine to generate electricity. IGCC is an advanced technology that can substantially reduce air emissions, water consumption, and solid waste production from coal and heavy fuel oil-fired power plants. In addition, IGCC technology offers the potential for separating and capturing carbon dioxide emissions (and producing pure hydrogen) by adding water-gas shift reactors to the syngas treatment system and physical absorption processes to remove carbon dioxide.[38] The captured carbon dioxide could then be stored or "sequestered," (depending on the carbon dioxide sequestration technologies discussed below).

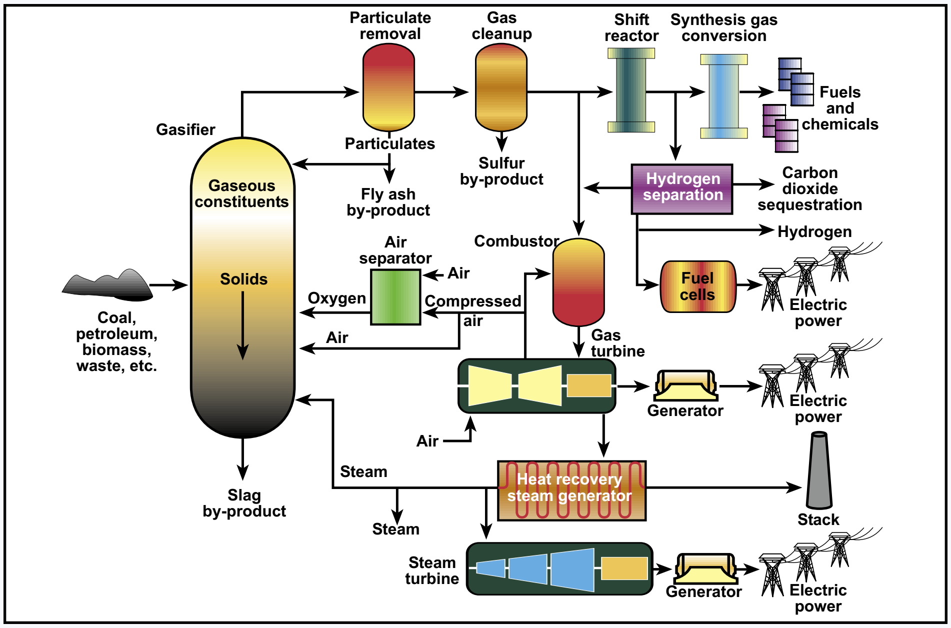
Because many experts believe that IGCC power plants have uncertain cost and performance characteristics, the US Department of Energy's Office of Fossil Energy is currently sponsoring an IGCC test project (FutureGen) to integrate testing of emerging energy supply and utilization technologies as well as advanced carbon capture and geologic sequestration systems (www.doe.gov).

In addition, there are technologies on the horizon that may completely change the industry. Often discussed are fuel cells, which use electrochemical reactions-like automotive batteries-to produce electricity.

Table 26. Electric Sector Natural Gas Consumption (MMcf/day)

Year	2004	Percent in 2004	2014	Percent in 2014
CFE	814	39	795	18
LFC	29	1	2	NM
Sub-Total	*843*	*40*	*797*	*18*
IPPs	896	44	3,159	74
Self-gen.	229	11	238	5
Export	89	5	112	3
Sub-Total	*1,214*	*60*	*3,509*	*82*
TOTAL	**2,506**	**100**	**4,306**	**100**

Source: Natural Gas Market Outlook, SENER, 2005.



Source: Rosenberg, *et.al.*, 2005.

Figure 13. Typical IGCC Power Plant

Most promising are fuel cells that can use natural gas as a feed stock for producing hydrogen. Fuel cells are smaller and modular and could be used to power individual buildings or neighborhoods with none of the noise and unsightliness of traditional generating stations. Fuel cells, improved solar technologies and other developments may lead to a "decentralizing" of electric power systems, allowing small scale applications and resolving many of the potential reliability problems that customers fear. These types of decentralized power systems could make a significant contribution to the provision of clean, efficient energy delivery systems in rural Mexico where much of the population lives without reliable electricity service.

Further into the future, economic nuclear fusion technologies may finally be achieved. Unlike nuclear fission, fusion is the combination of atoms to produce heat. Fusion is a long sought technology that holds tremendous promise of clean, renewable energy, if it can be achieved. Pebble-bed modular reactor (PBMR) technology (still based on fission), on the other hand, may yield its first commercial reactor by 2007. PBMR reactors are fuelled by several hundred thousand tennis-ball-sized spheres, know as pebbles, each of which contains thousands of tiny "kernels" the size of poppy seeds. As compared to pressurized-water reactor (PWR) technology used in more than half of the world's existing reactors, PBMR reactors are smaller and can be built faster. Proponents also argue that they are safer and cheaper. Both claims are challenged by critics.

Microturbines, solar power (either as large collector farms or photovoltaic cells on buildings), ocean power (using either the tidal currents or waves) are other technologies that are being closely watched by the investor community.

Many of these technologies discussed here are not new. All are being pursued at various universities and research institutes in Mexico including, but not limited to, CIE; Instituto de Investigaciones en Electricas (IIE); UNAM; Instituto Politecnico Nacional and the Consejo Nacional de Ciencia y Tecnologia. All are dependent on favorable economic and market conditions. A benefit of competition is that it will accelerate introduction of new technologies.

Carbon Dioxide Sequestration

Carbon dioxide sequestration refers to technologies being developed to "capture" carbon dioxide from potential emitting sources such as electric generation plants before it is emitted and to "sequester" or store it in a variety of places including: geologic formations such as oil and gas reservoirs, unmineable coal seams, and deep saline reservoirs; the deep ocean, and terrestrial ecosystems through the protection of ecosystems that store carbon so that carbon stores can be maintained or increased, and manipulation of ecosystems to increase carbon sequestration beyond current conditions.

Successful development and commercialization of such technologies could greatly improve the greenhouse gas impact of fossil fuel-fired electric generation plants, especially coal-fired and heavy fuel-oil fired plants.

The aim of current research is to provide a science-based assessment of the prospects and costs of CO_2 sequestration.

To be successful, the techniques and practices to sequester carbon must meet the following requirements:

- be effective and cost-competitive,
- provide stable, long term storage, and
- be environmentally benign.

Using present technology, estimates of sequestration costs are in the range of $100 to $300/ton of carbon emissions avoided. Research is being done to reduce the cost of carbon sequestration to $10 or less per net ton of carbon emissions avoided by 2015.

In the mid-term, sequestration pilot testing will develop options for direct and indirect sequestration. The direct options involve the capture of CO_2 at the power plant before it enters the atmosphere coupled with "value-added" sequestration, such as using CO_2 in enhanced oil recovery (EOR) operation and in methane production from deep unmineable coal seams. "Indirect" sequestration involves research on means of integrating fossil fuel production and use with terrestrial sequestration and enhanced ocean storage of carbon.

In the long term, the technology products will be more revolutionary and rely less on site-specific or application-specific factors to ensure economic viability.[36]

In addition to technology development, a commercial value chain must be created from capture to end use to make large scale carbon dioxide sequestration feasible. CO_2 value chain development and expansion will require new policies, regulations and market design. Work is underway in this regard at the Bureau of Economic Geology, University of Texas and the Gulf Coast Carbon Center and Center for Energy Economics.

[36] For additional information, please visit http://fossil.energy.gov/programs/sequestration/

Transmission, Distribution and Storage Technologies

Improving the existing capacity of transmission and distribution grid systems and transmitting electricity more efficiently are key stepping stones to facilitating a transition to alternative sources of energy and small-scale, decentralized distributed energy systems. An improved grid could revolutionize the ways in which we supply and use electricity. In Mexico, new transmission, distribution and storage technologies are being researched and developed by the organizations mentioned in New Generation Technologies above as well as by SENER's Committee of Technology and Development in association with UNAM.

As electricity travels over the transmission grid, much of it is lost (sometimes upwards of 10 percent). This is because the materials typically used in transmission wires can only withstand a certain amount of heat. New, superconducting materials may change that. At research centers around the world, including the Texas Center for Superconductivity at the University of Houston, scientists are developing new materials that can withstand levels of heat and stress beyond anything achievable with traditional metals. These materials, if they can be economically developed for applications like electricity transmission, will dramatically reduce the amount of electricity that must be generated and allow electricity to be efficiently transported over long distances. Experiments with short-distance high voltage lines that use superconducting materials have produced encouraging results.

For electricity to be more easily managed, new ways of handling electricity are needed that take advantage of superconducting materials and devices. One such technology is the use of superconducting devices for instantaneous management of electric power. Researchers at the Houston Advanced Research Center (HARC) have studied small superconducting switches and much larger superconducting energy storage devices for transmission enhancement applications. HARC (with a private and public sector consortium and the State of Texas) has examined the technical and economic feasibility of applying these technologies to constraints in the Texas transmission system. Such devices would enable various power management services such as stability enhancement, increased transmission capacity, voltage and frequency control and other quality enhancements for transmission.

Programs are also underway to study the implications of nanotechnology for energy. At Rice University in Houston, Texas, methods are being developed which would permit electricity to be carried over long distances economically via high-voltage carbon nanotube wires with little or no loss of supply, and facilitate the access of remote energy sources, such as solar power farms. Coupled with the development of enhanced battery storage, this technology could promote distributed energy.

Electric storage technologies are often viewed as the "holy grail" of all energy technologies. In particular, flywheel technology seems to be the most advanced. A Texas company, Active Power, developed the first commercially viable flywheel energy storage system and has distribution deals with companies such as Caterpillar, GE and Invensys. Other storage technologies include pumped hydropower, compressed air energy storage, superconducting magnetic energy storage, and ultracapacitors.

Information Technologies

The sophistication of electronic information systems is one of the most important factors for the effective functioning of efficient and competitive electricity markets. These information systems have removed many of the barriers to common carriage transmission by allowing real-time management of energy flows and exchanges.

In the United States, electronic bulletin boards and software systems for electricity transmission include information on capacities, prices, transactions and other variables. This information is necessary to facilitate a properly functioning marketplace. It also facilitates the development of "secondary" markets so that holders of excess capacity on transmission grids can release or resell that capacity. This prevents many of the kinds of disruptions and shortages that have posed serious problems in the past.

Finally, the advent of information systems for electricity has supported the growth and effectiveness of new businesses, independent third party marketers of power. These entities act as intermediaries in a complex marketplace. Using electronic information, they are able to package services and build flexible arrangements and contractual terms between suppliers of electricity and end users.

The development of electronic information systems has been one of the most important factors in the re-conceptualization of what constitutes monopoly in electricity service. These tools have enabled the separation of the commodity, electricity, from the physical systems used to deliver them to customers. The result is that the scope of regulation can be narrowed to the physical delivery systems, where before it applied to both the system and the commodity. This has been a critical step in the evolution of the electricity industry in the United States.

Technology Transfer in North America

Technology transfer – how it takes place, how the process can be improved and the notion that there is a "soft" technology associated with endeavors such as regulatory oversight – is an important issue for Mexico. With respect of the transfer of "hard" electricity technologies, one of the most important questions is whether Mexico will generate incentives, in the form of sufficient commercial opportunities, for foreign companies to share their proprietary technologies. In addition, Mexico's national electric companies must provide incentives for their own managers to adopt and implement new technologies and knowledge. A considerable transfer of knowledge with respect to policy and regulatory approaches has taken place in North American, primarily through informal channels, but implementation is key.

It is to the benefit of all stakeholders within the North American electricity market to be as well informed as possible of all options. Markets cannot function properly unless information is accessible. National energy policy bodies may have a role to play in this regard. Regulators as market facilitators play a role in reducing information asymmetries (recognizing, however, that information represents competitive advantage). Consumers in the United States and Canada have become much more astute with regard to what the market can offer them. Experience in the United States and Canada suggests that consumer education can be an effective agent of change and once consumers detect that choices exist it is difficult to return to the status quo. Experience in these markets also suggests that there are real limits to what private firms will share if they do not have profit incentives. Some years ago it was suggested that "technology dyads" between the United States and Mexico could go a long way toward resolving issues and ensure long-term electric security for both.

Risk Management

When electricity becomes a commodity, as it has in the United States, it becomes subject to considerable volatility in pricing. This is complicated by the diurnal or daily patterns of electricity use and the need for pricing to reflect fluctuations in demand and supply. Risk management has emerged as a powerful, though often not well understood, mechanism for managing volatility.

Risk management encompasses the array of financial instruments and the strategies used to implement them. Futures contracts, options, derivatives and swaps are some of the instruments that risk managers use. The basic principle is to separate the sources of risk in order to deal with them in a systematic way. One important source of risk in the electric sector is price volatility. Risk management instruments allow stakeholders to add varying degrees of certainty to future electricity prices.

Risk management is not new. Ancient civilizations used futures contracts for grains and other traded goods. The United States has long had futures markets for agricultural commodities, minerals like copper and, since the early 1980's, oil. Electricity is a relative newcomer. As risk management instruments have become both more sophisticated and more complex, problems have arisen in recent years for both suppliers and customers, some so serious that firms experienced liquidity crises or bankruptcy. The issues, however, do not lie with the instruments themselves but in their use for speculative purposes. Speculative use occurs when firms use risk management instruments to supplement income generation rather than reducing the firm's exposure to particular risk. For example, Enron's collapse is usually associated with the company's aggressive use of these instruments in their flagship trading operation and the aggressive accounting practices employed in recording the value of these trades.

When risk management instruments are used correctly, however, they are a powerful and important tool for both suppliers and customers in more competitive energy markets. For example, the inability of California electric utilities to engage in long-term contracts forced them to buy continuously from the more price volatile spot market in order to comply with their "obligation to serve." Combined with the retail rate freeze and hence the inability to pass on wholesale price fluctuations to customers, Pacific Gas & Electric had to file for bankruptcy and a state bail-out was needed to prevent Southern California Edison from doing the same. If the utilities were allowed to manage their price risk through long-term contracts (which is what the Department of Water Resources did for the state), these problems could have been avoided.

During the incredible summer 1998 heat wave in the United States, some electric power contracts soared to thousands of dollars per megawatt hour. This event triggered a surge in defaults among independent power marketers, shut downs of trading risk management operations (including at least one large utility), and a great deal of worry among consumers, regulators, policy makers and some suppliers that this was a portent of what competitive markets would be like. However, after extensive investigations, it appears that a root cause was lack of transmission access that caused capacity shortages in key regions, especially the Midwest. The lesson – risk management practices for electric power need work, but resolving non-competitive bottlenecks is an even greater task.

Global Electricity Trends

Around the world, reliance on markets to provide electric services has been a growing trend. With respect to Canada and the United States, there is already an active electricity trade between the two countries and there are possibilities for this activity to increase. Canadians, watching electric power restructuring in the United States, began to mimic and in some cases lead the process. Alberta and Ontario have been the two most active provinces. Although Alberta appeared prone to experiencing problems similar to those of California in the early days of reform, its market is now fully functional.

Western Europe is moving in a similar direction taken by the United States and Canada. Britain actually has been much more aggressive in restructuring its electricity sector than the United States. But state ownership of electric utilities was common practice in Europe. This system had to be dismantled before other steps could be taken to introduce competition. The European Community (EC) has formulated directives to liberalize member country electricity markets, with a goal of achieving 30 percent of the market open to competition by independent power suppliers in ten years. On November 25, 2002, energy ministers from member countries announced that retail markets for electricity will open by July 2007.

The issues in Western Europe include sensitivities to sovereign preferences (countries in which state-owned monopolies dominate electricity service are trying to protect these enterprises) and concerns about energy security. Many of the same consumer, environmental and financial issues that are seen in the United States prevail in Europe as well.

In emerging markets, the commitment to free market electricity is much more variable and the results will be much more difficult to predict. In Latin America, Chile and Argentina have been the leaders in encouraging privatization and private investment in electricity and natural gas (as well as other economic sectors). In Argentina, however, the government continues to expand its role in the electric and natural gas sectors in the wake of shortages in 2004. Electricity prices were frozen in 2002 and the artificially low prices spurred demand increases. Electricity tariffs cannot be increased until the licenses for electricity transmission and distribution are renegotiated. Natural gas supply shortages, also a function of price freezes and consequent underinvestment, caused generation problems in the electric sector in 2004.[37] Electricity rationing measures were implemented, power exports to Uruguay were suspended and emergency power was imported from Brazil. The Argentine government established in 2004 a new state-owned company, Enarsa, which will buy natural gas and gas transportation for power generators. It is uncertain whether this new state intervention will contribute positively to the development of robust and competitive electricity markets in the country.

Brazil's experience of inadequate electric power supplies in 2001, triggered by drought-constrained hydropower production and complicated by weak and confusing market rules for new investment in both gas and power, demonstrated the extent of work yet to be done. Concerned about the lack of diversification in Brazil's generation,[38] the government in 1997 provided incentives (eventually translated into law as the Programa Prioritário de Termelectricidade-PPT) for gas-fired generation including: a regulated, favorable price for gas supply which was less than the price payable by Petrobras for Bolivian gas; availability of

[36] Electric power generation accounts for about 30 percent of total gas demand in Argentina.

[37] In Brazil hydropower accounts for 83 percent of all generation.

long-term power purchase contracts from state-owned Electrobras, and favorable development loans from the state-owned national development bank BNDES.[27] Petrobras was also called upon to finance the projects, and later to assume the foreign exchange risk embedded in the different gas price adjustments in the Bolivian gas supply contract and the gas sales contracts with the power plants. Nevertheless, in 2001, Brazil experienced a critical electricity shortage due to drought conditions. Not a single PPT gas-fired power plant was ready, and work had just started on five. Power rationing was implemented which resulted in a permanent electric demand reduction of about 7 percent and this, combined with above-average rainfall in 2002, caused overcapacity in electric generation.

The role of natural gas in Brazil's electric generation mix remains unclear: permanent base-load diversification or back-up for low hydropower years? New power sector legislation enacted in 2004 requires that cheaper hydroelectricity generation be pooled with more expensive thermoelectric plants to determine a single national electricity price. By pooling the various sources, the government hopes to reduce electricity tariffs and to ensure that power is purchased from the newly constructed, predominantly gas-fired, thermal plants. However, with the new rules only recently issued and not yet tested in practice, it remains unclear whether investors will continue to build new gas-fired power plants in the country. Many investors see the new 2004 legislation as a means of increasing government influence on the electricity sector and enhancing the role of the state-owned companies.

In other countries where hydropower is predominant like Colombia, Ecuador, Peru and Venezuela, viable commercial frameworks to introduce thermal generation into their electric systems have not been developed, leaving them vulnerable to drought-induced shortages.

Issues surrounding regulatory independence, transparency and relevant commercial experience continue to exist in many Latin American and other emerging economies.

With respect to foreign investment in the electric sector, many US companies recently have shut down their operations overseas and focused back on US markets, in part because they did not realize the gains they expected in the restructured markets of Latin America and Europe. In part, this is because these markets have become quite competitive, which put pressure on prices, and hence on returns, and this competition especially penalized those that overpaid for assets. Another, larger factor, has been the difficulty of building sustainable markets in countries where governments still retain heavy influence in their electric sectors and/or market pricing of electricity is not permitted.

The story is similar in Asia, South Africa, Central and Eastern Europe and the Former Soviet Union. In all cases, much of the impetus for restructuring markets comes from general economic reforms and the need for private investment to build infrastructure and create jobs.

All emerging markets face similar constraints. Their economies traditionally have been highly centralized and dominated by government intervention and ownership. Corruption and poverty are pervasive. A specific political issue in many countries is the degree to which customers should be, or can be, exposed to energy price volatility. Energy prices, including electricity prices, tend to be controlled by the governments so that distortions and inefficient use of energy are rampant. Political and financial stability remain problems. Social backlash to reform initiatives is always a possibility as witnessed in Argentina and the myriad of market issues faced in the United States in recent years have had global repercussions. Nevertheless, in spite of these enormous constraints, even the most disadvantaged nations seem at least interested in trying to adapt to the prevailing trends. Many countries from Eastern Europe to Southeast Asia continue with their electric sector restructuring efforts based on these trends.

GLOSSARY

Btu (British Thermal Unit): A standard unit for measuring the quantity of heat energy equal to the quantity of heat required to raise the temperature of 1 pound of water by 1 degree Fahrenheit.

Capacity: The amount of electric power delivered or required for which a generator, turbine, transformer, transmission circuit, station, or system is rated by the manufacturer.

Cogenerator: A generating facility that produces electricity and another form of useful thermal energy (such as heat or steam) used for industrial, commercial, heating, or cooling purposes.

Combined Cycle: An electric generating technology in which electricity is produced from otherwise lost waste heat exiting from one or more gas (combustion) turbines. The exiting heat is routed to a conventional boiler or to a heat recovery steam generator for utilization by a steam turbine in the production of electricity. This process increases the efficiency of the electric generating unit.

Distribution System: That portion of an electric delivery system operating at under 60 kilovolts (kV) that provides electric service to customers.

Futures Market: Arrangement through a contract for the delivery of a commodity at a future time and at a price specified at the time of purchase. The price is based on an auction or market basis. In the United States, this is a standardized, exchange-traded, and government regulated hedging mechanism.

Gross Generation: Electricity produced by generators, measured at the generating plant.

Independent Power Producers: Entities that are non-CFE and non-LFC power generators. Independent power producers do not possess transmission or distribution facilities and sell electricity solely to the CFE.

Load: The amount of electric power delivered at any specified point or points on a system.

Load Profile: A representation of the energy usage of a group of customers, showing the demand variation on an hourly or sub-hourly basis.

Market-Based Pricing: Electric service prices determined in an open market system of supply and demand under which the price is set solely by agreement as to what a buyer will pay and a seller will accept. Such prices could recover less or more than full costs, depending upon what the buyer and seller see as their relevant opportunities and risks.

Net Generation: The electricity delivered to the SEN transmission grid. Net generation is usually equal to gross generation less the electricity used in the generation operations.

Open Access: A regulatory mandate to allow others to use gas transmission and distribution facilities to move gas from one point to another on a nondiscriminatory basis for a cost-based fee.

Outage: Removal of a facility from service to perform maintenance, construction or repair on the facility for a specified duration.

Parallel Path Flow: Electricity flows over transmission lines according to the laws of physics. As such, the power generated in one region may flow over the transmission lines of another region, inadvertently affecting the ability of the other region to move power.

Reactive Power: The product of voltage and the out-of-phase component of alternating current. Reactive power, usually measured in megavolt-amperes reactive, is produced by capacitors, overexcited generators and other capacitive devices and is absorbed by reactors, underexcited generators and other inductive devices.

Spinning Reserve: That reserve generating capacity running at zero load and synchronized to the electric system.

Transmission Losses: Difference between energy input into the SEN transmission grid and the energy taken out of the SEN transmission grid.

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