Production, Use, and Upgrading of Natural Gas in Argentina

by Carlos R. Apesteguía

This work briefly reviews the economic, energetic, industrial, and environmental roles that natural gas plays nowadays in Argentina. The evolution of natural gas production and consumption in Argentina over the last decades is analyzed and compared with other Latinamerican countries. The use of natural gas as ground transportation fuel is presented, taken into account that about 7% of the Argentine vehicle fleet are composed of natural gas fueled vehicles. The role of catalytic technologies for transforming natural gas into cleaner fuels and valuable chemicals is also discussed.

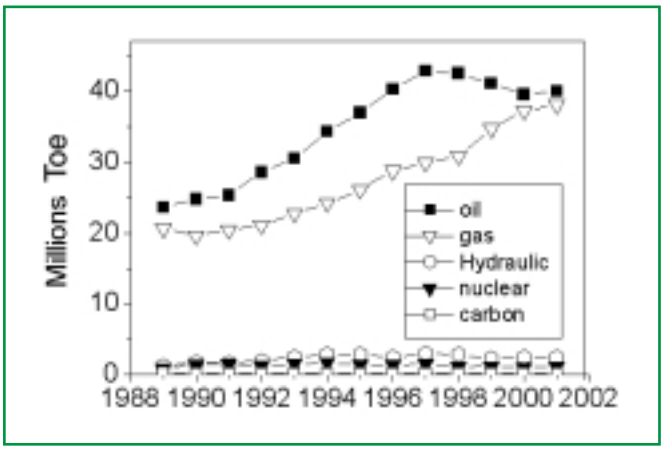

Figure 1 - Primary energy production in Argentina

Natural gas (NG) is the fastest growing primary energy source in the experts forecast [1]. Because it is a cleaner fuel than oil or coal and not as controversial as nuclear power, natural gas is expected to be the fuel of choice for many countries in the future. In particular, Argentina is rapidly developing into a major energy producer and exporter. The natural gas sector in Argentina underwent a profound change at the end of the 1980s as a result of regulatory and structural reforms. These reform measures were critical to achieve national economic restructuring, improve economic efficiency, and increase investment. Natural gas is today Argentina's most important energy source, and the country has the second largest proven reserves of natural gas in South America, after Venezuela. Consumption of natural gas reached 1,191 billion cubic feet in 1999 that accounts for about 46% of total energy consumption in the country.

Natural gas is substituting liquid fuels for electricity generation and ground transportation as well as industrial, residential, and commercial consumers. With more than 6 millions of consumers, the argentine NG market is still expected to increase rapidly in the coming decade. Because seven gas pipelines connect Argentina to Chile, Brazil, and Uruguay, the country has great potential to further increase energy exports throughout the region. This work presents data on NG production, reserves, and consumption in Argentina. The use of natural gas as ground transportation fuel and the research work that is currently carried out in Argentina on catalytic processes for converting natural gas to liquid fuels and chemicals are specially discussed.

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Energy production and consumption in Argentina

Figure 1 shows the evolution of the primary energy production in Argentina during the period 1989-2001. In 2001, oil accounted for nearly the half (48.5%) of Argentina's primary energy supply. Natural gas production was 38.1 millions tons of oil equivalents (MToe), accounting for about 46.5% [2]. This NG percentage is significantly higher compared to those of other Latinamerican countries (in Brazil, natural gas represents only about 4% of the primary energy production), Usa (27%), European countries (England, 33%; Germany, 22%), and the world NG fuel share (20.7%). Hydroelectric power is responsible for 3.4%, while nuclear power makes up 1.4% of the country's total energy supply. Argentina, with around 3.1 billion barrels of proven oil reserves, is a significant player in Latin American oil markets. The country produced in 2001 an average of 780,000 oil barrels per day (b/d) that represents approximately 13% of Latin American hydrocarbon production. It is the fourth-largest oil producer in Latin America, behind Venezuela, Mexico, and Brazil. Argentina's oil production increased rapidly throughout the 1990s, allowing net exports to grow from negligible levels in the 1980s to exceed 400,000 b/d in the late 1990s. Coal production and usage in Argentina is very modest. With only 77 MToe of coal reserves, the country produced 0.198 MToe bituminous coal. There is a small coal field at Río Turbio in southern Patagonia. The average gross heat content of Argentina's coal is approximately 25 kJ per kg. Since 1990, total energy consumption in Argentina has risen more than 60% from 51.40 MToe in 1990 to 86.43 MToe in 1999. Natural gas accounts for nearly 46% of Argentina's total energy consumption, followed by oil (38.4%), hydroelectric power (9.3%), nuclear (3.0%), and coal (1.5%). The country was the region's third-largest oil consumer, after

Figure 2 - Evolution of gas natural exports and imports

Mexico and Brazil, and also the third-largest exporter, behind Venezuela and Mexico. Exports go primarily to Chile, Brazil, Uruguay and Paraguay, with small amounts also bound for the U.S. Gulf coast. Argentina consumed 0.91 MToe of coal in 1999. Regarding the electricity sector, Argentina relies mostly on hydropower and natural gas to fuel its. Argentina has the third-largest power market in Latin America, behind Brazil and Mexico. In 2000, the country had 24.2 gigawatts of installed generation capacity, of which about 55% was fossil fuel-based (primarily natural gas), 40% hydroelectric, and about 4% nuclear [3]. Electric generation in 2000, which totaled 81.1 gigawatthours, was 60% thermal, 31% hydropower, and 9% nuclear. Consumption of natural gas for electricity generation was about 11,000 millions of m^3 in 2000. Argentina has developed a large amount of hydroelectric power generation because operating costs and pollution are low, but electricity from hydroelectric sources has been declining in recent years in favor of natural gas. In general, countries of Central and South America are expanding gas-fired electricity generation capacity at a rapid pace in an effort to diversify electricity sources. Hydroelectricity and other renewable resources accounted for 77% of the energy consumed for electricity generation in Central and South America in 1996; by 2020 the share is projected to fall to 53% because of expanded natural gas use.

Natural gas

Argentina has the third largest proven reserves of natural gas in Latin America, after Venezuela and Mexico, accounting for 10.7% of Latin America's proven reserves of natural gas. As of January 2000, proven gas reserves in Argentina were estimated at 24.3 trillion cubic feet (Tcf) and probable reserves are much higher. Argentina is the region's second-largest gas producer (Mexico is the largest producer) and consumption of natural gas reached 1,191 billion cubic feet (Bcf) in 1999. The largest producing basins are Neuquén, Austral, and Noroeste, with the Neuquén basin alone accounting for about 60% of Argentine gas production. Production in the Austral basin is constrained by the capacity of its pipeline to Buenos Aires. Supply of Argentine gas currently exceeds combined domestic and export demand, although demand is expected to increase rapidly in the coming decade. Argentina's natural gas industry (production, transportation, distribution, and marketing) is in the hands of the private sector and is operated within a competitive market structure. The natural gas industry was privatized in June of 1992. The Gas Law split state monopoly Gas del Estado into eight distributors (MetroGas, Gas Natural, Pampeana, Litoral, Sur, Centro, Cuyana, and Noroeste) and two pipeline companies (Transportadora de Gas del Sur SA (TGS) and Transportadora de Gas del Norte SA (TGN)). TGS delivers two-thirds of the country's natural gas, serving southern Argentina and Buenos Aires. Argentina's largest gas distributor is Metrogas.

Gas pipelines

Until 1997 the NG imports were higher than exports in Argentina. But from 1997 to 2000 net natural gas exports increased from 685 to 4890 millions of m^3, which represented about 10% of the total gas natural production in 2000 (Figure 2). This reflects not only the exports increase to Chile, Brazil, and Uruguay but also the drastic diminution of imports from Bolivia. More than US$ 1,300 millions were invested between 1996 to 2000 to built the seven exportation gas pipelines that exist currently in Argentina (Figure 3): five to Chile (Norandino, Gas Atacama, Gas Andes, Gas Pacífico and Metanex), one to Uruguay (Entrerriano) and one to Brazil (Transportadora de Gas del Mercosur). Between 1997 and 2000 gas pipeline exports represented more than US$ 1,000 millions. Chile is the largest export customer for Argentine gas, with significant exports starting in 1997. The Neuquén basin is the source for all four Argentina-Chile pipelines. The Gas Andes pipeline in central Chile has been in operation since 1997. The Gasoducto del Pacifico opened in November 1999, transporting 140 million cubic feet per day (Mmcf/d) over 530 kilometers to the Bio Bio region in southern Chile. The other two Argentine-Chilean pipelines run parallel to each other and supply a market that does not fully utilize the pipelines' capacities. The Gas Atacama pipeline, with a 300-Mmcf/d capacity, came onstream in July 1999. The NorAndino pipeline has a capacity of just over 280 Mmcf/d and came onstream in November 1999. It supplies two power plants. One Argentina-Brazil pipeline has come onstream. This pipeline of 440 km and 88 Mcf/d connects Paraná, Argentina, to Uruguaiana, Brazil. It provides gas to a 500-megawatt AES power plant in Uruguaiana. Service began in early July 2000. Plans to extend the pipeline to Porto Alegre, Brazil, currently are under construction and are slated to be complete in 2002. Additional Argenti-

Figure 3 - Gas pipelines: 1) Norandino, 2) Gas Atacama, 3) Gas Andes, 4) Gas Pacífico, 5) Metanex, 6) Entrerriano, 7) Transportador de Gas del Mercosur

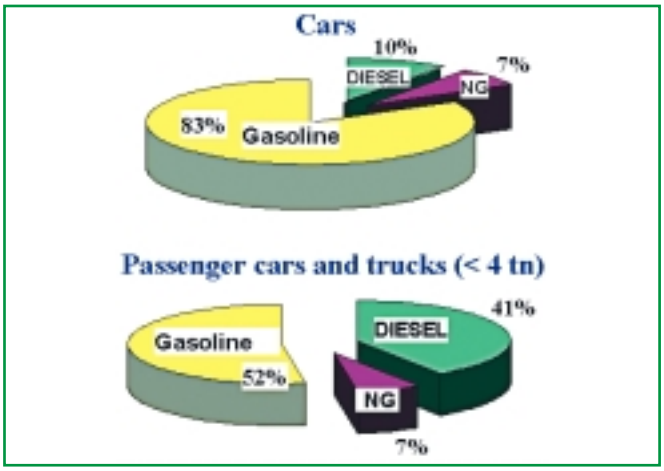

Figure 4 - Vehicle fleet distribution

na-Brazil pipelines are in various stages of the planning process.
Argentina has great potential to further increase energy exports throughout the region. The four pipelines connecting Argentina and Chile are still underutilized, awaiting a Chilean demand increase. Pipelines under development to Brazil will allow further exports from Argentina.
Likewise, Uruguay wants to diversify its energy mix, which is heavily dependent on hydroelectric power, by importing gas from Argentina.

Use of natural gas for ground transportation

Natural gas is an economical and cleaner alternative fuel. Its high hydrogen to carbon ratio results in the lowest (after pure hydrogen) CO_2 emissions per unit of energy produced. NG fueled engines are growing in popularity because of their clean burning characteristics and lower toxic emissions (CO, NO_x, particulates) relative to diesel and gasoline. In particular, CO_2 car emissions are 20-25% lower for natural gas compared to gasoline. Moreover, methane is a relatively unreactive hydrocarbon and does not participate in photochemical smog generating reactions. The table compares the engine emissions when fueled by gasoline, diesel, or natural gas for cars and heavy vehicles, respectively. The abundance of natural gas as well as the economical and environmental advantages of using NG compared to liquid fuels, motivated the argentine government for developing a ground transportation program to convert to NG a part of the national vehicle fleet. The program was conceived at the beginning of the 80s with the objective of converting in 10 years 134,000 vehicles fueled by gasoline or diesel. Specifically, the program addressed to substitute about two MToe for natural gas using dual NG-fuel technology. The massive use of NG in ground transportation started in Argentina in 1985. In general, the conversion program was successful and in ten years, in 1995, 340,000 vehicles, predominantly gasoline cars, were converted to natural gas, substituting 1.3 MToe. Nowadays, more than 500,000 vehicles are NG fueled in Argentina, and 850 NG stations have been installed. In the case of cars, passengers cars, and trucks (<4 tons), the NG fueled vehicles represent about 7% of the vehicle fleet (Figure 4) but for buses and heavy trucks (>4 tons) the proportion is only 0.5%.

Catalytic technologies for converting natural gas to clean fuels and chemicals

Natural gas is a readily available, inexpensive feedstock that can be converted to clean burning liquid fuels and chemicals. However, methane is thermodynamically one of most stable hydrocarbon so that its selective conversion to more useful organic chemicals is difficult. Natural gas conversion is the basis of a moderately sized, predominantly chemical business whose primary products are ammonia and methanol. This industry represents only about 5% of the global annual gas consumption [4]. A major focus of NG conversion R&D over the last few decades have been the manufacture of clean liquid fuels, fuel additives, and economical chemical feedstocks but also for the use of NG in fuel cells applications and in olefin industry. Figure 5 shows the multiple products that are produced from natural gas as the only hydrocarbon feedstock. Conversion of natural gas to liquids is normally referred as “Gas to Liquids” or GTL processes. The GTL technology proceeds in two stages, conversion to syngas ($CO+H_2$) followed by a syngas upgrading step such as Fischer-Tropsch, methanol synthesis, ammonia synthesis etc. GTL processes produce clean fuels. Natural gas derived fuels contain no sulfur or polynuclear aromatics (soot precursors) and produce less CO_2 than petroleum. Most of the natural gas derived products of Figure 5 are produced via catalytic processes. In Argentina, a considerable research potential in catalysis has been formed. In the academy, there are a number of active research groups working in the field of catalysis at Incape (University of Litoral, Santa Fe), Cindeca (University of La

Table - Automobile emissions

a) Cars (emissions in % relative to gasoline)

Fuel	*NO_x*	*CO*	*Hydrocarbons*	*Particulates*	*CO_2*
Gasoline	100	100	100	~0	100
	(0.2-0.4 g/km)	(2.1-6.0 g/km)	(0.1-0.8 g/km)		(181-256 g/km)
Diesel	305	20	57	100	77
				(0.2 g/km)	
Natural gas	67-100	23-25	75-129	~0	68-83

b) Heavy vehicles (emissions in % relative to diesel)

Fuel	*NO_x*	*CO*	*Hydrocarbons*	*Particulates*	*CO_2*
Diesel	100	100	100	100	100
	(14.1-16 g/km)	(0.5-4.3 g/km)	(0.4-0.5 g/km)	(1.1 g/km)	(880-1,200 g/km)
LPG	20-25	200-500	200-209	24	98-100
Natural gas	15-34	100-620	150-640	15	87-103

Source: Organisation for Economic Cooperation and Development (OECD), Automotive Fuels Information Service (AFIS). 1999

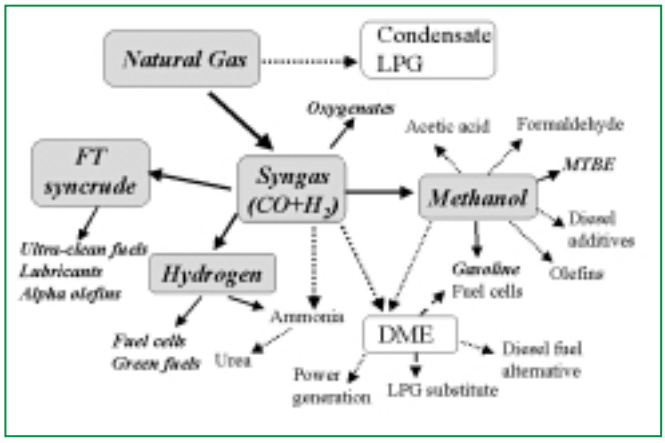

Figure 5 - Natural gas derived products. In grey and italics are noted the catalytic processes which are currently investigated by academia research groups in Argentina

Plata), Intequi (University of San Luis), Iniqui (University of Salta), Plapiqui (University of Bahia Blanca), Intema (University of Mar del Plata), Citeq (Technological University of Cordoba), Department of Chemical Engineering of the University of Buenos Aires. The basic research is directed to a wide range of problems of essential importance for the development of the catalytic science. Intensive applied studies are also being carried out. The technological and research activities in catalysis in Argentina, as well as the international cooperation and the formation of human resources are promoted and coordinated by the National Committee of Catalysis (Conaca). Conaca was founded by Conicet (Consejo Nacional de Investigaciones Científicas y Técnicas) in 1972 and has a membership over different units on professional catalytic researchers from National Universities, research Institutes from CONICET and industrial R&D centers. CONACA is also responsible for the biannual organization of the Argentine Congress on Catalysis, which congregates more than 200 scientists and researchers in catalysis from the academy and the industry.

Figure 5 shows the different catalytic processes, which are currently investigated in Argentina for obtaining NG derived products. The methane transformation into liquid aromatic hydrocarbons by activation with ethane was studied on Zn-ZSM-11 zeolites [5]. Methane reforming with CO_2 (dry reforming) to produce syngas with low H_2/CO ratios has attracted interest due to environmental and industrial advantages over the conventional steam reforming. Different supported catalysts based on Pt [6] or Ni [7] were used for syngas via reforming with CO_2. CO_2 reforming of methane may be also used for obtaining high-purity hydrogen for fuel cells, but CH_4 conversion is limited by the reaction reversibility. The use of membrane reactors has been widely studied lately to overcome this thermodynamic constraint. In general, development of cost effective membrane-based reactors is of considerable interest for applications in advanced fossil-based power and fuel technologies. Zirconia-supported Ni-Rh catalysts were prepared on a dense membrane made from Pd and tested for dry reforming of methane [8]. The water gas shift (WGS) process is mostly used in the production of hydrogen via the steam reforming of methane and is of importance for future energy technologies. The activity, reaction mechanism, and structure-sensitivity of the WGS reaction were studied over Cu-Zn-Al mixed oxide catalysts [9]. Regarding methanol synthesis from CO_2/H_2, it was investigated the enhancement of the catalytic performance by gallium or calcium addition to palladium/silica catalysts [10]. Methanol is regarded as the natural liquid vector for methane. It may be used as feedstock for chemicals (methanol-based chemistry) or gasoline synthesis (MTG process), fuel for transportation, and intermediate for production of fuel additives such as methyl *t*-butyl ether (MTBE). The reactions involved in MTG process were studied on amorphous silica-aluminas [11]. On the other hand, the deactivation of sulfonic resins by different poisons was detailed investigated for commercial MTBE synthesis from methanol and isobutylene [12]. Conversion of synthesis gas to heavy alkanes, known as the Fischer-Tropsch (FT) synthesis, is a key step in the chemical liquefaction of natural gas. Highly selective Fe/zeolite-L catalysts were prepared, characterized, and tested for the FT reaction under different process conditions [13]. Obtention of oxygenates (alcohols, ethers, aldehydes) from synthesis gas is an attractive route for obtaining valuable chemicals. Bimetallic Cu-Co/$ZnAl_2O_4$ catalysts were employed for obtaining linear C_2-C_6 alcohols [14] whereas $Cu_zMg_yCeO_x$ catalysts were found to be active and selective for the synthesis of isobutanol and other branched alcohols from H_2-CO [15].

Conclusions

Production of natural gas is rapidly expanding not only in Argentina but also in other Latinamerican countries, such us Colombia, Venezuela, Mexico, and Brazil. There is a need of new catalytic technologies for obtaining clean fuels and valuables chemicals from natural gas. It is especially important for the region the GTL processes for generation of sulfur-free diesel, high quality paraffins for petrochemistry, and alkanes to replace olefins. Also, the use of natural gas as raw material for petrochemicals, such as dimethyl ether, olefins, and halogenated derivatives.

References

[1] International Energy Outlook 1999, Report DOE/IEA 0484, 1999.
[2] Statistical Report, Boletin de Combustibles, Secretaría de Energía y Minería, 2001.
[3] Electricity Sector Report 2000, Secretaría de Energía y Minería, 2001.
[4] T.H. Fleisch *et al., Stud. Surf. Sci. Catal.,* 2001, **136,** 423.
[5] L.B. Pierella *et al., Stud. Surf. Sci. Catal.,* 1998, **119,** 235.
[6] S.R. De Miguel *et al., Trends in Chemical Engineering,* 2000, **6,** 113.
[7] N. Nichio *et al., Stud. Surf. Sci. Catal.*, 1998, **119,** 723.
[8] S. Irusta *et al., J. Catal., in press.*
[9] M.J.L. Ginés, C.R. Apesteguía, *Appl. Catal.,* 1995, **131,** 283.
[10] G.C. Cabilla *et al., Catalysis Letters,* 1998, **55,** 147.
[11] M. Quiroga *et al., Appl. Catal. A: General,* 1999, **177,** 37.
[12] R.A. Comelli, N.S. Fígoli, *Ind. Eng. Chem. Res.,* 1993, **32,** 2474
[13] M.V. Cagnoli *et al.*, *Stud.. Surf. Sci. Catal.,* 2001, **135,** 272.
[14] J.I. Di Cosimo, C.R. Apesteguía, *J. Catal.,* 1992, **134,** 594.
[15] C.R. Apesteguía *et al., Catal. Lett.,* 1997, **44,** 1.

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