Natural Gas Use in the Mexican Power Generation Sector: Political, Market and Regulatory Issues

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Abstract

We examine the main political, market and regulatory issues concerning natural gas use in the Mexican power generation sector. We also study the impacts of a technology diversification policy regarding the primary energy used to generate electricity. For that, we make use of the LEAP system (Long-range Energy Alternatives Planning-SEI Boston) in order to simulate two scenarios of evolution of the power generation system in Mexico between 2000 and 2020. The first one (business-as-usual) simulates government's current energy policies that consider most of the increase in installed capacity to be done by combined cycle plants. The second one evaluates the policy of diversification where both coal and hydro plants are added as a complement to facilities using gas. Impacts on the natural gas supply/demand balance are then discussed. Increasing gas imports will be necessary in the future to complement domestic supply as illustrated by simulation exercises reported in this work. Our simulation results also indicate that the adoption of a diversification policy concerning technologies used to generate electricity can be a way to limit foreign dependency on gas imports, especially in the long run (2010-2020). This is particularly relevant for the future supply/demand balance of the North American natural gas market. It is also suggested that efforts addressed only to the demand-side could be insufficient to control gas imports. Important measures should additionally be taken on the supply-side in order to increase domestic gas production, such as by relaxing PEMEX's budgetary constraints.

Introduction

Mexico is moving from the almost complete control of production, transmission and distribution of electricity by the government to increased private participation in the generation sector. As in the case of the petroleum industry, the Mexican electricity industry works almost entirely through a single state-owned producing company, the Federal Electricity Commission (CFE-*Comisión Federal de Electricidad*). The national transmission and distribution network is operated primarily by the CFE. Meanwhile, distribution and marketing in Mexico City and its periphery are handled by the state-owned Central Power and Light (LFC-*Luz y Fuerza del Centro*). Private participation in power generation projects has been allowed since 1992 when the Public Electric Power Service Law was reformed. Thus, the private sector (both domestic and foreign companies) can today invest in cogeneration, self-supply and small-scale production, in BLT projects (Built, Lease and Transfer) and as Independent Power Producers (IPPs). According to Mexico's Secretary of Energy (Sener, 2001b), about 25 GW of electric generation capacity is needed between 2001 and 2010 to keep pace with increasing demand[1]. Nearly 22 GW are slated to be run on natural gas, most of them (95%) using gas turbines in combined cycle. Some proposals for regulatory reforms are currently under examination in order to ensure sufficient resources to finance the expansion of the electric generation sector.

Mexico today has a considerable natural gas resource base. Approximately 190 Tcf of natural gas resources remain in Mexico, 30 Tcf of which are proved reserves (Pemex, 2001). Compared to the U.S. and Canada, Mexico is an immature gas region, but one with considerable up-side potential. Producing 1.5 Tcf per year, Mexico is thus considered as a "sleeping giant" with respect to gas production potential. *Petróleos Mexicanos* (PEMEX-the national oil company) maintains a monopoly on domestic gas exploration and production and a strong market power in transport systems. Private companies have been allowed since 1995 to participate in downstream projects. Because of PEMEX's strong budgetary constraints, there is uncertainty as to whether its indigenous production can be increased sufficiently to satisfy rising demand. Conversion of power plants from heavy fuel oil to natural gas, in compliance with new environmental regulations[2], and construction of new power plants using gas turbines in combined cycle are the most influential factors affecting future gas demand. The Mexican Secretary of Energy forecasts a growth in gas demand from 1.6 Tcf in 2000 to 3.5 Tcf in 2010 (Sener, 2001c). Imports would thus progress from 0.1 Tcf to 0.7 Tcf respectively.

The aim of this work is to discuss the main political, market and regulatory issues concerning natural gas use in the Mexican power generation sector. We also study the impacts of a technology diversification policy regarding the primary energy used to generate electricity. For that, we make use of the LEAP system, as earlier note, in order to simulate two scenarios of evolution of the power generation system in Mexico between 2000 and 2020. The first one (business-as-usual) simulates the government's current energy policies that anticipate that most of the increase in installed capacity will be accomplished by combined cycle plants. The second one evaluates the policy of diversification under which both coal and hydro plants would be added as a complement to facilities using gas. Impacts on the natural gas supply/demand balance are then discussed.

Natural Gas Use in Mexico's Electric Power Generation Sector

Political and Regulatory Issues: Restructuring the Electric Power Industry

Mexico's Political Constitution has established, since the electric industry's nationalization in 1960, the nation's exclusive right to provide public electric power service, among other activities. Electric power generation, transformation, transmission, supply, distribution and marketing activities for public service have thus been performed and coordinated by the state-owned companies CFE and LFC. A small amount of private participation was allowed in the generation sector by means of self-supply projects in the industrial and oil sectors.

The Mexican government adopted in the early 1990's a

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[1] See footnotes at end of text.

policy encouraging natural gas use thanks to its excellent environmental qualities (clean combustion), its suitability for use in more efficient technologies such as combined cycle plants and the presence of relatively abundant gas sources. This energy policy seeks to promote a change in the pattern of use of industrial fuels through a reduction in the use of fuel oil and an increase in the use of natural gas. The policy consists of four main strategies (Sener, 1997a):

1. Construction of the new combined cycle electric power plants.
2. Reconversion of several of CFE's electric power plants, substituting the use of fuel oil with natural gas as the basic element.
3. Greater industrial use resulting from the environmental measures instituted in 1998.
4. Promoting greater use of natural gas in industry and households.

In this regard, natural gas is a product with an enormous potential for utilization in Mexico. The program to substitute fuel oil with natural gas in CFE's plants, investment plans for building new combined cycle plants that will use this product, and the environmental regulations that went into effect in 1998 for all industries, ensure a strong demand for natural gas in Mexico.

The 1992 amendments to the Public Electric Power Service Law, and its regulations, created a significant opening of the generation segment to private companies in order to attract the additional investment needed to ensure the availability and supply of electricity. In accordance with the 1992 reforms, there are today four modalities for private participation in electric power generation: self-supply, co-generation, small-scale production and independent production. As provided in Article 36 of the Public Electric Power Service Law, self-supply is understood to mean utilization of electric power for one's own use when:

I. The electricity comes from plants intended to meet the needs of a set of co-owners or partners, and
II. The permit holder agrees expressly to use the electric power solely within the perimeters authorized by the Secretariat.

Cogeneration is understood to be:

I. Production of electric power together with steam or some other type or secondary thermal energy or both;
II. Direct or indirect production of electric power from thermal energy not utilized in the process; or
III. Direct or indirect production of electric power using fuel produced in the processes.

Small-scale production is understood to mean the generation of electric power intended for:

I. Sale to the CFE of all electric power produced. The project may not have a total capacity of more than 30 MW in an area determined by the Secretary of Energy.
II. Self-supply for small rural communities or isolated areas lacking in electric power service, in which case the projects may nor exceed 1 MW; and
III. Exportation up to a maximum limit of 30 MW.

Independent production is the generation of electric power provided by a plant with a capacity of more than 30 MW, intended exclusively for sale to the CFE or for export.

The Energy Regulatory Commission (CRE-*Comsión Reguladora de Energía*) is charged with granting permits for electric power generation, importation or exportation for an indeterminate period. Permits for independent power producers are granted for a renewable period of 30 years.

The more recent priorities for public investment have been oriented towards strengthening the transmission and distribution areas, while encouraging private participation in power generation through independent production, self-supply, cogeneration and small-scale production. In view of the current financial restrictions, it is possible that the levels of investment required cannot be provided entirely by the CFE and LFC, which means that in order to satisfy the nation's enormous electricity needs it will be necessary to supplement public investment with resources from the private sector in the areas allowed by existing or future legislation.

According to the Secretary of Energy (Sener, 1999), the outcome of the 1992 reform has not been very encouraging. In 1999, CFE's participation in the capacity of electric power generation was 90%, PEMEX 4.4%, LFC 2.3 and private companies 3.3%. However, of the increase in generation capacity carried out or to be carried out from 1998 to 2001, CFE resources will fund only 2%. The reminder will be BLT (build, lease and transfer) and independent producers (IPP) projects.

Another proposal for restructuring the Mexican electricity sector, seeking private participation throughout the electric value chain, arrived in 1999 at the end of the previous administration (1994-2000). The most important argument put forward was that the federal government did not have the financial resources to maintain or increase the level of operations of the electric sector, and that reforms to the 1992 law had not given the expected results with respect to private sector participation (García et alii, 2001). The proposal was unsuccessful due to general opposition within political parties other than the *Partido Revolucionario Institucional* (PRI), in control of government at the time. Since the 2000 presidential elections and the resulting change of government and political control, new proposals to restructure the electricity industry have appeared. Industrial organization of the sector and new modalities of financing the expansion of service are at the center of discussions. The political weakness of the present federal government may be a serious obstacle for its initiative to restructure the electric sector, especially if the opposition of "official trade unionism" is considered (García et alii, 2001).

Public Electric Power Service: the Use of Natural Gas Turbines in Combined Cycle

From 1990 to 2000, the public electric power service capacity[3] grew from 25 299 MW to 36 697 MW (Table1). The existing capacity is today sufficient to meet the present and foreseeable short-term demand. Electricity imports and exports represent less than 1% of total demand (self-sufficient market). Steam plants using fuel oil and/or natural gas are the most employed technology to generate electricity. As mentioned before, for environmental and efficiency[4] reasons mainly, a policy of transition from fuel oil consumption to natural gas use was adopted in the early 1990's by the Mexican government. As a result, 1711 MW of combined cycle capacity were installed between 1990 and 2000. The gas transition policy also expects to substitute fuel oil with natural gas in most of the existing steam plants. Gas consumption to

Table 1
Mexico's Public Electric Power Service:
Installed Capacity and Gross Generation 1990-2010

	1990		2000		2010	
Effective capacity by technology (MW)		**%**		**%**		**%**
Hydroelectric	7805	30.9	9619	26.2	12809	20.5
Steam (fuel oil and gas)	11367	44.9	14282	38.9	12621	20.2
Combined cycle (gas)	1687	6.7	3398	9.3	24912	40.0
Turbo gas (gas and diesel)	1779	7.0	2360	6.5	2578	4.1
Internal combustion (diesel)	86	0.3	116	0.3	328	0.5
Geothermal	700	2.8	855	2.3	978	1.6
Dual (fuel oil and coal)	0	0.0	2100	5.7	2800	4.5
Coal-fired (coal)	1200	4.7	2600	7.1	4000	6.4
Nuclear (uranium)	675	2.7	1365	3.7	1365	2.2
Wind power	0	0.0	2	0.0	2	0.0
Total	**25299**	**100.0**	**36697**	**100.0**	**62393**	**100.0**
Gross generation (TWh)	**114.3**		**192.8**		**329.4**	

Source: 1990-2000: (CFE, 2001); 2010: (Sener, 2001b).

generate electricity has thus grown from 144 PJ in 1990 to 333 PJ in 2000 (CFE, 2001).

According to the Secretary of Energy's document on prospects for the electric power sector 2001-2010 (Sener, 2001b), gross generation should rise from 193 GWh in 2000 to 329 GWh in 2010 (Table 1). The Secretary of Energy thus predicts an average annual growth of 5.5% in electric power demand. Combined cycle plants would provide most of the needed electricity. About 21,514 MW of this technology would be installed during the studied period (83% of total added capacity). Combined cycle plants would dominate the power generation sector because their participation would rise from 9% in 2000 to 40% in 2010.

Simulation of the Mexican Power Generation System

Methodology

In order to study the future role of natural gas in the Mexican power generation sector for public service, we simulate two scenarios of evolution of this activity between 2000 and 2020. We make use of the LEAP system (Long-range Energy Alternatives Planning-SEI Boston), based at the Mexican Petroleum Institute offices. For this simulation, we adopted a methodology consisting of three main steps:

1. Programming into LEAP of Mexico's energy balance for the base year (1996).
2. Definition and programming of variables driving the future national demand of energy. We have selected national Gross Domestic Product (GDP), in the form of energy intensity (energy/GDP) and population growth[5] as key drivers[6]. Demand analysis was done by sector (agriculture, households, commercial and public services, transport and industry) and by kind of energy (primary: oil, associated natural gas… and secondary: fuel oil, electricity…).
3. Programming of the transformation sector that includes electric power generation, oil refining, natural gas processing plants and coke refining. Simulation of oil refining took into account the reconfiguration project in Pemex's refineries, established mainly to decrease fuel oil production and to increase gasoline outputs. Natural gas processing plants produce natural gas volumes expected by PEMEX for the period 2001-2010. Expected volumes of gas to be produced for the next ten years are reported by the Secretary of Energy in its document on prospects for the natural gas market 2001-2010 (Sener, 2001c). For the period 2010-2020, gas production is projected following the same trend expected during 2001-2010. Coke refining system's inputs and outputs were extrapolated from 2000 to 2020 according to past trends (1990-2000).

We describe now the main characteristics of two scenarios studied.

Business-As-Usual Case (BAU)

Considered as the reference case, this scenario simulates the government's current energy policies from 2000 to 2010. Period 2010-2020 is analyzed using the trends of the preceding decade. The main assumptions of the scenario were as follows:

1. An average annual GDP growth of 5.2%, according to Secretary of Energy's predictions (Sener, 2001c).
2. A population increases from 97.2 million in 1999 to 118.7 million in 2020 (CONAPO, 1998).
3. Installed capacity of the power generation sector is assumed to evolve from 2001 to 2010 in the same way as capacity is anticipated by the CFE and published in the document on prospects for the electric power sector 2001-2010 (Sener, 2001b). From 2010 to 2020, we projected installed capacity to increase following the expected trend of the preceding decade.

Electric Power Diversification Case (EPD)

This scenario also simulates the government's current energy policies, with the exception of the evolution of the power generation sector. Annual growth in GDP and population are considered the same as in the BAU case. Regarding the power generation sector, a policy of energy and technology diversification is supposed to be adopted from 2007. The Secretary of Energy, in its document on prospects for the electric power sector 2001-2010 (Sener, 2001c), already reports first indications of this change of policy. Instead of installing almost all capacity using combined cycle plants, it is proposed to install additional hydro and dual plants.

Table 2
Mexico's Public Electric Power Service: Estimations of Gross Generation and Electricity Demand by Sector, Under SE, BAU and EPD Scenarios, 2000-2020 (TWh)

	2000 a	2005			2010			2015		2020	
	History	SE	BAU	EPD	SE	BAU	EPD	BAU	EPD	BAU	EPD
Gross generation (TWh)	193	239	252	252	329	330	330	405	405	492	492
Electricity demand by sector (TWh)											
Agriculture	8	8	11	11	9	13	13	16	16	20	20
HCPS	53	68	63	63	86	79	79	97	97	120	120
Transport	1	2	2	2	3	3	3	3	3	4	4
Industry	93	114	125	125	167	168	168	207	207	248	248
Total	**155**	**192**	**201**	**201**	**265**	**263**	**263**	**323**	**323**	**392**	**392**

a Source: (Sener, 2001b).
SE: Secretary of Energy's estimations (Sener, 2001b).
BAU: Business-As-Usual case.
EPD: Electric Power Diversification case.
HCPS: Households, Commercial and Public Services.

Table 3
Mexico's Public Electric Power Service:
Estimations of Installed Capacity by Technology Under BAU and EPD Scenarios, 2000-2020 (GW)

GW	Hydro		Steam		Combined Cycle		Turbo Gas		Internal Combustion		Geothermal		Dual		Coal		Nuclear		Total	
	BAU	EPD	BAU	EPD	BAU	EPD	BAU	EPD	BAU	EPD	BAU	EPD	BAU	EPD	BAU	EPD	BAU	EPD	BAU	EPD
2000	9.6	9.6	14.3	14.3	3.4	3.4	2.4	2.4	0.1	0.1	0.9	0.9	2.1	2.1	2.6	2.6	1.4	1.4	**36.7**	**36.7**
2001	9.6	9.6	14.3	14.3	6.7	6.7	2.4	2.4	0.2	0.2	0.9	0.9	2.1	2.1	2.6	2.6	1.4	1.4	**40.1**	**40.1**
2002	9.6	9.6	14.2	14.2	7.9	7.9	2.5	2.5	0.2	0.2	0.9	0.9	2.1	2.1	2.6	2.6	1.4	1.4	**41.3**	**41.3**
2003	9.9	9.9	13.9	13.9	11.4	11.4	2.5	2.5	0.2	0.2	1.0	1.0	2.1	2.1	2.6	2.6	1.4	1.4	**45.0**	**45.0**
2004	10.5	10.5	13.7	13.7	12.0	12.0	2.6	2.6	0.2	0.2	1.0	1.0	2.1	2.1	2.6	2.6	1.4	1.4	**46.1**	**46.1**
2005	10.5	10.5	13.4	13.4	14.9	14.9	2.6	2.6	0.2	0.2	1.0	1.0	2.1	2.1	2.6	2.6	1.4	1.4	**48.7**	**48.7**
2006	10.5	10.5	13.4	13.4	16.9	16.9	2.6	2.6	0.2	0.2	1.0	1.0	2.8	2.8	2.6	2.6	1.4	1.4	**51.5**	**51.5**
2007	10.5	10.8	13.4	13.4	19.2	19.0	2.6	2.6	0.2	0.2	1.0	1.0	2.8	2.8	2.6	2.6	1.4	1.4	**53.8**	**53.8**
2008	11.4	12.1	13.2	13.2	19.7	19.0	2.6	2.6	0.3	0.3	1.0	1.0	2.8	2.8	4.0	4.0	1.4	1.4	**56.3**	**56.3**
2009	12.8	14.5	12.9	12.9	21.8	19.0	2.6	2.6	0.3	0.3	1.0	1.0	2.8	3.9	4.0	4.0	1.4	1.4	**59.5**	**59.5**
2010	12.8	15.2	12.6	12.6	24.9	19.7	2.6	2.6	0.3	0.3	1.0	1.0	2.8	5.5	4.0	4.0	1.4	1.4	**62.4**	**62.4**
2011	12.8	15.2	12.6	12.6	26.0	20.8	2.6	2.6	0.3	0.3	1.0	1.0	2.8	5.5	4.0	4.0	1.4	1.4	**63.5**	**63.5**
2012	12.8	16.0	12.6	12.6	28.8	20.8	2.6	2.6	0.3	0.3	1.0	1.0	2.8	8.3	4.0	4.0	1.4	1.4	**66.3**	**67.1**
2013	12.8	16.0	12.6	12.6	31.6	22.8	2.6	2.6	0.3	0.3	1.0	1.0	2.8	8.3	4.0	4.0	1.4	1.4	**69.1**	**69.1**
2014	12.8	16.8	12.6	12.6	34.4	22.8	2.6	2.6	0.3	0.3	1.0	1.0	2.8	11.1	4.0	4.0	1.4	1.4	**71.9**	**72.7**
2015	12.8	16.8	12.6	12.6	37.5	25.0	2.6	2.6	0.3	0.3	1.0	1.0	2.8	11.1	4.0	4.0	1.4	1.4	**75.0**	**74.9**
2016	12.8	17.6	12.6	12.6	40.3	25.0	2.6	2.6	0.3	0.3	1.0	1.0	2.8	13.9	4.0	4.0	1.4	1.4	**77.8**	**78.5**
2017	12.8	17.6	12.6	12.6	43.7	27.6	2.6	2.6	0.3	0.3	1.0	1.0	2.8	13.9	4.0	4.0	1.4	1.4	**81.2**	**81.0**
2018	12.8	18.4	12.6	12.6	46.7	27.6	2.6	2.6	0.3	0.3	1.0	1.0	2.8	16.7	4.0	4.0	1.4	1.4	**84.2**	**84.6**
2019	12.8	18.4	12.6	12.6	50.1	30.4	2.6	2.6	0.3	0.3	1.0	1.0	2.8	16.7	4.0	4.0	1.4	1.4	**87.6**	**87.4**
2020	12.8	19.2	12.6	12.6	53.5	30.4	2.6	2.6	0.3	0.3	1.0	1.0	2.8	19.5	4.0	4.0	1.4	1.4	**90.9**	**91.0**

BAU: Business-As-Usual scenario.
EPD: Electric Power Diversification scenario.
Note:BAU case's total capacity and its technology are based on CFE's estimations in the period 2001-2010 (Sener, 2001b). For the EPD case, only total capacity is based on CFE predictions (Sener, 2001b). From 2007, technology choice is diversified from combined cycle to hydro and dual (fuel oil and coal) plants.

Discussion of Results

According to the results of simulation, gross generation would increase from 193 TWh in 2000 to 492 TWh in 2020 (Table 2). This table also reports forecasts of electricity demand by sector. The industry will continue to be the major and the most dynamic consumer (270% of augmentation during 2000-2020). Between official estimates (SE) and BAU and EPD cases there are no significant differences. In order to satisfy the rising demand, it would be necessary to install nearly 55 GW of additional capacity beyond current capacity for the next twenty years (Table 3). Thus, Mexico's installed power capacity for public service would increase from 37 GW in 2000 to 91 GW in 2020. Differences between BAU and EPD scenarios concern the technology employed in plants from 2007. Combined cycle capacity in 2020 would be 53 GW for the BAU case, while 30 GW under EDP case. In 2020, 19 and 20 GW of hydro and dual capacity should respectively be installed under EPD scenario, in contrast to 13 and 3 GW respectively for the BAU case (Table 3).

The differences in technologies to be employed for generating electricity would have impacts on patterns of fuel consumption. The generation of electricity would evolve from an industry characterized by fuel oil consumption to one dominated by natural gas. In both scenarios, fuel oil would dramatically drop from 955 PJ in 2000 to about 180 PJ twenty

Table 4
Mexico's Public Electric Power Service: Estimations of Fuel Consumption, Under SE, BAU and EPD Scenarios, 2000-2020 (Petajoules).

Fuel consumption	2000 [a]		2005			2010		2015		2020	
(Petajoules –PJ-)	History	SE	BAU	EPD	SE	BAU	EPD	BAU	EPD	BAU	EPD
Fuel oil	955	n.a.	514	514	381	393	390	281	266	189	161
Diesel	25	n.a.	9	9	7	12	12	12	12	13	13
Natural gas	333	n.a.	949	949	1347	1376	1170	2001	1500	2674	1761
Coal	183	n.a.	313	313	470	451	635	452	1002	444	1518
Uranium	90	n.a.	107	107	105	106	106	106	106	104	104
Total	**1586**	n.a.	**1892**	**1892**	**2310**	**2338**	**2313**	**2852**	**2886**	**3424**	**3557**

n.a. : not available.
a Source: (Sener, 2001a).
SE: Secretary of Energy's estimations (Sener, 2001b).
BAU: Business-As-Usual case.
EPD: Electric Power Diversification case.

years later as a result of substitution for this fuel by natural gas (Table 4).

Coal consumption would grow from 183 PJ in 2000 to 444 or 1518 PJ in 2020, under BAU and EPD cases respectively. In this context, it is important to note that the EPD case assumes the addition of considerable dual capacity primarily using imported coal at competitive prices. Natural gas would be the fuel experiencing the most important growth due to the fact that its consumption would rise from 333 PJ in 2000 to 2674 PJ (BAU) or 1761 PJ (EPD) in 2020. The participation of natural gas in the fuel consumption for generating electricity would increase from 21% in 2000 to 78% in 2020 under the BAU scenario (even more than current participation of fuel oil -60%-) and to 50% under the EPD case (Table 4).

The technology diversification policy assumed by the EPD case would have impacts on Mexico's natural gas supply/demand equilibrium as showed in Table 5. Official projections (SE) and the BAU case's projections are similar in the period 2000-2010 since they are based on almost the same assumptions, including the power generation sector. Once electric power diversification policy would have been adopted (2007), there would be significant differences between BAU and EPD cases. These differences lie in the oil and power generation sector. As the BAU case considers the installation of a bigger number of combined cycle plants than the EPD case, its natural gas needs would also be larger. Demand in the oil sector, under the BAU case, would also be higher because it mostly represents a percentage of gas volumes supplied to end-users (power generation and others). Natural gas imports can be influenced by the adoption of the diversification policy (Table 5). The rate of imports/demand would reach 23 or 35% during the studied period under BAU or EPD scenarios, respectively.

Conclusions

We have examined the main political, market and regulatory issues concerning natural gas use in the Mexican power generation sector. Some conclusions can be drawn.

Like many other developing countries, Mexico is facing

Table 5
Mexico's Natural Gas Supply and Demand: Estimations Under SE, BAU and EPD Scenarios, 2000-2020 (millions of cubic feet daily).

Millions of cubic	2000 [a]		2005			2010		2015		2020	
feet daily (mmcfd)	History	SE	BAU	EPD	SE	BAU	EPD	BAU	EPD	BAU	EPD
Supply	3824	6118	6327	6327	8207	8367	7654	11061	9371	13693	10683
National	3543	4321	4323	4323	6307	6309	6309	7189	7189	9016	9016
Pemex's processing plants	2791	3796	3796	3796	5155	5156	5156	5864	5864	7519	7519
Direct from fields	752	525	527	527	1152	1153	1153	1325	1325	1497	1497
Imports	281	1797	2004	2004	1900	2058	1345	3872	2182	4677	1667
Demand	3860	6118	6327	6327	8207	8367	7654	11061	9371	13693	10683
National	3836	6118	6327	6327	8207	8367	7654	11061	9371	13693	10683
Oil sector	1402	1578	1393	1393	1652	1516	1366	1849	1527	2092	1576
Industrial sector	1353	2125	2089	2089	2638	2586	2586	3007	3007	3454	3454
Power generation sector	871	2154	2591	2591	3471	3758	3195	5465	4097	7303	4809
Households and commercial	209	240	224	224	369	382	382	513	513	587	587
Transport	1	21	30	30	77	125	125	227	227	257	257
Exports	24	0	0	0	0	0	0	0	0	0	0
Statistical differences	-36	0	0	0	0	0	0	0	0	0	0

a Source: (Sener, 2001c).
SE: Secretary of Energy's estimations (Sener, 2001c) -reference case-.
BAU: Business-As-Usual case.
EPD: Electric Power Diversification case.

today an increasing demand for electricity. Its state-owned companies CFE and LFC are no longer able to finance the required expansion of the electric power industry. The generation sector is already open to private investment under different financing modalities that are currently obtaining poor results. A more competitive industrial organization and modalities of financing that would allow more private participation are now at the center of discussions to restructure the electric power industry.

For economic, environmental and efficiency reasons, combined cycle plants using natural gas constitute today the most convenient choice for expanding the Mexican power generation sector. However, the availability of domestic natural gas is restricted. Increasing gas imports will be necessary in the future to complement domestic supply as illustrated by simulation exercises reported in this work. Our simulation results also indicate that the adoption of a diversification policy concerning technologies used to generate electricity could be one way to limit foreign dependency on natural gas imports, especially in the long run (2010-2020). This is particularly relevant for the future supply/demand balance of the North American natural gas market. It is also suggested that efforts addressed only to the demand-side could be insufficient to control gas imports. Important measures should additionally be taken on the supply-side in order to increase domestic gas production, such as relaxing PEMEX's budgetary constraints or allowing new foreign investments to participate in the Mexican upstream gas sector.

Footnotes

[1] The planning of expansion of the electricity generation sector is done by the CFE (centralized planning). Fuel choices for power generation are also subject to national policy.

[2] In January 1998, the standard NOM-085-ECOL-1994 came into force in its more restrictive phase. This has substantially raised environmental standards concerning nitrogen oxides and sulfur emissions of industrial fuels in most major metropolitan areas. These measures, if implemented as planned, will change Mexico's fuel mix, clearly encouraging consumption of cleaner fuels such as natural gas in certain regions of the country (Elizalde, 1999).

[3] Cogeneration and self-supply plants are not included.

[4] Combined cycle using gas turbine is the most efficient technology available in the market for generating electricity (CFE, 2000). In Mexico, this technology can reach efficiencies of 52%.

[5] The National Council for Population projection of population growth (CONAPO, 1998) is used to obtain the energy consumption per capita in the household sector.

[6] This approach to demand drivers has been used extensively by the MODEMA model at the University Energy Program of the National Autonomous University of Mexico.

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