COAL IN MEXICO

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The object of this research is to undertake an analysis of the coal industry in Mexico as indicated in the title. This will include not only the extraction of coal but also its principle uses (coal-fired electricity generation with thermal quality coal and industry uses with coking quality coal). No research can overlook the politics of coal production and consumption, including coal imports and ecological results from the use of coal, the latter point pursued only as a first introductory attempt. An initial econometric analysis was attempted, though as of yet without adequate statistical significance.

Hypothesis: The relatively modest reserves and quality of coal in Mexico, considering present costs and technology, will determine increasing imports to satisfy demand at least for the needs of coal-fired thermal electric plants, and perhaps also for coking coal use in industry. In addition, apparently the problem of the ecological consequences of burning coal, though on the table of debate, still remains a secondary issue, as in many other countries, where energy security is the priority.

Contents:

A Simplified Classification of Grades of Coal[2].

From the lowest rank upward, including its heat potential in BTU's, coal is classified as lignite (together with brown coal, 7400 Btu), sub-bituminous (9,720 Btu), bituminous (12,800-15,160 Btu), super bituminous (15,360-15,480 Btu) and anthracite (14,440-14,880 Btu). Below the least developed grade of coal, lignite, is peat, which is not considered a coal but is the first stage in the formation of all coals. Bituminous coal is the most used and most desired coal throughout the world, chiefly for steam (production of electricity), heating, gas and coking. Anthracite, though smokeless and of high heating value, is quite restricted in distribution and magnitude of reserves.

The fuel rate, equal to fixed carbon per unit of volatile matter and the main feature determining the rank of coal, is high in anthracite and low in lignite. In addition, a sulfur content greater than 1.5% lowers the quality of coal, as also does a high ash content, which is the residual of non-combustible matter.

The Geological Ages of Coal Deposits:[3]

Coal is found in all post-Devonian periods, which itself is estimated to have ended about 354 million (M) years ago. The so-called Carboniferous (including the

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[2] Bateman, Alan M. Economic Mineral Deposits, 1955.

[3] See geologic time table: Hyne, Norman. Non-Technical Guide to Petroleum Exploration, Drilling, and Production, 2nd Ed., 2001.

Mississippian and Pennsylvanian periods) received its name because of its world-wide inclusion of coal formations. Beginning about 354M years in the past, the Carboniferous ended more or less 290M years ago, with the conclusion of the Pennsylvanian. The highest grade coals (bituminous and much lesser quantities of anthracite) on the North American continent, the Appalachian field of the eastern U.S., are mostly of Pennsylvanian age, although the Mississippian also contains good quality coal. The Age of Reptiles (Mesozoic Era), including three periods (from geologically oldest to youngest, Triassic, Jurassic and Cretaceous) contains coal bearing formations in various parts of the world. Of these periods, the Cretaceous (144M to 65M years ago) is next to the Carboniferous in importance. Finally, the Tertiary, a fairly recent period in the geological time scale (65 to 1.8M years ago) yields most of the world's lignite, which, as we saw, is of inferior quality. There are, however, some high-ranking Tertiary coals. Much of the coal found in the so-called Southwestern field of Texas is Tertiary lignite, though there are some bituminous seams of workable non-coking coal. The Sabinas field of Mexico, mostly located in Coahuila near the Texan border, is a geological extension of the Southwestern field.

Some International Data on World Estimated Recoverable Coal, Production, Exports and Imports by Country.[4]

Recoverable coal is less than the reserve estimates, particularly for underground mines using the room and pillar method of extraction. Longwall mining[5] underground is often more efficient. Surface open pit mines can sometimes reach recovery rates greater than 90% of estimated reserves. Of the world estimated recoverable coal total of 844,066 million metric tons (EIA, December, 2005), the estimate for Mexico is 1,211M metric tons, while that for the U.S. is 239,298M. The EIA (Energy Information Administration) covers all coal producing countries, but a few selected countries are included in Table 1. It is interesting to note that as of January 1, 2008, the EIA estimates a coal reserve base for the U.S. of 444 billion metric tons and recoverable reserves totaling over 238 billion, which results in an average recoverable rate of 54%.

Regarding production figures for 2007, four countries produce just under 70% of world hard coal and brown coal, the latter of minor importance in the production of these countries. China, the major producer (39.3%) is followed by the U.S. (16.2%) and then by India (7.5%) and Australia (6.1%). Other important coal producing countries are, in order of importance, Russia, South Africa, Indonesia, Poland, Kazakhstan and Colombia. The rest of the world only produced 13.6% of world hard and brown coal in 2007.

As for hard coal exports, Australia was number one in 2007 with 26.6% of the world total, followed by Indonesia (22.0%), Russia (10.9%) and Colombia (7.3%). Regarding imports in 2007, Japan with 20.4% was far ahead of second place Korea (9.9%). For more data, see Tables 2, 3 and 4.

Some International Figures on Electricity Production Using Fossil Fuels (Coal/Peat, Oil, Gas, 2006).

The 1973 world average coal share of electricity production was 38.3%, which by 2006 had risen significantly to 41.0 and is expected to reach 44% by 2015.[6] The EIA's

[4] EIA, World Estimated Recoverable Coal, December 31, 2005 (changed to metric tons).
[5] www.eia.doe.gov/cneaf/coal/page/coal_production_review.pdf
[6] ProspectivaSENER2008-2017.pdf, p. 35; original data from EIA.

growth estimate for coal-generated electricity is an astounding annual 4.2% for the 2005-2015 period. Of world coal generated electricity China was first among the top ten producers with 29.7% of electricity generated by this fuel, followed by the U.S whose share was 27.4%. My hypothesis contends that the energy security issue is of prime importance. In the case of the United States, coal will remain the principle source of its energy for electricity generation during the foreseeable future, although renewable energy resources should prove to be increasingly important also. In 2005 coal-fired electric plants accounted for 32.2% of total electricity generation capacity while producing just under 50% of total electricity in this country. China and India eclipse these figures for coal-sourced electricity production, with 77% and 74%, respectively. Other data of interest are found in Tables 5 and 6 and graphs.

Coal in Mexico.

The first known economic coal production in Mexico was initiated in 1884 near Sabinas Coahuila. Later, continued production on a small scale together with imports serviced the railroads and towards the latter years of the 19th century, coinciding with Porfirio Diaz's regime, the nascent metallurgical and steel industries, mostly located in northern Mexico, required increasing amounts of coal. Although the interest in coal suffered from the rapid development and production of oil in the early years of the 20th century, particularly affecting coal's use in electricity generation, it remained an indispensable input for steel and the mining-metallurgical industry. Nevertheless, even during the growth years 1902 to 1910, total production only summed a little over 10 million metric tons, and even in 1920, when Mexico's northern neighbor was extracting 600 Mt/year, Mexico was not able to surpass the 1.3Mt, it had produced in 1910.[7] Of course, the Revolution (1910-1917) caused an abrupt and ongoing decline in overall economic activity, as evidenced in the case of coal also by a total production of only about 4 million metric tons during the 1911 to 1921 period.[8] This stagnation was not much improved upon during the next two decades during which total production was about 12Mt, mostly of the coking variety.

Although traces of coal have been detected in numerous states, there are three locally important coal regions. The most important is the Sabinas basin and Fuentes-Río Escondido of north-central Coahuila including a small contiguous area of Nuevo León, covering approximately 12,000 km^2 mostly of the late Cretaceous Period and of the Eocene Epoch in the Tertiary Period.[9] The Sabinas basin (the source of mostly coking coal of lower ash content than thermal coal) and Fuentes-Río Escondido (mostly thermal coal) produce more than 90% of Mexican coal.[10] The next most important region, though vastly inferior, is found in the northwest portion of Oaxaca, where seams varying from a few centimeters to 3 meters are estimated to contain not much more than 30Mt (Corona,2006). The third field, located south of Hermosillo in Sonora and of Triassic age, is also of low estimated reserves (85Mt). The coal bearing Barranca

[7] Martin-Amouroux, Jean-Marie. Charbon, Les métamorphoses d'une industrie, Ëditions TECHNIP, Paris, 2008, Long Version, 2008. The figures are given in million metric tons.

[8] Corona-Esquivel, Rodolfo et al. Geología, estructura y composición de los principales yacimientos de carbón mineral en México. Boletín de la Sociedad Geológica Mexicana, Tomo LVIII, Núm. 1,2006. The figures are given in million metric tons.

[9] Querol, Francisco, Director General, Consejo de Recursos Minerales, Exploration and Coal Resources of Mexico. Summary in:GSA Abstracts, 2001. http://gsa.confex.com/gsa/2001AM/finalprogram/abstract_26383.htm

[10] Some authors do not refer to two separate basins, but only to the general name, Sabinas basin, which I will hereafter do.

formation in Sonora also contains graphite which is the ultimate pure carbon (element C) form of metamorphosed coal. Both the small Oaxacan and Sonoran deposits are in highly folded and faulted Triassic and Jurassic strata which make their exploitation difficult and costly, while the two economically exploitable coal seams in the Sabinas basin, varying from 1 to 2 meters in thickness and at first surface mined but now also by underground methods, produce a coal whose middle-range volatile matter content (20-25%) and fairly low sulfur content (1.2%) are acceptable, but whose high average ash content (23%) lowers the grading of this Sabinas coal (Martin,2008). All in all, it is not exaggerating to conclude with reputable estimates that Mexico has relatively low coal reserves (1.21Gt, 0.1% of World total), of which about 860 Mt are bituminous coal with minor quantities metamorphosed to anthracite and 350 Mt are sub-bituminous. Even more pessimistic are the resource estimates of 2Gt consisting also of much sub-bituminous coal not always of good quality in addition to inferior lignite whose current production is negligible. The proved reserves/production ratio at the end of 2007 was estimated to be about 99 years.[11] To put this into context, the U.S., with estimated reserves of 242.7Gt, had 28.6% of the world total in 2007. This country's 2007 reserve/production ratio was estimated at 234 years.

Nevertheless, after many decades of virtual stagnation or low growth, beginning in 1983 Mexican coal production increased significantly to 5.5Mt and, with minor fluctuations, reached 11.3Mt in 2000, after which it leveled off.[12] Of the 11.5Mt produced in 2006, 83% was sub-bituminous thermal coal destined for electricity plants and the rest, coking coal, mostly for the iron and steel industry. But even with the respectable increase of domestic production, the total amount was not enough to satisfy total demand, particularly for sub-bituminous coal demanded by the Comisión Federal de Electricidad (CFE), whose growing interest in coal-fired electricity plants apparently is due to a prudent skepticism regarding future Pemex oil and gas production (Martin,2008). For example, in 2006 national production of approximately 11.5Mt minus stock changes (-2.3Mt) was far short of satisfying demand (16.9Mt), thus requiring imports of 7.6Mt (See Table 8, domestic imports). The CFE absorbed 14.7 Mt of total supply (87%).[13] Undoubtedly, the country will have to import larger volumes to supply domestic demand, if production doesn't rise. Preliminary import figures for 2007 are estimated at 11.4Mt. Though potential reserves should be sufficient as far as volume is considered, the high investment required does limit production compared to total demand.

Of total Mexican electricity generation in 2006, coal was responsible for 12.7%, oil (21.6%) and gas (45.5%), giving a total participation of just about 80%.[14] Nevertheless, regarding the 51,029 MW of installed public service capacity, the electric generating plants using coal accounted for only 9.2% in 2007.[15] The coal-fired electric plant, José López Portillo (1200MW), at Río Escondido, Coahuila, launched in 1982, was followed by Carbón II (1,400MW) at the same location, both of which burn domestic and imported U.S. coal. Perhaps a part of the reason these two sites do not depend entirely on domestic Sabinas coal is that one of the power stations requires a higher grade of coal, so that the imported variety is blended with the too impure Sabinas variety. At least in 2004, the other plant only consumed imported coal. The author of this study

[11] BP Statistical Review of World Energy, June, 2008.
[12] EIA, World Coal Production, Oct., 17, 2008. Short tons converted to metric tons.
[13] IEA, Coal Statistics for Mexico, 2006.
[14] IEA, Electricity for México, 2006.
[15] ProspectivaSENER2008-2017.pdf, p. 16.

concludes that the high sulfur content of Mexican coal forces Mexico to be an importer of thermal coal, which contradicts a former opinion expressed in this paper that an average sulfur content of 1.2% is acceptable though not optimum.[16] The1993 inaugurated Petacalco, Guerrero dual fuel plant, Plutarco Elías Calles, though capable of burning either hydrocarbons or coal, for the above mentioned reason of supply security plus cost criteria preferentially chose to burn coal (4Mt/year of imports). Finally, a 651 MW capacity public financed thermal electricity plant based on coal at a Pacific coast site in Guerrero is expected to come on stream by 2010.[17]

There is a major difference regarding the demand forecasts for the use of coal in the electricity generating industry versus the iron and steel industry. To satisfy primary energy demand, total demand for coal is expected to grow at about 4.2% annually to 2030 in Mexico, while its chief competitor in the generation of electricity, natural gas, is forecasted to grow at a 3.3% annual rate. The expected increase in coal's share is largely due to the government's desire to diversify fuel usage in electricity generation and, thereby, reduce the country's high reliance on natural gas. Electricity generation is projected to be about 505 TWh by 2030, of which amount 59% will be provided by gas, 19% by coal, 10% by oil, 7% by hydro and 3% by nuclear plus renewable sources. However, industrial coal consumption decreased at 3.5% per year between 1990 and 2002, as a result of energy efficiency improvements in the iron and steel industry. This reduction of coal consumption is explained by a series of structural changes: the closing of inefficient open hearth furnaces by 1992; the increased introduction of continuous casting (from 10% in 1970 to 85% in 1996); the use of coke oven and blast furnace gases for on-site electricity generation, among other technological improvements. Furthermore, the Mexican iron and steel industry has a relatively high proportion of electric arc furnaces, providing about 60% of its crude steel production.[18]

During the early months of 2008, the international coal market was very tight. Initially relatively stable Australian thermal coal monthly export prices ranging from $US25/metric ton in 2001 Month 6 to $US29/t in 2003 M10, rapidly exploded to $US 98/t in 2008 M1 and a high of $US170 in 2008 M10. Although not as high, South African export prices followed a similar trend. The following January 18, 2008 CNN.EXPANSION.COM message expressed the urgency of the CFE to find an adequate supply for their coal based thermal plants. Obviously, domestic producers could not satisfy the CFE's needs. "Mexico's CFE urgently sought immediately deliverable coal for February and March after a failed tender process last year" (2007). Then, "on Friday, the state-owned CFE initiated a bidding process for 5.5 million tons of coal for delivery from March to December, (2008), according to operators and producers".
Needless to say, the market for Australian coal has softened with the present economic crisis, although its export price of $US73 for 2009 M2 is still historically robust. The average price of Mexican steam coal for 2007 was a significantly lower $US46/t, which goes to show that Mexican coal producers were unable or not contracted to fill the CFE's entire demand. Specifically, the Pacific coast CFE coal-fired electric generating plants probably find importing Australian thermal coal both cost competitive and

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[16] Barton, Barry. Energy Security, cited by Catherine Hedgwell et al, Google, May, 2004.
[17] Martin (2008) and CFE, "Datos técnicos de las principales centrales de CFE en operación en 2008"; "Proyectos de generación en proceso de construcción".
[18] APEC Energy Demand and Supply Outlook, 2006, www.ieej.jp/aperc/2006pdf/outlook2006//ER_Mexico.pdf

hopefully supply secure. Supplying Sabinas coal over the Sierra Madre Occidental to the coal-fired electric plants on the Pacific coast would surely be costlier per ton than importing from Australia or Indonesia. In July, 2003 a US$158 million dollar contract was awarded to Glencore International to supply 2.77Mt of Australia thermal coal through the port of Newcastle, which was the second time in 6 months that this world-wide, Swiss-based mineral commodity firm had won a contract issued by the CFE. The New South Wales Coal Industry reported that in 2006-2007 exports to Mexico were 5.6Mt. In March, 2008 the CFE confirmed a 4.17Mt supply contract for Petacalco with Ailia, a Mexico City company held by the Texas based International Commodity Consultants, which, in turn, was supplied thermal coal by a collective of Colombian producers. Ailia won the bidding with an offer of $US125/ton CIF, chiefly because it owns its own coal vessels, compared to BHP Billiton's $183, Macquarie's $193 and Glencore's $195.[19] Nevertheless, an internet note dated June 5, 2008 affirmed that the CFE temporarily shut down its Petacalco coal-fired plant in Guerrero due to a lack of coal supply. Interestingly, production for 2008 has been estimated at about 14.2Mt, all from the Sabinas basin, which appears surprisingly high to say the least.[20] Probably the estimation of 3Mt assigned to small producers was much too high. But even if the 14.2Mt turns out to be correct, it would still probably not have satisfied total demand in 2008. There was a short period in early 2009 when national producers cut off coal shipments to the CFE thermal electric plants at Nava, Coahuila, adducing that the prices paid by this state enterprise were far below prevalent international prices. A note in El Economista dated May 20, 2009 stated that the CFE had reached an agreement with the producers, in which this public monopoly will purchase up to 3.3 million domestic tons per year for three years at 827 pesos (62.31 dollars) per ton, renewable for another 3 years. The former paid price was 650 pesos/ton. Suffice it to say that in spite of the recent high and volatile coal prices, the Secretary of Energy (SENER) deems the use of coal for electricity generation an attractive proposition, mentioning that coal-fired power plants have the advantage of a mature though evolutionary technology. Furthermore, though Mexico, according to the SENER, does not possess large, cost competitive coal deposits, an increase in its use of coal for electricity generation would not present a serious problem since world coal reserves of good quality are enormous, so that a highly competitive world market normally will easily satisfy national demand. This increasing trend towards the consumption of coal for electricity generation is confirmed by the following news note.[21] The CFE plans to convert three oil-fired Tamaulipas thermal units to coal or coke. One, the 300MW Emilio Portes Gil thermoelectric plant at Río Bravo is slated to use coal or coke as feedstock. The CFE also launched a bidding process for the conversion of two units in its 800MW Altamira thermoelectric plant to supplant fuel-oil with coke. At the time, the reasoning was the high natural gas and fuel oil prices, which gave coal-fired plants a cost advantage. The CFE foresees that coal and coke prices will remain more or less at their current levels for the following two decades, while implicitly assuming that oil and natural gas prices will resume their long run upward trend.

The structure of Mexican mining changed profoundly with the 1961 mining code which in essence placed the control of capital in Mexican hands, the aptly named "Mexicanización", through purchase of international, mainly American, interests such

[19] Brenner, Catherine and Jim Marshall. Reuters, March 11, 2008.
[20] Alarcón Garza, Alejandro. Coalbed Methane Potential of México, Jan., 2009. www.methanetomarkets.org/events/2009/all/docs/-27jan09/techTransfer/coal/alarcon_012809.pdf
[21] Business News Americas, April, 6, 2009, through Google.

as the mining properties of Asarco (American Smelting and Refining Company). The 1975 mining code limited foreign interests to a maximum 34% of total capital in coal, as well as in sulfur among other essentially non-metallic mining products. In 1983, approximately 25% of coal production was controlled by government capital, the remaining 75% by private capital, mostly Mexican. Nevertheless, the new 1992 Mexican Mining Law, following a generally liberal international trend, now permits 100% control of coal mining properties (as well as sulfur, phosphate and other deposits) not only by private Mexican interests but also by foreign mining companies, subject to a standard, more facilitated concessionary process. One of two controlling share holders of Asarco[22], Grupo México, a world important copper producer with mines in Mexico (Cananea in Sonora among others) and in Peru is also an important owner of coal-mining properties, such as the sadly famous Pasta de Conchos mine in Coahuila, where 65 miners lost their lives in February, 2006, and are still entombed in the now abandoned mine. However, the most important coal producer in Mexico until recently was Mission Energy through the purchase of government owned Minera Carbonífera Río Escondido (MICARE), but this group apparently withdrew from most of its widespread international interests, including MICARE in 2004, which is now a 100% subsidiary of Altos Hornos de México (AHMSA), itself controlled by GAN (Grupo Acerero del Norte). Other important mining companies are Minera Monclova (MIMOSA), a 98% owned subsidiary of AHMSA and Carbonífera de San Patricio (a 100% private Mexican firm).[23] MICARE, basically a thermal coal producer, and MIMOSA, the principal producer of metallurgical coal, together produced about 82% of the nation's coal in 2007. Hidalgo Mining International (HMIT), headquartered in New York, with 300 Mt of coal reserves in northern Mexico, has been the object of a purchase offer by Consolidated Mining and Mineral (CMM).[24]

MIMOSA operated four underground mines and two open pit mines in 2007, while MICARE has one producing open pit mine and two underground mines. All are located in the Sabinas basin. MICARE's two underground mines employ the longwall (*frente largo*) method of extraction, which has proved so successful when geologic conditions are suitable. An idea of the importance of MIMOSA and MICARE in the context of the coal industry in Mexico is gleaned from the following simple table:

Concept (Million Metric Tons)	2003	2005	2007
MIMOSA Production of Metallurgical (Coking) Coal	1.56	1.50	2.12
MIMOSA-MICARE Production of Thermal Coal	6.38	6.49	7.91
Total Sales of Thermal Coal to CFE*	5.89	6.49	7.03

*Sales take into account direct sales, inventory adjustments, small purchases from third parties, and small sales to intermediaries who then sell to the CFE.

In 2003 MICARE contracted through an intermediary, Coahuila Industrial Minera (CIMSA), to provide the CFE with 68Mt of thermal coal within a minimum time frame of 5 years and maximum of 10. The contract price would depend upon the quality of the coal, inflation rates and exchange rate variations. This relatively long-term contract

[22] Grupo México and Asarco are now immersed in a litigation process in the Brownsville, Texas federal court pending a decision regarding Grupo México's controlling interest.
[23] AHMSA, Informe Financiero, 1st quarter, 2009; Torres Ivette, Mexico Country Specialist, USGS, 2005 report.
[24] Martin-Amouroux (2008), based on May 30, 2007 Business Wire announcement of Hidalgo Mining International in Google.

resulted in greater production rates as can be seen in the above table. Total production of MIMOSA and MICARE in 2007 was 10.03Mt out of a total Mexican output of about 12.2Mt, that is, slightly more than 82%. All sales of MIMOSA-MICARE thermal coal for 2007 serviced the CFE's José López Portillo and Carbón II coal-fired plants at Nava, Coahuila. However, only 77% of the JLP's needs were filled, while merely 54% of Carbón II's requirements were satisfied by MIMOSA-MICARE in 2007. The CFE is not tied to AHMSA's MICARE and MIMOSA, having access to numerous small local producers in the Sabinas basin and to international suppliers. If the state-owned CFE monopoly were to sever contractual relations with AHMSA, the company would be hard pressed to find a substitute outlet for its thermal coal. For example a rough estimate for 2008 shows small and medium producers located in the Sabinas basin with sales of 3.3Mt to the CFE's installations, though, as mentioned before, there is room for doubt regarding this high figure.[25] The CFE has indeed asked the small and medium-sized coal mines in Coahuila to increase production by 50% in 2009, though the effect of the economic crisis is yet to be seen. When prices on the European Energy Exchange threatened to soar to almost $US200/ton in August, 2008, and coal was selling for $US64/ton (slightly more than 650 pesos) in Coahuila, it's understandable why the Mexican government was clamoring for more Mexican coal.[26] AHMSA did respond to the challenge of increasing production not only of thermal coal for the CFE but also to meet most of its own growing needs of coking (metallurgical) coal. The company budgeted $US142.9 million of investment to MICARE (thermal coal) and $US143.7 to MIMOSA (coking coal) from 2002 to 2007. Though not huge sums, thermal coal production in MICARE increased from 5.1Mt in 2002 to 6.5Mt in 2007 and metallurgical coal output in MIMOSA rose from 1.7Mt to 2.1Mt during the same period. MICARE developed a new thermal coal underground mine and rehabilitated the Caterpillar heavy equipment at its open pit mine. MIMOSA came on stream with a new underground metallurgical coal mine in 2007. AHMSA deems its plentiful reserves of thermal coal to be more than enough to satisfy its contracts with the CFE, though in 2007 the company only fulfilled 87% of its own requirements of metallurgical coal and complemented its needs with foreign imports.[27]

Besides the oligopolistic structure of a few large coal mining enterprises (particularly, AHMSA's MIMOSA and MICARE), there are numerous, technologically backward, small miners mostly operating marginally in atrocious safety conditions, and, unsurprisingly, with very low productivity.[28] Though many small miners have operated on and off for more than a century in the Sabinas basin, in the latter months of 2006 sixty artisan mines were being worked, some rented out to businessmen by "ejidatarios" as a result of the government's elimination of restrictions on mining activities by "ejidos" during the 1990's, with the objective of both creating jobs and providing coal to the two huge power plants, Carbón I and II. The 58 mines apparently still working in 2008, by some given the name of "pocitos", averaged only 1,200 tons/month, and, as indicated, were notorious for serious accidents and deaths by occasional methane explosions and even flooding. As of September, 2008, apparently the Labor Secretary had only 5 safety inspectors assigned to the Sabinas area, who not only are charged with

[25] Alarcón Garza, op. cit.
[26] Rosenberg, Mike. Mexico's makeshift coal pits to boost output, Reuters, August 31, 2008.
[27] AHMSA, op. cit.
[28] Martín-Amouroux (2008). What follows has been taken (not verbatim) from this author's fascinating "Charbon, Les métamorphoses d'une industrie", subsection, "La relance des charbonnages du Coahuila au Mexique" and directly from Google.

inspecting the mines but also a multitude of factories, though these five inspectors were augmented by two more at a local office of the Geologic Survey of Mexico. According to Juan José López, project manager at the office, there has been significant progress in "pocito" safety standards during the last four years. He stated that the most dangerous mines have been closed or have made required changes, such as an alternative exit from the mine, basic ventilation systems when formerly none existed, and hand-held methane monitoring at the beginning of each work shift.[29] It should be mentioned, however, that the disaster fallen upon Grupo Mexico's Pasta de Conchos and that of Barroterán another large Sabinas basin coal mine where 153 miners died in 1969, show that coal mine dangers are all too present in Mexico's large, more modern mines also.

I translated the following paragraph from Martin-Amouroux (op. cit.) to pinpoint the situation which Mexican coal producers confront. "Is the Mexican coal production stagnation of around 11Mt since 2000 definitive? It's hardly probable, if one can believe the Energy Minister's declaration on January 11, 2008. A strong upsurge of oil prices, limited natural gas reserves, the will to keep electric prices low and preoccupation about energy supplies, all plead for a 60% increase of coal based thermal electric installations during the next decade. First of the 2,778MW to be constructed, the 700MW supercritical plant at Petacalco is to be built for the CFE by Mitsubishi Heavy Industries. This should be followed by another three of 700MW, one (Carboal II) at Lázaro Cárdenas port, the two others at Topolobambo, Sinaloa. But the CFE isn't the only one interested in coal thermal plants. In September 2008, Altos Hornos de México asked for authorization to build a 400MW fluid bed installation in Coahuila. What role will the Mexican coal industry play in supplying these new thermal plants which for the most part are geared towards the Pacific steam coal market? The reply will come from its competitiveness, thus from its organization."
As we saw in this paper, there have been efforts by Mexican producers to increase their coal output, but the most recent information seems to point to a continued need to import coal for the Pacific coast coal-fired plants and even steel producers such as AHMSA have not sourced all of their coal from domestic production.

Some Observations Regarding Coal and the Ecology
Coal being the most abundant fossil fuel, countries blessed with large reserves such as China and the United States are investigating liquefaction technology, while South Africa through its partially state-owned company, Sasol Ltd, for many years has employed the CTL (coal-to-liquids) process. Many industries in South Africa use liquefied coal. Sasol is even marketing its technology overseas.[30] Though the Fischer-Tropsch technology of converting coal to gas and then using the gas to make synthetic fuels has been known since the 1920s, the process of CTL is very expensive and, unfortunately highly pollutant. Ken Caldeira, a scientist at the Washington based Carnegie Institution estimated that burning liquefied coal emits 40% more CO_2 than oil.[31] Sasol says that future technologically-improved CTL plants can be built which trap and store greenhouse gas (GHG) underground. This optimism is shared by DKRW Advanced Fuels, a firm which is building a liquefied coal plant in the state of Wyoming.

[29] Sherman, Jerome. México's mine crisis: tiny coal mines escape inspections, Pittsburg Post Gazette, September 11, 2008, located by Google.
[30] Barta, Patrick. South Africa has a way to make oil from coal, The Wall Street Journal, August 17, 2008, found by Google.
[31] El Economista, Coal should be a warming concern, Dec. 18, 2008.

Certainly, the preoccupation of many countries, including Mexico's CFE and SENER, is to assure adequate sources of energy. This explains, for example, China's and the US's interest in CTL technologies. The perception of undue dependence on oil and natural gas is reinforced by figures of estimated years remaining of world reserves based on current production per year: oil, 41 years; natural gas, 60 years, while coal is abundant, 133 years of estimated reserves.[32] Mexico apparently has not envisioned the installation of CTL plants.

There are two coal mine methane (CMM) recovery projects in Mexico, both designed for active underground mines, one of which is now operational and uses the methane as an input for boiler fuel. The other proposed project contemplates using the methane for power generation.[33] The objective is to use the gas productively, better control the danger of coal mine explosions and reduce methane emissions into the atmosphere. The Mexican environment ministry's undersecretary for environmental norms estimated that approximately 2.14Mt CO_2e had been emitted into the air each year from the coal mines in the Sabinas basin,[34] A lower estimate for escaping methane emissions from solid fuels for 2002 was 1.39Mt CO_2e compared to 36.69Mt CO_2e from petroleum and natural gas, a far greater figure.[35] Nevertheless, the coal in Mexico generally has a high content of mostly methane gas. For example, MIMOSA estimates the coals in the Sabinas sub-basin contain 10 to 14m^3 per ton and that the total estimated gas resources in the upper Cretaceous coals of Coahuila are in the range of 1.2 to $2.2x10^{11}$ m^3.[36] It is estimated that MIMOSA's operating underground mines emit some 62Mm^3 yearly, all of which are vented into the atmosphere. However, the company in 2006 had plans for gas to be collected from underground in-seam boreholes which, combined with recovered gob gas, would be used to generate electricity in a 1-MW pilot project. According to AHMSA's 2007 annual report, MICARE had received a clean industry certification from the Procuraduría Federal de Protección Ambiental (PROFEPA) for two of its mines and MIMOSA had submitted the requisite paperwork for a clean industry certification. Grupo México also had a CMM/CBM (coal mine methane, coal bed methane) project under consideration for expanded degasification at its Pasta de Conchos mine, including plans for end-use options, before the methane explosion in February, 2006 which led to its closure.[37] The Pasta de Conchos CMM disaster also quickly led to a revision of the Mexican mining law on April 20, 2006. Where formerly the regulatory law emanating from Article 27 of the Constitution meant that coal mines could not legally sell CMM or use it to generate heat or electricity on site, since exploration, production, processing and sales of all hydrocarbons were the exclusive province of PEMEX, the amendments to the law now allow coal mines to recover and use CBM and CMM from their operations for self consumption or even their sale, though exclusively to PEMEX through a binding contract. Besides the objective of reducing the danger of methane gas explosions, another objective of the amendments is

[32] BP Statistical Review of World Energy, June, 2008.
[33] Torres Flores, Ramón, General Director for Energy and Mining, Mexican Secretariat of the Environment and Natural Resources. "Methane to Market Partnership (M2M), Recovery and Use of Methane Associated with Mexican Coal Mines", April 3, 2007.
[34] Bremer, Catherine. Mexico pushes law to help rid mines of toxic gas, Reuters, 2006. www. Redorbit.com/news/science/419391/mexico_pushes_law_to_help_rid_mines_of_toxic_gas/
[35] Third Mexican Government Communication within the United Nations Framework Convention on Climate Change (UNFCCC), Nov. 6, 2006.
[36] Santillán Gonzalez, Mario, Minerales Monclova (MIMOSA), 2006.
[37] U.S Environmental Protection Agency, Coalbed Methane Outreach Program, International Activities, Mexico, April 2005. www.epa.gov/cmop/intl/mexico.html

to aid in the elimination of methane venting from the mines. Finally it can be said that the economic utilization of CMM is probably limited to the coal mine operations themselves and to local electricity generation. CMM and CBM for power generation could become commercially competitive with natural gas or even coal if the prices for these latter commodities were to rise to high levels, but, as mentioned, market access for mine methane is limited by the legal requirement of its sale to PEMEX.

It is worthwhile mentioning that in the United States where more than 600 coal-fired power plants still produce about half of this country's electricity and, in addition, will continue to generate about 47% in 2030 according to the Energy Information Administration, 97 new coal-fired projects have been cancelled since 2001, including nine this year. These nine coal plants would have produced about 6,650MW of power, or sufficient heat for about 5 million homes. The cancellations of these planned coal plants are the result of pressures from environmental groups which, in turn have spurred political action by several state legislatures and, now, by the federal government under President Obama's tutelage, who has pledged to reduce greenhouse gas emissions by 80% by 2050. Several utility companies, feeling the political heat, have taken the initiative to cancel or postpone their plans for new coal-fired coal plants and proceed with a natural gas alternative and invest in renewable energy sources such as wind farms. It's important to recognize that renewable resources cannot as yet replace coal as power producers, which is why there is simultaneously great effort to use cleaner technology and probably introduce carbon-trading schemes.[38]

Table 1
World Estimated Recoverable Coal, by Selected Countries (December 31, 2005)
(Million Metric Tons*)

Country	**Anthracite and Bituminous**	**Lignite and Sub-bituminous**	**Total**	**% of World**
Mexico	860	351	1,211	0.1
United States	110,677	128,621	239,298	28.4
Colombia	6,578	381	6,959	0.8
Kazakhstan	28,170	3,130	31,300	3.7
Russia	49,088	107,922	157,010	18.6
South Africa	48,000		48,000	5.7
Australia	37,100	39,500	76,600	9.1
China	62,200	52,300	114,500	13.6
India	52,240	4,258	56,498	6.7
Rest of World			112,260	13.3
World Total	429,313	414,753	844,066	100.0

EIA (Energy Information Administration)
*Short tons converted to metric tons.

[38] The Economist, Coal-fired power plants, the writing on the wall, May 9th, 2009.

Table 2 Hard and Brown Coal Production by Country 2007 (million metric tons)

Producers	Hard and Brown Coal (Mt)	Percentage %
China	2549	39.3
United States	1052	16.2
India	485	7.5
Australia	395	6.1
South Africa	244	3.8
Russia	313	4.8
Indonesia	259	4.0
Poland	148	2.2
Kazakhstan	86	1.3
Colombia	72	1.1
Rest of World	885	13.6
World	6488	100.0

International Energy Agency (IEA), Key World Energy Statistics, 2008

Table 3 Hard Coal Exports by Country 2007

Exporters	**Hard Coal (Mt)**	**Percentage %**
Australia	244	26.6
Indonesia	202	22.0
Russia	100	10.9
Colombia	67	7.3
South Africa	67	7.3
China	54	5.9
United States	53	5.8
Canada	30	3.3
Vietnam	30	3.3
Kazakhstan	23	2.5
Rest of World	47	5.1
World	917	100.0

IEA, 2008

Table 4 Hard Coal Imports by Country 2007

Importers	**Hard Coal (Mt)**	**Percentage %**
Japan	182	20.4
Korea	88	9.9
Taiwan	69	7.8
India	54	6.0
United Kingdom	50	5.6
China	48	5.4
Germany	46	5.2
United States	33	3.7
Italy	25	2.8
Spain	24	2.7
Rest of World	273	30.6
World	892	100.0

IEA, 2008 (million metric tons)

Table 5 **Selected World Primary Energy Supply**

Most Important 1973 and 2006 Fuel Shares		
Fuel	1973	2006
Coal/Peat	24.5%	26.0%
Oil	46.1	34.4
Gas	16.0	20.5
Total	86.6%	80.9%

Table 6 **Electricity Production from Fossil Fuels (2006)**

Coal/Peat	%	Oil	%	Gas	%
China	29.7	Japan	11.0	United States	22.0
United States	27.4	Saudi Arabia	8.6	Russia	12.0
India	6.6	United States	7.4	Japan	6.7
Germany	3.9	Mexico	4.9	Italy	4.1
Japan	3.9	China	4.7	Iran	3.9
South Africa	3.0	Italy	4.2	United Kingdom	3.2
Australia	2.6	Indonesia	3.6	Mexico	3.0
Russia	2.3	Iran	3.2	Thailand	2.5
Korea	2.0	Kuwait	3.2	Spain	2.4
United Kingdom	2.0	India	2.8	Saudi Arabia	2.3
Rest of World	16.7	Rest of World	46.4	Rest of World	37.4
World	100.0	World	100.0	World	100.0

IEA, 2008

Table 7 **Coal Production Mexico (Million Metric Tons), 1981-2007**

1981	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**
3.0	3.7	4.6	5.1	5.2	5.6	6.2	5.6	6.0
1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
6.9	6.5	6.1	6.6	8.9	9.3	10.3	10.4	11.2
1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
10.3	11.3	11.3	**11.1**	**9.6**	**9.9**	**10.8**	**11.5**	**12.2**

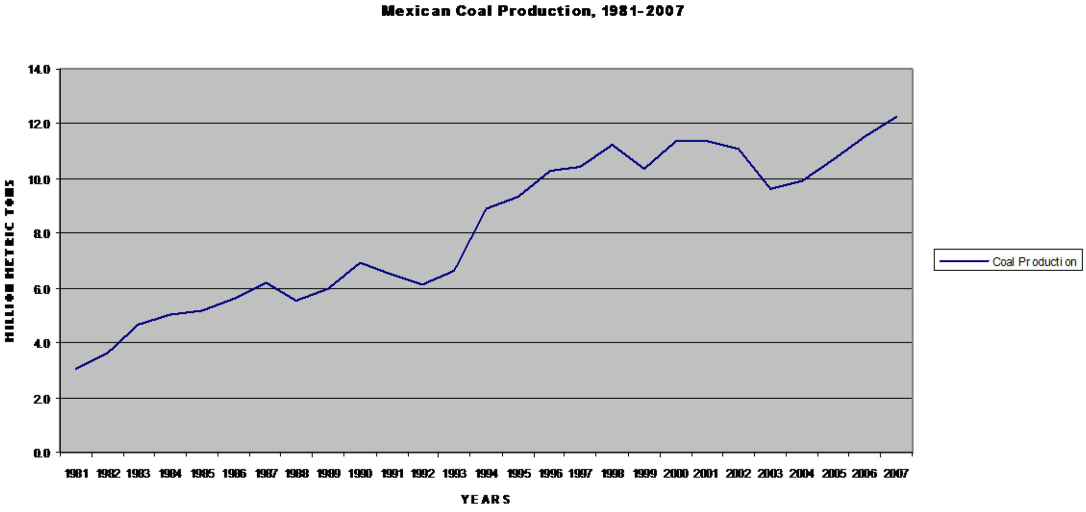


Table 8 Coal Imports Mexico (Million Metric Tons), 1999-2007

1999	2000	2001	2002	2003	2004	2005	2006	2007
4.0	2.432	3.439	5.894	7.233	4.089	7.259	7.619	11.37(p)

(p) preliminary
www.coalportal.com/production_trade_data.cfm?data_type=Import

Table 9
Production of Primary Energy (in terms of petajoules) in Mexico, 2007

Concept	Percentage, %
Total	100.0
Coal	2.4
Hydrocarbons	90.0
Crude Petroleum	65.8
Condensates	1.0
Natural Gas	23.2
Primary Electricity	4.4
Nuclear Energy	1.1
Hydro Energy	2.5
Geothermal Energy	0.7
Wind Energy	n.s
Biomass	3.3
Sugar Cane	0.9
Wood	2.3

Source: SENER
n.s: not significant

GEOLOGICAL TIME SCALE

Era	Period	Epoch	Absolute Age (years)
--------------------------	-----------------	-------------	0
		Holocene	
	Quaternary	-------------	10 thousand
		Pleistocene	
Cenozoic -------------	-----------------	-------------	1.8 million
(age of mammals)		Pliocene	
		-------------	5.3 million
		Miocene	
	Tertiary	-------------	24 million
		Oligocene	
		-------------	34 million
		Eocene	
		-------------	55 million
		Paleocene	
(The great killing)	-----------------	-------------	65 million
	Cretaceous		
	-----------------	-------------	144 million
Mesozoic	Jurassic		
(age of reptiles)	-----------------	-------------	206 million
	Triassic		
(The great extinction)	-----------------	-------------	248 million
	Permian		
	-----------------	-------------	290 million
	Pennsylvanian		
	-----------------	-------------	323 million
	Mississippian		
Paleozoic	-----------------	-------------	354 million
	Devonian		
	-----------------	-------------	417 million
	Silurian		
	-----------------	-------------	443 million
	Ordovician		
	-----------------	-------------	490 million
	Cambrian		
--------------------------	-----------------	-------------	543 million
Precambrian			
--------------------------	-----------------	-------------	4.5 billion

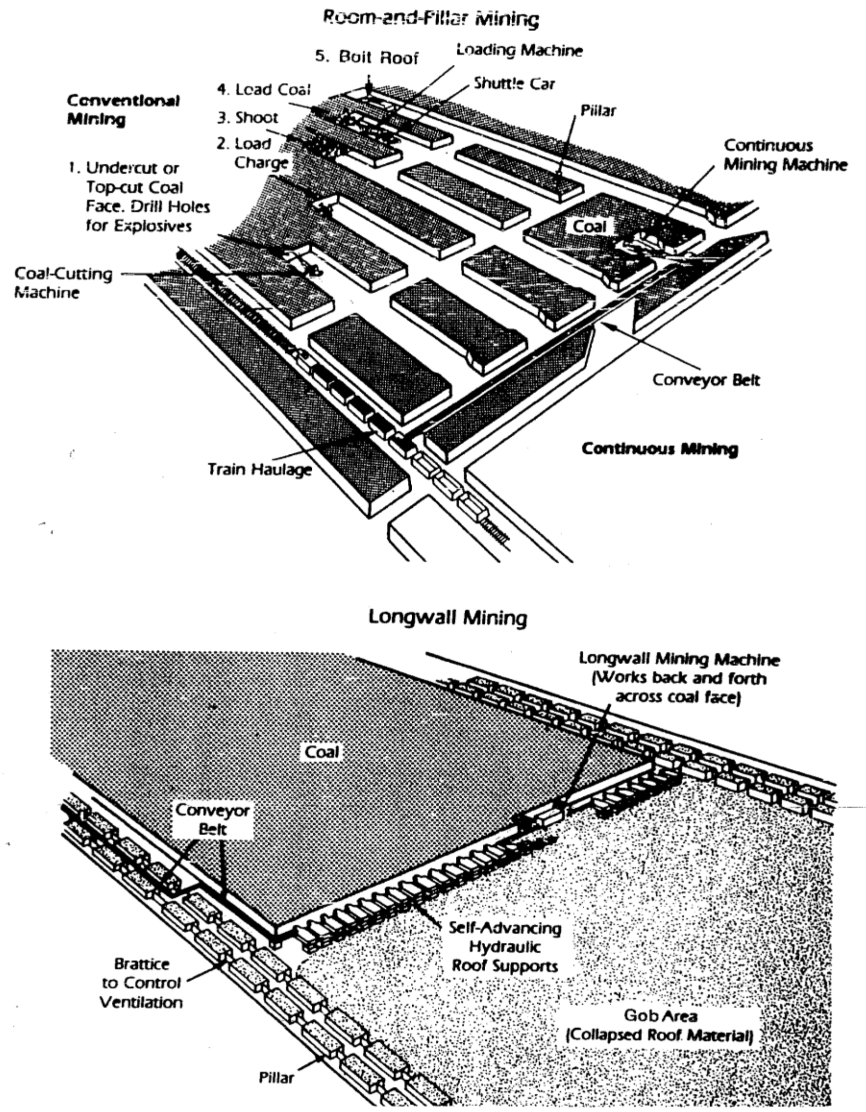
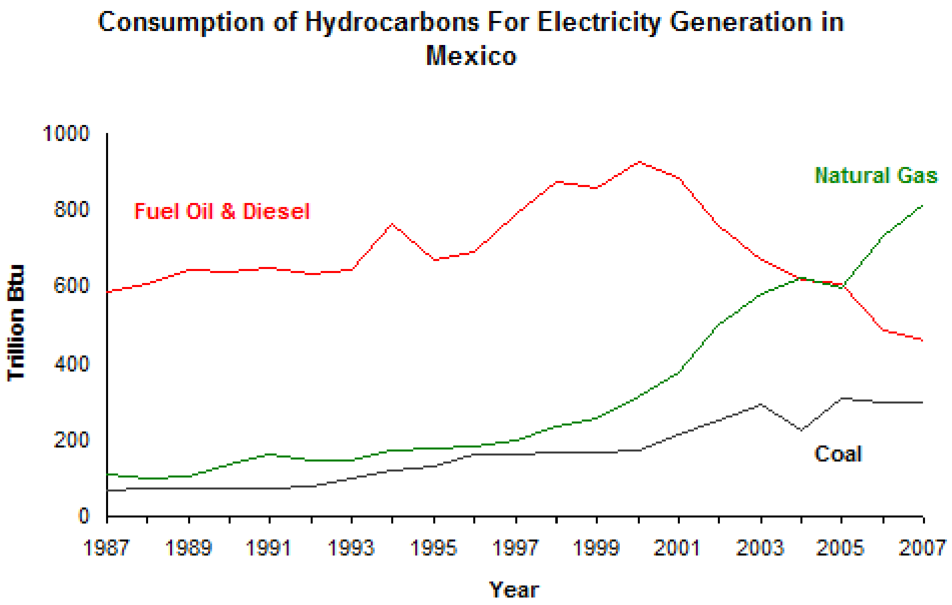
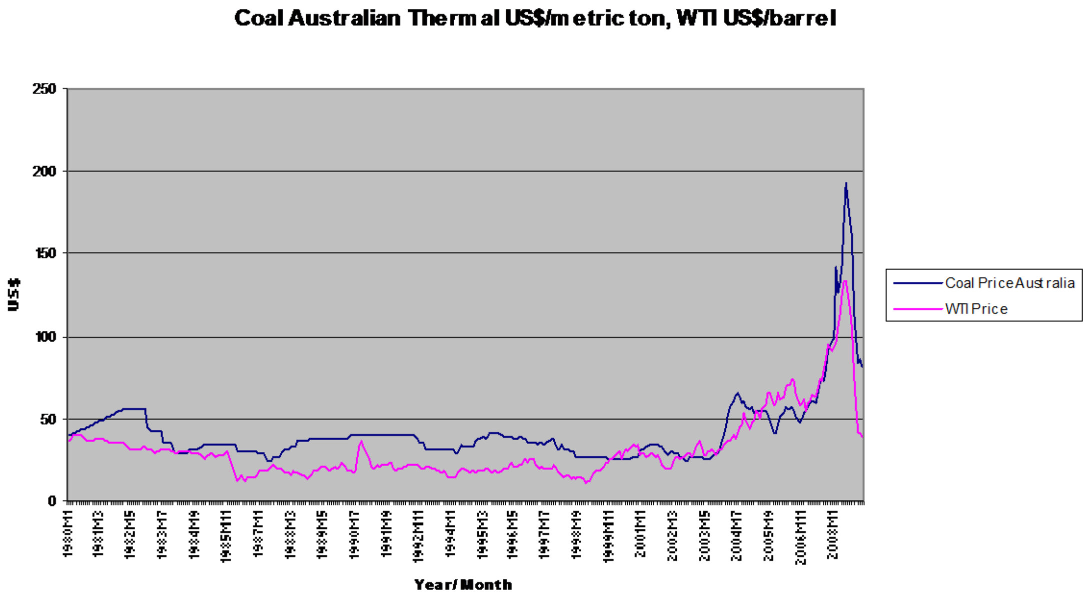


Figure 2-3. Underground Mining Systems.

Source: EIA 1995b, 4.



Source: Sener Balance Nacional de Energia

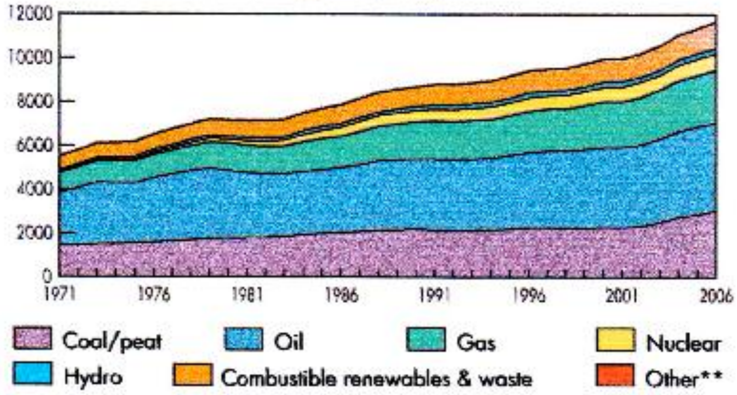


SUPPLY

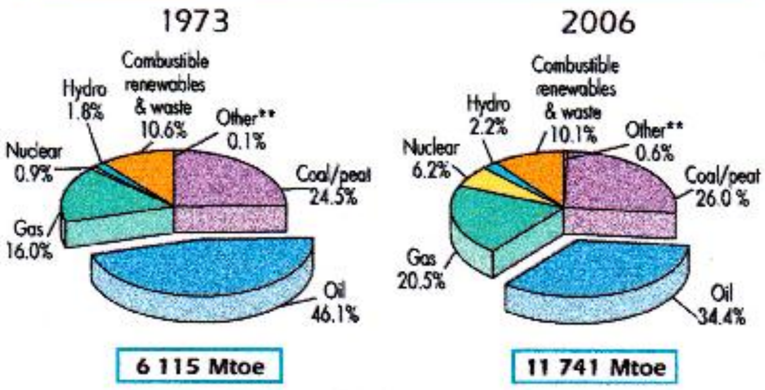
TOTAL PRIMARY ENERGY SUPPLY

World

Evolution from 1971 to 2006 of world total primary energy supply* by fuel (Mtoe)



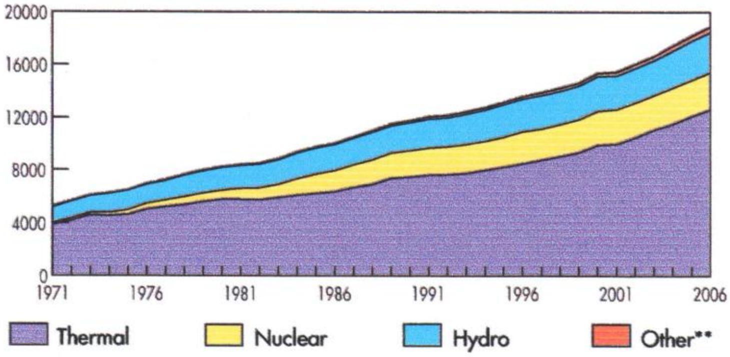
1973 and 2006 fuel shares of TPES*



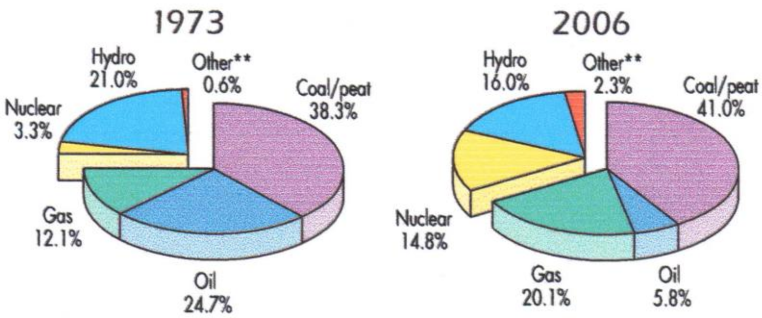
*Excludes electricity trade.
**Other includes geothermal, solar, wind, heat, etc.

Electricity Generation* by Fuel

Evolution from 1971 to 2006 of world electricity generation* by fuel (TWh)



1973 and 2006 fuel shares of electricity generation*



6 116 TWh

18 930 TWh

*Excludes pumped storage.

**Other includes geothermal, solar, wind, combustible renewables & waste, and heat.