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COMPARATIVE ANALYSIS OF DIESEL AND NATURAL GAS USAGE

Rafaela Veloso de Oliveira
Universidade Federal de Itajubá (UNIFEI), Itajubá – MG – Brasil.
rafaelaveloli@gmail.com

Dalton Garcia Borges de Souza
Universidade Federal de Itajubá (UNIFEI), Itajubá – MG – Brasil.
dalgarbor@gmail.com

Rogério José da Silva
Universidade Federal de Itajubá (UNIFEI), Itajubá – MG – Brasil.
rjs.unifei@gmail.com

Abstract. *The use of natural gas has substantially increased stimulated by its high efficiency in power generation, the development of new technologies and by standing out among non-fossil energy sources due to its clean burning. On the other hand, diesel engines are known by its great power saving and high torque so that it stills the major fuel in Brazilian automotive industry and it is also used in general industry. Thus, this paper presents brief and comparative data of natural gas and diesel oil, taking into account the main applications, Brazilian market, production, changes in demands of domestic industry, costs and pollutant emissions of these fuels.*

Keywords: *natural gas; diesel; costs; pollutant emissions; comparative analysis*

1. INTRODUCTION

The term natural gas is used to distinguish liquid and gaseous natural hydrocarbons obtained by extraction from those that are "artificially" produced. Natural gas is mainly formed by methane, which is extracted from underground deposits of oil and accounts for more than 70% of the total volumetric composition. The relative abundance, wide dispersion and clean burning make natural gas stands out among the other fossil fuels and becomes an important global commodity (Foss, 2004; Wang, 2009).

This fuel has no taste, color or odor, but it is very flammable. Thus, a sulfur-based odor is added to natural gas to facilitate its identification in order to prevent possible accidents. Natural gas is classified according to their use in:

• Industrial Natural Gas: It is used in industrie, including food, ceramic, automotive, metallurgical, chemical and other sectors.

• Compressed Natural Gas (CNG): Alternative fuel widely used in lightweight vehicles, taxis and passenger vehicles. It promotes savings between 40-60% compared to gasoline. This segment accounts for 9.5% of the sales volume of natural gas.

• Residential Natural Gas: Fuel used for cooking, bath heating and general heating.

• Commercial Natural Gas: Fuel for bakeries, hotels, hospitals, swimming schools, clubs, laundries, restaurants, malls, etc (COMGÁS, 2012).

On the other hand, diesel oil is an oil by-product, essentially consisted of hydrocarbons and residual amounts of nitrogen, oxygen and sulfur. It is a flammable product with average toxicity, it is volatile and has sharp and characteristic odor.

Diesel is obtained through petroleum refining, where it is formulated by mixing various derivatives such as kerosene, gas oil, heavy naphtha, light diesel, heavy diesel, and others. The values of such derivatives vary according to the type of diesel fuel that is desired and consumer market demand (Baptista, 2009).

According to DNC, Petrobras produces the follow diesel oil types:

• Type A: Automotive diesel, used in small industries and diesel engines for cars.

• Type B: Metropolitan diesel, unlike type A, this type has a maximum 0.5% sulfur content, which implies lower pollution by this element and its compounds. In Brazil, it is currently used only in big cities like: São Paulo, Rio de Jaineiro and Belo Horizonte.

• Type D: Maritime diesel, it is used in ships engines and differs from type A by having flash point minimum of 60 ° C. As stated above, some properties of diesel vary according to the requirements of use (PETROBRÁS, 2010).

2. MAIN APPLICATIONS

The natural gas is widely used in many industrial sectors, mostly in petrochemical and chemical sectors. This fact is explained by the burning of the fuel on drilling platforms, for steam generation and manufacturing processes such as hydrogen and thermal fluid heating.

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In addition to conventional applications, natural gas can also be used in electricity co-generation, which produces both heat and electricity in order to use the gas with greater efficiency and reduced costs (Szklo and Soares, 2004).

In a second place, natural gas is commonly used in ceramics, pulp and paper industries. In the first case the gas is present in practically all stages of flooring and wall tiles obtainment process, because it increases the equipment's life cycle and improves the quality of the final product. In addition, natural gas has no needing to be stored, which is an advantage, reducing maintenance costs while increasing security.

In the case of pulp and paper industries, natural gas has been replacing other petroleum derivatives that present greater pollution power. In this kind of industry 90% of the gas is used in steam generation and 10% in other processes such as drying and finishing. The co-generation is widely used because of the high electrical and thermal energy needs of this sector. Figure 1 shows the share of natural gas by industry sector in São Paulo state in 2005 (COMGÁS, 2012).

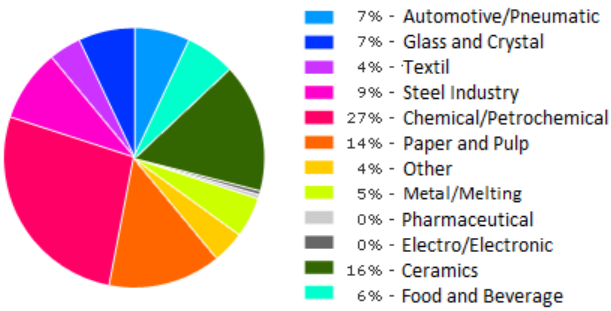

Figure 1. Natural gas: sectorial participation 2005 in São Paulo state in 2005 (ANP - SCM, 2010)

On the other hand, diesel fuel is essentially used in engines with internal combustion and compression-ignition, or diesel cycle engines. Thus, it can be applied in automobiles (cars, vans, trucks, pickups and buses), boats, locomotives and industrial sector, which is used like fuel for electric generators and large machinery (Pereira *et al*, 2005).

3. EXTERNAL TRADE AND PRODUCTION

3.1 Natural Gas

Rio de Janeiro state was the major brazilian producer of natural gas, followed by Amazonas and Bahia states in 2008 (Pacheco, 2008).

Furthermore, in Brazil, 80% of the extracted gas is associated with the oil. Thus, there is a production profile dependent on the oil sector, which leads to a high rate of non-use of this fuel, intensified by the location of 55% of reserves in deepwater (Gracias, Lorenzo and Rafkov, 2012).

This lack of use occurs because a certain volume of gas is not intended for sale, however it is used in the following ways:

- Own consumption - part of the production is used to meet the needs of the facilities;
- Burning and loss - part of the extracted gas that is burned or lost during production;
- Re-injection - part of the natural gas that is injected back into the reservoirs;
- LNG - liquid portion of the gas or share of heavier hydrocarbons (ethane, LPG and natural gasoline) extracted from natural gas processing plants (ANP - SCM, 2010).

Figure 2 shows the evolution in the use of natural gas over the last decade:

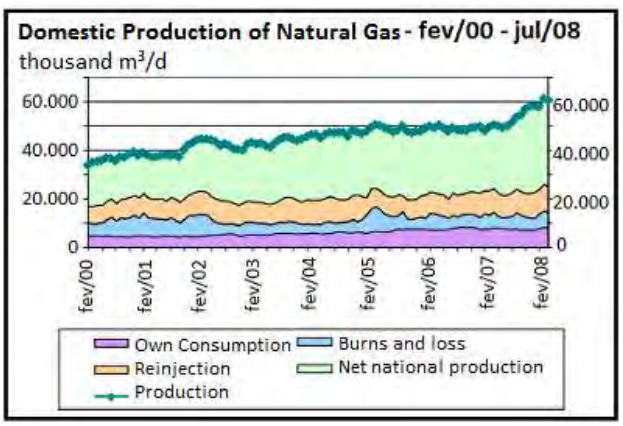

Figure 2. Natural Gas Production (ANP – SCM, 2010).

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After the domestic market opening, Brazilian companies began to import natural gas under the criteria established by ANP. A significant part of these imports corresponds to natural gas originated in Bolivia that is transported through the Bolivia-Brazil gas pipeline - GASBOL. Figure 3 shows the composition of the gas supply in Brazil in 2008.

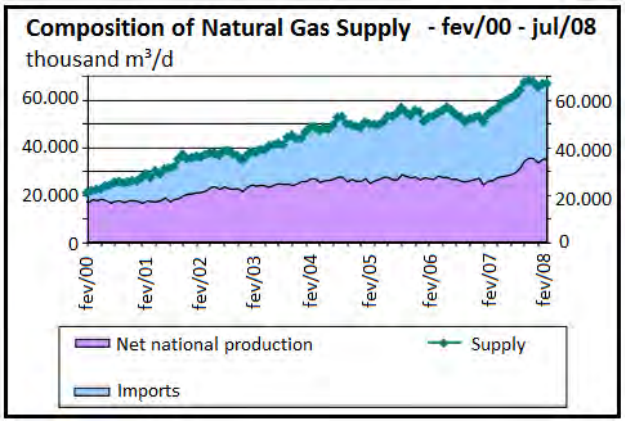

Figure 3. Composition of the gas supply in Brazil (ANP – SCM, 2010).

In a effort to reduce dependence on imports of natural gas, Petrobras has deployed the program PLANGÁS, comprising a portfolio of projects for expansion of the gas production in the country. In addition, in early 2000, Petrobras signed an agreement with the ANP named Zero Burn, aimed at gradually reducing the burning of this resource.

The agreement with ANP aims to increase the use of associated gas of 79.1% in 2009 to 95% in 2015. That goal is a challenge facing the new exploration in the Brazilian pre-salt (Filgueiras, 2009).

3.2 Diesel

There was an increase in the production of diesel fuel until 2008, followed by a stabilization between 2009 and 2010 (BEN, 2011). One may visualize such a situation in Figure 4.

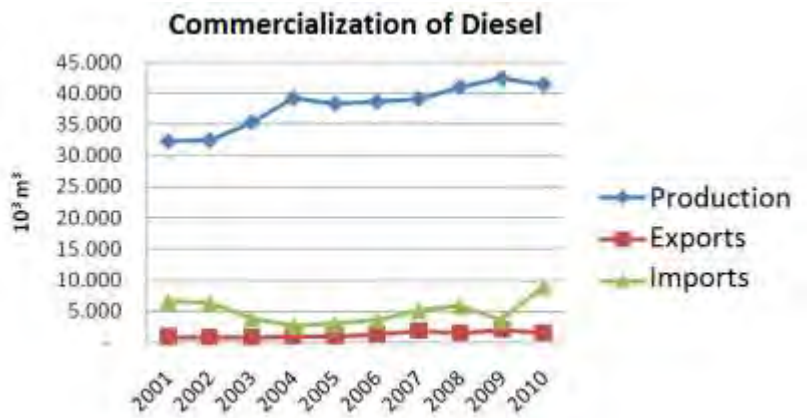

Figure 4. Commercialization of Diesel from 2001 to 2010 (BEN, 2011).

Brazil is characterized as a large consumer of diesel oil due to the dominance of road freight transport in the country. The increases in demand caused by economic growth boosted domestic production, reducing imports. However, in 2010, net imports significantly enhanced, demonstrating that the expansion of refining capacity has not included the expansion of consumption (Bonfá, 2011).

4. EVOLUTION OF DEMAND IN DOMESTIC INDUSTRY

4.1 Natural gas

The natural gas demand in development countries will increase about 2.3% a year until 2030. This growing will lead to a strategic energy planning and the development of new ways to move the gas (Reymond, 2012; Gracias, Lorenzo and Rafkov, 2012).

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In Brazil, an imbalance between supply and demand of natural gas is being seen, due to public policies that incentives the natural gas use in several segments, but there is not a compatible supply growing of this input on the domestic market.

Among these incentive policies, there is the prices maintenance between 2003 and 2004 in order to maximize the use of the GASBOL and the Massification Program of Natural Gas Use in 2004 that granted tax incentives in this sector. For this reason, industrial plants was modified to use this fuel, thermoelectric have been built and the compressed natural gas was expanded, primarily in southeast region.

In this scenario, there was an intensification of the risk associated to the volatility of natural gas prices. Thereby, a rise in the gas price to slow the increase in demand due to the possibility of future supply constraints was discussed, while Government encouraged the domestic production of this input (Pacheco, 2008).

In March 2009, for example, the law 11.909 was created in order to intensify the activities of new players in the sector of gas transport through the establishment of a new role for government, which became responsible for the coordination of new investments, paving the way for private companies operations (Ferraro and Hallack, 2012).

4.2 Diesel

The demand for diesel is closely related to transport sector. Despite diversification of fuel usage with the increasing use of ethanol and natural gas, diesel stills the main energy source in the Brazilian automotive sector, as shown in Figure 5.

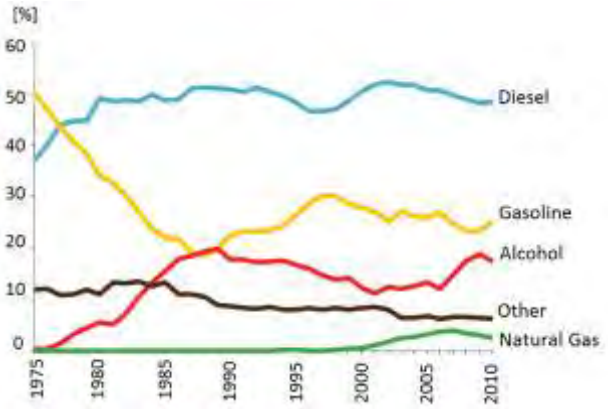

Figure 5. Contribution of different fuels in the automotive sector (BEN, 2011).

On the other hand, there is a reduction in the use of this input in industrial sector, imposed mainly by new environmental laws. Figure 6 shows the evolution of the the energy mix in Brazil. It shows a decline in oil and some growth in demand for natural gas (BEN, 2011).

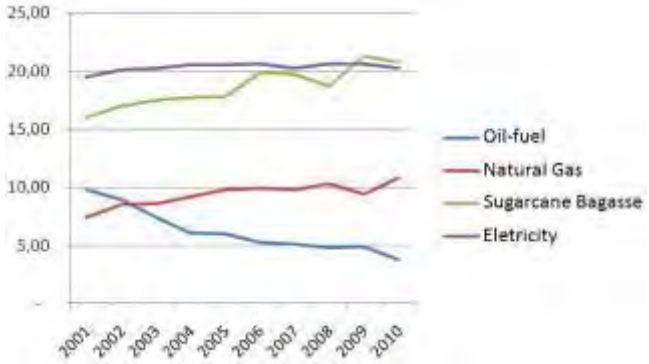

Figure 6. Contribution of different energy sources in the manufacturing sector from 2001 to 2010 in % (BEN, 2011).

5. COSTS

5.1 Natural gas

The pricing of Brazilian natural gas involves, at different ratios over time, both government decisions and market trading. So that these prices are established according to a dimness pricing between managed regulation and market regulation.

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The gas market in Brazil is still considered slightly mature in view that this market is often more controlled by regulations and inflexible contracts, than by variations between supply and demand. Moreover, one can say that it is a market characterized by monopoly. This immaturity of market can be partly explained by the late development of the transport system, which has not kept pace with the development of cities (Filgueiras, 2009).

There are three forms of pricing the natural gas: one for the gas produced domestically, another for imported gas, and a third for gas used in power plants. Figures 7 and 8 show the evolution of natural gas prices along the last decade.

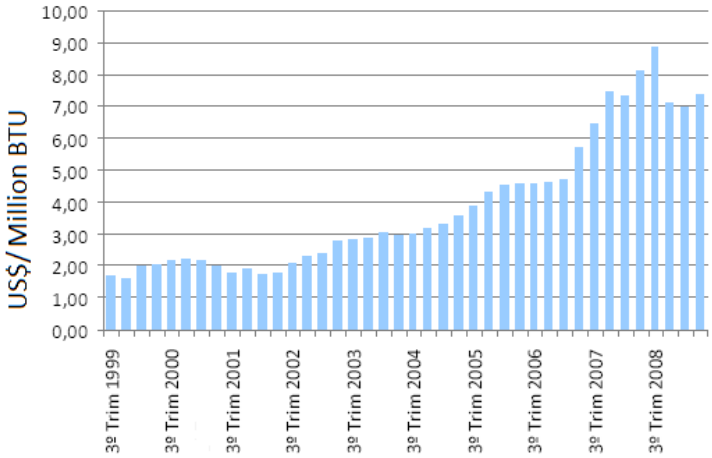

Figure 7. Historical Average Prices of Natural Gas at *City Gate* (PETROBRAS, 2012).

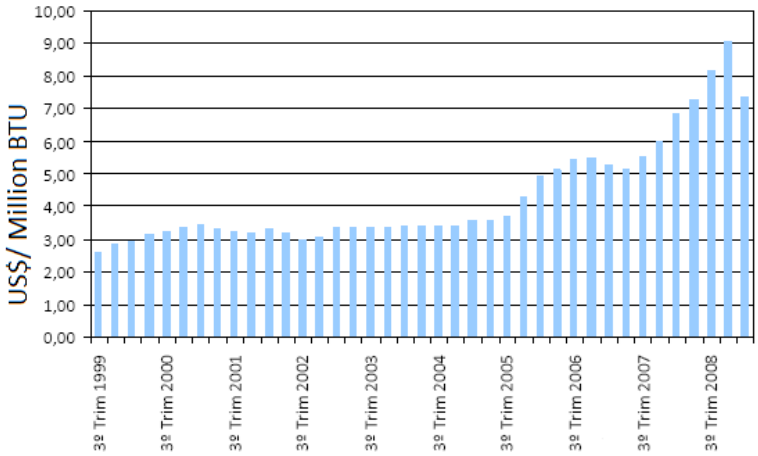

Figure 8. Historical Average Prices of Imported Gas at *City Gate* (PETROBRAS, 2012).

5.2 Diesel

The price of diesel are basically composed of two variables in particular: oil prices and environmental levies. Thus, Figures 9 and 10 show the variation of oil prices and the change in the price of diesel in the country, respectively.

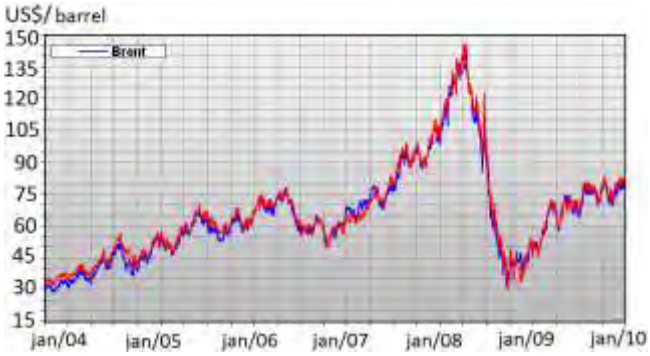

Figure 9. Oil prices from Jan/04 to Jan/10 (BDCD, 2012)

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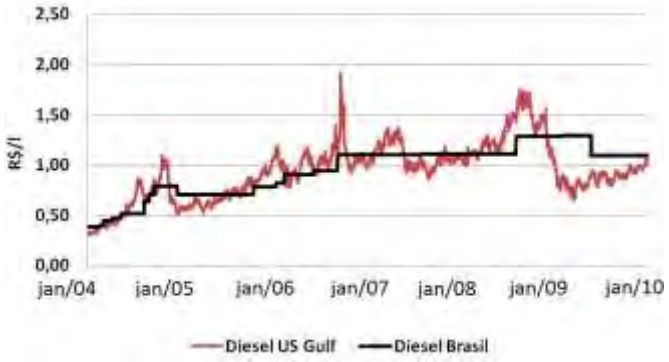

Figure 10. Evolution of Diesel Prices (BDCD, 2012)

We note that the high diesel prices practiced in the country is closely connected with the large increase in oil prices in 2008. Furthermore, Figure 11 shows that the taxes and profit margins contribute to increase the cost of petroleum-derived (BDCD, 2012).

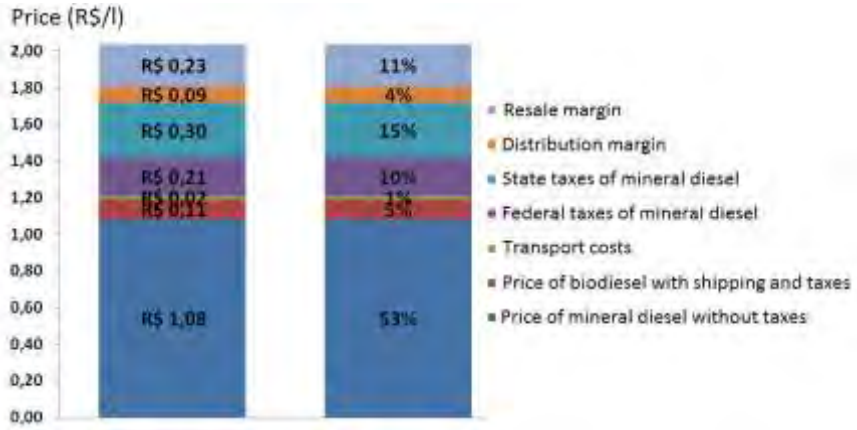

Figure 11. Diesel Prices in Brazil (BDCD, 2012)

6. POLLUTANT EMISSIONS

The generation of greenhouse gases in thermal power plants with the same characteristics in terms of the amount of produced power can be used as a basis for comparison between natural gas and diesel pollutant emissions.

Villela and Silveira present a study on the emission of pollutants from these fuels in a thermal power plant using combined cycle technology, (total power: 41441 kW; 27170 kW for gas turbine and 14271 kW for steam turbine) without burning additional fuel in the boiler. Table 1 shows a summary of the results obtained in the comparison between the emissions of pollutants by natural gas and diesel, according to this study. It indicates a great benefit of using natural gas in terms of air pollutants generation when compared with diesel.

Table 1. Comparison between the results for pollutant emissions from a natural gas thermoelectric plant and a diesel power plant (Villela and Silveira, 2006):

Pollutant emission (kg/kg of fuel)	Diesel	Natural Gas	Diesel / Natural Gas
$(CO_2)_e$	3,21	3,01	1,1
Particulate material	13890×10^{-7}	3039×10^{-7}	4,6 times
SO_2	9861×10^{-6}	-	-
NO_x	2778×10^{-5}	856×10^{-5}	3,3 times
CO_2	3,1059	2,7038	1,2 times
Total (kg/kg of fuel)	3,1187	2,7070	1,2 times
Ecological efficiency (cycle with 54% yeld)	91,4	94,4	-

Natural gas produces 240kg of particulate matter for one million cubic meters of fuel, while diesel emission is 1.2kg per cubic meter of fuel. Natural gas has a low sulfur concentration that generates SO_2, whereas the SO_2 factor of diesel is 17.04 kg/m³ for each 1% sulfur in its composition. As for NOx, 856 mg/kg are produced by using natural gas, while a diesel power plant generates 2.4 kg/kg of diesel.

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In the thermal natural gas power plant, the generation of carbon dioxide on a dry basis and corrected to 12% free oxygen is 2.7038 kg of CO2 per kg of natural gas. For a power plant generation through diesel this value is 3.1058 kg CO2 per kg of diesel (Villela and Silveira, 2006).

Figure 12 shows the ecological efficiency for both fuels.

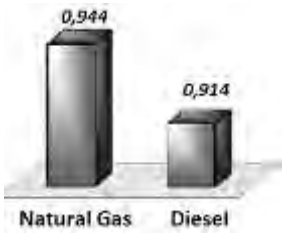

Figure 12. Ecological Efficiency of Natural Gas and Diesel (Villela and Silveira, 2006).

7. CONCLUSIONS

There is a great increase in the use of natural gas in recent years, while the use of diesel fuel in industries has been decreasing. This situation can be explained, in part, by new environmental levies of law and society, which make gas more advantageous for being a less polluting source.

However, diesel fuel still represents the main fuel in the Brazilian automotive sector, despite of the incentives to use natural gas in this sector. Furthermore, both fuels presented are petroleum derivatives and therefore susceptible to changes in price according to the market price of the barrel.

8. ACKNOWLEDGEMENTS

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