A COMPARISON BETWEEN THERMOELETRIC POWER PLANTS OPERATIGN WITH NATURAL GAS AND DIESEL: ENVIRONMENT IMPACTS

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***Abstract**: This paper analyzes the environmental implications of the Brazilian Thermoelectric Priority Program implementation (PPT). This program was created by the Federal Government in accordance with ACT nº 3371, February 24, 2000, in order to stimulate the electrical energy generation by means of thermoelectric power plants, encouraging the natural gas use as a fuel. In this context, the comparative environmental impact caused by the natural gas use is evaluated as well as the main pollutants generated by the Thermoelectric power plants: Nitrogen Oxide (NO_x), Sulphur Oxide (SO_x), Carbon Monoxide (CO), Particulate Matter (PM), Volatile Organic Compounds (VOC) and Total Organic Compounds (TOC-Hydrocarbons). It can be said that the fuel burning in thermoelectric power plants is considered to be the major pollutant emission source, but in Brazil, little emphasis has been given to this subject and here it can be cited the CONAMA 008/90 Resolution, that sets SO_2 and total particles (emission standards) maximum emission limits for external combustion processes in fixed sources. For the other fuels, the decision on setting the emission maximum limits is up to the Environment State Agencies. This resolution limits only the Sulphur and particulate oxides, not mentioning anything concerning CO_2 and NO_x emissions. It can be concluded that the natural gas is an environment low impact fuel, capable of substituting almost all the other energetic. The principal natural gas utilization advantage compared to the diesel is the environment preservation, besides the economical benefits: its combustion is clean, what exempts the treatment with products launched in the atmosphere.*

***Keywords**: Natural gas, Diesel, Brazilian Thermoelectric Priority Program, Environmental Impact.*

1. Introduction

Through the years, Brazil has been suffering with the differences in the energetic sector expansion program, due to the lack of investments, inexistence of a reformulation coherent proposal in the field and to the increasing demand, around 6% per year. Thus, the government decided to privatize some energy distribution sectors, in order to augment the foreign capital investment in the country and improve the area, creating new laws, decrees and several different arrangements to allow the feasibility of a more and more expressive participation of the private branch in the country electrical power industry. The 2001 energetic crisis that Brazil faced made the country decide for other sources of energy, and the government introduced in the market the Thermoelectric Priority Program (PPT) aiming to increase the country generation capacity in order to face its electricity demand.

In the Brazilian System, it is important the exploitation of the hydroelectric potential since it is economically feasible, with a thermoelectric generation adequate complement. The thermal generation is fundamental in the energetic area to minimize new rationing risks and improve the system electrical liability as the thermals have no hydrological hazard and help the transmission system. In other countries, thermal generation is the prevailing system, with practically no rationing risk, while in Brazil the prevailing system is still the hydroelectric one, offering approximately one rationing every 20 years (Abraget, 2003).

Table 1 presents the Brazilian thermal generation percentages compared to other countries.

Table 1. Thermal Generation International Comparisons

Brasil	Canada	United Kington	Portugal	France	Germany	USA
11%	39%	98%	61%	81%	91%	86%

Source: Abraget 2003

The changes in the thermoelectric market traditional structure have been induced by the increasing environment restrictions to the use of charcoal, especially in the industrialized countries, which present a natural gas transportation solid infra-structure. The chief gas natural advantage, compared to charcoal, relies on the smaller carbon dioxide emission intensity. The natural gas arises as an interesting alternative to the petroleum products, for it is an energetic that produces lower environment impact, burns easily and may be canalized and safely conducted to the final consumer.

Economically, the thermoelectric power plant most efficient option is the combined cycle (CC), which consists in the association of steam turbines, using natural gas as fuel. In terms of emission, the utilization of steam gas in cycle combined with natural gas is the most adequate because it presents greater thermodynamic efficient and consequently lower fuel consumption.

In this context, this work presents the thermoelectric environment implications in Brazil, comparing natural to diesel utilization, yet reporting technical aspects associated to the implementation of the Brazilian Thermoelectric Priority Program.

2. Kyoto Protocol

In December of 1996 in Kyoto (Japan), 160 countries reached an agreement that legally limits the greenhouse gas emission in the industrialized countries. Thus, from 2008 to 2012 the control and reduction will be approximately 5% below the levels for 1990. The USA agreed upon a 7% reduction, The European Union on 8% and Japan on 6%. After some years, several of the countries, almost all of them being developing countries, ratified the Protocol, but the United States, responsible for the most CO_2, emission, decided not to confirm the agreement. In July, 2001, the Bonn convention was realized, a political mark in the slow international negotiations. The ministers of 180 countries settle an agreement which includes relevant rules and procedures for the implementation of the results of the Convention in the developing countries (financing, technological transference, qualification, adaptation to the climatic changes impact) and in the Kyoto Protocol mechanisms (emission business, Clean Development Mechanism Combined Implementation). The agreement created fundamental foundations to allow the countries to ratify and implement the Protocol and for the negotiation of still more reduced emissions, in the future financing kit, which included commitment of the USA, New Zealand and Switzerland to supply US$ 140 millions per year until 2005 to the developing countries, with a new analysis in 2008 (Kyoto Protocol, 2003).

3. Diesel and Natural gas

3.1. Diesel

Petroleum subproduct, basically composed of hydrocarbons, diesel oil is a compound formed mainly by carbon atoms and low concentration Sulphur and nitrogen. It is flammable, moderately toxic, volatile, clear, suspension matter free and with strong and particular scent (Energy Gas, 2004).

According to Petrobras, the enterprise produces 85% of the diesel oil and the rest of the market is supplied with imported product. In Brazil, the diesel oil consumption is imputed to the transportation field, which represents 80% of that market. 94% of this oil is destined to the transportation branch. The Brazilian diesel, compared to the American and the European ones, exhibits high Sulphur content in its composition. Searching for a better motor performance and the atmospheric emission reduction, Petrobras implanted the Diesel Oil Quality Evolution Program, in which approximately US$ 1.2 billion will be invested. Besides the Sulphur compound emission reduction, the diesel oil quality evolution provides a better motor performance, scent and smoke decrease. Since January, 1998, the maximum Sulphur percentage allowed for the national diesel is 0.5% (Carvalho et al., 2002).

In general, the diesel generator unitary power, compared to the one of the big thermopower or hydropower plants, is not that big. It is necessary, however, to consider that the number of units installed is significant and that, together, they represent a significant fraction of the total installed power in Brazil. Only the diesel plants nowadays authorized to supply electrical energy to the network respond for 26.6% of the total installed power in Brazilian thermopowers. Normally, this potential remains idle due to the diesel oil cost and its use is reasonable only in special situations like eventual interruptions in the network supply and peak consumption hours, when the power demand is high, and in localities far away from the electrical network. The power nowadays installed in the Brazilian thermopower industrial estate is around 10.4 GW: the diesel plants supply 2.8 GW of this total. It can be pointed out, in the diesel plants universe, the units of the State of Amazonas: these represent 30.7% of the total power installed in diesel generator in Brazil. Mato Grosso (22.1%), Bahia (10.7%) and Rondonia (9.5%) come next. Hydroelectricity is the most consumed energetic, responsible for 43.4% of the total. Next come the ones that use diesel oil (13.1%), sugar cane products (including ethylic alcohol, 8.2%) and firewood (6.2%). Petroleum subproducts, together, respond for 28.5% of the total Brazilian energy consumption. Among these the diesel oil is pointed out, second energetic in the Brazilian matrix (it is the most utilized subproduct), responsible for almost half of subproducts consumed.

3.2. Gás Natural

It is a scentless, flammable and suffocating gas when inhaled in high concentrations, and because it is gaseous, does not need to be vaporized, as, for instance, the fuel oil, to burn, thus resulting from it a pollutant emission reduced clean combustion. Natural gas is a mixture of light hydrocarbons, which at surrounding temperature and atmospheric pressure, remains in gaseous state. It is found underground in the nature, accumulated in porous rocks, generally accompanied by petroleum, making up a reservoir (Salomon, 2003).

According to Comgas, the largest gas distributing company of the state of São Paulo,the natural gas volumetric composition may be:

CH_4 (methane): 89.3%
C_2H_6 (ethane): 8%
C_3H_8 (propane): 0.8%
C_4H_{10} and C_5H_{12} (butane and pentane): 0.1%
CO_2 (carbon dioxide): 0.5%
N_2 (nitrogen): 1.3%

In one Nm^3 of natural gas at CNTP (Normal Temperature and Pressure Conditions) its mass is approximately 720 grams. At CNTP the m^3 is denoted by the symbol Nm^3 (N means normal). The maximum total Sulphur in one Nm^3 of natural gas will be 20 mg, corresponding to 0.0028% of the fuel mass (Carvalho and Lacava, 2003).

Regulation 41, April 15, 1998, emitted by the Petroleum National Agency, grouped natural gas in three families, according to the calorific power range. The Brazilian natural gas belongs to the (M) medium group, with the following specifications (Aneel, 1998):

- calorific power higher than 20ºC and 1 atm: 8800 – 10200 kcal/Nm^3
- air relative density at 20ºC: 0.55 – 0.69
- total Sulphur: maximum 80 mg/Nm^3
- H_2S: maximum 20 mg/Nm^3
- CO_2: 2% at maximum volume
- O_2: 0.5% at maximum volume
- inert: 4% at maximum volume
- water dew point at 1 atm: maximum-45ºC
- free of dust, condensed water, injecting scents, gums, gum-forming elements, condensable hydrocarbons; flavor compounds, methanol or other solid and liquid elements.

In Brazil, only 2.5% of the energetic matrix are composed of natural gas, but Petrobras intends to increase up to 10% until year 2000, due to the Brasil-Bolívia gas line and Santos and Campos wells, which will supply South, Southeast and Center-South regions in the years to come. A series of small gas lines are being constructed between the cities of Salvador to supply the Northeast part of the country and in the Amazon region we have gas from the fields of Urucu and Juruá (Gas is the way, 2004)

4. Pollutant Emissions

Brazil has committed, in the Kioto Protocol, to not increase its carbonic gas emissions, but the government decision on solving the energetic crisis by building a series of gas thermopowers and the recent big demand for gas and diesel generators as an alternative to the energy breaks only contribute to increase the greenhouse effect. Countries worried about the global heating and the pollution, as Denmark, for instance, are extinguishing the thermopower installations and Brazil, once more, runs against the world tendencies, with the perspective of installing tens of thermoelectric power plant, according to the Thermoelectric Priority Plan (Knowing to preserve, 2004).

It can be said that a thermoelectric power plant environment impacts refer to the gaseous pollutant emission in the atmosphere and to the use of cooling water for the steam condensation, among others like the disposal of oily and chemical reagent, electromagnetical emission and ashy infected waters. In a twenty-year term, it would represent 87 million Brazilian tons of extra carbon launched in the atmosphere. If we consider a lower natural gas participation alternative from 10% to 8%, for the fuel oil benefit, it is possible to verify that it would bring an increase of 3% for the year of 2020 and a CO_2b gas accumulated increase of 35 million Brazilian tons launched in the atmosphere (Economy & Energy, 2000)

In the thermopowers that use natural gas as fuel, the chief pollutants are: carbon monoxide (CO), nitrogen oxides (NO_x), hydrocarbons (HC) and carbon dioxide (CO_2), while for the ones that utilize diesel they are carbon dioxide (CO_2), Sulphur oxides (SO_x) and particulate matter. The presence of these acids that form the photochemical oxidatings, secondary pollutants generated by the nitrogen oxides by the time they react with other compounds present in the air, ozone, for instance, is very harmful to the human health and to the vegetation, as well as the acid rain.

Cetesb (2004) requires that the Environment Impact Studies of the thermoelectric power plant be made taking in consideration the following pollutants: nitrogen oxides ((NO_x), carbon monoxide (CO_2, Sulphur dioxide (SO_2), Particulate matter (MP), volatile organic compounds (VOC) and Total organic compounds (TOC-hydrocarbons).

Next we have the characteristics of the main pollutants generated by the thermoelectric power plants:

- Nitrogen oxides (NO_x) – Comprises fundamentally nitrogen oxide (NO) and nitrogen dioxide (NO_2). They are formed in the process of combustion due to the oxygen and nitrogen chemical reaction. Both can be from the air or present in the fuel, being the NO formation more remarkable that the one from the NO_2. However, when discharged to the atmosphere the NO is completely converted into NO_2. NO_2 is a less reactive gas with biological tissues and is not considered as having adverse effects to the health in the concentrations found in the atmosphere. NO_2 reacts with all the body parts exposed to the air (skin and mucous), exerting its toxic effect principally in the lungs and peripheral respiratory system (Saldiva, 1991). They are toxic gases generated in all kinds of Thermopower units subjected to chemical and photochemical reactions promoting the tropospheric ozone and also compounds that contribute to the acid rain and the greenhouse effect formation, causing respiratory passages and lungs infections.

Sulphur Oxide (SO_x). Its emission depends on the amount of Sulphur contained in the fuel produced during the combustion, mainly in the oil and charcoal Thermopower Units. Practically all Sulphur contained in the fuel reacts to the hydrogen in order to form SO_2, SO_3 and H_2SO_4. Sulphur oxide is a colorless gas, detected by its characteristic Sulphur odor, very irritating for the mucous, principally the conjunctive one and the respiratory system (Saldiva, 1991). In the atmosphere, SO_2 reacts to existing air water steam and to the oxygen and forms the sulphates and the Sulphur acid, giving berth to the acid rain. SO_2 is an irritating gas for the eye mucous and respiratory system causing the bronco-pneumonia

Carbon Monoxide (CO): Colorless, odorless and insipid, produced from charcoal combustion and petroleum subproducts, toxic, harmful to the tissue oxygenation, also acts as a systemic choker.

Particulate matter (PM): According to Braga et al. (2002), particulate matter is the solid and liquid matter, capable of remaining suspended in the air, as for instance, dust, soot and oil particles, as well as pollen. These particles may be the result of volcano activity, pollen scattering, and the majority has 0.1 – 10 microns diameter. Those particulate matters are generally emitted in Thermopower Plants that use mineral charcoal with different characteristics (particle dimension and density, concentration, etc.). The particle diameter develops an important role in its respiratory system penetration efficiency, and the emission of particulate matter lower than 2.5 microns besides being harmful to the environment may cause severe damage to the human being health. These inhaling particles reach the lungs very deeply, causing coughs, asthma, difficulty of breathing, bronchitis, reduction of visibility in high concentrations besides helping form acid rain.

Volatile organic compounds (VOC): The pollutants classified as VOC may reach a large volatile organic compound spectrum, some of which are dangerous air pollutants. These compounds are launched in the atmosphere when part of the fuel is not burned or is partially burned during the combustion process (Curral, 2003).

Total organic compounds (TOC-Hydrocarbon): A lot of hydrocarbons present in the atmosphere result from the incomplete fuel burning, as well as from the evaporation of these fuels and other materials, like the organic solvents. These hydrocarbons are relatively inert, like the paraffinic; others are extremely reactive, like the paraffin-base oils and combine with NO in presence of sunlight, forming highly oxidizing compounds (Braga et al., 2002).

4.1. Emissions Standards

The air quality and pollutant emission standards are settled considering the effects of the pollutants on the human beings, animals, plants and materials, as a final result of the process of atmosphere pollutant launching. It can be said that fuel oil, charcoal and natural gas burning in the thermopowers for the production of energy Is considered to be the larger SO_X,NO_x, CO_2, C_xH_x and particulate source of emissions, which are directly related to the quality and the type of fuel used. In Brazil, little emphasis has been given to this subject. It is possible to cite the CONAMA 008/90 Resolution, which establishes maximum SO_2 and total particles emission limits (emission standards) for the external combustion processes in fixed sources. For other fuels, the decision on settling maximum emission limits is up to the Environment State Agencies. This resolution limits only the Sulphur oxides and particulate, not presenting any mention to the NO_x emission. According to Kubowski et al. (1997), the nitrogen oxide emission standards in the European Community, Austria and Japan are 650 mg/Nm^3, 200 mg/Nm^3 and 411 mg/Nm^3 respectively, considering new thermoelectric power plants burning solid fuels.

Table 2 presents the Brazilian air pollutant emission standards, according to Conama 008/90 Resolution (Pronar, 2003)

Table 2. Pollutant Emission Standards (Conama 008/90 Resolution)

Areas/Classes	Potência (MW)	SO2 (g/million kcal)	Total particulate (g/milion kcal)	
			Fuel oil	Charcoal
I	< 70	2000	120	-
II	< 70	5000	350	1500
III	> 70	2000	120	800

Fonte: (Pronar, 2003)

Table 3 presents emission standards settled for the thermoelectric units in other countries, which are more severe than Brazil.

Table 3. Emission standards in use for Austria, Japan (Kucowski et al., 1997) and USA (EPA, 1995) thermoelectric power plants

Country	Fuel	New units			Units in use	
		SO_x (mg/Nm^3)	**NO_x (mg/Nm^3)**	**MP (g/GJ)**	**SO_x (mg/Nm^3)**	**NO_x (mg/Nm^3)**
Austria	solid	200	200	-	200	200
	liquid	200	150	-	200	150
	gaseous	-	150	-	-	150
Japan	solid	233	411	-	644	200 - 400
	liquid	233	267	-	644	130 - 180
	gaseous	-	123	-	644	60 - 130
USA	solid	un	un	13	un	un
	liquid	un	un	13	un	un
	gaseous	un	un	13	un	un

un - unavailable

The use of international data is due to the fact that the Brazilian NO_x emission standards are inexistent, and for the other pollutants these standards are very conservative. Thus, the referred countries standards are utilized since they are more rigorous. However, it must be pointed out that when we copy the international standards we forget that they are performed from pollutant gases continuous monitoring mechanisms, considering the operation and the type of industrial plant. In Brazil it should be adopted, for instance, performance standards in accordance with the previous legislation, taking in account the unit operation parameters and pollutant concentration measurement per exhausting gas volumetric unit (mg/Nm^3).

Table 4 refers to the World Health Organization air quality standards published in 2000, based on epidemiologic studies and the existing pollutant relations on human being health.

Table 4. World Health Organization Air Quality Standards (Who, 2003)

Pollutant	Concentration	Coments
NO_x	1 hour: 200 $\mu g/m^3$ Ano: 40 $\mu g/m^3$	Clean air natural concentration: 1-9 City yearly mean value: 20-90 90$\mu g/m^3$ Minimum concentration that affects asthma patients in 30-110 Minutes of exposition: 565 $\mu g/m^3$ Respiratory effects on children during long period exposition Time: 50-75 $\mu g/m^3$
SO_x	1 hour 125 $\mu g/m^3$ Ano: 50 $\mu g/m^3$	Clean air natural concentration: 1-9$\mu g/m^3$ City yearly mean value: 20-40 $\mu g/m^3$ Minimum concentration that affects asthma patients during 10 minute exposition: 500 $\mu g/m^3$ Adverse effect minimum concentration for long period: 100 $\mu g/m^3$
Ozonio	8 hours: 120 $\mu g/m^3$	Clean air natural concentration: 40-70 $\mu g/m^3$ City yearly mean value: 300 $\mu g/m^3$ Minimum concentration that affects asthma patients during several hours of exposition: 280-340 $\mu g/m^3$ respiratory effects on children during short period exposition: 100 $\mu g/m^3$

5. Comparison between Natural gas and Diesel as fuels

According to Carvalho and Lacava (2003), the CO_2, NO_x and Particulate Matter (PM) (SO_2) generated from the diesel and natural gas combustion, respectively, are determined. Thus, considering NO_2 in the combustion products from these fuels, we have the following equations for normalized α air excess:

- diesel

$$1C_{12}H_{26}+18,5\alpha O2+69,56\alpha N_2 \rightarrow 12CO_2+13H_2O+139,12\alpha N_2 \quad (1)$$

- natural gas

$$0,893CH_4+0,08C_2H_6+0,008C_3H_8+0,0005C_4H_{10}+0,0005C_5H_{12}+0,005CO_2+0,013N_2+2,118\alpha O_2+7,965\alpha N_2 \rightarrow 1,087CO_2+2,064H_2O+7,965\alpha N_2+2,118(\alpha-1)O_2 \quad (2)$$

By using the natural gas and diesel combustion equations (1 and 2), it is possible to compare the atmospheric emissions between natural gas and diesel. The results show that:

- a diesel thermoelectric power plant generates 3.1059 kg of CO_2 /kg of diesel and for a natural gas thermoelectric power plant the CO_2 generated (in dry base, corrected to 12% of oxygen) is 2.7038 kg of CO_2/kg of natural gas.
- for the NO_x, a diesel plant generates2.4 kg of NO_x/m^3 of diesel. On the other hand, a thermoelectric power plant using natural gas generates 2270 kg of NO_x per million of fuel cubic meter.
- For the diesel, the particulate matter emission factor is 1.2 kg per fuel cubic meter and for the natural gas this factor is 240 kg of particulate matter per fuel cubic meter The SO_2 emission factor in the diesel is 17.04 kg/m^3 for each 1% of Sulphur in its composition; however, the natural gas shows a very low Sulphur percentage and this implies in a very low SO_2 emission factor.

Table 5 shows the atmospheric emissions comparative results between natural gas and diesel.

Table 5. Comparison of the pollutant emission results between a natural gas thermoelectric power plant and diesel plant

Pollutant Emissions (kg/kg)	diesel	gas natural	diesel/natural gas
CO_2	3.1059	2.7038	1.2 times
NO_x	2778.10^{-6}	856.10^{-6}	3.3 times
Particulate matter	13890.10^{-7}	3039.10^{-7}	4.6 times
SO_2	9861.10^{-6}	-------	-------

6. Thermoelectric Priority Program

The Thermoelectric Priority Program (PPT) was created by the Federal Government according to ACT nº 3371, February 24, 2000, in order to stimulate electrical generation by means of thermoelectric power plants. The thermal generation in the years to come should increase from 7% to 20% and the thermoelectric power plants integrating this Program will have the right to the following prerogatives (Presidence Of The Republic, 2000):

- guarantee of natural gas supply for 20 years according to rules to be set by MME.
- guarantee, by BNDES, of access to the Electrical Sector Financial Support and Prioritary Investment Program.
- guarantee of application of the normative value to the electrical energy distribution, for a period up to 20 years, according to Aneel regulation.

Another benefit, provided in Law 10438, article 29, is the ampliation of the deadline for the enterprises to start the commercial operation of the thermoelectric power plants admitted in the PPT, initially defined by the regulation 551/2000, MME (Ministerio de Minas e Energia), which would end in December 31, 2003 and was prorogated to December 31, 2004.

Decree 43, February 25, 2000, that sets the national energetic policy and aims to increment, under economical basis, the utilization of the natural gas, valorize the energetic resources, protect the environment and promote energy savings. It considers the goals set for the electrical sector of implanting a thermoelectric generator industrial estate, reaching in the year 2000 a hydrothermal profile of 20% and 80%, respectively, thus altering the natural gas share in the national energetic matrix from 3% to 10% MME. Thermal generation is fundamental in the electrical energy sector, to minimize rationing risks and increase the system electrical reliability. In the Brazilian system, it is important to exploit the economically feasible hydroelectric potential, with adequate thermal generation complement.

6.1. Thermoelectric power plants integrating the PPT

Decree 43, February 25, 2000, article 1, defines the thermoelectric power plants integrating the PPT in accordance with the criteria set by CAET – Thermoelectric Expansion Follow on Committee, distributed according to Table 6 (MME, 2000).

Table 6. MME 2000/2003 Thermoelectricity Priority Program

Power Plants	Nº of power plants	Power (MW)
Natural gas Cogeneration	11	2450.00
Natural gas in combined cycle	30	12,785.00
Natural gas in open cycle	2	84.00
Other fuels (charcoal, schist, asphalt residue)	6	1786.00
Sub-Total	**49**	**17,105.00**
Existing to be converted into natural with energy conservation process (Manaus, Santa Cruz, Camaçari and Bongi)	4	2701.00
Added to PPT after Decree nº 43/00, with no fuel type specification		
Added to PPT after Decree nº 43/00, with no fuel type specification)	5	1689.80
TOTAL	**58**	**21,495.80**

Next a situation global resume is found of the 40 thermoelectric power plants: some works have not been initiated yet due to the environment license delay or to agreement with Petrobras concerning gas supply.

According to the PPT, It was foreseen, for the period 2001-2003, 10807 MW in operation, 801 MW for 2004 (this goal was not met). This program aimed to increase the country energy potential offer in 17,1 GW, besides foreseeing the conversion for natural gas use of four in-use plants (Manaus, Santa Cruz, Camaçari and Bongi), but at the end of year 2000, because of the scarcity of electrical energy, 6 more projects were inserted in the PPT, which would represent the addition of 1,69 GW to the Program thus totalizing 21,5 GW (Energy channel, 2004).

The PPT resulted in a remarkable change in Brazilian electrical system expansion matrix short term planning, for the thermoelectric generation expansion was significantly altered in the period of 2000-2003. Besides incrementing the natural gas use, the PPT also guaranteed the utilization of national fuels as the charcoal, schist and alternative fuels, like the sugar cane bagasse.

Nowadays, the installed Brazilian generator industrial estate capacity comes to 80.9 thousand MW in operation, distributed among 1190 power plants that utilize several types of fuel, but the country still has 86 businesses being built, which will totalize 12,3 thousand MW and 334 more, authorized by Aneel, capable of generating 6,3 thousand MW (Enegy Channel, 2004).

According to Aneel (2004) authorization, the Table 8 shows the thermoelectric power plants to be in operation between 2001 and 2006.

Table 8. Thermoelectric power plants to start operation in the 2001-2006 period

Plants	Quantify	Power (MW)
Are not included in the PPT	50	8300.5
PPT	27	11,053.1
PPT Cogeneration	14	371.1
TOTAL	**91**	**19,724.7**

Table 9 presents a prevision for the plants that will start in operation from December 16, 2003 to December 31, 2007 (Aneel, 2004).

Table 9. Prevision for plants to start operation from 2003 to 2007

Usinas	2003	2004	2005	2006	2007
Thermoelectric plants	2580.3	1981.5	1871.1	1140.6	727.0
PPT power plants	2787.2	5513.9	1454.2	1013.9	283.9
PPT - Cogeneration	36.5	236.6	98.0	-	-
Small Hydroelectric Centrals - SHC	86.0	789.9	1170.8	1091.8	88.0
Hydroelectric plants	40.0	2138.7	2563.9	3285.9	1576.3
Eolian power plants	1811.2	2219.6	1732.4	803.4	63.0
TOTAL	**7341.2**	**12,880.2**	**7719.6**	**7335.6**	**2738.2**

There are restrictions to the operation of these plants as, for instance, environment licensing, judicial preliminary or enterprise environment unfeasibility. According to this prediction, it is possible that we will not need to import energy, differently from what happened between 1999 and 2002. But in some places, like in the northeastern part of the country, the first emergency power plants were put in operation in order to prevent lack of energy risks: 800 MW from the rationing security supply working with fuel oil and three PPT thermoelectric power plants working with natural gas that will be generating 400 MW, totalizing an average of 1100 MW of thermoelectric energy.

6.2. Thermoelectric Priority Program Difficulties

The lack of a well-structured policy kept investors that visualized some difficulties in the PPT away from the program. Among those difficulties we can cite (Abraget, 2003):

- natural gas price policy;
- energy sale price;
- financial sources;
- problems with long term contracts;
- mechanisms to protect the investor against disadvantages;
- difficulties concerning environment problems;
- instability of rules (MAE prices – The Energy Wholesale Market had four changes from September 2001 to January 2002);
- MAE guarantees (market breach of contract) and
- exchange risk (external market remuneration).

Approximately 80% of the natural gas would be imported from Bolivia and under the agreement signed by President Gonzalo Sanchez de Lozada and President Fernando Henrique Cardoso, in 1996, the price would be subjected to exchange variation; thus, it would set in Real value for 12 months and the supplier would pay the difference between the price in dollar and the price in Real.

In this aspect, the Brazilian government is already negotiating with the Bolivian government the imported gas price reduction, a complicated arrangement to the neighbor country, which counts on the incomes from the gas exploitation and production. Concerning the thermal close to the big consumer centers transmission tariff it is under the Aneel regulations.

According to the Abraget – Thermoelectric Generator Brazilian Association (2003), it must be discussed, rapidly, the introduction of the natural gas in the Brazilian matrix, through the thermoelectricity, in order to reduce the dependency of the hydrological conditions and, if possible, to reduce the natural gas price up to 30%, along with the transmission tariff fall; the PPT thermoelectric energy price can fall from the actual US$ 43/MWh for something around US$ 38 and US$ 39 per MWh.

The thermal generation needed, according to the Abraget (2003), to decrease future rationing risks, at short term, would be 15% of the installed capacity and, at long term, 20-25%, what is equivalent to about 15 thousand MW, a little lower than what has been predicted in the PPT chronogram.

Created in February, 2000, the PPT initially predicted a the construction of 53 power plants, among cogeneration, combined cycle, natural gas and other fuels, besides the repowering of some hydroelectric power plants. Two years and one rationing later, only 10 projects have been concluded, generating 2484 MW, for some of the power plants are working in partial operation regime. Six undertakings are being processed, 7 are late and 16 have been suspended. Abraget (2003) calculates that up to 2004 the thermal generation will reach 6870 MW, equivalent to only 44% of the original PPT program. The issue is that the natural gas power plants depend on several disputes have to be worked out urgently.

The PPT objective was to attract private capital determined to build thermoelectric power plants, but the program collided with the investors´ insecurity concerning the tariffs by the time of the natural gas price readjustment.

7. Conclusion

This paper shows the environmental impact in thermoelectric power plants utilizing natural gas and diesel as fuels. Thus, it can be concluded that:

- in Brazil there are no NO_x emission standards, but according to the air quality standards mentioned in this paper, it can be inferred that the emission levels for a thermoelectric power plant utilizing natural gas and a diesel thermopower are respectively 2.7038 and 3.1059 kg/kg of fuel for CO_2, 856.10^{-6} and 2778.10^{-6} kg/kg of fuel for the NO_{x1}, 3039.10^{-7} and 13890.10^{-7} kg/kg of fuel for the particulate matter and 0.00 and 9861.10^{-6} kg/kg of fuel for the SO_2. Thus, the diesel thermoelectric power plant emissions compared to a natural gas thermoelectric power plant are 1.2 times for the CO_2, 3.3 for the NO_x and 4.6 for the particulate matter, respectively, based on kg/kg of fuel.
- the PPT, created with the intention of comprising more than 50 thermoelectric power plants, still depends on measurements to be adopted by the government and among those measurements are principally the reduction of the price of natural gas acquired from Bolivia and the reduction of the transmission tariff value, whose reduction for the thermals close to the consumer center still needs to be regulated by Aneel.

The use of natural gas is the best option compared to the diesel, which presents a lower total emission level: 1/1.2 times, concerning the diesel.

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