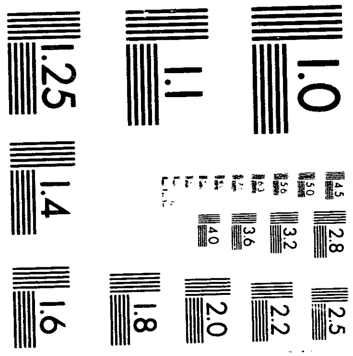
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HOW TO USE THIS REPORT

This study examines the history, current status and future prospects for increased coal use in Mexico. Environmental implications of the power-generation capacity expansion plans are examined in general terms. Mexican environmental law and regulations are briefly reviewed along with the new sense of urgency in the cleanup of existing environmental problems and avoidance of new problems as clearly mandated in recent Mexican government policy initiatives. It is expected that new capital facilities will need to incorporate the latest in process and technology to comply with existing environmental regulation. Technology developments which address these issues are identified.

What opportunities have new initiatives caused by the recent diversification of Mexico's energy economy offered US firms? This report looks at the potential future use of coal in the Mexican energy economy, examining this issue with an eye toward identifying markets that might be available to US coal producers and the best way to approach them. Market opportunities are identified by examining new developments in the Mexican economy generally and the energy economy particularly. These developments are examined in light of the current situation and the history which brought Mexico to its present status.

The headings in the otherwise blank "scanning column" at the left of each page follow the hierarchical convention shown below:

LEVEL 1

Level 2

LEVEL 3

Level 4

LEVEL 5

The organization of this study is as follows:

- **EXECUTIVE SUMMARY:**
  including an overview; major findings; and examples of existing US-led energy development projects.

- **THE MEXICAN COAL PERSPECTIVE:**
  covering Mexico's coal resources, beginning with the history of the coal industry in Mexico; presenting the country's current status; the future of coal use; the Mexican coal market and the demand for coal.

- **KEY FACTORS IN MEXICO'S ENERGY FUTURE DECISION:**
  including the effects of the North American Free Trade Agreement; environmental aspects; technologies; financing alternatives; and summaries of the competitors for the Mexican coal market.

Throughout this report, tables, charts and maps illustrate the text, and detailed information is included in the Appendix.

EXECUTIVE SUMMARY

Overview

Will US producers of coal be able to compete in the future with other supply sources for the emerging Mexican coal market?

While, worldwide, coal is the primary fuel used to generate electricity due to its cost effectiveness, Mexico has only recently introduced coal as an energy source for this purpose. Comparing Mexico's limited coal resources to the country's plans for a five-fold increase in coal use for power generation by the end of this decade, it is readily apparent that such use is predicated on coal imports. However, in order to take advantage of these imports, significant up-front investment in port facilities, transportation, construction of power generating plants, and technology for compliance with increasingly stringent environmental regulation are required. Mexico does not have the available resources internally to implement its plans. Of the international suppliers capable of meeting Mexico's coal needs, one player stands apart: the US.

The US offers a unique combination of strengths that address Mexico's needs. Paramount among these is the US direct investment already in place in Mexico. This relationship, together with US expertise in design and construction, quality of capital goods industries, and experience with environmental compliance, give the US a significant edge over other potential competitors. The US ability to marshall the scope of project financing necessary to implement port and rail development and state-of-the-industry electricity generation facilities further sets it apart. No other country offers all these advantages together with geographic proximity.

However, the immensity of the projects involved suggests that a US-led consortium or joint venture would more likely be able to fund such projects than would an individual corporate entity. Assuming that, due to excess capacity, US coal can be supplied close to least cost, then US producers could win the contracts. US coal and/or transportation companies would be well-advised to seek equity participation in these projects.

Data on average delivered cost per ton of coal were obtained for US suppliers and their major competitors for delivery to the Gulf Coast electric utility market, which includes east coast Mexican ports. Based upon other economic factors, particularly the shortage of capital in Mexico, changes in the institutional and legal environment for foreign investment, and privatization of more of the formerly government sector enterprises, it is believed that Mexico will seek more than simply the lowest cost coal supplier.

Major Findings

Based upon this research, including conversations with knowledgeable private and government sector individuals in the US and Mexico, the following findings emerge:

- Indigenous Mexican coal resources do not appear to be of the quality and quantity that would support a major increase in mining such as is implied by the most recently published electric sector capacity expansion plan;
- Mexico's coal resources are approximately 4 billion metric tons, approximately equivalent to 4 years' US production;
- Electric system planners are planning new capacity based upon import of coal for power generation;
- Coal imports could begin in 1994 and will gradually increase in volume until they reach the range of 11-21 metric tons per year in 2001;
- Mexico's economy is recovering from the difficulties of the 1980s and is expected to grow at significant rates in the near to intermediate term. Demand for electricity is expected to grow rapidly, due to increased individual incomes and the potential for greatly increased penetration of electricity in the residential market;
- The passage of the North American Free Trade Agreement (NAFTA) would give the Mexican economy a boost;
- The market to supply coal to the Gulf Coast will be extremely competitive. Colombia will be a particularly cost competitive supplier. Based upon average delivered cost, the US will be a marginal supplier and will need the NAFTA tariff (10%) and value-added tax (VAT, 6%) relief to compete on the basis of cost alone;

- Significant excess capacity exists in US coal mines, coal transportation systems and coal export facilities. This might mean that US firms could set their prices based upon marginal cost and underbid suppliers who are installing new capacity completely oriented to export;
- The climate in Mexico toward foreign investment has changed dramatically in the last few years and will continue to improve, particularly with the implementation of NAFTA;
- The US is by far the largest source of capital for the Mexican economy. This will be an advantage in the future for US firms, particularly as the world resolves itself into major trading blocs;
- US firms have many other advantages over competitor countries in the Mexican foreign investment market. These include proximity, cultural similarities, similar government structures, and a long history of trading;
- Mexico will seek the most up-to-date operational technology for coal conversion to electric power. Adherence to environmental regulation will be of utmost importance; and
- The environmental market for goods and services pertaining to coal transportation, coal storage and coal conversion will be very attractive and will continue to grow rapidly;
- If NAFTA is ratified, delivered cost of coal from the US would be $29.43 per ton versus $29.70 from Columbia and $33.41 from South Africa;
- Major expansion at the ports of Los Angeles and Long Beach will facilitate delivery of Western US coal (Utah, New Mexico, Powder River Basin, etc.) to Mexico's west coast ports.

Case study projects:

SAMALAYUCA

The Samalayuca project concerns a natural gas fired combined cycle power plant that is to be financed entirely through private sources of capital. The plant consists of three modules of combustion and steam turbines. It is located 22.7 miles south of the Mexican border city of Ciudad Juarez. The plant will have a capacity of 700 MWe and will consume an average of 105 million cubic feet of natural gas daily when the plant becomes fully operational in 1994. The arrangement with the Comisión Federal De Electricidád (CFE)involves build-lease-transfer.

The bid for the project was won by a group of US firms led by General Electric. The Mexican partner is Grupo ICA which is Mexico's and Latin America's largest construction company. The other US firms involved are Bechtel Enterprises, Inc., El Paso Natural Gas, Inc., and Coastal Pan American, Inc. The winning bid submitted by this group was US$ 628 million, US$ 72 million less than the second lowest bid also submitted by a US-led group involving Transco, EBSI of Ireland and the Nacional Financiero of Mexico. Financing for the project will include Citicorp and internal funds of the joint venture partners.

In addition to the cost of the power plant, infrastructure work on pipelines to supply natural gas to the plant and to supply gas to the rapidly growing border area will involve an additional investment of approximately US $250 million. The additional infrastructure would integrate US and Mexican supply systems through the services of four natural gas distribution centers: Valero Energy Company in Reynosa, Coahuila and Monterrey, Nuevo Leon; El Paso Natural Gas in Texas; Coastal Panamerican in Chihuahua; Arizona and California, and Western Gas Interstate which shares the Monterrey, Chihuahua and Coahuila markets with Valero Energy and El Paso Natural Gas. These four firms will gradually take over services which were formerly provided by Petróleos Méxicanos (PEMEX).

Related natural gas pipeline infrastructure development necessary to integrate the systems included two additional pipeline projects, one between Clint and Cornudas, Texas, and the other from the Paso del Norte terminal (operated by Western Gas Interstate) to Ciudad Juarez and Samalayuca. With the linking of these systems, El Paso Natural Gas joins its distribution systems in Texas with its infrastructure in Yuma and Ehrenberg, Arizona. From these locations, industry in Sonora (including the city of Naco) and parts of Baja California receive their natural gas supplies. It is reported that El Paso Natural Gas has approached PEMEX with a request to build an additional pipeline between Arizona and Naco, Sonora, the point from which Mexico ships much of the maquiladora export product. Other pipeline projects not specifically related to the Samalayuca project are proposed by these companies and some specific overtures have already been made to PEMEX.

Environmentally, the project is commendable because it uses natural gas, a clean fuel. The efficiency of the plant is improved by its use of a combined cycle operation which is the most fuel efficient technology presently available for this fuel source.[1]

CARBÓN II

This project is of greater relevance because it involves coal. The plant is located in northern Mexico a short distance southwest of Ciudad Piedras Negras, very close to the US border. Carbón II was acquired by ENERGAN, Inc., a joint venture involving Mission Energy Company, the unregulated subsidiary of Southern California Edison, and Grupo Acero Norte (GAN). Ownership of ENERGAN is 51% by GAN and 49% by Mission Energy. GAN is a joint venture involving the Autrey family with other private interests in Mexico. The Autrey family has been heavily involved for a long time in Mexican mining. GAN owns OPIN, S.A., which owns Carbón I. GAN also owns MESA which, in turn, owns the MICARE mines. Mission Energy has, through ENERGAN, bought 49% of the mine and the power plant. The Autrey family, through some mechanism or company, also bought the Altos Hornos de

México (AHMSA) steel plant at Monclova, Coahuila, but Mission Energy is not involved in this facility.

The Carbón II plant consists of four, 350 MWe coal combustion boilers. Unit 1 is operating, unit 2 is 98% complete and will be operating very shortly and units 3 and 4 are slated to be completed by 1994 and 1995 respectively. Units 1 and 2 are Combustion Engineering boilers and Units 3 and 4 will be Foster-Wheeler units. Coal supply will be 75-80% from the local mines since both Carbón I and Carbón II are mine-mouth facilities. Remaining coal supplies will be from the Sabinas region and possibly from US sources. Persons knowledgeable of this project indicated that US coal was about 20% higher in price on a delivered basis than coal from the local mines on either a $/ton or $/mbtu basis. Tariff reduction through NAFTA will approximately equalize the local and US delivered coal prices.

Coal consumption at the Carbón I plant is approximately 4.0 million TPY, maximum, and projected coal consumption at the Carbón II plant will be a maximum of 6.0 million TPY. The Carbón II boilers are designed for a coal with the following proximate analysis: 7800 btu/lb, 8% moisture, 42% ash and 1% sulfur. Coal will be delivered to the new plant by a combination of belt conveyor and truck. The coal that will be imported from the Sabinas region and possibly from US suppliers will be used for blending to achieve the most desirable coal for the boiler design. Blending has been employed with the Carbón I plant. It was reported to the author that the cost of coal from the local mines is approximately $30/ton and the cost from the next best source, presumably the US (probably the four corners region in New Mexico), is $36/ton. Some of the local coal will be beneficiated prior to combustion. It has been stated that the local coal mines probably could not support additional capacity beyond the two plants that are now there.The plant has electrostatic precipitators for removal of particulates and achieves 99.3% removal. The plant also has

NOx burners and with low sulfur coal (<1%) complies with current Mexican laws and International Finance Corporation (IFC) standards. It has been reported to the author that, should air pollution regulations become more stringent so that the plant could not meet new regulations, operators would retrofit scrubbers to remove sulfur from the flue gases.

Financing for the plant is a combination of private capital and other sources. Other sources probably means IFC funding since representatives of ENERGAN have indicated that the plant is being designed to meet IFC standards for air pollution. It is believed by the author that financing of the units remaining to be installed has not yet been completely secured.

This plant is being built as an independent power project (IPP) and it was reported to the author that ENERGAN has a power purchase agreement with CFE.[2]

THE MEXICAN COAL PERSPECTIVE

Historically, coal has not been perceived as a significant energy fuel in Mexico, except in the relatively short era of the steam locomotive. Several factors have governed the direction of the utilization of Mexico's coal resources, limited in both quantity and quality. The geographical location of major coal producing regions is distant from population centers where it could be used for power generation. The mountainous terrain makes mining expensive and difficult and complicates transportation. The quality of the majority of coal found is also below the level desirable for power generation or coking, particularly in light of current environmental regulation. These factors will limit Mexico's future use of its domestic coal resources.

However, due to its current perspective on energy fuels, imported coal is destined to play a larger role in Mexico's energy future. The desire to diversify primary energy use away from petroleum will lead Mexico to rely more heavily on imported coal in the future. Concurrent with this desire, favorable changes in the business environment, including privatization, relaxation of foreign investment rules, and opening of energy markets to private operation will aid Mexico in making the transition to a new energy fuel mix.

Mexican coal resources

Mexico has not used its domestic coal resources to the extent that industrialized countries have used theirs. This is the result of the relative lack of quantity and quality of coal resources in Mexico and also of government policy decisions which tended to emphasize the development and use of oil rather than coal.

Since the early 1900s, Mexico's energy economy has developed largely around domestic reserves of petroleum. These relatively inexpensive reserves have displaced the significant development of other energy fuels.

The social and industrial development programs resulting from the foreign exchange generated by high oil prices of the 1970s set the stage for the economic problems of the 1980s. The dramatic reduction in the world price of petroleum at the beginning of that decade created a crisis for the Mexican petroleum sector, indeed, for the whole country, as the costs of long-term commitments for these ambitious programs began to outstrip revenues from sales in foreign oil markets. The Latin American debt crisis followed. The experience was similar for other Latin American oil exporters (Venezuela, Ecuador). Oil importers were hurt directly by the high oil prices of the 1970s.

Today, Mexico is reexamining the thinking of the past and making dramatic changes to remove the government sector from much business and investment activity. These changes in Mexican institutions are the basis for the opportunities that are being afforded to American businesses. While the petroleum sector, unlike many of Mexico's other formerly quasi-government organizations, remains largely in government hands, PEMEX is facing escalating challenges. Increasing domestic demand is outstripping PEMEX's production capacity. Inadequate investment and inefficient management have limited the growth of known reserves and production. Mexico's hydrocarbon reserves of oil, condensate, and gas at the end of 1989 were 66.45 billion barrels of crude oil equivalent. This level represented a 1.7% drop from one year earlier and continuation of the decline from reserves of 72.5 billion barrels in 1983. Through NAFTA and the likely additional future overtures the Mexican government will make in order to help PEMEX with these challenges, even the Mexican oil industry will be opened to increased outside involvement.

Recent news reports are also casting some doubt on the credibility of PEMEX's reserve estimates. Mexico's crude oil production has declined from 2.75 million barrels per day in 1982 to 2.5 million barrels per day in 1989.[3] While this may indicate nothing more than a lack of investment in exploration and development during the latter decade, it has nonetheless demonstrated one benefit of energy fuel diversification to Mexican energy policy decision makers and other government officials. Diversification will spread risk as well as take some of the supply pressure off PEMEX.

Over the decade between 1981 and 1990, coal consumption in Mexico was mostly from domestic resources and remained relatively constant. However, the ratio of total consumption between metallurgical and thermal uses changed significantly. In the early 1980s, most coal consumption was for conversion to coke for the steel industry. As the 1980s proceeded, consumption shifted increasingly to thermal uses and away from the steel industry due to decreased demand for steel.

This was not the first time such a shift in major end uses occurred in the history of coal use in Mexico. In the early days of the coal industry, thermal uses predominated in smelting and railroads until the pre-World War II days when diesel fuel replaced steam in locomotives. About this same time, the domestic steel industry was developed and coal found a new end use.

HISTORY

Mining of coal on a commercial basis reportedly began in the northeastern State of Coahuila in the middle 1880s for thermal use in the copper smelters in northern Mexico. During the development of the Mexican railroads in the last 20 years of the 19th century, production of coal for thermal use increased rapidly, reaching approximately the 1M ton per year (TPY) level by the early 1900s.

During the consolidation of the steel industry in the 1980's, other factors were at work in the economy to induce a shift back to increased steam coal use. Energy planners, concerned with Mexico's heavy reliance on fuel oil and natural gas for electric power generation, were making plans to diversify Mexico's primary energy sources by introducing coal-fired electric power generation. These plans came to fruition in the early 1980s with the construction of the mine mouth José López Portillo plant at Río Escondido. This 1200 MW plant consumes approximately 4M TPY of local coal and accounts for the re-entry of steam generation as a use for domestic coal.

Thus, coal use in Mexico has experienced wide swings in the basis for its use: from its emergence in the late nineteenth and early twentieth centuries as a source of heat to produce steam to its use primarily to produce coke for the domestic steel industry during the middle decades of the twentieth century. More recently, significant quantities of coal are used to raise steam. Mexico's coal economy has not evidenced a growth pattern either in steam raising or in coking uses comparable to that experienced in many industrialized countries.

Current coal resources

Mexico's coal deposits represent less than 1% of the world's coal reserves. Coal is found in the States of Coahuila (the principal region), Sonora, Oaxaca, Tamaulipas, and Chihuahua.[6] With the exception of the deposits in the southern state of Oaxaca, all of Mexico's known reserves of coal are in the states bordering the US, as illustrated in Map 1. Proven reserves are relatively small, perhaps due to historically limited exploratory activity. Table 1 lists pertinent information about the coal resources in each of the regions.

Map 1

Mexico's Major Coal Deposits

Table 1

MEXICO: COAL BASINS AND RESOURCES

BASIN AND STATE	AGE OF COAL AND FORMATION	COAL CLASSIFICATION	LATITUDE / LONGITUDE	POTENTIAL RESOURCES	RECOVERABLE RESOURCES
Fuentes-Rio Escondido, Coahuila	Upper Createous Olmos formation	High volatile bituminous C	28°37'N 100°37'W	1,216 MMT	240 MMT
Sabinas-Monclova, Coahuila	Upper Cretaceous Olmos formation	Medium to high vol bituminous A	27°30'N 101°15'W	2,556 MMT	625-875 MMT
Colombia-San Ignacio Coahuila, Nuevo Leon, Tamaulipas	Eocene Bigford and El Pico clay form	High volatile bituminous C	27°30'N 100°45'W	252 MMT	—
de la Mixteca, Oaxaca	Middle Jurassic Rosario, Zorillo and Simon formations	Low volatile bitumin to semi-anthracite	17°20'N 97°45'W	1,625 MMT	—
Barranca, Sonora	Triassic-Jurassic Barranca formation	Anthracite	28°37'N 109°30'W	143 MMT	—
Cabullona, Sonora	Lower Cretaceous Cintura formation	Low volatile bituminous	31°10'N 106°40'W	80 MMT	—
San Pedro Corralitos, Chihuahua	Upper Cretaceous Olmos formation (?)	Medium volatile bituminous	30°45'N 107°40'W	23 MMT	—
Ojinaga, Chihuahua	Upper Cretaceous Olmos formation (?)	Sub-bituminous	29°10'N 104°10'W	90 MMT	—

Source Flores Galicia E. 1988. "Geologia y Reservas de los Yacimientos de Carbon en la Republica Mexicana", pp 174-217, in Geologia Economica de Mexico, G P Salas Editor Fondo de Cultura Economica, S A , Mexico 544p hereafter, increased use of coal to make coke by the metallurgical industry balanced decreased thermal use of coal as a locomotive fuel while production remained at 1M TPY until the early 1950s. During WWII, Mexico experienced difficulty obtaining sufficient iron and steel from traditional supply sources in western Europe and the US. This brought the country to the realization that iron and steel were strategically important industries for Mexico.[4] Plans for domestic development of these industries followed, with the resultant need to identify a source of coke. Coahuila was found to have suitable resources.

In the period following WWII, metallurgical coal production increased gradually from approximately 1M TPY in the early 1950s to approximately 10M TPY in the middle 1980s with most of this production being used in the domestic steel industry. The main consumers of coke made from this coal were the steel plants of Fundidora de Monterrey, S.A. (FMSA) and Altos Hornos de México, S.A. (AHMSA) located in the northeastern Mexican state of Nuevo León in the city of Monterrey, and Siderúrgica Lázaro Cárdenas, S.A. (SICARTSA) located in the south-central state of Michoacán. Then, as the economy faltered in the early-to-mid 1980s with the onset of the Latin American debt crisis, the steel market went into decline, reducing the demand for coking coal.

During the years since 1980, mine closings in the Sabinas Region, the principal metallurgical coal producing area, have reduced the number of operating mines in this region from 30 in 1979 to six today.[5] The middle of the 1980s saw the FMSA, owned by Siderúrgica Méxicana (SIDERMEX), closed. Production by AHMSA was cut back, further reducing the demand for coking coal.

While many factors influence the determination and definition of reserves, data presented by Schmidt[7] indicates that a seam with a thickness of 1.4 meters facilitates mine exploitation by either conventional or continuous mining methods, or a combination of the two. Reserve data from different sources suggest that measured reserves of coal in Mexico with a thickness greater than 1.4 meters are on the order of 1.1 billion tons of raw coal; however, no estimate of recoverability has been reported. [8]

Two regions — the Fuentes-Río Escondido and Sabinas — in Coahuila have been a principal source of supply of coal to date. The Sabinas Region, often referred to as the Sabinas Basin, actually consists of four basins: Sabinas, Las Esperanzas, El Saltillito, and Monclova, lying between the towns of Monclova and Sabinas, a distance of approximately 62.5 miles. Nearly 65% of Mexico's proven reserves are located in the Sabinas Basin, which is Mexico's largest coal producer, yielding in the neighborhood of 7.5M TPY. Virtually all of the coal mined from this area is used for coke, with the exception of the middlings that are shipped from the washing plant to the Río Escondido power plant.[9]

Numerous producers have mined coal from the Sabinas Basin during its producing history. Most of the recent production was by one of three major operating groups: SIDERMEX, Industrial Minéra México, S.A. (IMSSA), and the Comisión de Fomento Minéro. These mines, within seventy-five miles of each other, are operated by their owners as captive mines to supply coal to make coke, which in turn supplies steel making facilities owned by these same entities.

The SIDERMEX operations are the most significant and consist of several mines and washing plants at the towns of Las Esperanzas, Palau and Barroteran. The Comisión de Fomento Minéro operates a mine and washing plant at Agujita. The IMMSA has its mines and a washing plant at the town of Nueva Rosita, which is about

75 miles south of the Texas border town of Eagle Pass. Coke plants are operated by IMMSA at Nueva Rosita and by AHMSA at its Monclova, Coahuila steel works. Monclova is another 70 miles further south of Nueva Rosita along the same highway.

Washed coal is also shipped by rail a distance of approximately 700 miles to the SICARTSA steel works on the southwest coast at Lázaro Cárdenas, Michoacán, for coking. Production from the Sabinas region has been in the neighborhood of 7.5M TPY.

The Fuentes-Río Escondido Basin from which steam coal is mined runs approximately parallel to the Río Grande River (Río Bravo in Mexico) southward from the town of Piedras Negras, Coahuila, which is on the US border across from Eagle Pass, Texas. The mining area as presently outlined extends for about 22 miles south of Piedras Negras. Beyond this, the increasing depth of cover and the presence of hydrocarbons may cause the coal to be unmineable. The steam coal was mined by Minéra Carbonífera Río Escondido (MICARE) in which the Comisión Federal de Electricidád (CFE) is a major shareholder . These mines operate to supply a highly volatile, bituminous "C" coal with approximately 33% ash, 1% sulfur, and a heat value of 4,580 cal./gm. that is used to raise steam at the 1200 MWe José López Portillo plant. This plant is sometimes referred to as Carbón I.

Two open pit and two underground mines are producing coal at between 4 - 5M TPY, sufficient to supply the needs of the power plant. The potential exists to increase output at these mines if an increase in the capacity of the power plant warrants such investment. Total measured reserves in the Fuentes-Rio Escondido Basin are on the order of 600M tons and total resources are upwards of 1.2 billion tons.[10] It has been reported that coal sufficient to supply 75-80% of the plant's needs is available for Carbón II, but that supply could not be increased beyond that.

Some of the coal produced at the Río Escondido mine is shipped to the washing plant at Agujita where it is washed and blended with other coals to make coke. In return, middlings from the Sabinas coals are shipped to the Río Escondido power plant.

In addition to Fuentes-Río Escondido and Sabinas, the principal coal-producing regions, coal is known to occur in six other basins in Mexico. These are the Colombia-San Ignacio Basin in Coahuila, Nuevo León and Tamaulipas; the de la Mixteca Basin in Oaxaca; the Barranca and the Cabullona Basins in Sonora; and the San Pedro Corralitos and Ojinaga Basins in Chihuahua (see Maps).

- The Colombia-San Ignacio Basin overlies the Fuentes-Río Escondido Basin on the western flank of the Río Grande embankment in the states of Coahuila, Nuevo León and Tamaulipas just west of Laredo, Texas, and contains lignites and cannel coal. The de la Mixteca Basin is located west of the city of Oaxaca and contains several lenticular coal seams in folded and deformed rocks of middle Jurassic age. This field consists of several deposits which are generally small and contain coals ranging from bituminous to anthracite. The increased rank is the result of volcanic influence which has also caused in-situ coking in some areas. The seams are irregular and do not contain large resources.[11]

- The Barranca Basin in Sonora is the second largest producing field in Mexico and lies southeast of Hermosillo. It contains lenticular coal seams which date from the lower half of the Triassic-Jurassic age. Contact metamorphism of these seams by intrusive rocks gives rise to the graphite deposits of the Hermosillo region.

- The Cabullona Basin, in northeastern Sonora just south of Douglas, Arizona, includes about 12 square miles which are underlain by several discontinuous coal seams of lower Cretaceous age.

- In northwestern Chihuahua, about 87.5 miles southwest of Ciudad Juarez, the San Pedro Corralitos Basin contains coals which appear to be correlative with those of the Sabinas-Monclova Basin.

- Opposite Presidio, Texas and the area of the Big Bend National Park, the Ojinaga Basin, in eastern Chihuahua, contains at least one seam of coal similar to that in the San Pedro Corallitos Basin.

Many other occurrences of coal or lignite have been reported in Mexico but have not been studied in sufficient detail to assess their possible economic significance.

Using the coal reserve classification schematic developed by P. Averitt,[12] Mexico's reserve base (which includes demonstrated, identified resources that are economically mineable) lie only in the two regions of the state of Coahuila mentioned above. There are approximately 1,250M tons in the Carbonífera Region (Sabinas-Monclova) coal basins of which between 50% and 70%, respectively, can be extracted. The Fuentes-Río Escondido basin contains a total of approximately 629M tons of proven reserves, 240M tons of which are considered mineable on mining engineering criteria. Costs of mining might further reduce these figures for potentially extractable coal.

As indicated by the figures for potential resources in Table 1, application of Averitt's criteria for demonstrated, identified reserves together with economic criteria, would render insignificant most of the coal in regions other than the Carbonífera and Río Escondido, with the possible exception of the de la Mixteca Basin in Oaxaca. Two entities, the World Energy Council and British Petroleum, have published estimates of recoverable reserve extimates. For Mexico, both entities estimated 1.4 billion tons of anthracite and bituminous coal and 516 million ton of sub-bituminous coal and lignite.

To put Mexico's relatively small percentage of world coal reserves in perspective, the US currently produces about 1 billion tons of coal per year. Less than four years' US production would be approximately equivalent to Mexico's total potential reserves.

Production

Table 2 represents coal production by mining company, by category of coal and by year for selected years between 1980 and 1989. Metallurgical coke production is also shown. Figures indicate that metallurgical coal production dominated the use of Mexican coal until 1983 when the José López Portillo coal-fired power plant came on line. Coal production for iron and steel making increased 11% between 1980 and 1985, remained approximately stable until 1987 and then declined by 10% and 7%, respectively, in 1988 and 1989, reflecting the decline in steel output.

Meanwhile, steam coal production grew significantly as the José López Portillo plant came fully on line in the middle 1980s. Steam coal production increased almost five-fold between 1980 and 1985, almost 50% in 1986 and 30% in 1987, and then leveled off as the José López Portillo plant rose to full design power output. As the mining subsidiary of the CFE, MICARE is responsible for mining, washing and transporting coal to the José López Portillo power plant and has therefore been the sole producer of steam coal in Mexico.

The principal mines in the Carbonífera area prior to privatization were operated by the mining units of the government-owned steel companies grouped under SIDERMEX, which produced 5.7M tons

Table 2

MEXICAN COAL AND COKE PRODUCTION BY COMPANY

Million Metric Tons

METALLURGICAL COAL		1980	1985	1986	1987	1988	1989
SIDERMEX (ex-FMSA)	Run-of-mine coal	1358	1400	1220	1104	529	249
	Washed coal	772	623	506	575	440	430
	Metallurgical coke	678	561	300			
SIDERMEX (AHMSA)	Run-of-mine coal	3682	4397	4015	4590	5099	5106
	Washed coal	1950	1776	1779	1883	2087	2096
	Metallurgical coke	1418	1542	1546	1516	1511	1486
SIDERMEX (SICARTSA)	Metallurgical coke	464	511	541	565	548	549
IMMSA	Run-of-mine coal	874	590	412	382	410	388
	Washed coal	329	213	190	191	217	234
	Metallurgical coke	241	161	146	127	125	158
Comision de Fomento Minero	Run-of-mine coal	278	1071	1246	878		
	Washed coal		623	552	380		
Others	Run-of-mine coal	298	410	269	197	372	187
Totals	Run-of-mine coal	6430	7868	7160	7151	6410	5930
	Washed coal	3051	3246	3027	3027	2744	2760
	Metallurgical coke	2801	2778	2533	2533	2184	2193
STEAM COAL							
Minera Carbonifera Rio Escondido S.A.	Run-of -mine coal	367	2160	3173	4122	4300	4136
GRAND TOTALS	Run-of -mine coal	6857	10028	10333	11273	10310	10066
	Washed coal	3051	3240	3027	2980	2344	2760

Source: The Mineral Economy Of Mexico, US Department of the Interior, Bureau of Mines, 1992 of coal in 1987; Grupo IMMSA, a private mining concern, which produced 573,000 tons; and the Comisión de Fomento Minéro, another government-owned operation, which produced 878,000 tons. Total run-of-mine production was slightly greater than 7M tons, almost all of which was shipped to washing plants, where metallurgical coal was recovered. Raw coal wash was 6.9M tons, from which 3M tons of washed coal was recovered. Reported shipments of clean coal were 3M tons, of which 2.2M tons went to coke plants in the Coahuila area, 7,833 tons went to the CFE for power generation, and the balance of 742,000 tons went to the SICARTSA steel plant in Lázaro Cárdenas, Michoacán. Reported coke production was 2.3M tons, whereas total shipments were reported to be 2.4M tons, indicating an inventory drawdown of about 100,000 tons. Shipments to steel plants were 2.1M tons, or 85% of total shipments. [13]

Coke production declined for the fifth year in a row, and was 25% below the record high level of 3.1M tons produced in 1981. During the same period, production of pig iron remained relatively constant, reaching a high of 3.9M tons in 1984 versus a prior low of 3.5M tons in 1983. The overall pattern of declining coke production with stable pig iron production suggests that the Mexican steel industry has achieved a substantial reduction in the coke rate (coke consumed per unit of iron produced) in the last several years.[14] This may be due to the larger share in total production comprised by output of the more modern Lázaro Cárdenas mill after the closure of the FMSA, an old mill based on out-moded technology.

Coal production figures issued by the Energy Information Administration in that organization's International Energy Annual for 1991 are shown in Table 3.[15] These data corroborate data obtained from other sources and show that Mexican coal production has grown modestly in the years between 1982 and 1991. Coal consumption has roughly tracked coal production with shortfalls being made up by imports of coal, mostly from the US, but also

Table 3

MEXICO'S COAL PRODUCTION, CONSUMPTION AND IMPORTS, 1982-91

Millions of Short Tons

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Production	8.00	10.00	10.00	9.00	9.00	12.00	12.00	11.00	11.00	12.00
Consumption	9.08	10.5	10.45	9.9	9.92	8.43	11.04	11.09	11.50	12.07
Imports	1.08	0.5	0.45	0.9	0.92	3.57	0.96	0.09	0.50	0.07

Source: International Energy Annual, 1991, Energy Information Administration, US Department of Energy, 1992.

from Canada. While import data was not independently available from the EIA source, apparent imports (obtained for Table 3 by subtracting consumption from production) were substantial in some years. Negative numbers show an excess of production over consumption. Imports of coal are also shown in Table 4.

Preparation of coal

Very little coal is used directly as it comes from the mine (run-of-mine coal). Most coal is prepared or beneficiated prior to shipping or use according to a variety of practices. Increasing amounts of coal are beneficiated prior to combustion and levels of beneficiation are increasing as environmental regulations become increasingly stringent. Beneficiation removes the impurities and non-combustibles prior to combustion thereby reducing the waste streams from combustion and the need for special handling of these waste streams. Phillips *et al.*[16] defined six levels of preparation ranging from level A, which essentially amounts to no preparation prior to shipping or use, to level F, which involves full beneficiation to produce two or more products from the raw coal.

Clearly, costs of preparation rise as the level of preparation increases. However, when costs of transportation and cleanup of waste streams from use of coal are included, beneficiation may partially or completely offset the costs of even the highest level of preparation. Accordingly, each case must be examined separately to balance the full costs of preparation of coal as mined against the costs of cleaning up the waste streams resulting from coal use.

Coking coal requires washing and perhaps other levels of preparation. Thus, virtually all of the coal that is used in the Mexican iron and steel industry is washed and blended with imported coal to achieve a product that is suitable for coking. Blending of coal to achieve a product with more desirable properties is practiced in all of the industries that use coal. A generalized reason to blend coal is provided by the increased need to reduce waste streams from coal use.

Table 4
MEXICAN COAL AND COKE PRODUCTION AND TRADE
Million Metric Tons

	1960	1965	1970	1975	1980	1981	1982	1983	1984	1985	1986	1987	1988
COAL													
Production													
Run-of-mine coal	NA	NA	NA	5193	6942	8086	7637	8999	9348	9771	10158	11136	10586
Consumable coal	1776	2006	3004	3083	3457	4273	3906	5395	5670	5882	5077	7148	6487
International Trade													
Imports of consumable coal	NA	56	153	450	823	681	651	278	372	1071	243	23	81
Exports of consumable coal												45	74
Apparent Consumption	NA	2062	3157	3533	4280	4954	4557	5674	6042	6952	5320	7126	6494
Trade with the US													
Imports from the US	NA	5	153	450	676	355	427	172	22	585	133	18	80
Exports to the US												45	74
COKE													
Production	835	845	1300	1641	2952	2974	3019	2996	2928	2901	2604	2340	2332
International Trade													
Imports	NA	56	343	113	121	157	89	53	80	156	84	70	125
Exports					79								68
Apparent Consumption	NA	901	1643	1754	3073	3131	3108	3048	3008	3057	2684	2413	2389
Trade with the US													
Imports from the US	NA	4	340	106	111	147	89	33	53	80	45	33	54
Exports to the US													68

Source: "The Mineral Economy of Mexico, US Department of the Interior, Bureau of Mines, 1992, p. 71.

Coal that is to be used to raise steam for electric power production technically does not have to be beneficiated. In the initial planning for the Carbón I plant at Río Escondido, the decision was apparently made to use run-of-mine coal that was not prepared in any way. However, over time, operational problems grew to the point where a washing facility was necessary. The reasons behind introducing washed coal into the electricity industry were essentially based on the technical and economic factors related to working with coals as well as on operational problems. As a result of the washing process, time spent in the homogenization of the mineral and the maintenance and operation of the boilers is reduced, with a consequent reduction in costs. Apart from these advantages are others dealing with ash and the use of by-products, such as alumina and earth silicon.[17] With the advent of new and more stringent air quality regulations, it is likely that thermal coal use in Mexico will require either a higher level of coal preparation or the use of a higher quality of coal.

Transportation of coal

Despite the relatively large size of the country and the mountainous topography, Mexico possesses a well-developed transportation and communications infrastructure. The road and rail network connects the economically most important parts of the country and is connected to US roads and highways of fourteen border cities stretching from California through Texas (see Map 2). The rail network is connected at four locations along the common border (see Map 3). Port facilities support the existing ocean-based international trade network, although much of the general trade with the US, Mexico's major trading partner, travels overland via trucking routes.

Other forms of communication bespeak an industrializing country:

- Telecommunication facilities link the economically important areas to Mexico City and to the world beyond.

Map 2

The US - Mexico Border Area

Map 3

The Rail Network and Major Ports

- The electric grid is extensive although an estimated 3,000 rural, isolated villages are not connected to it.[18] (Map 4 shows the electricity grid together with the generating facilities identified.)

- Air transportation serves most population centers with scheduled and unscheduled service available.

Mexico's rail network consists of 16,925 miles of mostly standard gauge track. Of the six different lines that are integrated into the rail network, five of them are owned by the government and the sixth is a small, private freight line operating in the state of Sinaloa. Ferrocarrílles Naciońal de México (FNM) and Ferrocarrílles del Pacífico (FP) are the two largest railroads and are autonomous agencies of the government under common management.

The FNM is the largest railroad owning approximately 70% of the track and carrying approximately 80% of the freight and passengers that are carried by rail. The three remaining smaller rail lines owned by the government are units of the Ministry of Communications and Transport. Map 3 contains a map locating the rail lines, showing connections with US railroads and major ports of the country.

The Mexican constitution requires that ownership of track and operation of locomotives be vested in the government. Recent moves to privatization in other areas of infrastructure and business have not yet affected ownership and operation of railroads. However, prior restrictions on private ownership of railcars have been relaxed somewhat within the past few years.

The Mexican road network includes Federal, State and local roads of which most are constructed for year-round use. Mexico possesses 131,250 miles of roads of which 40,625 miles are paved. While

Map 4

Electricity Grid and Major Generating Stations

Mexico's road network is advanced by most standards, the large quantity of passenger and freight transport by road often means that some roads and highways are choked with heavy traffic (see Map 5).

Further development of the road system, as with most infrastructure, is hampered by a shortage of capital. In response to this shortage, the Mexican government has granted concessions to private industry to develop modern toll highways. To date, approximately 1500 miles of toll roads have been developed under these concessions. Another 1000 miles are planned over the next five years.

The coal that is mined and used in the northeastern part of the country for use at the José López Portillo power plant and for the AHMSA steel works at Monterrey is transported by truck because these are effectively mine-mouth facilities. However, road transportation is not considered to be important to expanded future use of coal in Mexico, because increased coal use will probably be based upon imported coal and bulk handling by rail and port facilities. Shipping the large quantities of coal by truck would be uneconomical.

Mexico's port facilities are adequate for current uses but would need significant development to handle bulk quantities of coal being imported into the country. With more than 80 ports in the country, major port facilities formerly existed only in the five cities of Tampico and Veracruz (on the Gulf of Mexico side of the country) and at Guaymas, Manzanillo and Mazatlán (on the Gulf of California and Pacific Ocean coasts). These five major ports presently handle 80% of the cargo tonnage (see Map 3).

The port expansion program pursued in recent years has added new capacity on the east coast at Altamira, north of Tampico, Dos Bocas and Laguna de Ostión.

Map 5

Mexican States

- The port at Altamira has bulk handling facilities for iron ore imports and is capable of servicing ships up to 100,000 deadweight-ton capacity.

- Dos Bocas was developed by PEMEX primarily for petroleum.

- The port at Lázaro Cárdenas, built to service the SICARTSA steelworks, was also expanded in the port development program and serves the FERTIMEX fertilizer plant at the same location.

- The petroleum port at Salina Cruz on the south coast of the State of Oaxaca has been expanded and upgraded and the road from the east coast port of Coatzacoalcos was developed to service the adjacent container facility at Salina C z.

- Channels were dredged at the ports of Ensenada, Mazatlán, Puerto Madero, Salina Cruz and Topolobampo.

- Electrical service at the dockside was upgraded at Guaymas and Manzanillo.
- The principal PEMEX oil port is at Pajaritos near Coatzacoalcos and contains 12 berths at 8 docks and has an offshore buoy to accommodate larger tankers.

- Oil storage capacity at Pajaritos has almost tripled from 3M to 8.3M barrels.

Few of Mexico's ports have the type of bulk cargo handling facilities that would be required to handle large quantities of imported coal. Also, most of the ports are not close to the intended locations of the planned new power plants. Hence, major port development may be required to implement the expansion plan developed by the CFE.

Consumption of coal

The majority of coal consumed in Mexico has been primarily in support of the domestic steel industry. Due to its geography and topography, Mexico has not required fuels for home heating. Fuels for thermoelectric power generation have been provided by large domestic resources of petroleum and natural gas with some use of nuclear, hydroelectric and geothermal resources. Therefore, Mexico's energy economy has developed with coal playing a limited role.

COAL CONSUMPTION IN THE MEXICAN STEEL INDUSTRY

Iron ore was first discovered in Mexico at Cerro del Mercado in the state of Durango but was not mined in significant quantities until the opening of Mexico's first steel mill in 1903, the FMSA mill in Monterrey, Nuevo León. Mexico recognized the importance of developing a domestic steel industry during the second world war when supplies of steel from its traditional sources in Europe were interrupted by the war and by the interruption of international trade across the Atlantic Ocean. Mine output began to increase with the opening of Mexico's second integrated steel works, AHMSA in Monclova, Coahuila, in 1944 and has increased steadily ever since. In 1942, Hojolata y Lamina, S.A. (HYLSA) opened a plant in Monterrey, Nuevo León to produce tinplate. Mexico's steel industry is highly evolved and vertically integrated and in Latin America is second in size only to Brazil's. Table 5 shows that 6.3M tons of finished steel was shipped in 1988. Iron ore is mined in the States of Coahuila, Chihuahua, Colima and Michoacán. As we have seen, metallurgical coal is mined only in the State of Coahuila. Integrated steel plants are located in Monclova, Coahuila; Monterrey, Nuevo León; Puebla; Lázaro Cardenas, Michoacán; and Veracruz.

The iron ore deposits presently in production may be grouped into three units: the Hercules deposits in northern Mexico that supply

Monclova; the Peña Colorada, El Encino and the newly opened Cerro Nahuatl deposits in the states of Colima and Jalisco that provide iron ore for HYLSA and TAMSA; and the deposits of the Las Truchas district in Michoacán that supply SICARTSA I and II. [20]

The country is virtually self-sufficient in all of the basic raw materials and has found it necessary to import only limited quantities of iron ore, metallurgical coal and specific alloying commodities, such as chromite. Unless the steel industry grows dramatically in the near to intermediate term, new resources for these raw materials will be unnecessary. However, over the long term, it may be necessary to import larger quantities of higher quality raw materials to take advantage of productivity improvements and to circumvent bottlenecks and high costs associated with long distance overland transportation.

Mexico's steel industry has a three-part structure. A group of government-owned companies is administered by SIDERMEX. Two integrated private sector companies make up the second group and a third is comprised of a group of non-integrated private sector companies. The state-owned companies include AHMSA with its steel works at Monclova, Coahuila, and SICARTSA with its works at Lázaro Cárdenas, Michoacán. The SIDERMEX group includes Grupos Materias Primas which provides raw materials for the SIDERMEX operations. The FMSA, Mexico's first steel company, was declared bankrupt in 1986 and the works have been demolished.

The integrated private sector companies are HYLSA, which is part of the Grupo Industrial Alfa and has its principal works at Monterrey, Nuevo Léon and Puebla; and Tubos de Acero de México, S.A. (TAMSA) with its works at Veracruz. These latter two companies either own or have interests in iron ore and pellet production facilities and produce steel from direct reduced iron. The non-integrated companies include eight firms which have both melting-refining and rolling-finishing facilities, and twelve others which manufacture rolled products as well as pipe and tube of various kinds.

The oil boom of the 1970s helped the Mexican steel industry to rapidly expand output as industry developed. Output peaked in 1981 with production of 7.7M tons and apparent consumption of 9.8M tons. Production then declined to under 7M tons in 1983 while apparent consumption also declined due to government import restrictions. Production has since recovered to approximately its 1981 peak level. Imports remain low, however, as Mexico appears to have achieved self sufficiency in basic steel product (see Table 5).

The trends of the last few years toward increasing production, consumption and trade will likely continue into the near future. Production will increase as the Stage II expansion at SICARTSA becomes fully operational. Apparent consumption will also increase from the low levels of the mid 1980s as economic problems are resolved and growth continues. Steel imports will continue at relatively low levels and consist primarily of specialty products, as the demand for these products on the domestic market is too small to be cost effectively produced locally. Exports may decrease as growth in domestic demand outstrips increasing production capacity, but the government will push to keep exports up as they are a significant source of foreign exchange.[21]

While the gradual growth scenario for the steel industry outlined above is perhaps the most likely, the Mexican economy seems poised for another substantial growth spurt. If increased trade with the US and Canada takes place in the near to medium term (two to five years), stimulated in part by the implementation of NAFTA, growth in industry could result in a greater demand for

Table 5

MEXICO'S IRON AND STEEL PRODUCTION AND TRADE

Thousand Metric Tons

	1980	1985	1986	1987	1988
Production					
Iron ore: crude ore mined	12,668	13,898	14,547	14,335	14,864
Product shipped	7,708	7,820	7,298	7,523	8,431
Iron content of ore	5,087	5,161	4,817	4,956	5,564
Pig iron	3,639	3,595	3,737	3,712	3,678
Sponge iron	1,636	1,500	1,420	1,551	1,686
Crude steel	7,156	7,399	7,225	7,642	7,779
Steel products	6,220	6,052	5,622	6,007	6,314
Trade					
Imports	2,906	726	553	357	563
Exports	78	459	1,202	1,410	1,247
Apparent consumption	9,048	6,319	4,973	4,954	5,630
Trade with the US					
Imports from the US	1,294	n/a	n/a	161	n/a
Exports to the US	61	248	446	488	n/a

Source: The Mineral Economy of Mexico, Us Department of the Interior,Bureau of Mines, 1992 steel. Moreover, since increased trade may require increased infrastructure (i.e., port facilities, transportation facilities and electric power generation facilities), larger than expected growth in steel demand could easily result in the need for increased steel-making capacity.

While expansion in steel-making capacity might be necessary to meet future demand generated by a spurt in Mexico's economic growth, this increased demand for steel might not result in a large increase in demand for coke. Advances in steel-making technology are proceeding along several alternative approaches.[22] Because the production of coke is probably the most economically and environmentally sensitive aspect of coke production,[23] one potential solution to this is direct reduction steel-making that uses coal and eliminates the need for coke. In this process, iron ore, scrap steel and ordinary coal are mixed in a bath of molten iron. The coal acts as both a fuel to provide heat for the process and as an oxygen reductant. Steel made via direct reduction usually needs further refinement.[24] Another alternative is the use of the traditional basic oxygen furnace with refinements to address environmental and economic shortcomings.

Coke production liberates many organic chemicals as by-products. Without emission-control technology, coke plants have the potential to be serious polluters of air and water. The construction of a new coke plant requires not only coke ovens but also facilities for treating the waste water and for minimizing the escape of gaseous pollutants. A new coke plant, complete with emission-control facilities, costs about $350 M. New coke plants are difficult to finance.[25] The overall productivity of the basic oxygen furnace will be improved with new bottom-blowing and ladle-refining techniques. Coke-making in existing coke ovens will be fitted with advanced control systems. Coke needs will be reduced by using new methods for injecting coal and other fuels. The enhanced basic oxygen furnace provides an alternative route for the steel industry.

As electric arc furnace steel is used for more demanding applications, scrap-based steel-making techniques will improve. Efforts to reduce residual copper, tin, and other unwanted elements in scrap metal have already produced the use of scrap substitutes such as direct reduced iron. Efforts to reduce energy consumption in electric arc furnace steel-making have produced new techniques, such as the use of hot exhaust gases from the furnace to preheat scrap metal, and new tools, such as the energy optimization furnace, a steel-making facility designed to accept a charge varying from 100% liquid iron to 100% scrap. Thus, it would appear that increased demand for steel will increase either the demand for coal to make coke or for electric power which, in turn, would increase the demand for energy fuels, coal included.

Known raw material resources for the steel industry, with iron ore and metallurgical coal, are not adequate to support the industry on a long-term basis. Thus, the Mexican metals and fuels industries require significant investment in exploration and raw materials development to expand their resource base and provide for adequate strategic planning and long range development. [26]

COAL USE IN ELECTRIC POWER GENERATION

Existing electric generation capacity in Mexico is comprised mainly of fuel oil (65%) and hydro (25%), with the remaining 10% being comprised of other fuel sources including coal, natural gas, nuclear, geothermal and small amounts of diesel, bagasse and miscellaneous others. Mexico is trying to diversify its fuel sources by introducing more coal and natural gas fuels into its generation capacity mix. In addition, with the recent passage of the law removing the monopoly held by the state-owned CFE to generate electric power, Mexico signals its intent to diversify the location/concentration of electric power plants. By opening the power generation market to cogenerators and to third parties producing power for sale to the grid, Mexico will, in effect, be reducing the average size of each generating facility, a deliberate risk reducing strategy. Coal is slated to play a more significant role in facilities constructed in the future to generate electricity. The existing and planned generating facilities by fuel type are detailed later in this section.

OTHER POTENTIAL SOURCES OF INCREASED COAL CONSUMPTION

We have seen that coal has played a minor role as a fuel to raise steam or to provide direct heat for other types of industrial processes. Given the ready availability of petroleum and natural gas in process heat, the likelihood is that coal will continue in its current insignificant role. Cement production is the one possible exception. The production of cement requires a large enough quantity of heat that coal could be competitive with natural gas and fuel oil in this use. However, cement production facilities are normally widely dispersed because of the low value of the product relative to the cost of shipping it long distances. Thus, cement production is typically located close to consuming markets which would also be served by natural gas and/or petroleum facilities. Coal fired electric power plants located close to industrial areas might open a market for coal to be used in cement plants that are also located in the same industrial areas.

Another area of opportunity for the Mexican mineral industry is the further development of the industrial minerals sector. The Mexican cement industry has identified and capitalized on the opportunity to serve the southwest US market. [27] If, for this purpose, new cement facilities are constructed, coal as a source of fuel for process heat could be economically viable. Such facilities would likely be located in the border region. In this region, low sulfur coal from the four corners area of New Mexico and possibly other western coal producing states could be shipped overland by rail and delivered economically to markets in northern Mexico.

Mexican coal cost and pricing

BACKGROUND [18]

Mexico's historical experience with use of coal has unique characteristics due to the ownership structure of both the producing and the consuming sectors. In the category of thermoelectric use of coal, the consuming entity plays the role of the monopoly buyer of the commodity (the CFE) and the supplier (MICARE) was the monopoly seller. It is known from simple economic theory that this situation gives rise to an indeterminate price. The situation is further complicated by the fact that the buyer of the commodity, until recently, held a significant ownership interest in the commodity producer (MICARE). In this situation it would be preferable to consider the two entities as one and the price at which coal is "sold" to CFE a "transfer" price. The category of metallurgical use of coal by steel-making entities presents a similar situation since most of the firms used coal from captive mines to produce coke. For this reason, a coal market as we know it in the US has never developed in Mexico.

The exact business relationship between MICARE and CFE is partly a product of the requirements of third party financing of the coal and electric power development. At the inception of the mine development, MICARE had successfully negotiated a loan from the Inter-American Development Bank (IADB) for the purpose of acquiring coal mining equipment. Financing for construction of the electric power plant was obtained by CFE from several sources including internally generated capital, loans from the Mexican government and from foreign sources, the latter of which supplied the largest portion.

In order to obtain financing, the IADB/MICARE loan agreement included stipulations, many of which had to do with capitalization and with the necessity for MICARE to operate at a profit. When the two companies entered a sales contract for the coal, the commitment that MICARE had made to IADB to operate profitably was effectively transferred to CFE by virtue of contract language which stated that MICARE would be compensated for ". . . all its costs incurred in reaching its objectives." This statement can be interpreted to mean that whatever price was set to reach its objectives would have to be paid by CFE whether or not this fuel price was ultimately justified by the delivered cost of electricity produced from coal. [28]

The CFE/MICARE coal price history has been reported as follows. "The basic coal price established when the contract was signed in August, 1978, was 400 pesos per ton; there were no exact parameters for its evaluation. At the time deliveries commenced, the first requests for price reviews had already been made; for the first semester of 1981, the price was increased to 700 pesos per ton. In early 1983, a price of 2,500 pesos per ton was proposed and the last official figure obtained in June, 1984, was 4,128 pesos per ton. The exact current figures on coal prices are known only within MICARE and CFE. Furthermore, previous figures could reflect the interests of either one of the parties. Consequently some observers have tried to calculate a coal transfer price, which they put at around 7,300 pesos per ton. In 1984 this figure was fairly close to the international coal price, which was 7,730 pesos per ton at the peso-dollar exchange rate for that year. [29]

"As shown in Table 6, despite the heavy increase in domestic coal prices, in over two years the total cost ratio between fuel oil and coal has not changed, with coal maintaining the position of advantage. Furthermore, these evaluations were made using international fuel oil prices. For domestic prices (costs) the ratio would certainly be inverted more than proportionately because the domestic coal price is between 4.5 and 4.9 times greater than that for fuel oil (see Table 7)." [30]

Considering opportunity cost, the value of using a resource domestically is at least equal to what a unit of the resource could bring on the world market. Thus, using foreign fuel oil prices is the appropriate comparison. An analysis of the figures in Tables 6 and 7

Table 6

MEXICO'S COST OF ELECTRICITY GENERATED

Percent of Total Cost

Cost Category	OCTOBER 1982 FUEL OIL	OCTOBER 1982 IMPORTED COAL	JULY 1984 FUEL OIL	JULY 1984 IMPORTED COAL
Investment	25%	45%	24%	49%
Fuel	69%	42%	74%	46%
Operation and maint.	6%	13%	2%	5%
Total	100%	100%	100%	100%
Ratio to fuel oil		74%		74%

Source: Nora Lina Montes, 'Planning and Development in the Coal Industry In Mexico,' in Energy Policy in Mexico: Problems and Prospects for the Future.

Table 7

FUEL OIL AND COAL PRICE COMPARISON

At 1983 Prices and 120 Pesos/$US

FUEL	PESOS/UNIT FOREIGN	DOMESTIC	PESOS/M KCAL FOREIGN	DOMESTIC	PESOS/KWH FOREIGN	DOMESTIC
Fuel oil/cu. mt.	160548	2130	1.6028	1.2126	4.111	0.545
Coal/t	4631	4128	0.6668	0.9549	1.83	2.62
Fuel oil/coal			41.6	449	44.5	480

Source: Nora Lina Montes, 'Planning and Development in the Coal Industry in Mexico,' in Energy Policy in Mexico: Problems and Prospects for the Future shows no substantial advantage in using international coal over local coal.[31] These price comparisons are somewhat dated and a more current analysis is warranted, particularly taking into account recent changes in regulations regarding emissions of sulfur dioxide, and the cost of applying the technology to meet these regulations.

New concern for environmental quality particularly in the border area where these mines and the two power plants, Carbón I and II, are located may now require a more comprehensive analysis of the least expensive coal to purchase. If FGD and coal handling and disposal equipment must be retrofitted onto the existing plants, it could be that a lower sulfur, lower ash, imported coal might be less expensive than using the domestic coal in conjunction with retrofitted capital equipment.

MEXICAN MINING TAXATION[32]

Mexico possesses an abundance of energy fuels, particularly petroleum and natural gas. The ready availability of petroleum and natural gas have, in the past, tended to sway fuel use decisions in favor of these fuels. Considering the potential for exporting these and the potential for their higher value use domestically, Mexico is examining fuel choice from a new perspective and with a broader range of considerations.

In January, 1991, the Salinas de Gortari administration terminated the "Derecho de la Minería" or mining rights tax. This tax was the subject of numerous complaints regarding the basis for it, which was the amount of mineral extracted from the mine. Representatives of the mining sector argued that the tax was an inducement not to produce. A revised tax replaced the Derecho de la Minería. This new tax placed a 5,000 peso per hectare levy on lands held for exploration, 22,000 pesos per hectare for non-metallic minerals under production and 30,000 pesos per hectare for metallic minerals in production.

The framework of the new tax acts as an inducement to mining companies, and others holding lands, to explore and develop them. Prior to this change in the tax basis, mining companies could prevent others from gaining access to the properties by holding them, at little or no cost, ostensibly for exploration at a later date.

Mines in some areas pay a water use tax that ranges in cost from 300 pesos per cubic meter of water to 520 pesos per cubic meter of water, depending upon the location of the mine. The law provides that this tax can be increased from time to time with a ceiling of 900 pesos per cubic meter. Mining firms pay property taxes and are also subject to a minimum 2% fixed assets tax. Mining companies pay the usual corporate income tax of 35% on their net income. Mining companies have often been instruments of social policy promoting the development of isolated communities surrounding mines and mining facilities. Such development has included road building and maintenance, electricity, medical care, schools, and even postal facilities in some remote areas. At one Mexican mine, the company even provides a pig farm and a chicken farm, although these are organized to a certain extent by the mine workers themselves. Other mines pay the cost of bringing fresh farm products to the community from agricultural areas.

Recent changes in ownership in coal mining and steel making

In November, 1991, the Mexican government divested itself of all of its holdings in the iron and steel industry, including its coal mine properties. Private sector investors purchased the assets as follows: the Autrey-Ancira Group purchased AHMSA facilities in Monclova, Coahuila. Grupo Villacerro purchased SICARTSA I (the original installation at Lázaro Cárdenas) and Caribbean Ispat, an East Indian company, purchased SICARTSA II (the expansion in facilities at Lázaro Cárdenas). Recently, Autrey-Ancira bought the MICARE mining operation that supplies the Río Escondido power plant.

It has been reported that Mexican observers of the iron and steel industry were surprised that HYLSA, which owns the Monterrey and Puebla steel plants, did not obtain any of the properties divested by the government. All of the new owners are emphasizing efficiency and there has been some loss of jobs as a result of the privatization. The result is that coal mining, and iron and steel production are now entirely in the private sector. [33]

Changing role of government and private sectors in energy development

Under the Administration of President Salinas de Gortari, the decision-making environment in the Mexican Government is changing significantly and rapidly. The President's attempts to privatize much of the economic activity that was formerly in the government sector changes the whole picture surrounding coal use and energy production. This will dictate that decisions in the sector will henceforth be made based more upon market considerations than previously, a positive development. This should result in an overall increase in the efficiency of the mining sector. However, confusion and indecision regarding responsibility may arise during the transition.

The Administration of President Salinas de Gortari is pursuing privatization initiatives across most of the sectors of the Mexican economy in an attempt to almost totally eliminate government sector activity from the mining industry. Former government organizations involved in mining, manufacturing, energy, transportation, communications and finance are being sold to private investors. These trends are supported by changes in the legal and regulatory structure that make acquisition of these industries attractive to private investment.

Recent changes in energy law and regulation

Among the major changes important in the energy sector that have been initiated in recent years are the following:

- All of the government sector organizations engaged in coal mining have been eliminated or privatized.

- The MICARE organization that was formed in 1977 to mine coal for the Río Escondido plant was sold to private interests (Autrey-Ancira) who also bought the AHMSA steel complex at Monclova, Coahuila.

- The Comisión de Fomento Minéro which was operating coal mines and coal washing plant at Agujita was eliminated in recent months.

Recent changes in regulations now permit the private production of electricity. Private sector companies raising steam for process heat are now permitted to use excess steam to produce electricity. On a negotiated price basis, they may sell electricity generated from the steam to the CFE. Also, private sector companies are permitted to install plant and equipment for the sole purpose of generating electricity and negotiate with the CFE to sell the electricity into the grid, although the CFE still holds the sole right to transmit and distribute electricity. There are examples of independent power projects.
Other changes have relaxed the restrictions that were previously in force regarding direct foreign investment. [34] Under the Mining Law of 1975, a minimum of 51% Mexican ownership of mineral ventures was required. Mineral concessions could only be issued to companies organized in Mexico. Under that regulation, companies could issue stock in the form of class "A" shares to Mexican individuals or Mexican companies, and up to a maximum of 49%, in the form of class "B" shares to non-Mexicans.

Changes in these regulations were made in 1990, allowing a viable workaround for companies unable to meet the 51% Mexicanization requirement. A trust (fideicomiso) to hold the class "A" shares necessary to comply with the Mining Act of 1975 is established with a Mexican bank or fiduciary organization. Once the trust is created, exploration for and exploitation of minerals can proceed. The trust holds these shares for a defined period of time after which the class "A" shares must be sold to Mexican investors. The duration of the trust depends upon the extent of the exploration and/or development activity, but can last 30 years or more. To represent the equity interests of foreign developers, a new class of stock, "F" shares, were created which can be issued to the international development agency. These are not treated as foreign investment for purposes of calculating the minimum amount of Mexican capital required for the issuing company.

New policies have had the additional effect of limiting the geographical areas within Mexico that are subject to the more stringent National Mining Reserves regulations, increasing the rental on prospecting concessions, facilitating access to ownership records regarding mineral tenure, simplifying the administrative procedures for acquiring prospecting rights and other actions. All of these have the effect of stimulating mineral exploration and development.

Mexico's senior government officials and energy planners are engaging in a concerted effort to diversify the nation's energy fuel sources. Efforts at this diversification span increased efficiency of fuel use in all consuming sectors, conservation, and increased use of fuel sources that have not played a significant role in the past. Coal has been identified to play a key role. However, two factors indicate that the future use of coal in Mexico will depend upon imports: the conspicuous absence of exploration and development of domestic coal resources in the national mining development plan issued by SEMIP, and the expansion planning being done by CFE which explicitly includes imported coal. From this, it is apparent that Mexicans do not believe that exploration for coal in Mexico would likely yield results.

The discussion in this section is intended to show that Mexico has planned to increase the contribution of coal to electric power capacity expansion on several previous occasions. Plans have not been realized until recently.

FUTURE USE OF COAL IN MEXICO

ENERGY PLANNING HISTORY

Mexico has planned to expand its national electricity capacity for some years.[35] Formal, written plans date from the mid-to-late 1960s. As early as the mid-1970s, fuel diversification of the Mexican energy supply network was a part of the planning strategy. Coal was considered a significant diversification opportunity in both the electricity and iron and steel industries. Government ministries were set up to develop coal as part of this strategy.

The run-up of oil prices in the early 1970's stimulated Mexico to project rapid development of the petroleum sector. However, diversification was also to be taken into account. Planned to take place first in the electricity sector, fuel diversification plans saw coal plants with a capacity of 5400 MWe to be built between 1981 and 1984. The decision to build the first plant at Río Escondido was made in 1976.

In 1977 MICARE was formed to ensure the coal supply for Río Escondido and construction on the plant began in 1978. The Programa de Obras e Inversión del Sector Eléctrico (POISE) became a government program in 1979. POISE planned capacity of 9,600 MWe in coal-fired electric generation by the end of the century. This figure was later revised downward to 6,800 MWe.

The Plan Nacional de Desarrollo Industrial (PNDI) forecast development of industry that would support rapid growth in the petroleum sector. This plan anticipated a higher rate of expansion in the electric sector than did POISE. Therefore, another electric sector planning document based on PNDI was endorsed by the government in November, 1980. This document, the Plan de Expansión del Sector Eléctrico al Año 2000 (PESE), called for coal to provide 8.5% of Mexico's primary energy by 1990. Two 1400 MWe coal plants were to be completed in addition to the Río Escondido plant for a total of 4,000 MWe of coal-fired electricity generation capacity.

Nora Lina Montes [36] reports that the PESE 2000 plan focused more on the advantages and disadvantages of using coal versus natural gas in the iron and steel industry than with proposing a coal development policy. Her conclusion was that the possibility of mining domestic coal should be assessed carefully and that the potential for development of the international market for natural gas should also be examined. The plan relegated the importance of coal in the national energy diversification strategy to its use in thermal applications in the electric power industry. While this discussion was taking place, coal use continued such dynamic growth that it became evident a plan should be developed to address the role of coal in the national energy economy.

The Plan Nacional de Desarrollo Carbonífero (PNDC) was released in August, 1982. It was authored by a group of expert, independent, local and foreign consultants who had been working for CFE and MICARE. This plan called for the installation of 6,800 MWe of coal-fired generation capacity, similar to POISE and PESE 2000 revised goals. The PNDC suggested that available domestic coal reserves could support 21,000 MWe of additional generation capacity. Table 8 shows the PNDC schedule for additional capacity by the year 2000 and Table 9 shows the breakdown of potential coal-fired electric capacity based upon reserve category and location suggested by PNDC authors. Note that the plant designations are shown here as coal rather than dual coal/oil as the more recent plan shows. Also, note that the planned unit size is 350 MWe and that the new plants are comprised of four 350 MWE units. Table 10 shows the coal reserve breakdown which supports the electricity generation potential shown in the previous Table.

Table 8

EXISTING AND NEW COAL PLANTS

Years 1983-2000

PLANT	YEAR ONLINE	CAPACITY (MWe) TOTAL	CUMULATIVE
José López Portillo	1978	1,200	1,200
New coal II	1987	1,400	2,600
New coal III	1989	1,400	4,000
New coal IV	1994	1,400	5,400
New coal V	1998	1,400	6,800

Source: Montes, "Planning and Development in the Coal Industry, from, Plan Nacional de Desarrollo Carbonifero, Mexico City, August 1982.

Table 9

COAL ELECTRICITY POTENTIAL BASED ON DOMESTIC COAL RESOURCES

(MWe)

STATE	TYPE OF RESERVE			ADDITIONAL	TOTAL
	PROVEN	PROBABLE	POSSIBLE	RESOURCES	
Coahuila	3780	900	1190	2250	8120
Tamaulipas	315	393	715	2145	3563
Sonora	43	65	1150	3287	4545
Chihuahua			250	2570	2820
Oaxaca	121	213	213	1420	1967
Total	4259	1571	3518	11672	21015

Source: Nora Lina Montes, 'Planning and Development in the Coal Industry In Mexico,' from Plan Nacional de Desarrollo Carbonifero, Mexico City, August, 1982.

Table 10
COAL RESOURCES
Million Metric Tons

STATE	TYPE OF RESERVE: PROVEN	PROBABLE	POSSIBLE	ADDITIONAL RESOURCES	TOTAL
Coahuila	576	140	185	350	1251
Tamaulipas	44*	65	100	300	509
Sonora	6	9	160	800	975
Chihuahua			40	400	440
Oaxaca	17	30	30	200	277
Total	643	244	515	2050	3452

Source: Nora Lina Montes, 'Planning and Development in the Coal Industry In Mexico,' from Plan Nacional de Desarrollo Carbonifero, Mexico City, August, 1982.

PNDI forecasted rapid growth in the steel industry during the middle 1970s. Growth of this scale would have necessitated the concurrent expansion of coal development. In the early 1980s, after a scale-back of plans following the recession, a discussion arose concerning the appropriate technology for growth in the steel industry. It was suggested that rather than install coke-based blast furnaces, steel could be produced via direct reduction using natural gas, accessible through an extension of the Cactus-Reynosa pipeline. The debate was never resolved officially, but construction of the coke-based blast furnaces at SICARTSA's facilities in Michoacán for practical purposes settled the issue for the time.

It is apparent policy makers have not clearly defined the role of coal in Mexico's energy-economic future, except that it will probably evolve out of decisions concerning other energy resources. A hedging strategy appears to be emerging. new electric generation capacity is slated to use either fuel oil or coal. What is not apparent at this point is whether boilers for future power plants will be designed to use either fuel, or if this is simply a strategy for postponing a fuel decision. Dual fuel boilers have a direct impact on overall plant economics, a factor we will discuss in a later section on new technologies.

Increased use of coal in Mexico, should it occur, will probably result from the installation of more coal-fired electric power generating plants as we have been discussing. A presentation of the current electric generating situation is an integral part of any examination of potential future use of coal to raise steam in the electric power sector.

Mexico's electric energy generating system is owned and operated by the state-owned CFE, which plans capacity additions and operates the existing generating system. In 1992, CFE served 17M customers, and sold 96,994 GWh (gigawatt-hours) of electricity generated from installed capacity of 26,997 MWe. Consumption breaks down to 23% by domestic users, 54% by industrial users, 9% by commercial users, 7% by agricultural users, 5% by service users and 2% to exports.

Mexico's electricity generating capacity

The country's existing capacity can be categorized by fuel-type as shown in Table 11. In addition to firm capacity, CFE has additional power resources in the form of industrial cogeneration, which currently adds almost 3,000 MWe and is concentrated in the petrochemical, oil, steel, sugar, chemicals and pulp and paper industries. Table 12 shows the installed industrial cogeneration capacity as of 1990 by type of motive force.

Sales of electricity to each of the above six sectors for the three years between 1989 and 1991 are shown in Table 13. Growth in electric sales has averaged 3% - 4% between each of the combinations of the two most recent years. Problems in the agricultural sector are evident as sales have declined in each year. Historically, the agriculture sector consumed increasing amounts of electricity, more than doubling between 1980 and 1990. Should problems in this sector be resolved, it could again represent a significant increased component to electricity demand. Most robust, apparently, is the domestic sector which posted 8.4% and 7.7% growth rates respectively in each combination of years. Mexico's rapidly expanding population points to great potential for increased use of electricity in the domestic sector. This is a significant area for future growth in sales for the CFE.

It is apparent from Table 13 that rates of growth in demand have varied considerably from sector to sector, as they have from period to period during recent history. In the most recent years, industrial use grew most rapidly. Industry represents over half (56.5%) of the demand faced by CFE. On the other hand, residential demand, which grew at an average annual rate of 10% through most of the 1980s, slowed to 8.3% in the 89-90 period. The residential sector is

Table 11

NATIONAL ELECTRIC SYSTEM INSTALLED CAPACITY

December - 1991

FUEL TYPE	%	MWe
Oil	46%	12,327
Hydro	30%	8,039
Gas Turbine	7%	1,876
Combined Cycle	7%	1,876
Coal	4%	1,072
Geothermal	3%	804
Nuclear	3%	804
Total	100%	26,797

Source: Unpublished presentation materials, Ing Horacio Lombardo, Cancun, June 1992

Table 12
INSTALLED INDUSTRIAL COGENERATION CAPACITY (MWe)
December 1990

INDUSTRY	TOTAL	PERCENT	MOTIVE FORCE			
			HYDRO	STEAM	INT. COMB.	GAS
Oil	1555	52.40%		836.4	30	688.4
Steel	374	12.60%		220.1		153.9
Paper	260	8.80%	7.3	214.1		38.5
Sugar	181	6.10%	1.6	177.2	2.1	
Ind. Group	151	5.10%		109.7		41.8
Chemicals	147	5.00%		143.9		3.2
Textile	111	3.70%	31.3	79.4	0.8	
Minerals	78	2.60%	5.9	25.8	46.4	
Other	69	2.20%	23.5	13.2	30	0.1
Beer	44	1.50%	6.1	34.9	1.8	0.8
Total	2970	100.00%	75.7	1,854.70	111.1	926.7

Source: Energy and Environment Marker Conditions in Mexico US Agency for International development, March 1992

Table 13

NATIONAL ELECTRIC SALES (GWh)

and Growth Rates

SECTOR	1989	1990	GROWTH 89/90 (%)	1991	GROWTH 90/91 (%)
Domestic	19,009	20,605	8.40%	22,191	7.70%
Commercial	7,781	8,265	6.22%	8,574	3.74%
Industrial	50,284	52,213	3.84%	52,987	1.48%
Services	4,443	4,569	2.84%	4,726	3.44%
Agriculture	7,216	6,707	-7.05%	6,497	-3.13%
Exports	1,932	1,946	0.72%	2,019	3.75%
Totals	90,665	94,305	4.01%	96,994	2.85%

Source Unpublished presentation materials, Ing. Horacio Lombardo, Cancun, Mexico, June 1992 the second largest consumer of electricity, comprising approximately 22.3% of demand.

There are many reasons to expect that demand for electricity will grow rapidly in the next ten years. Mexico's economy is expected to grow at a rate of 3% to 4% in the near term. Should NAFTA be passed, this will likely boost the economy significantly. The US Department of Commerce's International Trade Administration prediction is that real wages in Mexico, as a result of NAFTA, will increase by between 0.7% and 16.2%.[38] Projected long-term gains in employment in Mexico are of the order of 7%. Given the relatively low rate of penetration of electric using applications in Mexican households and the increased purchasing power afforded by the projected employment and real wage gains, it is likely that growth of demand for electricity will be very large. The electricity forecast scenarios developed by CFE are shown in Table 14.

Forecast growth in demand together with the advancing age of CFE's existing generation facilities suggests the likelihood that facilities for substantial new capacity in the next decade will be necessary. "Nearly 17% of existing power plants are more than 30 years old. 16% are between 20 and 30 years old, and nearly 43% are between ten and 20 years old. [38]

Based upon analysis of growth in demand in each sector, CFE has forecast that the capacity expansion required will increase an average of 6.0% each year, which translates to an additional 17,000 MWe within POISE's ten year planning horizon. POISE envisions reviews each year to adjust the plan to the unfolding situation and to ensure balance between growth in demand and capacity additions. Table 15 lists the percentage increases in capacity by fuel type required to meet the anticipated demand between 1988 and 2001. The capacity expansion plan for coal and dual plants by year is shown in Table 16.

Table 14
ELECTRIC ENERGY CAPACITY AND GENERATION FORECAST
Thousands of GWh and MWe

	1995		2000		Growth
GROWTH SCENARIO	Generation	Capacity	Generation	Capacity	Rate (%)
High	165,900	28,700	236,800	40,500	7.80%
Most Likely	158,400	27,400	218,500	37,400	6.90%
Low	150,900	26,100	200,300	34,300	6.00%

Note. Figures refer to peak load forecast Source CFE, 1990

Table 15
INSTALLED CAPACITY (%)
by Fuel Type 1988-2001

FUEL TYPE	1988	1994	2000	2001
Petroleum	46.8	43.3	37.2	35.5
Hydro	32.4	28.6	25.6	25.7
Coal fired and dual	5.0	11.4	19.1	21.2
Geothermal	2.9	2.6	2.5	2.3
Nuclear		2.1	3.2	3.1
Natural Gas	12.5	11.5	12.1	11.9
Other	0.4	0.5	0.3	0.3

Source: Unpublished presentation materials, Ing Horacio Lombardo, CFE, Cancun, Mexico, June 1992

Mexico's electric power capacity expansion

A formula to convert the needed capacity additions to the needed amount of coal requires that several assumptions concerning electric system and plant operating characteristics be made. The first involves the *capacity factor*. This is the total megawatt hours generated by a unit for a period of time (usually one year), divided by the potential generation of the unit, assuming that it is operating at rated capacity for the entire period. A typical capacity factor for coal electric plants is 70%. The second assumption involves the heat rate. Heat rate is the amount of heat energy required per kilowatt-hour of electricity generated. A typical heat rate is 10,000 BTU per KWh. If the heat content of a given type of coal is 10,000 BTU per pound, then 1 pound of coal is required to produce 1 KWh of electricity. These simplified assumptions may or may not be realized in the case of the planned coal-fired power stations that the CFE will install; however, they do allow the development of an order-of-magnitude estimate of the quantity of coal that may be required by the plants shown in Table 16.

These assumptions, applied to the capacity expansion plan obtained from POISE for dual-fired stations, estimate the amount of coal required as shown in Table 17. Several cautions should be considered in order that the data in Tables 16 and 17 are not misinterpreted. While the capacity expansion plan presented in POISE is up-to-date (May 1992) it is not clear that the pace of expansion can or should be maintained. The plan must be monitored to ensure that significant excess generating capacity does not result. Also, financing or other constraints may result in a pace of development slower than that planned. In terms of coal consumption, the author assumed that all of the facilities would immediately begin to use coal as the fuel to raise steam. This may not be the intent of CFE. Although long-term plans are to use coal to fuel these plants, domestic resources and facilities to handle imported coal may not be developed rapidly enough to accommodate the increased quantities of coal implied by the program. Accordingly, since fuel oil is available through domestic sources, it can be used

Table 16

ELECTRICAL SECTOR INVESTMENT PROGRAM (POISE)

1992-2001 — Capacity Additon (MWe)

PLANT NAME	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	TOTAL
Petacalco	350	700	700	350							2,100
Carbón II	700		350	350							1,400
Dos Bocas						350	350				700
Puerto Altamira								1,300	1,300		2,600
Colmi										1,300	1,300
Total	1,050	700	700	700	0	350	350	1,300	1,300	1,300	7,750

Note This table includes only those plants scheduled for dual (fuel oil and coal) use Other plants with different fuels total an additional 9425 MWe Units 3 & 4 of Carbon II scheduling differs slightly CFE had planned units 3 & 4 to come on line in 1995 INTERGAN plans the indicated scheduling

Source Unpublished presentation materials. Ing Horacio Lombardo CFE. Cancun. Mexico. June 1992

Table 17

ESTIMATE OF COAL USE IMPLIED BY THE PROGRAM OF ELECTRIC SECTOR WORKS AND INVESTMENTS (POISE) 1992-2001

	ANNUAL AND CUMULATIVE COAL CONSUMPTION (mt)										
PLANT NAME	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
Petacalco	0.9	1.9	1.9	0.9							5.8
Carbon II	1.9		0.9	0.9							2.9
Dos Bocas						0.9	0.9				1.9
Puerto Altamira								3.6	3.6		7.2
Colmi										3.6	3.8
Total	2.8	1.9	2.8	1.8	0	0.9	0.9	3.6	3.6	3.6	21.9
Cumulative Total	2.8	4.7	7.5	9.3	9.3	10.2	11.1	14.7	18.3	21.9	

in the short-term to bring these facilities on line until sources of imported coal can be fully developed.

Given these caveats, it is clear that this expansion plan could greatly increase the use of coal in electric power generation. The Carbón I plant presently operating at Río Escondido consumes approximately 4M metric tons of coal annually. A five-fold increase in coal use could occur by the year 2000 as a result of this expansion plan. CFE has officially stated that imports of coal will begin in 1994 and will gradually increase until they reach somewhere between 11M and 21M TPY in 2001.[39]

Location of the plants indicates an intent to utilize imported coal to fuel these facilities. The Puerto Altamira plant is near the coastal town of Tampíco and Dos Bocas is located near Veracruz, on the Gulf of Mexico. Colmi and Petacalco are located on the Gulf of California near the steel plant at Lázaro Cárdenas. Thus, coal from west coast US ports such as Los Angeles could be shipped to supply Colmi and Petacalco, and from Texas Gulf ports to supply Puerto Altamira and Dos Bocas.

In addition to the planned capacity which CFE will be adding during the decade preceding the year 2000, there is significant potential for expansion of cogeneration. Indeed, since the industrial sector consumes over 50% of the electricity generated by CFE, there is ample potential for these consuming entities to become producers as well.

Because of the anticipated rate of growth of electricity demand and the advanced age of existing facilities owned by CFE, the need to add capacity to meet growing demand and replace aging facilities will be significant.

Cogeneration can be an attractive alternative to adding central station power plants from a variety of perspectives. When the capital cost of the facilities is spread over a greater number of firms, it spreads the risk and permits the system to have lower reserve capacity, which in turn reduces the cost of generation for the whole system.[40] Operationally, the system is inherently more reliable than it would be with fewer but larger generating units.

CFE is willing to negotiate attractive prices for electric power sold into the grid as evidenced by dropping the cost to consumers to equal that charged to industry. Pressure from creditors (multilateral banks) to reduce subsidies to some classes of customers and to raise prices for cogenerated electricity sold to the grid are new factors that CFE is taking into account in its planning activities.

Clearly, the major opportunities for development of cogeneration lie in the industrialized portions of the major metropolitan areas in Mexico. Thus, the industrialized areas surrounding Monterrey, Nuevo León; Hermosillo, Sonora; the State of Jalisco; and the Federal District are high electricity consuming centers. Additionally, the petroleum complexes around Coatzacoalcos, Veracruz, and Salina Cruz would be candidates for new cogeneration development as well as some of the centers of tourism such as Cancún.

THE MEXICAN COAL MARKET

Mexico does not have a coal market as would be defined by a number of buyers and sellers who engage in transactions in a standard product. For all of the recent history of Mexican coal mining, with the exception of the recent several months, Mexico's coal mines have been captive entities of public sector organizations who mined coal for their own use in subsidiary operations. Since coal is not traded openly in markets, price information is not available. This section will accordingly be very brief.

Demand for domestic coal

The demand for coal supplied from domestic Mexican sources will arise from the existing Carbón I electric power plant, the Carbón II plant that is now under construction, and the remaining steel plants at Monclova and Lázaro Cárdenas. These facilities were designed and sited to use coal from domestic Mexican mines. The additional dual-fired plants in the generation expansion plan detailed above were sited in coastal locations with a view to having them supplied from foreign sources.

KEY FACTORS IN MEXICO'S ENERGY FUTURE DECISION

The major institutional changes made by Mexico in preparation for NAFTA have paved the way for unprecedented opportunity in energy trade and investment. Liberalization of the rules regarding foreign direct investment, particularly repatriation of profits, are of utmost importance to foreign investors. Permission for independent power projects to be developed based upon negotiated sale of electricity opens the Mexican market to opportunities for investment and will result in cheaper electricity for Mexican consumers.

Privatization of coal mining, steel-making and other major sectors gives investors confidence that market forces, rather than government fiat, will be the basis for investment decisions. New plant facilities can be designed to meet future environmental regulations, resulting in more efficient and cost-effective compliance. Finally, NAFTA will give investors confidence that changes implemented are permanent and will not be undone by any future administration.

If the delivered cost of coal were the only consideration, even under NAFTA, US coal producers would be marginally competitive. However, because of Mexico's need for turn-key projects that bundle all aspects of design, construction and financing into a finished facility that will be operated under one of the BLT, BOT, BOOT or IPP arrangements, the ultimate supplier will likely be determined by factors other than simply the delivered cost of coal.

American firms will be very competitive in this bigger picture. The US has the technical know-how; the capital goods; knowledge of design, construction and operation under environmental compliance; and access to financing resources that can be matched by few other competitors in the world.

Competition for Mexican Coal Markets

THE PLAYERS

The competition to supply Mexican coal markets will pit suppliers in the US against those from Colombia, Venezuela, South Africa, Australia, and Indonesia. All of these countries vie to supply the world's coal markets, and competition is based on delivered price of coal to major markets in eastern and western Europe, the Pacific Rim, and the US Gulf Coast.

Superficially, it would appear that delivered price is the key consideration. However, other factors are important as well. Reliability of supply, quality of product, assistance with compliance in waste/pollution regulations, technology, financial resources, willingness to partner with Mexico for long-term benefits, and each entity's national agenda must all be considered. Each country has advantages and disadvantages in attempting to secure the additional coal business in Mexico. A review of some of these factors will prove instructive.

The United States

The US has numerous advantages when it comes to dealing with Mexico. Many of these are historical and institutional. The US's long history of trading relationships with Mexico will serve effectively as a basis for expanded business, as well as the fact that it is Mexico's largest trading partner. In 1991, the value of Mexico's exports to the US accounted for almost 70% of its total exports. For the past five years, Mexico has been the third largest market for US exports behind Canada and Japan, and ahead of Germany.

Accumulated US private direct foreign investment in Mexico totaled about $20 billion in 1992, approximately 56% of the total, and ahead of Great Britain's significantly smaller 6.5%, which was second. It is clear that even without NAFTA, the US and Mexico have been and will continue to be active trading partners.

A whole range of international political and economic issues must be recognized and addressed as a result of the two countries' geographic proximity. The similarity in historical settlement patterns and the common cultural heritage, particularly with the southwestern US, yields important common bonds and understanding. As Mexico moves forward with its privatization campaign and its efforts to open up and reform its political system, it will become increasingly easier and more comfortable for US businessmen to invest in and do business with Mexico. If NAFTA is ratified, it will give substantial additional impetus for greater trade and investment.

While this idea of cultural similarities between Mexicans and Americans, particularly in the southwestern United States shouldn't be pushed too far, it also shouldn't be permitted to be too much of a psychological barrier either. Certainly there will be differences between the business approach, ethics, etc. in the two countries. However, this difference has never hampered the Japanese in making inroads into 65 US markets, for example, and shouldn't be permitted to hamper the US.

In concert with the increasing environmental awareness and more stringent regulatory requirements in Mexico, US firms are accustomed to working within tight environmental regulation. This experience will transfer well to the Mexico market and will help Mexico bring its environmental improvement and management up to standards of industrialized countries much more rapidly.

US producers, however, have limited coal pricing advantages due to several factors. Required to comply with a variety of health, safety and environmental regulations, increased production costs put the US at a disadvantage with its competitors who may not have to face these added costs. In addition, while mine labor productivity is much higher in the US than in most competitor countries, it does not fully compensate for the higher wages that US miners are paid. Also, the majority of US coal fields are in the interior states necessitating long-distance, overland shipment via rail to US ports or overland directly to Mexican markets. Thus, on a cost per delivered ton or cost per MBTU basis, US coal producers face difficulty competing on price alone.

Columbia

Colombia has language, heritage and cultural similarities in common which facilitates working with Mexico. While these cultural ties are important, they are not likely to be as significant as the many relationships that exist between Mexico and the US. Colombia's proximity to Mexico and the geographic location of its new coal mines near the coast are significant factors. It is necessary to transport coal only 75 miles from the major new mine, El Cerrejon, to vessels that can deliver it to east coast Mexican ports in a timely manner. Colombia has already exported small amounts of coal to Mexico. While Colombia is cost competitive in delivering coal to the east coast Mexican ports, this does not hold true for exports to Mexico's west coast. Routing through the Panama Canal necessitates the use of smaller vessels carrying smaller loads and a longer delay in delivery which increases the cost of supplying coal. Colombia is a member with Mexico of the Organization of non-OPEC Oil Exporting Countries.

Venezuela

Venezuela has cultural and historical ties to Mexico similar to those of Colombia. Both would probably rank high in a second tier of countries that can identify significant non-price factors. Venezuela is also a member, along with Mexico and Colombia, in the Organization of Non-OPEC Oil Exporting Countries. Mexico and Venezuela have worked together to ensure the effectiveness of the San Jose Pact to supply oil to Central American Countries. Furthermore, Mexico, Venezuela and Colombia have a history of cooperation in energy agreements.

Australia

Australia would appear to have no particular advantage in common language, culture or heritage that would enable it to compete with other nations wishing to develop export markets for coal in

Mexico. It will need to rely primarily on the delivered cost of coal to Mexican ports in order to develop these markets as their only leverage. Shipping to west coast Mexican ports is via an uninterrupted, but long, ocean voyage. Shipments to east coast Mexican ports would duplicate the problems Colombia faces through use of the Panama Canal.

Canada

Canada has little common historical or cultural heritage with Mexico. Coal in the western Province of British Columbia could be shipped to west coast Mexican ports via a relatively short ocean voyage, but Canadian coal being shipped to east coast Mexican ports would have to pass through the Panama Canal. Therefore Canada has limited means to supply Mexico's needs. Canada is, of course, a signatory country to NAFTA.

South Africa

Like Canada, South Africa does not appear to have any advantage in common heritage or cultural roots with Mexico, either. South Africa has limited geographical advantage. It could ship coal to Gulf Coast ports in Mexico passing around the east and north coasts of South America. Shipping coal to west coast ports by going around the horn of South America, however, involves a significant shipping distance.

Indonesia

No common heritage or culture exists between Indonesia and Mexico. Indonesia would have to compete in Mexican coal markets solely on the delivered cost of the coal. Shipping distances would be a little longer than those to Mexico from Australia.

As demonstrated by the accompanying Table 18, each country has ample resources on its own to meet all of the potential needs of Mexico.

Table 18

COAL RESOURCES OF SELECTED COUNTRIES

Billions of Short Tons

COUNTRY	RECOVERABLE RESERVES	PERCENTAGE OF RECOVERABLE RESERVES
Australia	100.2	22.3
Canada	7.5	1.7
Colombia	10.6	2.4
Indonesia	3.3	0.1
Mexico	2.1	0.1
South Africa	60.4	13.4
United States	265.2	59.0
Venezuela	.5	—
TOTALS	449.8	

Source: EIA International Energy Annual 1990, Energy Information Administration, Washington, DC, January 1992, P.95.

Comparative Costs

One means of analyzing the relative competitiveness of coal delivered to specific markets from specific supply sources is to estimate the cost of transportation. This cost is then added to the cost of mining coal to arrive at a delivered cost per ton of coal, or per MBTU of energy content. While coal sales may not take place at any of the exact delivered costs estimated by this process, the lowest cost producer can deliver to the designated market with the greatest degree of latitude in pricing to win a contract. Price is not the only factor used to determine a source. Some other considerations were mentioned in the discussions of each country in the previous section. To these factors are the quality of the coal, the consumer's estimate of the reliability of the supplier's delivery, and other factors. Price may well be the most important factor.

In the middle 1980s, when Colombia began delivering coal to US Gulf Coast markets, Congress was concerned that the foreign competition might damage the domestic coal industry. Furthermore, injury to the US coal industry's export markets might follow.

Recently, although the US has the capacity to export approximately 200M tons of coal annually, it has been able to export roughly only half the potential quantity. Congress directed the US Department of Commerce, International Trade Administration, and the US Department of the Interior, Bureau of Mines, to undertake an examination of the costs of mining coal in various potential supplier countries. The study would also report the cost of delivering coal to selected world markets.

A comparative analysis can be developed from the results of several of the Bureau of Mines studies analyzing mining costs in Colombia, South Africa, Australia and Canada; countries with the potential to compete with US suppliers in world coal markets. Studies of Venezuela and Indonesia are soon to be released.[41]

These studies employ a consistent financial analysis methodology —discounted cash flow rate of return analysis (DCFROR)— to arrive at the average cost of mining a ton of coal in several different types of mines that are typical of each foreign producer's mining methods. A US mine is selected to closely resemble the type of geology and mining procedures found in the subject mines. Costs are then determined for a zero percent and 15 percent rate of return to capital and are compared given the legal and regulatory climate.

Transportation cost to move the coal from the mine to the market represents the actual or typical cost that would have been incurred by the shipper at the time the cost data was collected. Shipping costs were obtained from a variety of sources including governments; Bureau of Mines site reports; truck, rail, barge, steamship and stevedore companies; terminal and mine operators; and port authorities.

Because transactions typically take place in US dollars, the exchange rate between the local currency in the coal exporting country is time dependent and can vary significantly over time, greatly affecting the cost comparison. Thus, the costs that will be quoted from the studies cited must be viewed as reflecting conditions at the time the studies were conducted (last half of decade of the 1980s). Conclusions about relative competitiveness are therefore time dependent.

The US versus Colombia

Data comparing the US and Colombia is contained in Table 18. These data show that Colombia had a mine-mouth cost advantage in 1986 of between 10-15% for coal mined and exported from the El Cerrejon project. As the authors of the study state, this is the only mine in Colombia that is capable of export volumes of coal. The large cost advantage (approaching 50%) in the small underground mine is due to the labor intensity of production at this type of Colombian mine which uses large numbers of very low-wage,

Table 19

COLOMBIA VS. US COAL MINE COST COMPARISON SUMMARY
100% EQUITY FINANCING

in 1984 Dollars per Short Ton

	LARGE SURFACE MINE		SMALL SURFACE MINE		UNDERGROUND MINE	
COST AT 0% DCFROR	WYOMING SIMUL'N	EL CERREJON	WEST VIRGINIA	SAN JORGE	WEST VIRGINIA	ANTIOQUIA
Production	25.92	21.98	30.3	19.36	32.15	15.05
Transport	3.27 - 33.10	15.17	3.27 - 33.10	15.17	3.27 - 33.10	15.17
Total	29.19 - 59.02	37.15	33.57 - 63.40	34.53	35.42 - 65.25	30.22
COST AT 15% DCFROR						
Production	54.49	49.14	33.79	28.35	34.99	16.8
Transport	3.27 - 33.10	15.17	3.27 - 33.10	15.17	3.27 - 33.10	15.17
Total	57.76 - 87.59	64.31	37.06 - 66.89	43.52	38.26 - 68.09	31.97

SOURCE: "A Cost Comparison of US and Colombian Coal Mines," Prepared by the Department of Commerce, International Trade Administration and The US Department of the Interior, US Bureau of Mines, Washington, DC, January 1986.

unskilled miners. However, these mines do not have the capability to produce coal in sufficient volumes to allow them to export.

Transportation of coal from the mine to Gulf Coast Mexico ports involves loading the coal on a train for a short 75 mile trip from mine to port at Puerto Bolívar where it would then be loaded onto a ship to carry it to the Gulf Coast of Mexico port. The use of large vessels or barges is feasible. This is a relatively short ocean voyage which would be low in cost compared to the distances that coal is often shipped, say, from Australia or South Africa into these same markets.

As compared to this relatively short shipping distance, coal exported from the Powder River Basin in Wyoming would be shipped by rail to the nearest port (probably Houston, Texas) and then loaded onto vessels or barges which would deliver it to the Mexican Gulf Coast port. This involves a relatively lengthy overland shipment which tends to be expensive compared to ocean shipping.

From the data presented, it would appear that Colombian coal could compete with US coal in Mexican markets. Colombian coal has been supplied to some Gulf Coast utilities in the state of Florida at prices that are competitive with US coal.

The US versus South Africa

Table 20 displays the cost information comparing the delivered cost of South African versus US coal in Gulf Coast markets. Other things being equal, South African coal is competitive with US coal when delivered to Gulf Coast markets. As indicated, South Africa has a substantial mine-mouth production cost advantage of approximately 65% at both the lower and upper end of the range of costs per ton. South Africa's production cost advantage is almost completely nullified by the increased ocean freight, rail and port charges. From this data, one can conclude that US coal producers will face stiff competition from their South African counterparts.

Table 20

GULF COAST THERMAL COAL IMPORT MARKET
US VS. SOUTH AFRICA DELIVERED COST SUMMARY

in January 1989 Dollars per Short Ton

COST CATEGORY	US RANGE	SOUTH AFRICA RANGE	
AT 0% DCFROR	LOWER	UPPER	LOWER
TOTAL MINE-MOUTH COST	$22.34	$44.50	$7.81
Production	$18.72	$39.95	$7.72
Land and taxes	$1.42	$4.55	$0.01
TRANSPORTATION	$12.70	$17.20	$25.58
Trucking (from mine)	$0.00	$0.00	$0.00
Rail rate	$3.27	$6.85	$8.72
Port charges	$1.00	$1.80	$4.37
Ocean freight	$0.00	$0.00	$10.25
TOTAL DELIVERED COST	$35.04	$61.30	$33.41

Source: "A Cost Comparison of Selected US and South African Coal Mines," Prepared By US Department of Commerce, International Trade Administration US Department of Interior, US Bureau of Mines, Washington, DC., April 1990.

The mine-mouth cost advantage that is enjoyed by South Africa is due somewhat to the superior geology of its mines. Both open pit and underground mines are relatively shallow with seams that are somewhat thick. Additionally, the mines are fairly new, incorporating the latest in technology for efficient coal mining. Approximately equal contributions from lower costs of mine operation (labor costs, mine safety and health, environmental), lower land costs and lower taxes strengthen South Africa's position. Aspects of corporate tax laws in South Africa also contribute to the cost advantage. This is particularly true with regards to capital costs, which are permitted to be treated as expenses. This results in taxes which are deferred until capital is fully recovered.

The rail transportation cost differential between South Africa and US mines is somewhat surprising, given the very efficient South African rail line that has been constructed between the mining region and the Richards Bay coal terminal. This rail line was built entirely to carry coal unit trains. The coal is hauled from the coal fields in 100 car units a distance of about 100 miles on an electrified section of the line. Cars are then amassed into 200 car trains which are pulled the remaining 250 miles to the Richards Bay terminal by four specially designed engines. Turn around time, including unloading at the terminal, is just under three days.

The US versus Australia

The data in Table 21 compares US and Australian costs of delivering coal into the Gulf Coast steam coal markets. Costs are similar for Australia and the US at the mine-mouth, with Australia maintaining a slight cost per ton advantage. At the upper end of the range, Australia has a cost advantage of approximately 40%. Transportation of the coal to market reverses the advantage at the lower end of the cost scale in favor of US producers who now enjoy a 10-12% cost advantage. However, at the upper end of the range, the higher transportation costs for Australian producers does not fully eliminate their mine-mouth production cost advantage.

Table 21

GULF COAST THERMAL COAL IMPORT MARKET
US VS. AUSTRALIA DELIVERED COST SUMMARY

in January 1989 Dollars per Short Ton

COST CATEGORY	US RANGE		AUSTRALIA RANGE	
AT 0% DCFROR	LOWER	UPPER	LOWER	UPPER
TOTAL MINE-MOUTH COST	$27.35	$45.65	$24.13	$29.06
Production	$21.90	$40.89	$22.49	$27.49
Land and taxes	$4.77	$5.45	$1.57	$1.65
TRANSPORTATION	$19.02	$22.07	$29.21	$31.60
Trucking (from mine)	$0.00	$0.00	$4.69	$4.69
Rail rate	$19.02	$22.07	$7.07	$7.07
Port charges	$0.00	$0.00	$7.75	$7.75
Ocean freight	$0.00	$0.00	$11.34	$11.34
TOTAL DELIVERED COST	$49.30	$64.67	$55.73	$58.28

SOURCE: "A Cost Comparison of Selected US and Australian Coal Mines," Prepared By US Department of Commerce, International Trade Administration, and the US Department of the Interior, US Bureau of Mines, Washington, DC, April 1989.

Australian producers, therefore, continue to have a cost advantage of about 10% at the upper end of the range.

It is clear from the information presented in this section that the Gulf Coast market for coal will be very competitive. All of the countries mentioned have the potential to supply coal to this market profitably. Because coal transactions will take place in US dollars, the state of the world economy as well as the economies of each of the potential supplier countries can have an effect on which country eventually is the lowest cost supplier. This could change from time to time based upon fluctuations in exchange rates. The good news for US coal producers is that no competitor country appears to have a clear and definite cost advantage across the board. Based on delivered cost, the US could be competitive in this market.

One important factor to bear in mind is that Mexico does not presently have the ports and facilities to handle bulk shipments of coal. While it is possible to speak generally about the cost of delivering coal to Mexican Gulf Coast ports, there currently is no port that could efficiently handle the quantities of coal that would need to be delivered to keep a large coal-fired power plant operating. Thus, as with electric power generation, the coal supplier who can ally itself with a group to propose a package deal to the decision-makers in the CFE may get the jump on firms from countries basing their proposals on delivery of product only.

Another factor affecting the outcome of this competitive situation is the nature of the coal export sector in each country. In the United States, it is linked to and an integral part of the "for domestic consumption" portion of the industry. At the present time, the export sector in the US is operating at significantly less than full capacity. Some estimates suggest that exports could double with the production and transportation capital that is currently in place.

This idle capacity results in returns to capital that are lower than they would be if the capacity were being fully utilized. Therefore, US producers with slack capacity could set prices based on marginal cost to be more competitive in world markets. This would serve the dual purposes of reducing slack capacity and increasing returns to capital at the margin. This pricing strategy could be used by an integrated transportation and coal production company which could combine the profits in both segments of the supply process. Average cost of production and delivery to market is one important criterion determining who supplies the market. However, price can diverge from average cost if marginal cost is lower than average cost. Also, each country, or the lowest cost producer in each country, could be expected to attempt to win the market. Thus, whether a mine in Colombia has a similar mining plan to a mine in the US or South Africa isn't really relevant to the consumer. The important features determining coal quality must be similar for each supplier because, presumably, the coal-using facility is designed to burn coal of a given ash, sulfur and moisture content. Thus it would be valid to compare coal from the lowest cost mine in each country to get a better idea of which producer is really of lowest cost.

An Updated Three-way Comparison

GULF COAST ELECTRIC UTILITY

In a report to be released in the near future, the US Bureau of Mines updated and put on a consistent basis the four cost studies that they have produced regarding relative costs of coal exports from different countries. The author has obtained a copy of this report in draft form and it permits a direct comparison of delivered costs of coal from the least costly mine in each of these countries. The method of analysis in the updated report is the same as was applied in each of the country studies. The data and time-frame of the study is the same for all countries. Results of the analysis for the market of interest, the Gulf Coast electric utility market, are shown in Table 22.

Table 22

DELIVERED COST COMPARISON GULF COAST ELECTRIC UTILITY MARKET

in 1989 Dollars per Short Ton

COUNTRY	MINE-MOUTH COSTS	TRANSPORT COSTS	DELIVERED COSTS
Australia	$24.13	$29.21	$55.73
Colombia	$14.53	$15.17	$29.70
South Africa	$7.81	$25.58	$33.41
United States	$22.34	$12.70	$35.04

Source: 'A Cost Comparison of Selected Coal Mines from Australia, Canada, South Africa, and the United States' US Bureau of Mines, February 1992, Draft.

With the exception of Australia, all of the countries mentioned have the potential to supply coal to this market. Based upon mine-mouth cost and the distance that coal would have to be transported to either east or west coast Mexican markets, Australia is probably unable to compete.

Delivered cost from South Africa is calculated to be $1.63 per ton less than delivered cost from US suppliers. If NAFTA is ratified, South African costs for delivery to Mexico will increase by $5.35 per ton relative to US costs. Colombian costs would increase $4.75 per ton delivered to Mexico. This would leave the US the low cost supplier. However, Mexico is currently negotiating with Colombia to establish freer trade between their two countries, which could possibly extend the same advantage the US has through NAFTA to Colombia. In this case the US would no longer have the advantage.

WEST COAST ELECTRIC UTILITY

The largest coal-fired power plant planned for development in Mexico is the Petacalco plant already under construction on Mexico's west coast. This plant is scheduled as a dual facility and plans are to burn residual fuel oil in the facility and then convert to coal when the coal handling facilities are complete. A likely 3-way competition will develop to supply this coal market. Canada, the US and Australia are potential suppliers. Based on information contained in the draft Bureau of Mines document cited for the Gulf Coast markets, cost comparisons can be developed. Table 23 shows the methods of estimating these costs.

These outlays, both for Canada and the US, land coal at the port of, say, Los Angeles. Additional shipping cost would be incurred for the remaining distance to Mexico's West Coast at, say, Petacalco. For the US, this would involve additional cost of loading and handling a the Los Angeles port and shipping charges to Petalcalco where additional port charges would be incurred. For Canada, this would not involve offloading the coal at Los Angeles but would incur additional costs of shipping to Petacalco.

Table 23

US WEST COAST INDUSTRIAL PLANT COAL MARKET

Delivered cost in 1989 Dollars per Short Ton

COUNTRY	CANADA LOW	CANADA HIGH	UNITED STATES
Total mine mouth cost (country of origin)	$25.49	$30.12	$25.17
Production	$24.00	$28.80	$20.09
Land & taxes	$1.32	$1.80	$5.09
Transportation			
Trucking (from mine)	$0.00	$0.00	$5.41
Rail	$16.61	$21.00	$30.65
Barge	$3.63	$3.63	$0.00
Port charges	$3.63	$3.63	$0.00
Ocean freight	$3.50	$3.50	$0.00
Total delivered costs	$55.47	$61.87	$61.23

NOTE: Sums of line items may not match the totals because line items and totals may be from different mines.

Table 24 shows the process of adjusting the two countries' costs for delivery to Mexico.

Ocean freight distance from Robert's Bank, British Columbia in Canada is approximately 1400 nautical miles. Shipping distance from Los Angeles to Petacalco is approximately 800 nautical miles. Thus, assume that shipping costs from Canada doubles. This is reflected in Table 24.

Note that ocan freight charges from Roberts Bank to Los Angeles are included in the costs for Canada as are the port charges for this leg of the shipment. Coal from both these countries would be treated the same in terms of tariffs and taxes for delivery to Mexico, both with or without NAFTA.

Australia offers additional competition for delivery to the Mexican West Coast via a long but unobstructed ocean voyage. Table 25 estimates delivered costs from Australian mines. For this comparison we can use the Bureau of Mines data for coal delivered to the Japanese electric utility market and make appropriate adjustments.

Shipping distance from mines in Victoria is approximately 6000 nautical miles from Japan. Distance to Mexico from mines in Victoria approximates 7600 miles. Thus, an additional shipping cost of $1.57 per short ton is incurred to ship to Mexico. (6000/7600 x $5.90 = $7.47). Based upon these calculations, it would appear that Australia's cost would be significantly lower that either Canada of the US.

This cost comparison excludes the possibility that Australian vessel owners might have the opportunity to backhaul potash from Mexico, thereby reducing the cost of ocean transportation as compared with a situation in which they would need to deadhead. If

Table 24

ESTIMATED DELIVERED COST FROM CANADA & US TO MEXICO'S WEST COAST

in 1989 Dollars per Short Ton

COUNTRY	CANADA LOW	CANADA HIGH	UNITED STATES
Total delivered cost from country of origin	$55.47	$61.87	$61.23
Charges at Port of L.A.	$0.00	$0.00	$3.50
Ocean freight	$3.50	$3.50	$3.50
Port charges in Mexico	$0.00	$0.00	$3.50
Total Landed cost in Mexico	$58.97	$65.37	$71.73

Source: "A Cost Comparison of Selected Coal Mines from Australia, Canada, South Africa, and the United States" US Bureau of Mines, February 1992, Draft.

Table 25

ESTIMATED DELIVERED COST FROM AUSTRALIA TO MEXICO'S WEST COAST

in 1989 Dollars per Short Ton

	AUSTRALIA LOW	AUSTRALIA HIGH
Total delivered cost	$28.92	$35.20
Less: ocean freight to Japan	($5.90)	($5.90)
Add: ocean freight to Mexico	$7.47	$7.47
Port charges in Mexico	$3.50	$3.50
Total Landed cost in Mexico	$33.99	$40.27

Source: "A Cost Comparison of Selected Coal Mines from Australia, Canada, South Africa, and the United States" US Bureau of Mines, February 1992, Draft.

this were possible, ocean transportation costs would be reduced somewhat.

Development plans at the ports of Los Angeles and Long Beach will help US coal suppliers win markets in Mexico. At the Port of Los Angeles, or Los Angeles Export Terminal (LAXT), Japanese and US investors are engaged in a $120 million expansion of the terminal's capacity. When completed in late 1996, the dry bulk terminal will be able to handle large capesize vessels and will have a loading capacity of 30-40 tons per day and ground storage for 1 million metric tons of coal and/or petroleum coke. This will make vessel loading and train unloading much more efficient and cost effective. Ownership of the port at the completion of the upgrading will be 49% Japanese and 51% US.

At the port of Long Beach an expansion plan is also underway. An additional 150,000 metric tons of ground storage for coal is being added so that total ground storage at this teminal will be 200,000 metric tons. These upgraded facilities will help western US coal be more cost competitive in important coal markets, including Mexico.

We have not examined the possible impact of carbon taxes and other energy taxes that are currently under discussion on the national scene. To the extent that such policy initiatives raised costs of domestic coal relative to our major competitor's prices, US producers would have more difficulty competing.

Environmental concerns

Increased use of coal in the generation of electric power could have incremental environmental implications. It is clear that with demand for electric energy growing in the neighborhood of 6-7% per year and with existing installed capacity aging rapidly, new capacity will be required. The relevant question to be addressed is the incremental environmental impacts that will occur as a result of the installation of the new capacity as compared to the capacity that would have been installed in the absence of any involvement from US firms.

MEXICO'S ENVIRONMENT: EVOLVING PROTECTION

Mexico is experiencing an increasing awareness of the need to maintain standards of environmental protection in all aspects of economic activity. Mexico City, the seat of the federal government, is widely regarded to be the most air polluted city in the world. Since Mexico City is home to approximately 20% of the population, the impact of degraded environmental quality is an issue which directly affects and concerns many Mexicans.

The passage in November, 1987, of the General Law of Ecological Equilibrium and Environmental Protection reflects the country's most recent attempt to develop and implement standards of environmental protection. This Law, effective on March 1, 1988, superseded the Federal Law of Environmental Protection of December, 1981, which in turn amended the 1976 Mexican Environmental Act. Mexico's first environmental law went into effect in 1972, just two years after the formation of the EPA in the US. The General Law of Ecological Equilibrium is Mexico's comprehensive environmental statute addressing pollution, environmental impact and risk assessment, resource conservation and enforcement. It establishes environmental standards comparable to those of industrialized nations, enforcement procedures, and penalties for non-compliance. This Law established much higher penalties for violations of Mexican environmental laws than previously in effect and devolves enforcement onto Mexican state and local governments. Environmentalists concerned about the lax enforcement of earlier laws believe that this new law may lead to stronger prosecution of violators and a cleaner maquiladora industry along the border area.[42]

However, while Mexico has had laws on the books designed to protect its environmental resources, it hasn't, until recently, made a serious effort to implement and enforce regulations. This change in the country's attitude is readily detectable. The Under Secretary for Ecology stated recently that new industrial plants would be subject to an environmental impact study, review and approval by the environment agency. It was also stated by the secretary of the environmental agency that projects rejected for environmental reasons in the United States or Canada would not be welcome in Mexico. The country's commitment to environmental protection is further demonstrated by the Salinas administration's increasing the environment budget for 1992 by 700 percent to $4.6 billion, committing $460 million to infrastructure improvements and enforcement in the US/Mexico border area, and making $100 million in credits available to Mexican firms for the purchase and installation of anti-pollution equipment. In May, 1992, the government established SEDESOL (the Secretariat of Social Development) to broaden the scope of the predecessor organization, SEDUE (the Secretariat of Urban Development and Ecology), which it replaced.

As in the US, Mexico regulates pollution through establishment of standards for criteria pollutant concentrations in the primary receptors, air and water. The USEPA developed a comparison of the process and procedure for air and water pollution regulation which effectively compares the Mexican system for environmental control with that of the US. The comparison is very informative and for that reason has been reproduced in its entirety in Figures 1 and 2. Any major development will be required to undertake an environmental impact study and apply for the necessary authorizations from SEDESOL based upon the data reported.

COMPLIANCE AND THE BORDER AREA

The Border area, defined in the Border Environmental Agreement signed by Mexico and the US in 1983, includes the terrain within approximately 65 miles on either side of the political boundary. The accompanying Map 2 identifies this area. This area is special for environmental purposes largely because the actions taken by individuals on one side of the border may have effects on individu-

Figure 1

COMPARISON OF AIR POLLUTION REGULATION IN THE US AND MEXICO

	US	MEXICO
NATIONAL LAW	1990 CLEAN AIR ACT • sets national ambient air quality standards (NAAQS) for criteria pollutants (O_3, SO_2, PM10, CO, NO_2, Pb) • requires EPA to set technology-based controls for toxic air pollutants	1988 GENERAL ECOLOGY LAW • sets maximum permissible levels (MPLs) for O_3, SO_2, NO_2 & TSP (Pb and PM10 to be covered) • requires prior authorization for air toxics emissions, but does not establish specific limits
IMPLEMENTING MECHANISM	STATE IMPLEMENTATION PLAN • combines state & local air quality planning to ensure NAAQS attainment • periodically reviewed and approved by EPA	NATIONAL AIR POLLUTION REGULATION • sets technical ecological standards (NTEs) that limit emissions from stationary & mobile sources MEXICO CITY AIR POLLUTION REGULATIONS • covers traffic, motor vehicle emissions & inspections in Mexico City
MONITORING	EXTENSIVE NATIONAL & LOCAL SYSTEM • National Air Monitoring System • State and Local Air Monitoring System • Toxics Air Monitoring System	NATIONAL NETWORK NOT FULLY DEVELOPED • few air quality monitoring stations outside Mexico City • SEDUE plans to establish networks in 20 cities • no toxics monitoring

KEY DIFFERENCES

- US states are responsible for ensuring NAAQS attainment with federal oversight; Mexico relies on source permitting program in which states have authority to regulate most types of sources without federal oversight
- 95% of EPA's administrative and civil judicial actions concluded as negotiated settlements; process of negotiating voluntary compliance agreements with SEDUE not clearly defined or adequately funded

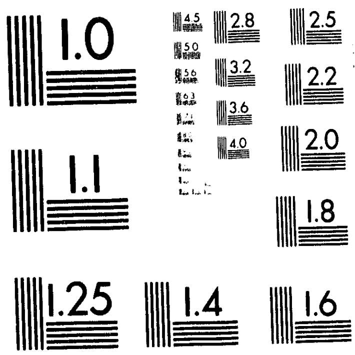
SOURCE: US ENVIRONMENTAL PROTECTION AGENCY

Figure 2

COMPARISON OF WATER POLLUTION REGULATION IN THE US AND MEXICO

	US	MEXICO
LAWS AND REGULATIONS	1972 CLEAN WATER ACT (CWA) • established national technology-based effluent standards to be factored into permitting process 1987 WATER QUALITY ACT (WQA) • additional standards for individual water sources to be factored into permitting process	NATIONAL WATER REGULATION (CURRENTLY BEING DRAFTED) • sets Technical Ecological Standards (NTEs) limiting effluents and special conditions applicable to particular receiving bodies
IMPLEMENTING MECHANISM	NATIONAL POLLUTANT DISCHARGE ELIMINIATION SYSTEM (NPDES) • permitting process that combines national effluent & water quality standards tailored to facility's conditions • EPA & state agencies share permitting resonsibilities	AUTHORIZATION TO DISCHARGE • National Water Commission (CNA) authorizes discharges into continental receiving bodies • state and local authorities authorize discharges into drainage and sewer systems • not clear if authorization equivalent to issuing a permit
MONITORING	SELF-MONITORING • NPDES requires companies to report monthly and sometimes daily discharges	FEDERAL INSPECTION • most monitoring done by federal inspectors with limited resources for testing and reporting
KEY DIFFERENCES	• EPA has strong jurisdiction over state permitting process; lack of strong federal oversight in Mexican system may weaken enforcement of NTEs • In US, each water segment has designated use supported by water quality criteria, and permitting reflects these criteria and uses; not clear that every body of water is regulated in Mexico	

SOURCE US ENVIRONMENTAL PROTECTION AGENCY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als and businesses on the other side. Indeed, economic and industrial development along the border and particularly in Mexico, has already resulted in significant environmental degradation. This pollution in Mexico is much the result of international expansion of US based firms. Understanding the unique concerns and special conventions to deal with border environmental issues led to formation of the International Boundary and Water Commission (IBWC) which has dealt with border water issues for almost 50 years.

In 1983, the USEPA and SEDUE agreed that distinct steps were necessary to redress environmental degradation along the developing border area. At a time of generally poor relations between the two countries, the negotiation of this agreement was a significant step forward in addressing bilateral environmental dangers.

Five technical annexes to the Border Environmental Agreement were negotiated. Plans were undertaken to construct waste water treatment facilities, develop a Joint Response Team to respond to accidental spills of oil or other hazardous substances, establish procedures to govern transboundary shipment of hazardous substances, require copper smelters in the border area to comply with certain emissions limits, and to provide for an assessment of the causes of and solutions to air quality problems in the sister cities of the border area.

At the meeting of the Presidents of Mexico and the US which took place in November, 1990, in Monterrey, Mexico, each instructed their environmental ministries to cooperate to develop a comprehensive Integrated Environmental Plan for the Mexican-US Border Area. The first stage of the plan covering the years 1992-1994 was completed in late 1991.[43] The goal of the Plan is to protect human health and natural ecosystems along the com mon border. To attain this goal, both countries agreed to commit to four objectives:

- Strengthen enforcement of existing laws;
- Reduce pollution through new initiatives;
- Increase cooperative planning, training and education; and
- Improve understanding of the border environment.

Developments in the border area will be more carefully examined and may be required to achieve a higher standard of pollution control than would be required of a project outside the border area on either side of the political boundary.

The maquiladora industrial development has been in existence for almost 20 years. The border area which contains most of the maquiladoras has been a focus area of concern over environmental degradation. The Carbón I and II plants are located within the border area as are many of the coal mines. As concern for border air quality and other environmental impacts grows, operations at these plants and mines could be affected. In our earlier discussion of the cement industry we indicated that new cement plants might be located in the rapidly industrializing border area to serve local markets and those in the southwestern US. If the cement plants used coal for process heat, operations of these plants could be affected by more stringent regulation.

REGULATION IN COAL MINING

The National Program for the Modernization of the Mining Industry 1990-1994, published by the Secretaría de Energía, Minas e Industria Paraestatal (SEMIP), has as one of its goals the development of an "Operative Program for the Protection of the Environment in the Mining Industry." The objective is priority attention to environmental control and surveillance, to enhance its protection, reducing to tolerable limits the pollution generated by the mining-metallurgic activity in accordance with the norms in force. The course of action to implement these goals and objectives is to promote those mining-metallurgic projects that take into account the aspects related to the protection of the environment; to promote those measures tending to reduce or avoid the air, soil, and water pollution provoked by mining industries in their areas of influence; to apply programs for environmental protection and preservation on the basis of an agreement among the government, private, and labor sectors; and, to reforest the areas of influence of the mining industry. [44]

The extractive phase of most mining operations often takes place in remote, mountainous regions, sometimes underground. Accordingly, air pollution that might otherwise present a problem to the industry is not readily visible. At mines, air pollution problems may be limited to airborne dust particles generated by the handling of loose coal or overburden. Loosely compacted tailings or overburden dams contribute to air quality problems when strong winds dislodge particles and blow them into the atmosphere.

Emissions from smelters, refineries and beneficiation facilities are more noticeable because these facilities are usually nearer markets and population centers. For example, concern in the Arizona/Sonora area over the 8 copper smelters located in that region (six in Arizona and two in Mexico) led to the development of Annex IV to the Border Environment Agreement. This agreement dealt with emissions from smelters, requiring them to meet the EPA'S New Source Performance Standards (NSPS). New smelters in Mexico must now comply with the same standards.

Over the last 50 years, Mexico's mineral resource industries have installed a variety of pollution-control devices at smelters and refineries to protect workers' health and reduce nearby communities' exposure to pollutants. Some of these devices include baghouses and electrostatic precipitators. The height of smoke stacks has also been increased. Though those involved in mining activities have made significant advances toward environment, safety, and health, they will have to become even more cognizant in the future.

Water pollution from coal mines is potentially a more severe problem for Mexico, presenting problems in both water quality and quantity. The existing major mines in Mexico are located in an arid region of the country. Several of the mines are underground. Dewatering these to facilitate mining could lead to a lowering of the water table, making it difficult and expensive to obtain water for regional users. Acid mine drainage can result from either surface or underground excavation. However, the remoteness of the mines in the Coahuila region will ensure that these problems will probably not be serious.

REGULATION IN COAL PREPARATION

Firms engaging in the activities of coal preparation, beneficiation, transportation, or use will be subject to the emission standards developed in the General Law of Ecology. Proposed developments in the border area or the area surrounding the Federal District may be subject to more stringent environmental regulation.

MEXICO AND GREENHOUSE GAS EMISSIONS

Mexico has made significant efforts to demonstrate its commitment to environmental improvement. In 1991, President Carlos Salinas de Gortari received the first Earth Prize jointly conferred by the United Nations and the Nobel family. President Salinas de Gortari received this award for his numerous environmental initiatives. These included his four-year, $4.6 billion program to improve air quality in Mexico City through the introduction of lead-free gas and closure of the Mexico City PEMEX refinery. He also prohibited capture of and trade in marine turtles thereby protecting seven of the world's eight endangered species.

More recently, President Salinas de Gortari canceled a major hydroelectric project planned for the Selva Lacandona, a rain forest in the southern state of Chiapas bordering Guatemala and noted for its biodiversity. He also redirected a road project around an important nature preserve in that same state.

Mexico has demonstrated similar leadership in the battle to control CFC's and similar ozone-eroding substances by being the first country to sign the 1986 Montreal Protocol. This sets separate schedules for the phase-out of the use and production of these substances. Mexico has adopted the schedule for developed nations which implements compliance ten years before that of developing countries.

In order to meet the schedule, SEDESOL, which is charged with implementing Mexico's program, has formed a partnership with the USEPA, the Industry Cooperative on Ozone Layer Protection and Northern Telecom. Specific activities that will be undertaken by SEDESOL are:

- creation of an information clearinghouse for ozone protection technology in Mexico;
- fostering recycling technology for CFC-12, the cooling agent used in automobile and truck air conditioning systems; and
- channeling investment toward hydrocarbon aerosol technology, a safe process that does not harm the ozone.

OPPORTUNITY FOR US INDUSTRY

Both the Mexican government and Mexican industry are acutely aware that environmental issues will be extremely important to the US Congress' passage and implementation of NAFTA. Of particular concern will be the US/Mexico border area, where Mexico will need to demonstrate its intention to improve upon its environmental record and maintain a standard of quality that is acceptable to the international community. As the requisite environmental control technologies and expertise are largely unavailable in Mexico, a great opportunity exists for US firms which possess these strengths.

The size of the international environmental market in terms of the value of goods and services transacted each year has been estimated by the OECD to be $200 billion annually.[45] This estimate is widely accepted by knowledgeable industry observers.

The United States is the world's largest producer/consumer of environmental products and services, and in 1990 was reported by the OECD to have produced $80 billion of the $200 billion market. Most of this production is used domestically with only $8 billion exported as compared to Germany's exports of almost $11 billion. Germany is the largest exporter of environmental products with the US ranking second. Japan, France and the United Kingdom follow, respectively, in order of value of exports.

Based upon its lead in production, the US is well-positioned to capture the lion's share of the Mexican environmental technology market.

In 1991, Mexico's market for environmental products was valued at $1 billion including equipment and services. By the year 2000 it is expected to grow to $10 billion. Because the United States is already supplying a large proportion of exports to this market, it will have the opportunity, reinforced by NAFTA's reduction of tariff barriers, to meet growing demand. Because the USEPA is working with SEDESOL to establish regulations for the border area, this opportunity is further enhanced.

Clean coal technology

Combustion of coal in boilers with outmoded technology without cleanup of stack gases is one of the significant contributors to degraded air quality in the US. Technologies have been developed to retrofit boilers and stacks so as to reduce the quantity of pollutants, particularly SO_2 loading. Retrofitting boilers to permit burning of a different kind of fuel combustion and/or retrofitting stacks with "scrubbers" are expensive solutions to the air quality issue.

At the same time, boiler technologies have improved such that handling emissions of pollutants becomes part of the process technology or emissions are eliminated in the combustion process. Fluidized bed combustion boilers were developed to aid in the process of pollution reduction. Pollution reducing technologies are available now for new plant construction. Sufficient demonstration and government R & D efforts have gone into their development that some of these technologies are ready for commercialization.

Mexico is fortunate in that there is only one coal-fired electric generating facility that represents the old technology. By carefully choosing the technology for new plants scheduled to be built in the future, Mexico can reduce overall cost, coal consumption, emissions of pollutants and greenhouse gas emissions, all the while maintaining emissions within limits that would be acceptable under the New Source Performance Standards (NSPS) in the US.

PREPARATION AND BENEFICIATION OF COAL

These are processes for preparing coal so as to remove potential pollutants prior to its combustion. The processes involve pulverizing the coal and then running it through a series of physical cleaning methods to remove noncombustible materials. Because the impurities in coal are typically denser than the coal itself, it is possible to separate them from the bulk of the coal via jigs, concentrating tables and hydrocyclones. In this manner, much of the ash and pyritic sulfur (sulfur not chemically bonded to the coal) can be removed before combustion. The preparation process is usually found to be a more cost effective means of sulfur removal that FGD. Various levels of coal beneficiation are available with cost directly related to the level of preparation. Mexico's only coal plant currently in existence, the José López Portillo plant, burns coal with a very high 35-40% ash. This coal is beneficiated prior to combustion. Newly installed coal plants should employ the fluidized bed combustion technology so that environmental compliance can be achieved at reasonable cost.

A CLEAN COAL TECHNOLOGY PROGRAM

To obtain an idea of how desirable it is for Mexico to establish a clean coal technology program we briefly review a study conducted by the Electric Power Research Institute (EPRI) which compares two alternative strategies for reducing SO_2 and CO_2 emissions by 10M tons per year from 1980 levels by the year 2000. The two alternative strategies were the retrofit strategy, that required a rapid reduction of emissions through fuel switching (retrofitting boilers to burn natural gas), or installing FGD equipment to scrub stack gases, and the replacement strategy which involved installing more efficient coal burning technologies on all new plants and the repowering and retiring of all old technology plants by age 55.

The effects of the two strategies were compared on a variety of bases over an analysis period stretching from 1991 to 2050. Key results of the comparison relevant to this study are briefly described in the following several paragraphs. The replacement strategy is the more cost effective strategy and saves between $4 billion and $28 billion in present value of cumulative capital cost over the retrofit strategy, depending upon the particular scenario evaluated. The cumulative annual costs saved over the study period by the replacement over the retrofit strategy ranged between $66 billion and $724 billion in constant 1989 dollars. The replacement strategy allows a more orderly transition from the old to the new technology and does not involve the expensive retrofit process. Hence, it is the more cost effective strategy.

Because the new coal technologies are more fuel efficient, the replacement strategy reduces coal consumption by between 0% and 4% and CO_2 emissions by approximately 0% to 4% (between 54 million tons and 15 billion tons of CO_2) relative to the retrofit strategy. Solid waste production (coal ash and SO_2 scrubbing waste) is reduced by 1% to 18% (representing between 300 million and 4 billion tons of waste material) relative to the retrofit strategy.

Understandably, the retrofit strategy reduces SO_2 deposition by a larger cumulative amount. The disparity is larger in the early years of the study period when the retrofit strategy is actively retrofitting existing plants. Between the years 2000 and 2010, the SO_2 depositions range between 15% and 70% lower for the retrofit strategy, depending upon the scenario. The model was unable to detect significant differences in the differential effects of the SO_2 emissions from each of the strategies on acidic conditions in lakes and streams, forests and crops and in human health. Visibility would be improved by the retrofit strategy in the years 1991 to 2014. After 2015, the two strategies would produce virtually the same visibility levels.

Fortunately for Mexico, it is not necessary to choose between these or other alternatives, except perhaps for the one coal plant that is presently in existence. However, the policy guidance is clear. Mexico energy planning officials should ensure that the new coal plants that are built embody new technology. US firms that propose to build new facilities should be prepared to install the latest of operational technologies.

The NAFTA provisions concerning importation of US equipment will remain somewhat restrictive in that duties on some types of equipment run as high as 20%. However, duties on equipment will be phased out over a period of ten years with an immediate 20% reduction (to a maximum duty of 16%) occurring in the first year of phasing.

many types of capital goods and equipment that are important in the electric power industry are not manufactured in Mexico and therefore there is no domestic industry to protect. Boilers, turbine-generators, pollution control equipment, etc., are not produced in Mexico. Thus, producers of such equipment will not have to compete with Mexican producers but will have to compete with pollution control equipment exported by Germany, Japan, France, and possibly Great Britain.

ADVANCED COAL TECHNOLOGY

Mexico, which has substantial quantities of indigenous petroleum and natural gas resources, does not need to consider advanced coal technologies to provide liquid or gaseous fuels for transportation and industry. This is a significant factor in the country's energy future because it avails Mexican energy planners a broader range of options to meet changing conditions. While Mexico has limited time before its indigenous liquid and gaseous fuel resources are depleted, this time horizon can be extended through broader use of coal coupled with the application of more advanced coal utilization technologies

Fluidized Bed Combustion

Fluidized bed combustors were the subject of intense interest and R&D during the 1970s and 1980s and have now begun to penetrate commercial markets. They were developed in response to several market needs. These include: the need to reduce the capital cost of initial installation of plant and equipment required to burn fuel efficiently, economically and in an environmentally compliant way; and the need to allow for greater flexibility of operation in regard to quality of fuel feed and changing load demand in an electric power system.

A fluidized bed combustor uses air or some other gas or liquid that is injected upwards through a bed, generally consisting of pulverized coal particles that are suspended in the air flow. As fuel particles mix in the bed, the turbulence provides an excellent medium for heat transfer. Rapid movement of the fluid across the surface of particles provides continuous removal of reaction products and a continuous supply of the reactant. [46]

A key advantage of fluidized bed combustion is that the operating temperature remains low enough to avoid the undesirable properties of coal combustion by-products. For example, ash fusion is not a problem because combustion takes place at 1350-1850°F, lower than the lowest ash fusion temperature. Coals that would otherwise tend to cake, do not, because the particles are small and widely enough spaced that they will not agglomerate. Also, thermal production of oxides of nitrogen is avoided, a significant advantage because these gases are among the more problematic in the waste streams of fossil fuel combustion.

The low combustion temperature is also below that at which calcium sulfate decomposes. Thus, it is possible to introduce an additive, such as limestone or dolomite, so that calcium sulfate and some magnesium sulfate will be produced. By controlling the ratio of calcium to sulfur, enough of the SO_x can be captured to meet air quality regulations without the need to install a flue gas de-sulfurization system. This achieves a substantial capital cost reduction. Coals that contain enough magnesium and calcium in the ash such that the ratio of calcium to sulfur is naturally above 2:1 may not even require the limestone injection. These typically low-sulfur coals rely on the natural alkalinity of the ash to capture enough SO_x to meet air quality standards.

The quality of fuel supplied to a fluidized bed combustor is much less important than in most other coal combustion technologies. The fluidized bed combustor can efficiently burn a wide variety of fuels including almost any type of coal, out-wash from coal preparation plants, wood, heavy oil and even garbage. This permits greater flexibility of operation because the operating entity need not be concerned with obtaining a long-term contract for a very specific grade of coal. Finally, the fluidized bed combustor can be efficient over a wide range of operating rates, allowing the unit to follow demand.

Combined Cycle Plants

A variation on the theme of cogeneration is provided by combined-cycle plants. These produce electricity by combining the combustion turbine and steam turbine technologies in one plant. The gas turbine is operated by direct combustion of gases that reach temperatures in the range of 2,000°F when entering the turbine and are ejected at a temperature of about 950°F. This approximates the temperature of the steam in a conventional boiler system that takes in steam at a temperature of about 1050°F and exhausts it at 90°F. A combined cycle plant operates with a temperature gradient from 2,000° to 90°F., greatly increasing the efficiency of fuel usage and reducing the rejection of waste heat.

Combined cycle plants of two types have been developed. One type uses a fluidized bed combustor that is operated at high pressure and produces hot gases for direct burning by the combustion turbine. The other uses a coal gasifier to produce a fuel gas that runs the combustion turbine. This technology is termed an integrated gasification combined cycle plant (IGCC). In both cases, the hot gases leaving the gas turbine are used to raise steam to power the turbine. Of the two, the coal gasifier/combustion system is more efficient because the gas can be inlet to the turbine from the gasifier at a higher temperature. It also has the advantage of achieving 99% removal of sulfur, superior even to the fluidized bed combustor system.

The incremental energy efficiency of a combined cycle plant operated with a gasifier is approximately 3% above a conventional boiler/steam turbine facility. Turbines that will withstand a temperature of 2600° to 2700°F., boosting the efficiency another 2%, are upon the horizon. Thus, an overall energy efficiency improvement of 5% will be available in the not-too-distant future as the IGCC plants move from demonstration to commercialization. While these efficiency improvements may seem small, they nonetheless result in significant reductions in the quantity of fuel that is used over the life of a plant and over the course of time. [47]

Magnetohydrodynamics (MHD)

MHD is based on the principle that an electrical conductor moving through an electrical field produces a current. In a coal-based MHD system, coal is burned with pre-heated oxygen or oxygen-enriched air to produce combustion gases of 4900 degrees F. These extremely hot gases are passed through a duct that contains electrodes inside two opposing walls. Combustion gases are rendered electrically conductive by introducing a "seed" of an easily ionized material, such as potassium (the standard for this purpose). A strong magnetic field is thereby established perpendicular to the duct causing the electricity generated to flow out through the electrodes in the walls. [48]

In addition to the direct generation of electricity by this process, MHD systems typically include a steam cycle based on the exhaust of hot gases from the duct similar to a combined cycle plant. By this combination, engineers hope to obtain energy efficiencies in the neighborhood of 50%.

The technology also offers environmental advantages besides those of higher fuel efficiency and therefore lower fuel consumption. Sulfur in the coal combines with the potassium carbonate "seed" to produce potassium sulfate that can be collected and recycled. Research suggests that the sulfur emissions of an MHD plant would be only 10-20% of the current EPA limits. It is also thought that particulate emissions would be reduced.

A disadvantage of MHD is the large quantities of nitrous oxides produced by the process. Scientists have investigated the possibility of using this material as a source for nitrogenous fertilizer. [49]

The extremely high temperatures that are required for the MHD process suggest that materials problems could be difficult in commercialization of this technology. Erosion of the interior surfaces of the duct by the flow of the supersonic gases results in corrosion and formation of slag coatings on the electrodes and channel walls. These problems and the high temperatures at which the process operates necessitate new designs for heat exchangers. The high cost of the materials for combustion points to the need for better seed recovery techniques.

Although this technology is still in the developmental stage, it is anticipated that operating units built on a commercial scale will be installed in the decade of the 90s, particularly for re-powering existing facilities. However, the technology is probably not appropriate for installation in Mexico at this point, as further experience with the units is required before they can be considered a commercially viable option.

Coal conversion for liquid fuels or chemicals

Mexico has ample reserves of petroleum which preclude the need for processing coal to obtain liquid or gaseous fuels. However, coal as a feed stock from which to obtain chemicals is a process that may, in the future, be appropriate for Mexico.

Coalfineries (coalplexes) are sites at which a number of coal conversion processes are performed. At such facilities, a number of processes for obtaining useful fluids, gases or chemicals from coal are grouped.

In the early 20th century, the by-products of coke manufacture were the basis for the organic chemical industry. As demand for organic chemicals to manufacture everything from fertilizers to plastics to fabrics grew, the coke industry could not keep up. Phenol was the primary ingredient used in the chemical industry and 95% of this product was a by-product of coke production. The chemical industry grew to such an extent that, eventually, phenol from coke represented only 5% of total consumption. Today, technology in the organic chemical industry relies on petroleum as a source for raw materials. It is comforting to know that if and when petroleum supplies decline and thus become too expensive to use as a source of feed stocks for the organic chemical industry, the relative abundance of coal will be available to supply the needed chemicals. However, the new organic chemical industry based on coal will rely on new and different processes. A brief description of some of the candidate processes follows.[50]

CO-PROCESSING

Since before WWII, substitutes for natural gas have been produced from coal. Because the price of petroleum remains relatively low there exist no economic incentives to use this technology. Co-processing that combines coal and petroleum refining in the same plant offers a way for coal to be used in the liquid fuel and petro-chemical industries. One possibility is to use coal-derived liquids to extend the petroleum feed stock in a refinery. Another alternative is to use the heavy residue from petroleum distillation as a solvent to slurry coal for feed to a coal-liquefaction reactor.

Since organic chemistry based on petroleum is primarily that of aliphatic compounds, while coal chemistry is primarily that of aromatic compounds, conversion to a new organic chemistry based on coal will require a new type of chemical industry.

SYNTHESIS GAS

Synthesis gas, ethylene, propylene, butadiene, benzene, toluene, xylenes and phenol are the main chemicals of today's organic chemical industry. The technology to convert synthesis gas to chemicals is well-established. Synthesis gas is made by reacting methane or naptha with steam and once made, its subsequent conversion to other chemicals does not depend on the original source of the gas.

Synthesis gas can be made from coal and then used as would synthesis gas from methane or naptha. However, coal requires additional facilities for unloading, handling, and grinding.

Furthermore, the raw gas made from coal may require further cleaning, thereby increasing cost. The gas made from coal has a hydrogen to carbon ratio of 0.8 as compared to synthesis gas from methane (4.0) and naptha (2.0) and therefore may require further adjusting before it can be used. Some experts believe that because the technology for converting synthesis gas to chemicals is well-known, the initial return of coal to the chemical industry may be via synthesis gas.

HYDROCRACKING

Products of the solvent extraction of coal can be reacted with hydrogen to break apart the aromatic molecules to produce naptha and liquefied petroleum gas (LPG), that contains mostly propanes and butanes. In the past, the goal of coke production was to maximize the production of solids and minimize liquids; the goal in a chemical industry based on coal would be the antithesis. The char from hydrocracking could be burned to provide heat or steam requirements in the plant, gasified to generate either synthesis gas or hydrogen, or could be burned in an electric power plant.

SUPERCRITICAL FLUID EXTRACTION

A supercritical fluid is a material used at a temperature and pressure higher than its critical point, that is the temperature and pressure at which gas or liquid phases of a substance in equilibrium can no longer exist separately. The supercritical fluid has no surface tension and can penetrate the entire internal pore system of coal to the point at which access to the pores is limited only by the physical bulk of the molecules of the fluid. At the same time, the supercritical fluid can act much like a true liquid in its ability to dissolve components of coal and transport them out of the system. If the solvent ability of a supercritical fluid can be matched to the compounds in the coal, the compounds of that class can be selectively extracted, eliminating the need to separate complex mixtures to obtain them. Low molecular-weight compounds extracted by a supercritical fluid can be treated with hydrogen to remove oxygen, nitrogen, and sulfur; this treatment produces a clean, distillable product.

As a process for making chemicals from coal in the future, supercritical fluid extraction offers a number of attractive features, including the possibility of using such inexpensive fluids as water or carbon dioxide, or tailoring the fluid for selective extraction. The leftover char is fairly reactive and is a good candidate for gasification; it can even serve as a low-grade of activated carbon for waste-water treatment. These features need to be balanced against the operation of the process at elevated temperatures, that adds an operating cost for heating, and at elevated pressures, that adds an increasing capital investment for the reaction vessels needed to withstand the pressures.[51]

ACETYLENE

Alternatively, chemicals can be made from coal by utilizing the chemistry of acetylene. At one time acetylene was used as the starting point for synthesizing many compounds. It was made by reacting coal with calcium oxide, producing calcium carbide, and then reacted with water to produce acetylene. Because calcium oxide is not readily available today, a new chemistry based on acetylene would need to identify a different process to produce acetylene. Experts believe this new process might involve the rapid pyrolysis of coal in the presence of hydrogen. When the reaction from these two elements is run at a temperature of approximately 3600 degrees F° and the particles are heated for only one-one thousandth of a second before being quenched, acetylene is a produced. Rocket engine technology is being researched as a method of producing the desired temperatures and duration times.

COALFINERIES

Experts envision major capital installations, termed coalfineries or coalplexes, built around the use of coal to provide products for the organic chemical industry. These facilities could be versatile coal-processing plants producing a range of fuels, chemicals, and electric power tailored to a variety of potential markets. Much of the technology is already in existence and consists of the Fischer-Tropsch coal gasification technology and the Solvent Refined Coal (SRC) liquefaction process. The main impediment to development of such facilities is the availability of low priced petroleum and the financial market's resistance to investing large sums of money in a complex containing several new technologies.

While these processes based on coal may prove feasible in the future, they are not likely to appear before the end of the century in the US. The appropriate strategy for the near term in Mexico would be to import coal for electric power production so that reserves of natural gas and petroleum for feed stocks to the organic chemical industry could be extended.

Prospects for the US capital goods industry

The opportunities for US industry to install more advanced boiler and/or turbine generator systems depends upon the ability of US firms and/or consortia to win the contracts for these purposes. Based upon the evidence that we have to date, it would appear that US companies have a good chance to win these contracts. As has been noted, a consortium led by General Electric won the contract for the Samalayuca plant which will be a natural gas-fired, combined cycle system. This gives the US-led consortium the opportunity to install what is regarded as a more advanced electric generating system. Mission Energy Company, the unregulated subsidiary of Southern California Edison, is involved in a consortium of firms who have purchased the MICARE mine at Río Escondido and the Carbón II mine-mouth power plant. Unit 1 of this plant is in operation and unit 2 is nearing completion. Units 3 and 4 will be completed in the next several years. While it would be possible to install a new boiler technology, such as a fluidized bed boiler, the fact that two conventional boilers are already installed probably means that the remaining two units will use the existing technology.

Since these facilities and more like them that are to be built in the future are contracted under build, lease, own or transfer, or power purchase agreements, the consortia will be operating them for some period of time. This will offer the opportunity for engineers in these companies to become familiar with the operating characteristics and requirements of more advanced systems, and should help the US entities in the consortia to market the technologies in the US and elsewhere.

As the companies constructing the facilities will be responsible for their operation for some time, attempts to install new technology will less likely be construed as the introduction of inappropriate technology in a newly industrializing country.

The North American Free Trade Agreement

The implementation of the NAFTA Treaty would give US and Canadian coal producers an immediate 16% cost advantage over other producers as compared with pre-NAFTA arrangements. This is comprised of the 10% tariff presently charged on imports of coal from any source and the 6% VAT that is now charged on imported goods.

With the exception of natural gas, the flow of energy product exports between Mexico and the US has been primarily south to north in the past, due to a number of market and institutional factors. The United States has been a major market for Mexican petroleum and is its largest single customer for crude oil (approximately 56 percent). During the 1980's, it was proposed that Mexico supply natural gas to the US, but negotiations broke down largely over pricing issues. Due to availability problems at this time it does not appear that Mexico will export natural gas. Rather, gas will flow from the US to Mexico to supply facilities in the northern border area which are beyond the reach of Mexico's pipeline system.

Historically, Mexico's energy sector has been largely state-owned with carefully controlled access to every part of the industry. This environment limited opportunities for US industry participation.

New and significant opportunities for US industry to participate actively in the growth and development of the Mexican energy sector are due to changes that Mexico has made in its energy industry and the prospect for implementation of NAFTA. Under NAFTA, exports of natural gas from the southwestern US to northern Mexico are sure to grow, and exports of coal from the US could fuel Mexico's expansion of coal-based electricity generation.

THE EFFECT OF NAFTA

The Department of Commerce, International Trade Commission, recently released their "NAFTA Effects Study."[52] In this study the authors detail the expected impact of the implementation of the current version of the Agreement on the US and Mexican economies. Overall, the authors suggest that the impact on the US economy will be limited, except in specific sectors and regions that will benefit or be harmed in a significant way. Although both economies are expected to benefit, that to Mexico should be proportionately greater due to its relatively smaller size and because it has heretofore been fairly closed to foreign competition.

NAFTA'S EFFECTS ON THE ENERGY SECTOR

Energy sector impacts are expected by the authors of the NAFTA effects study to be minor. This is partly due to the special nature of many of the energy minerals or energy fuels and also partly due to the many significant changes in the structure of the energy sector and the regulations pertaining to foreign investment and ownership that have already been made. Prior to the recent past, most of the energy activity was in the public sector. Now, large segments of the industry have been privatized. Thus, the specific impact of the NAFTA agreement is greatly moderated. The largest public sector energy company, PEMEX, will remain in the public sector and will retain control of a great deal of the activity in the sector. US oil field contractors will have somewhat greater access to the procurement process than they have had in the past. However, because their presence has been large in the past, it is not expected to grow significantly. Risk sharing in exploration, something the US oil industry was hoping to achieve, was specifically excluded from the agreement at this time.

Thus, while NAFTA itself does not open the floodgates of trade in the energy sector, the opening of the Mexican economy to foreign participation in the 5-6 years that preceded the NAFTA negotiations has opened significant opportunities for US business. The Samalayuca project and the Carbón II plant, together with the purchase of the MICARE coal mine, are evidence of the changing environment. For certain sectors of US business, there are expanded opportunities for substantial business ventures. In the reindustrialization of Mexico's energy sector there are many opportunities for the US capital goods industry, architect/engineering firms, natural gas and coal suppliers and the financial markets. US based businesses have many advantages over their foreign competitors in this new environment.

NAFTA'S IMPACT ON COAL EXPORT TO MEXICO

Specific trade liberalization aspects of NAFTA eliminate the ten percent tariff on imported coal shipped from NAFTA member countries and the 6% VAT. Thus, immediately upon NAFTA implementation, US coal producers will enjoy a 16% price advantage over its competitors (other than Canada). This also means that US coal will compete with Mexican coal on a straight, delivered-cost basis.

Inter-fuel competition (i.e., oil/coal/natural gas) is enhanced by relaxation of import and export restrictions that have the effect of maintaining monopoly markets for certain fuels. The Agreement also permits US investment in Mexican mining properties (new mines only) at equity ratios up to and including 100%.

In the electricity sector, significant opportunities are opened to US firms to develop and own cogeneration and independent power production facilities in Mexico, with excess power sold to the CFE at negotiated prices.

Bidding for service and procurement contracts with government industries has been liberalized. Initially, only 50% of the procurements undertaken by CFE will be opened to qualified bidders from NAFTA origin countries. Scheduled relaxation of this limit means that in ten years, all government industry procurement will be open to firms from NAFTA countries. In addition, any government sector procurement financed by any organization other than the Mexican government is completely open to bidding once NAFTA is in force. The treaty calls for adherence to international norms for open and fair bidding and provides opportunities to challenge bid awards on the merits of proposals submitted.

The Agreement's bottom line with respect to exports of coal to Mexico is that the commodity price plus the cost of delivery to the point of use will be the sole determining factor for competition with other fuels. Non-NAFTA suppliers will suffer a 16% cost disadvantage compared to US suppliers.

NAFTA'S IMPACT ON CAPITAL GOODS EXPORTS

CFE will be issuing request for bids for electrical generation equipment and facilities that will require boilers and turbine/generator systems, and equipment for coal handling and preparation. Architect/engineering firms will be required to design the plants, construction firms to build them, and specialists will be needed to ensure environmental impact compliance. As power generating capacity is increased, the electricity transmission and distribution systems will need to be upgraded commensurately, offering further opportunity for sale of capital goods and services by foreign vendors.

US vendors in the oil and gas field service industry have established a good reputation with PEMEX and thereby obtain a substantial proportion of the contract business let by that public sector entity. Similar relationships with CFE can be established. In light of contracts already won, it would appear that US companies have made great strides.

NAFTA'S IMPACT ON DIRECT INVESTMENT

There is simply not enough indigenous coal of the quantity and quality required for long term use in the Mexican electric power industry available or mineable at competitive cost. Thus, beyond developing the existing mine at Río Escondido to service the Carbón II plant, new investment in coal mining does not appear justified for Mexico. The implementation of NAFTA would reinforce this conclusion as US coal would then be imported at a price 16% lower than pre-NAFTA, and well below the cost of further Mexican coal mining development.

The opportunity for the US to do business with major coal-using industries, especially the electric power production sector, is significant. In addition to the electric generation site facilities required to convert coal to electric power, facilities for transporting and handling coal will need to be upgraded. If coal is to be shipped overland, track will have to be improved to handle the increased volume of rail traffic. In the more likely situation that coal is shipped via ocean carrier, bulk handling facilities at coal ports will need to be constructed. This creates opportunities for increased investment and business in transportation and handling of coal implied by the fuel diversification strategy of CFE.

The new generating stations will have to be connected to a grid that itself will require upgrading. Thus, a series of upstream and downstream investments is involved in the implementation of the generation expansion plan, offering US business concerns a large scope of possibilities.

NAFTA'S IMPACT ON COAL TRANSPORT

Volume shipments of coal will be transported by rail or by marine transport. This section explores the effects that NAFTA will have on the shipment of coal by rail, ship or barge, or some combination of these modes.

NAFTA's effect on rail transport

In general, the US transportation industry stands to gain from NAFTA. Mexico has committed to allowing US and Canadian railroads to continue to market their services, operate unit trains with locomotives, construct and own terminals, and finance infrastructure. Among the measures to be implemented is an agreement to make standards-related measures compatible with respect to motor carrier and rail operations. NAFTA signatories will therefore make available information on operating authorizations and safety requirements that will facilitate each side in issues of compliance.

Mexico has already opened its rail sector to some activities by US and Canadian firms, the continuation of which will be guaranteed by the Agreement. US railroads, among them the Atchison, Topeka and Santa Fe Railway companies, state that they expect the agreement to develop major opportunities in US-Mexico trade.

Union Pacific Railroad anticipates that NAFTA's cutting of freight duties will increase cargo demand and its CEO, Dick Davidson, says his firm will participate in the construction of a $12-$15M inter-modal freight facility north of Mexico City. In talks with Mexico's President, Davidson indicated that Union Pacific would be interested in buying into the Mexican railroad system. The company's trucking partner, J. B. Hunt Trucking, is also developing its own infrastructure in Mexico.[53] Southern Pacific may possibly stand to gain most from the trade agreement because it has more gateways into Mexico than any other US railroad company.

Integrated rail carriers that own rolling stock, track and coal mines are in a position to benefit significantly from the liberalization. These can look to profits from both the sale of coal and transportation of it to consumption points in Mexico. This may allow them to be more price competitive than independent companies handling these activities separately. Additionally, a rail firm's capacity utilization can increase through coal exports to Mexico, thereby improving the potential for US vendors to be even more competitive.

The potential for long-term benefits from infrastructure investment in the rail transport system is high. Coal deliveries to new electric generating facilities will probably be by long-term contract that will permit cost saving investments in track, terminals and coal handling facilities. US companies may benefit from concerted action when coal companies participating in joint ventures or as part of consortia build and operate power plants, allowing each entity to be more price competitive.

One impediment to progress is that trains crossing the international border are required to change crews. This practice, slated to continue in effect after NAFTA's implementation, is a restriction US transportation interests will be working to have relaxed or removed once the Agreement is signed.

NAFTA's *effect on ocean transport*

The marine segment of ocean transport is regulated by international conventions. However, the landside aspects are determined by the destination country. Mexico has opened opportunities for 100% ownership and control of ports and port facilities to firms from countries that are NAFTA members. Although Mexico will need new port development to handle the magnitude of the bulk shipments of coal to supply power plants planned for coastal locations, it does not have the internal capital to upgrade existing ports or build new ones. The US is the only potential source of coal in which the suppliers have the choice of shipping mode. All other suppliers must use ocean transport.

OPPORTUNITY FOR US FIRMS

It is well-established that trade follows investment. Based on this rule of thumb, US firms wishing to sell commodities and services to Mexico can anticipate ample opportunities. Electric power development in general, including coal-based electric power development, is capital intensive. The US is competitive in the kinds of capital goods that will be needed to develop the electric power sector.

The US is by far the largest single source of foreign direct investment (FDI) for Mexico. Over the past decade, the US share of FDI has remained stable at between 60 and 70% of total FDI in Mexico. Signs indicate that this percentage may increase in the near term. Japan appears to be reducing its investment in Mexico as it deals with economic problems at home. In addition, it may be focusing its direct investment in the Asian Rim countries. This same strategy of focusing on the region close to home may be driving the European countries, particularly Germany and France, to direct their investment in European Common Market countries.

Sources of finance for Mexico's electric capacity expansion

There are two main financing alternatives that are available to firms, joint ventures, and consortia to leverage private capital. While private firms will be seeking to leverage their own capital, the international organizations or US organizations which finance exports will be seeking to leverage public capital. Thus, private firms seeking financing will require an amount of their own capital.

INTERNATIONAL FINANCE CORPORATION (IFC)

The IFC is a member of the World Bank Group and was established to lend to private companies doing business in developing countries. The IFC offers both debt and equity financing directly to private companies. In addition to investment funds, the IFC provides resource mobilization and fee-based management services. Investment funds can be denominated in the currency of choice to the private firm. Terms of the financing are negotiable and the limit on percentage of financing that the IFC will supply is 25%. In addition to loans or equity financing they also offer loan guarantees, underwriting, indirect financing for small projects and loan syndications. Advisory services offered by the IFC include financial analysis, business plan development, physical plant and production process consulting services.

The IFC does not want to be the leading shareholder and they are passive in terms of equity participation and management in projects. The IFC is considered a local shareholder in Mexico meaning that funds from the IFC will count towards minimum local participation if that is pertinent to the deal.

The project selection criteria that are employed by the IFC include the existence of the project in a developing country and private sector ownership. The project must be financially viable and must be beneficial to the domestic economy. Management of the project will be evaluated as to their knowledge of the business in which the project is included, experience in the business and knowledge of the country. The project must be technically and environmentally sound and must have current or prospective local participation.

EXPORT IMPORT BANK

Eximbank encourages US based businesses to sell their goods and services overseas by offering export credit insurance, pre-export financing through working capital guaranteed loans, and medium and long term loans and guarantees to overseas buyers. The relevant services available from the Eximbank are identified and described below.

Credit services

Eximbank uses its repayment records to provide credit information for US exporting firms and the commercial banking community. Eximbank can provide information useful in the financing of export sales to a specific country or an individual company abroad. However, Eximbank will not divulge confidential financial data on foreign buyers to whom it has extended credit, nor will it disclose classified or confidential information regarding particular credits or conditions in foreign countries.

Contact: Edward So, (202) 566-4690 or (202) 566-8790, FAX (202) 566-7524

Working capital guarantee program

The program helps small and medium-sized businesses obtain critical pre-export financing from commercial lenders. Eximbank will guarantee 100 percent of the principal and interest on loans or revolving lines of credit that are extended to eligible exporters. The funds may be used for such pre-export activities as buying raw materials and foreign marketing.

Contact: James Crist, US Division, (202) 566-8819, FAX (202) 566-7524

Export credit insurance

Eximbank offers insurance that covers political and commercial risks on export receivables.

- The New-To-Export-Policy is available to firms just beginning to export with average annual export credit sales of less than $2 million for the previous two years and who meet US SBA guidelines for the definition of a small business. The policy offers enhanced coverage and a lower premium than usually found in regular insurance policies.
- The Umbrella Policy is available to commercial lenders, state agencies, export trading companies and similar organizations to insure export receivables of their small business clients.
- The Bank Letter of Credit Policy insures commercial banks against loss from irrevocable letters of credit issued by foreign banks for US exporters.
- The Multi-Buyer Policy insures all or a reasonable spread of exporter's short-term or medium-term export credit sales.
- The Financial Institution Buyer Credit Policy insures individual short-term export credits extended by financial institutions to foreign buyers.

- The Short-Term Single-Buyer Policy and the Medium-Term Single-Buyer Policies allow exporters to insure their receivables against loss due to commercial and specified political risks on a selective basis.

- Lease Insurance Policies offer a lessor the opportunity to expand its overseas leasing program by providing comprehensive insurance both the stream of lease payments and the fair market value of the leased products.

Contact: Robert Chramella, Insurance Division, (202) 566-8955, FAX (202) 566-7524

Gurantee Program, Export-Import Bank

The program provides repayment protection for private sector loans to credit worthy buyers of US capital equipment and services exports. Coverage is available for loans of up to 85 percent of the US export value. For the most part, Eximbank lending rates are the official minimum rates based upon US Treasury rates and a spread agreed to by members of the Organization for economic Cooperation and Development (OECD) and depend upon the repayment period. An OECD matrix rate is available for poorer countries.

Contact: Ken Telesca, Export Finance Group, (202) 5666-8187, FAX (202) 566-7524

Lease Guarantees, Export-Import Bank

The program provides competitive, fixed interest rate financing for US export sales of US capital equipment and related services. Eximbank extends direct loans to foreign buyers of US exports and intermediary loans to responsible parties that make loans to foreign buyers. Coverage is available for loans of up to 85 percent of the US export value. For the most part, Eximbank lending rates are the official minimum rates based upon US Treasury rates and a spread agreed to by members of the Organization for Economic Cooperation and Development (OEDC, and depend upon the repayment period. An OECD matrix rate is availabe for poorer countries.

Contact Ken Telescak, Export Finance Group, (202) 566-8187, FAX (202) 566-7524

Engineering Multiplier Program, Export-Import Bank

Eximbank offers lease guarantees for finance and operating leases to foreign entities covering US manufactufed goods.

Contact: Arthur Pilzer, Latin American Division, (202) 566-8943, FAX (202) 566-7524

Export credit insurance

The program stimulates exports of US architectural, industrial design and engineering services. Eximbank will extend loans or guarantees for up to 85 percent of the US export value of services involving projects with the potential of generating export orders of $10 million or double the original export contract, whichever is greater. It also will guarantee commercial financing for approved project-related costs in the host country of up to 15 percent of US export value.

Contact: John Wisniewski, Engineering Division, (202) 566-8802, FAX (202) 566-7524

Operations and Maintenance Contracts Program

This program helps US firms competing for overseas contracts to operate, maintain, and upgrade new or established projects. Eximbank will provide loans or guarantees for up to 85 percent of the US export value of operations and maintenance transactions with repayment terms of up to five years. The contract must provide a long-term benefit to the owner, such as training local personnel to take over operation or establishing permanent procedures to assure good operation of the project.

Federal International Energy and Trade Development Opportunities Program

This interagency program under the US Department of Energy/Agency for International Development/Trade Development Agency, offers financial support to US firms for pre-feasibility studies leading to potential energy trade development opportunities.

Contact: Peter Cover, Office of Fossil Energy, USDOE, (202) 586-7297, FAX (202) 586-1188

Feasibility Studies, Trade and Development Program

A primary activity of the TDP is the grant funding of feasibility studies, consultancies, and other project planning services for mahor projects in developing countries. The studies are conducted by US private sector firms and represent a wide range of host government, high priority sectors including: agribusiness, educational technology, electronics, energy minerals development, telecommunications, transportation, and waste management. TDP's participation usually ranges from $150,000 to $750,000 for public-sector projects. Applications for feasibility studies are accepted with host government endorsement.

Contact: Ask for Regional Director for the country in which the study will take place, (703) 875-4357, FAX (703) 875-4009

Grants to Multilateral Development Banks, Trade and Development Program

In recent years, TDP has established grants at the World Bank and other multilateral development banks (MDBs). These MDBs use TDP funds to hire consultants for projects being considered for financing by the mulitlateral banks. Other donor countries have established similar funds to ensure that multilateral bank-funded projects use technical specifications, and standards that favor or at least do not discriminate against their companies. TDP funds are directed for the same purpose, and TDP exercises its right to veto projects that are unlikely to benefit the US economy.

Contact: Barbara Bradford, (703) 875-4375, FAX (703) 875-4009.

APPENDIX A: FOOTNOTES

Information for this summary was taken from periodical sources and from a telephone conversation with Mr. George Aguilera, General Electric, Mexico City, February, 1993.

2. Information for this summary was taken from periodical sources and from a telephone conversation with Mr.Tom Reed, Mission Energy Company and written responses to written questions provided to the author by Mr. Reed.
3. "Energy and Environment Market Conditions in Mexico" US Agency for International Development, Office of Energy & Infrastructure in cooperation with Bureau for Latin America and the Caribbean. Washington, DC, 1992, p. 19.
4. "Planning and Development in the Coal Industry in Mexico." Energy Policy In Mexico: Problems and Prospects for the Future. Wionczek, Miguel S., Oscar M. Guzman and Roberto Gutierrez, Editors. Boulder, Colo.: Westview Press, 1988.
5. "Coal in Mexico," Salomon Camhaji Samra, Director General, Minera Carbonifera Rio Escondido (MICARE), pII-2.
6. This discussion of resources is taken principally from an unpublished internal paper given to the author by US Embassy staff employed at the Embassy in Mexico City. Other sources are footnoted as appropriate.
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21. *Ibid*., p. 75.
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24. Groliers Encyclopedia.
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29. *Ibid.*, p. 122.
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31. *Ibid.*, p. 122.
32. Much of this discussion of taxation is taken from "Industrial Outlook Report - Mining," issued in May 1991 and authored by US Embassy staff in the Mexico City Embassy.
33. "Industrial Outlook Report - Mining," an unpublished manuscript authored by US Embassy staff in the Mexico City Embassy, April 1992.
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35. This discussion of Mexican energy planning history is based largely on Nora Lina Montes, "Planning and Development in the Coal Industry in Mexico," pp. 102-105.
36. *Ibid.*, p. 104-107.
37. "Potential Impact on the US Economy and Selected Industries of the North American Free Trade Agreement," USDOC, ITC Publication 2596, January, 1993, p. VII-VIII.
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50. The discussion of chemicals from coal is taken from Harold H. Schobert, *Coal: The Energy Source of the Past and Future*, pp. 267-270.
51. This discussion of supercritical fluid extraction from coal is taken almost verbatim from, Harold H. Schobert, *Coal: The Energy Source of the Past and Future*, pp. 268-269.
52. Larry Brookhart and Robert K. Wallace, *et al*, "Potential Impact on the US Economy and Selected Industries of the North American Free-Trade Agreement, "US Department of Commerce, International Trade Commission Publication Number 2596, Washington, DC, January 1993.
53. Information in this paragraph was obtained from the journal of Commerce, "Railroads See Gains in Mexico from North America Trade Pact," by John Boyd, August 18, 1992.

APPENDIX B: ACRONYMS

AHMSA - Altos Hornos de México, S. A. - The public sector organization that formerly owned the steel facility at Monclova, Coahuila that was recently purchased by a private company with Mexican ownership. The letters S. A. after a company name is Sociedad Anonima, in Spanish and means the company is incorporated. If the S. A. is followed by the letters de C. V. it means Capitál Variáble in Spanish which means that the capital account of the corporation can fluctuate with profits or losses made by the company or with injections of capital from investors.

CFE - Comisión Federal de Electricidád - The Federal Electricity Commission which is the public sector organization charged with the responsibility for the generation and distribution of electricity throughout Mexico. Because of the purview of its activities, CFE is powerful and influential. In ranking of organizations in Mexico is probably second in power behind PEMEX.

CFM - Comisión de Fomento Minéro - The mining development commission, a public sector organization, owned mines and other facilities in the Sabinas basin. Facilities have either been closed or sold to private interests. The CFM is no longer in operation.

EXIM BANK - The Export Import Bank. A US organization that finances acquisition by foreign countries of goods and services produced in the US. The agency is essentially an export promotion organization.

FERTIMEX - Fertilizantes de México - A public sector fertilizer manufacturer.

FMSA - Fundidora de Monterrey, S. A. - The name of the public sector company which owned the Monterrey Foundry, a steel works which was the first steel plant to be built in Mexico. This foundry was closed during the latter half of the 1980's when the steel industry was experiencing difficulties in Mexico.

HYLSA - Hojalata y Lamina, S. A. - A private company with manufacturing plants located in Monterrey and Puebla. The Spanish word hojalata means tin plate. HYLSA is part of the Grupo Industrial Alfa. Has interests in iron ore and pellet production and produces steel by the direct reduction process. This company developed a special process for tin plating that was a leading edge technology.

IADB - Interamerican Development Bank - Sometimes the acronym for this international bank appears as IDB. A development bank that focuses its activities on projects in Latin American countries and Mexico. Will finance projects in either the private or public sectors as well as joint public-private projects. Will finance only on debt instruments.

IBRD - International Bank for Reconstruction and Development. The "World Bank" finances public sector projects on a debt basis anywhere in the world to developing countries.

IBWC - International Boundary Water Commission. The bilateral organization created by Mexico and the US to deal with border water issues. This organization has a history of dealing with these problems for over 50 years of its existence.

IFC - International Finance Corporation - An international financial organization that is a member of the World Bank Group. The IFC finances projects worldwide in developing countries on a debt or equity basis but only in the private sector. Can finance a maximum of 25% of a total project.

IMMSA - Industrial Minera México, S. A. - A large private mining company that has mining operations throughout Mexico. The IMMSA group at one time had coal mining, washing, and coke operations in the Carbonífera area.

MICARE - Minéra Caribonífera Río Escondido, S. A. - The public sector company which owned the coal mining and washing facilities that supplied the José López Portillo electric power plant in the same locality. The mines and other facilities were recently purchased by private operators.

NAFTA - North American Free Trade Agreement - The Treaty signed by the governments of the US, Canada and Mexico to create a free trade area for the north american continent. Calls for the sequential reduction of tariff barriers in the three countries over a period of 10 years.

PEMEX - Petróleos Méxicanos - The public sector organization charged with responsibility for all aspects of petroleum development including exploration, development, production, refining, and distribution. Also responsible for research and development through its subsidiary the Instituto Méxican del Petróleo (IMP). Formed in 1938 when the industry was nationalized. Has been one of the most powerful and influential public sector organizations partly because its revenues contribute significantly to the treasury.

PESE - Plan Nacional del Sector Eléctrico - A forecast of electric energy demand that showed coal supplying 8.5% of Mexico's primary energy by the year 1990.

PNDC - Plan Nacional de Desarrollo Carbonífero - A plan for development of the Mexican coal industry that was released in August 1982. It was authored by a group of local and foreign expert consultants under contract to CFE and MICARE but who were otherwise independent of the Mexican coal industry.

PNDI - Plan Nacional de Desarrollo Industrial - This plan was a forecast of electricity development based upon rapid industrial development fueled by the rapid growth of the petroleum sector in Mexico through exports of petroleum.

POISE - Programa de Obras e Inversion del Sector Eléctrico - Program of investment and electric sector works. The most recent plan for the development of the electric sector containing a forecast of electric energy demand and the planned capacity additions by fuel type to meet that demand.

SEDESOL - Secretaria de Desarrollo Social - The Secretary of Social Development. The organization that is presently charged with implementing the General Law of Ecological Balance and implementing and enforcing the regulations that follow from this law.

SEDUE - Secretaria de Desarrollo Urbano y Ecologia - Secretary of Ecology and Urban Development. The government organization responsible for ecology and environment until 1987 when the organization was replaced by SEDESOL.

SICARTSA - Siderúrgica Lázaro Cárdenas, S. A. - The public sector organization that owns the steel making facilities at Lázaro Cárdenas, Michoacán on Mexico's Pacific coast. The Spanish term siderurgia means siderurgy in English which is iron and steel metallurgy, hence, the name. This is the only public sector steel mill operating in Mexico today.

SIDERMEX - Siderúrgica Méxicana - A public sector enterprise which owned several coal mines and washing plants in the towns of Las Esperanzas, Palau and Barroteran. Operations of the company have been closed for some time.

TAMSA - Tubos de Acero, S. A. - An integrated private sector steel making company with its principal works in the city of Veracruz. This company also has interests in iron ore and pellet production and produces steel by the direct reduction process.

TPY - Tons Per Year - Measures quantity of product flow in English units; that is, a ton of 2,000 pounds.

USEPA - United States Environmental Protection Agency. The organization responsible for implementing and enforcing environmental regulations in the United States.

VAT - Value-added Tax - A tax levied on the increment to the value added at each stage of production and distribution from the raw material to the final product.

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