CARBON EMISSION COMPARISON BETWEEN NATURAL GAS AND ELECTRIC RESISTENCE FOR WATER HEATING

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Abstract

The use of electric showers has become a habit for most Brazilian people, being responsible for a great part in the house consumption of electric energy. This article aims to evaluate the difference between the use of electric showers or natural gas boilers in terms of energy use and greenhouse gases emissions, exposing both energy scenarios in Brazil: electric and natural gas. Therefore, it will be estimated the amount of energy necessary to heat the water average used by a person per year, for each type of shower, comparing the results and estimating the carbon emissions for both type of energies.

Key words

Carbon emissions, natural gas, water heating, electric shower, energy consumption, energy generation.

1. Introduction

A. Energy generation and greenhouse gases emissions

More than half of the Brazilian energy matrix in 2010 (52,5%) was composed of non-renewable sources, while renewable sources represented 47,5%, being hydraulic (13,7%), firewood (10,3%) and sugarcane products (19,3%) the most significant. The oil and its products responded for 42% of the primary energy production that year [1].

However, when it comes to electric energy, Brazil can be told to have a “clean” matrix, composed mostly by hydropower, as shown in Figure 1.

It is estimated that the participation of renewable sources of energy in the Brazilian matrix is three times bigger than the world average [2]. This leads to lower values of average carbon dioxide emissions per energy produced,

in comparison with the rest of the world, since the greatest contribution of the energy industry is that of power plants that burn fossil fuels, and in this case they account for less than 12% of the electric energy production.

Figure 1 – Brazilian internal offer of electric energy by source (adapted from [1]).

Notes:

1. Includes coke gas.

2. Includes firewood, sugarcane bagasse, black liquor and other wastes.

The electric energy system in Brazil is called SIN - Sistema Interligado Nacional (or National Interconnected System), and it works with all the powerplants interconnected – private generation aside.

Since the country covers many different geological and climatic regions, the behavior of the precipitation varies from one watershed to another, which may result in the need to transfer energy from one basin to another in times of drought, or even to evaluate whether the thermal

plants should begin operating or not, through both atmospheric and hidrologic modeling.

The system includes almost one thousand hydropower plants wick are responsible for a capacity of 82 GW [3]. The ten biggest plants are responsible for almost 40% of the entire hydropower generation.

In 2000, the government launched a program called *Programa Prioritário de Termoeletricidade* (or Thermoelectricity Priority Program), which would foment the construction of almost 50 [4] new natural gas plants to meet the energy demand of the projected economical growth.

However, the plan did not predict the infrastructure growth of natural gas suply that would feed the plants, so the plan failed to attract the investors interest, and most of the planst built function nowadays as a side plan only put in practice in times of drought, or some punctual excessive demand.

B. Natural gas panorama

The use of natural gas in developing countries is still small, with an average 20% of their energy matrix [4]. However, due to certain factors such as the low environmental impact compared with other fossil fuels, its simple processing and also high efficiency, the natural gas investiments on infrastructure and exploring have been growing for the last three decades.

In 2005, the natural gas represented only about 9% of the production in the Brazilian energy matrix [5]. Almos half of this amount was consumed by the industry (47%), while 22% was unreclaimed or reinjected in the oil wells, 18% consumed in electric energy generation and 8% used as fuel for vehicles [5].

The natural gas production and consumptions rises year by year, along with the entire Brazilian energy matrix. However, its significance within this matrix remains stable, since 2001, around 9% [1], as shown in Figure 2.

Analysing the data in the chart, one can infer that despite the constant growth of natural gas offer and consumption in Brazil, the industry as a whole shows signs of stagnation in the national framework.

Figure 2 – Natural gas production and consumption along the decade 2000, in 10³ toe and % of the total energy matrix.

Since almost half of the natural gas is used by the Brazilian industry, the improvement of its use as a fuel is limited by the natural gas pipelines' reach, becoming an obstacle for new industries to adopt it, or to insert themselves in determined places where this fuel is not yet available.

The importance of the industry can be exemplified by the fall in the production and consumption of natural gas in 2009 when, due to the arrival of the world crisis in the Brazilian economy, the industrial demand for natural gas fell more than 15% in comparison to the previous year [6]. Furthermore, the reservoirs of the hydropower plants were mostly full that year, which lead to a great decrease in the demand for natural gas for powerplants, higher than 54% [6].

On the other hand, the recovery given by the great increase of the production and consumption seen in 2010 can be related to the addition of 1.600 km of pipelines, more than 17% of the new reach, 9.300 km [1].

Also, the big rise observed in 2008 is due to the low level of the hydropower plants reservoirs at the end of 2007, combined with the full operation of the Brazil - Bolivia pipeline, which lead to the activation of all natural gas power plants in the country, increasing in 81,5% the consumption of natural gas for this purpose [6].

All the data on the production and consumption of natural gas, and their relation to the energy matrix is shown in Table 1.

Table 1 – Natural gas panorama in the decade 2000 [1]

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
NG Production (10³ toe)	13.894	15.410	15.681	16.852	17.575	17.582	17.988	21.398	20.987	22.771
NG Production (%*)	8,9	8,8	8,5	8,9	8,8	8,3	8,1	9,0	8,7	9,0
NG Consumption (10³ toe)	8.254	10.066	10.880	12.185	13.410	14.384	15.456	16.652	15.245	17.268
NG Consumption (%*)	4,8	5,6	6,0	6,4	6,8	7,1	7,2	7,4	6,9	7,2

*Percentage related to the total amount of the energy matrix.

C. Electric showers and energy consumption in Brazil

The electric shower is a Brazilian invention that took place in the 1930 decade. From the first models, which used less efficient and more hazardous materials, it has evolved into a safe and economic choice for residences without gas supply, a very common situation in Brazil. It was largely adopted during the 1960's due to the plastic popularization, which turned its productivity into a faster and more economic process, resulting in a product affordable for all social classes.

Besides the hygiene habits, the water heating is also used for other residential, commercial and also industrial uses. Like the showers, the water can be heated either by direct heat – given by the burn of a fuel – or through an electric resistance.

In the year 2005 the electric shower was used in 73,5% of residences in Brazil, while only 5,9% used gas and 18,2% were not provided with water heating [7]. That made the electric shower responsible for 99,6% of the residential water heating in the country [7].

Plus, the average rate of electric shower units per house was 0,89, reaching values greater than 1,0 in three of the five regions of the country [7]. The result was that 24% of the Brazilian residential consumption of electric energy in 2005 was due to the electric showers [7].

The electric energy consumption for the residential sector in 2005 was 22,2% of the total amount consumed in the country that year [5].

That means that the electric shower alone was responsible for more than 5% of the entire electric energy consumed in Brazil in 2005, or approximately 20 GWh.

2. Objectives

This paper aims to evaluate the amount of energy spent per year by a person, by heating bath water for two showers a day with electric showers, and the carbon emissions related to it, to compare with the emissions of burning natural gas to achieve the same water heating.

It is important to reinforce that this estimation is given by burning gas directly to heat water, instead of burning it to generate electric energy to be used by the electric showers.

3. Methods

A. Energy use

The electric shower doesn't vary its power, *e.g.*, it can't control the water temperature at a constant flow. With higher flows come lower temperatures, and vice-versa. Therefore, in order to estimate the amount of energy, different scenarios were established.

First, the energy spent by the electric shower was calculated for an entire year with 2 baths per day lasting 10 minutes each, by multiplying the powers by the complete time of use. The powers chosen were 3, 5, 7, 9, 11, 13 and 15 KW.

Then, it was estimated, for four different models of gas heaters, the volume of natural gas needed to provide that same amount of energy, for each power described above. The data used for the heaters are shown in Table 2.

Table 2 – Equipment data for natural gas (NG) usage

Flow (l/min)	6	8	10	15
Power (kcal/h)	9000	12000	14700	22800
NG consumption (kg/h)	0,76	1,02	1,25	1,94
NG density (kg/m ³)	0,66	0,66	0,66	0,66

B. Carbon emissions

The emissions for the electric energy generation were calculated using the factor given by the Ministry of Science and Technology of Brazil [8] to convert the energy production into carbon emissions, for the year 2010: 0,0512 tCO₂/MWh.

The emissions related to the volume of natural gas burn were estimated using the spreadsheet given by the GHG Protocol Brazilian Program [9], which is based in the Intergovernmental Panel on Climate Changes (IPCC) methodology, with adaptations for local specificities, for the year 2010.

4. Results and discussion

Figure 3 is a graphic representing the carbon emissions for each different flow at all powers chosen, related with the water temperature increase. As one can see, for the same power, the carbon emission values calculated are very similar, being slightly smaller for the lower flows – with relative differences smaller than 1%. Hence, they will be represented by their average.

Figure 3 – Carbon emissions of natural gas

Table 3 contains the power chosen, the energy related to it, the volume of natural gas calculated and both carbon emission amounts, as well as their ratio.

Table 3 – Carbon emission results in tons of CO₂ equivalent

Power (kW)	3	5	7	9	11	13	15
Energy (x 10 ³ kcal)	314	524	734	943	1153	1362	1572
EE emissions (x 10 ⁻³ tCO ₂ eq)	18,7	31,1	43,6	56,1	68,5	81,0	93,4
Average GN emissions (x 10 ⁻³ tCO ₂ eq)	76,4	127,3	178,3	229,2	280,1	331,1	382,0
Average GN Volume (m ³)	40,4	67,4	94,3	121,3	148,3	175,2	202,2
Ratio EE/GN	0,25	0,25	0,25	0,25	0,25	0,25	0,25

The values estimated for the emissions due to the natural gas were higher than those of the electric energy. That could be explained by the strong presence of the hydropower in the Brazilian energy matrix, whose emissions are lower than the average.

5. Conclusions

As shown in Table 3, the ratio between the electric energy and natural gas emissions is nearly constant, and not very significant. Besides, both energies are amongst the “cleanest”, and ought to be seen as options to the future, when the oil wells may no longer attend the world’s demand.

The hydropower should be more explored, but properly. The construction of very big dams has shown to be very impacting to the environment, especially in Brazil, where most part of the capacity lies in the Amazon basin. Besides that, there are the losses of energy during generation, transformation and distribution of this electric energy, where the system is integrated and the energy flows through over 100.000 kilometers of transmission lines [10].

The reach of gas systems nowadays in Brazil is limited because of the transport infrastructure, which scope doesn’t include regions that already demand it: there are less than 10.000 km of natural gas pipelines around the country [11]. Furthermore, the country’s location allows an insolation that is not properly explored.

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