DEVELOPMENT OF METHODOLOGY AND SOFTWARE FOR ANALYSIS OF ENERGY AND ECONOMIC VIABILITY OF THE INTRODUCTION OF INSTALLATIONS FOR NATURAL GAS IN THE RESIDENTIAL AND COMMERCIAL SECTOR

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Abstract. *The increasing search for alternative sources of energy that take care of, beyond the energy necessities, the current ambient standards, has made with that the participation of the natural gas in the world-wide and national energy matrix is extended. Thus, they are important studies that make possible the expansion of the use of this fuel in the diverse energy sectors, i.e., industrial, advertising, residential, to propagate, among others. The residential sector is what it faces the biggest problems to consolidate itself as consuming of the natural gas. This if must the great cultural barrier in the civil construction, that the use of the NG in its projects does not foresee, and of the technological deficiency, that the affirmation of the sector limits. This work has as objective to establish a methodology adjusted for analysis of the energy and economic viability of installations for natural gas in the residential and commercial sector, beyond the implementation of a software that will more facilitate to the taking of decisions of this the confection of the plant low of the enterprise until the choice of the material adjusted for the tubing, showing the viability technique - economic of the natural gas for supplying the energy necessities of the construction or the use set with electric energy or LPG. The methodology will have support in the laws of the thermodynamics and Norms ABNT for that sector, considering itself involved energy referring the fixed and changeable costs to the construction and. One expects, on the basis of the literature, that the introduction of installations for natural gas in the residential and commercial sector presents viability economic technique and, increasing with this the demand of this fuel and consequently its participation in the national energy matrix..*

Keywords*: Natural Gas, Residential, Software, Energy Matrix*

1. Introduction

With the increasing participation of the natural gas in the world-wide and national energy matrix, beyond the constant search for an alternative source of energy that has an acceptable behavior of the ambient point of view, they become each time more necessary studies to make possible the expansion of the use of this fuel in the diverse energy sectors, such as: Industrial, advertising, residential, to propagate, among others; Of these sectors, the residential one is what more it needs innovations and/or technological adaptations to exert a massive participation in the demand of the natural gas.

One of the biggest obstacles to the diffusion of the use of the residential natural gas is the culture of the sector of the civil construction, that originally projects electric installations (Santos, 2002). The transformation of this culture demands an effort in the direction to still extend the degree of information of the professionals of that sector on the comparative advantages of the natural gas, in special the reduction of costs of investment in the phase of project and workmanships, considering itself it economic participation of the involved and beneficiary energy concessionaires of the project (gas and electric energy). According to Alonso et. Al., the participation of the natural gas in the residential sector must arrive 3% of the participation of this energy one in the national matrix up to 2007.

So that if it can evaluate the magnitude of the viability technique - economic of the implantation of natural gas installations in commercial constructions and/or establishments the development of a methodology becomes necessary that, with basement technician - scientific, it provides a previous study of the possible economic scenes that they can exist between main the involved ones, to know: Concessionaire of natural gas, Concessionaire of electric energy, companies of engineering and projects and the Consumer. This methodology will have support in the first law of the thermodynamics and in the Norms established Brazilian Techniques for the sector of the civil construction. Such norms are mainly based on the phenomena of fluid draining, establishing correlations for determination of the loss of load in pipes and its sizing. Of this form, the cost with the pipes can be esteem in such a way, how much the consumption of the fuel, making possible the forecast of the total cost of the investment and its viability technique - economic.

This work has as objective to consider a methodology for analysis of the energy and economic viability of the introduction of installations for natural gas in the residential and commercial sector, as well as the applicatory implementation of a computational one that will more facilitate to the taking of decisions of this the elaboration of the plant low of the enterprise until the choice of the adjusted material for the installation of the tubing, besides showing to the viability technique - economic of the use of the natural gas for supplying all even though the energy necessities of this construction or of its joint participation with the electric energy or with the GLP.

2. Methodology

The estimate of the fuel consumption and the sizing of the pipes are essential for the estimate of the viability economic technique and of the implantation of the natural gas in the sectors residential and commercial. Such estimates will be established, mainly, on the basis of the Norms Brazilian Techniques and in the first law of the thermodynamics.

2.1. Characterization of fuels

The fuels present essential physical-chemistries properties for the estimate of your consumption in a certain application, be her of stamp industrial, commercial or residential.

Some properties of LPG are shown in the Tab. 1. The composition of the natural gas influences directly in your characteristics, as shown the Tab. 2. Like this, the parameters used in the calculations they should be obtained at the dealer place of the fuel.

Table 1. Some Properties of LPG.

Properties	Value
PCI (kcal/m^3)	26,085
Specific Mass (kg/m^3)	2.35
Relative Density (Air)	1.82

Source: BEN, 2003

Table 2. Composition and Some Properties of the Natural Gas of States of the Bahia, Ceará, São Paulo and Paraná.

Substance	%Volume			
	Bahia	Ceará	São Paulo	Paraná
Methane (CH_4)	88.82	89.24	91.80	89.11
Ethane (C_2H_6)	8.41	7.86	5.58	5.87
Propane (C_3H_8)	0.55	0.24	0.97	1.86
Iso-Butane (i-C_4H_{10})	-----	-----	0.03	1.06
N-Butane (n-C_4H_{10})	-----	-----	0.02	
Pentane (C_5H_{12})	-----	-----	0.10	
Carbonic Gás (CO_2)	0.60	1.25	0.08	1.17
Nitrogen (N_2)	1.62	1.34	1.42	0.91
Oxigen (O_2)	-----	0.07	-----	
Some Properties				
Specific Mass (kg/m^3)	0.6200	0.6130	0.6425	0.6340
PCS (kcal/m^3)	9,400	9,190	9,631	9,560

Source: Bahiagás, Cegás, Comgás e Compagás.

2.2. Characterization of the equipments

The equipments more used as in residences, as in commercial establishments they are: stoves, heaters of water, drying of clothes, ovens, among others. This way, the characterization of those equipments is necessary for the estimate of the consumption of fuel. The Tab. 3 shown some of the principal equipments and your respective nominal potencies.

The rate of fuel is calculated by the Eq. (1).

$$Q = \frac{P_{eq}}{PCI} \tag{1}$$

Table 3. Average Nominal Potency of the mais Equipaments Used in the Section Residential and/or Commercial.

Equipments	Average Potency (kcal/h)
Heaters of Water	3.8000 – 57.000
Dryers of Clothes	2.200 – 4.000
Stoves	1.200 – 4000
Ovens	5.100 – 5.300
Conditioned Air	3.500 – 4.500
Pots of Rice	1.000 – 1.800

Fonte: http://www.comgas.com.br

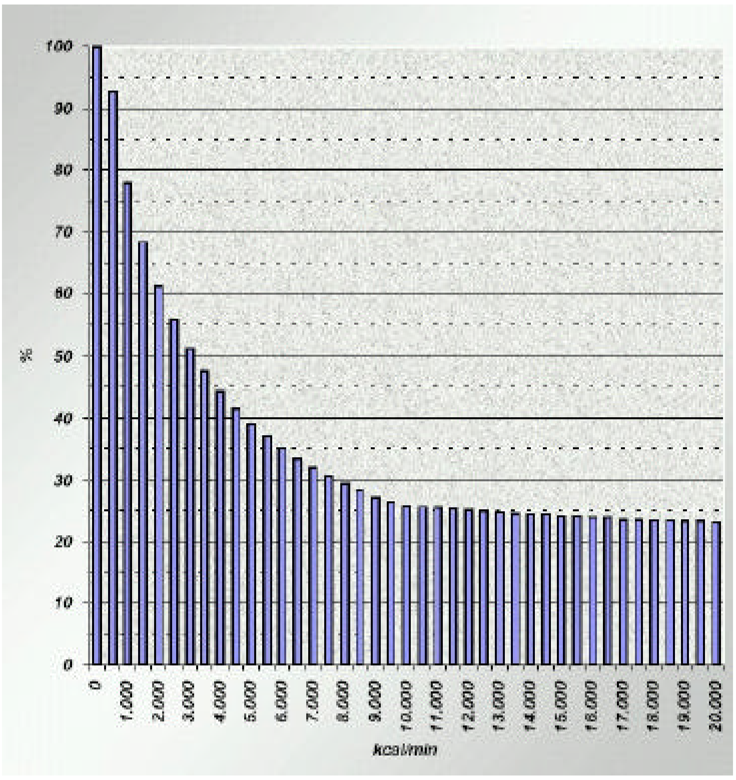
2.3. Sizing of pipes

The sizing of the pipes of gas should take in consideration, mainly, the material to be used and the loss of load of the fuel. The Eq. (2) and (3), according to the ABNT should be used to estimate the diameter of the pipe (NBR 13.933, NBR 14.570, NBR 13.932).

$$H = \frac{206580.Q^{1,8}.S^{0,8}.L_T}{D^{4,8}} \quad (2)$$

$$Pa^2_{(abs)} - Pb^2_{(abs)} = 4,67.10^{5}.S.L_T.\frac{Q^{1,82}}{D^{4,82}} \quad (3)$$

For nets in low pressure (up to 5kPa = 500mmca) the Eq. (2) is applied, already for nets of high pressure (35 and 150kPa) the Eq. (3) it should be used. The rate, Q, denominated adopted rate, it is resulted of the correction of the total rate by the simultaneity factor (F). This factor is determined in function of the total consumption of fuel through graphs, as it illustrates the Fig 1, or through the Eq. (4), (5), (6) and (7).



Fonte: http://www.compagas.com.br

Figure 1. Simultaneity Factor ,%, in Function of the Computed Potency, kcal/min.

$$C < 350 \rightarrow F = 100 \quad (4)$$

$$350 \leq C < 9612 \rightarrow F = \frac{100}{1 + 0{,}001.(C - 349)^{0{,}8712}} \quad (5)$$

$$9612 \leq C < 20000 \rightarrow F = \frac{100}{1 + 0{,}4705.(C - 1055)^{0{,}19931}} \quad (6)$$

$$C \geq 20000 \rightarrow F = 23 \quad (7)$$

2.4. Description of the study of case

It was accomplished a comparative of sizing of pipe and cost for a fictitious apartment that uses a stove (with nominal potency of approximately 11,000kcal/h) and a heater of passage of 10L/mim (nominal potency approximately 14,700kcal/h). The initial pressure of the system is of 200mmca (1,96kPa, approximately) and the fall of pressure admitted maximum equal to 10% of the initial pressure. PCI of the natural gas will be same to 8,500 kcal/m3 (Source: Bahiagás, 2004) and of GLP same to 11,100 kcal/m3. The Fig. 1 shown the configuration of the problem.

All the connections, as well as the material to be used in the pipes, they follow the NBR corresponding.

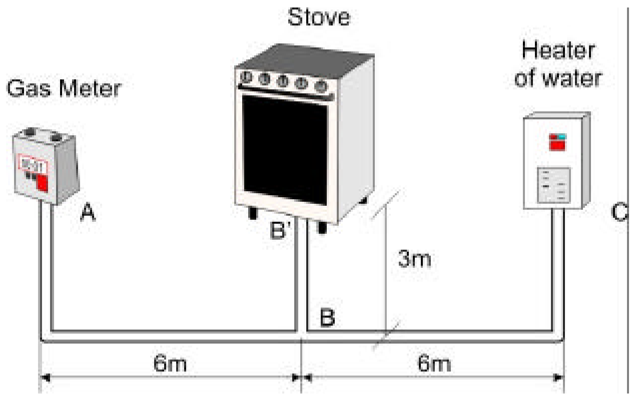


Figure 1. Representative layout of the study of case.

2.5. Methodology of calculation

Firstly it becomes separated in spaces the pipe between the exit of the gas meter and the equipments and it is determined the total potency of the equipments the jusantes of this space and, consequently the rate of fuel in this space, using the Eq. (1). The connections are counted in each space to obtain the equivalent length to each one of them, basing on the loss of equivalent load, as they show the Tab.4 and 5. Through the Eq. (2) and (3) and of the loss of existent load, it is calculated the diameters of the pipes. Of ownership of those values it is considered the cost with the pipes and with the fuel.

Table 4. Equivalent length of connections in a net of copper.

Connections	Equivalent length of the pipe (m)								
	15 (mm)	22 (mm)	28 (mm)	35 (mm)	42 (mm)	54 (mm)	66,7 (mm)	79,4 (mm)	104,8 (mm)
Cot. 90^o	1.1	1.2	1.5	2.0	3.2	3.4	3.7	3.9	4.3
Cot. 45^o	0.4	0.5	0.7	1.0	1.0	1.3	1.7	1.8	1.9
Curva 90^o	0.4	0.5	0.6	0.7	1.2	1.3	1.4	1.5	1.6
Curva 45^o	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Tê	2.3	2.4	3.1	4.6	7.3	7.6	7.8	8.0	8.3
Valv. Esfera	0.1	0.2	0.3	0.4	0.7	0.8	0.9	0.9	1.0

Source: http://www.compagas.com.br

Table 5 - Equivalent length of connections in a net of malleable iron.

Connections	Equivalent length of the pipe (m)								
	½''	**¾''**	**1''**	**1. ¼''**	**1. ½''**	**2''**	**2. ½''**	**3''**	**4''**
Cot. 90^o	0.47	0.70	0.94	1.17	1.41	1.88	2.35	2.82	3.76
Cot. 45^o	0.22	0.32	0.43	0.54	0.65	0.86	1.08	1.30	1.73
Curva f. 90^o	0.27	0.41	0.55	0.68	0.82	1.04	1.37	1.64	2.18
Curva mf. 45^o	0.20	0.30	0.41	0.51	0.61	0.81	1.02	1.22	-----
Tê pass ret	0.08	0.12	0.17	0.21	0.25	0.33	0.41	0.50	0.66
Tê flux dup	0.83	1.25	1.66	2.08	2.50	3.33	4.16	4.99	6.65
Cot. 90^o c/ saída lat.	0.81	1.22	1.63	2.03	2.44	3.25			
Tê 45^o	0.44	0.66	0.88	1.10	1.31	1.75	2.19	2.70	3.51
Valv. Esf.	0.10	0.20	0.30	0.40	0.70	0.80	0.90	0.90	
	¾'' x ½''	**1'' x ¾''**	**1'' x ½''**	**1. ¼'' x 1''**	**1. ¼'' x ¾''**	**1. ½'' x 1. ¼''**	**1. ½'' x 1''**		
Niple red.	0.44	0.41	0.41	0.41	0.34	0.27	0.34		
Luva red.	0.32	0.29	0.32	0.16	0.43	0.12	0.27		
Bucha red.	0.24	0.24	0.24	0.19	0.22	0.20	0.24		
Tê red.	0.59	0.95	0.68	0.71	0.56	1.22	0.79		
	2'' x 1.½''	**2'' x 1.¾''**	**2'' x 1''**	**2. ½'' x 2''**	**2. ½'' x 1. ½''**	**3'' x 2.½''**	**3'' x 2''**		
Niple red.	0.64	0.60	0.52	0.89	0.65	0.86	0.77		
Luva red.	0.38	0.35	0.30	0.64	0.48	0.71	0.70		
Bucha red.	0.43	0.40	0.36	0.39	0.36	0.75	0.69		
	½'' x ½''	**½'' x 1''**	**½'' x 1.½''**	**¾'' x ¾''**	**¾'' x 1''**	**¾'' x 1.½''**	**1'' x 1.½''**		
Curva Transpos.	1.17	0.96	0.93	1.06	1.03	1.23	1.57		

Source: http://www.compagas.com.br

3. Results and discussions

The pipes for natural gas request smaller diameters of those necessary ones for LPG (Tab. 6 and 7), taking in consideration that they are of the same material, as specified in the Tab. 4 and 5. Besides, the uniformity of the sizing is larger in the pipes for natural gas than for LPG. In that way, an installation sized for exclusive use of one of those fuels should not be used, even if provisory, for transport of other energy. That position it will avoid that there is flaw in the supply and damages in the equipments, since these possess specific adjustments for each one of the fuels.

Table 6. Sizing of the spaces of pipe to natural gas.

	Spaces		
	A - B	B – B'	B - C
Calculated potency (kcal/h)	25.700	11.000	14.700
Simultaneity factor (%)	95,7	100,0	100,0
Adopted potency (kcal/h)	24.589	11.000	11.000
Rate (m^3/h)	2,8929	1,2941	1,7294
Length of the space (m)	9,0000	3,0000	9,0000
Equivalent Length (m)	2,4000	3,6000	2,4000
Total Length (m)	11,4000	6,6000	11,4000
Pressure In (mmca)	200,0000	196,1868	192,9250
?P (mmca)	3,8132	3,2618	9,4948

Pressure Out (mmca)	196,1868	192,9250	183,4302
Diameter (mm)	22	15	15

Table 7. Sizing of the spaces of pipe to LPG.

	Spaces		
	A - B	B – B’	B - C
Calculated potency (kcal/h)	25.700	11.000	14.700
Simultaneity factor (%)	95,7	100,0	100,0
Adopted potency (kcal/h)	24.589	11.000	14.700
Rate (m^3/h)	0,9426	0,4217	0,5635
Length of the space (m)	9,0000	3,0000	9,0000
Equivalent Length (m)	2,4000	3,6000	2,4000
Total Length (m)	11,4000	6,6000	11,4000
Pressure In (mmca)	200,0000	199,6132	198,5601
?P (mmca)	0,3868	1,0531	0,4982
Pressure Out (mmca)	199,6132	198,5601	198,0725
Diameter (mm)	28	15	22

The costs, in R$/h, for each studied space were smaller with the use of NG, as shown in the Fig. 2, showing the economical viability of that fuel in relation to LPG, in spite of the rates in the spaces studied for LPG they be smaller than the rates for NG (Tab. 6 and 7). The uniformity of the distribution of the diameters of the pipes for NG is visibly better than for LPG, being considered the same material, as shown the Fig. 3.

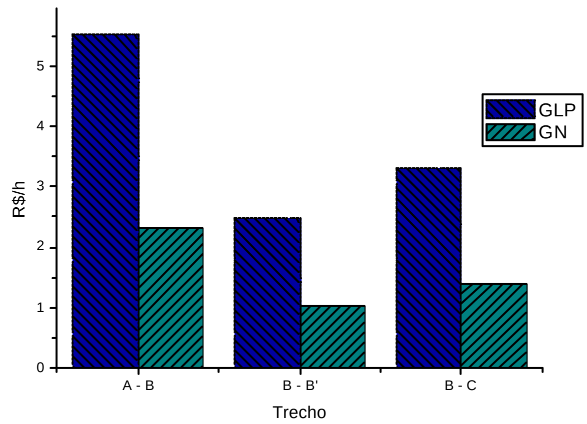


Figure 2 – Comparative graph of the Costs of NG and LPG, in Each Studied Space.

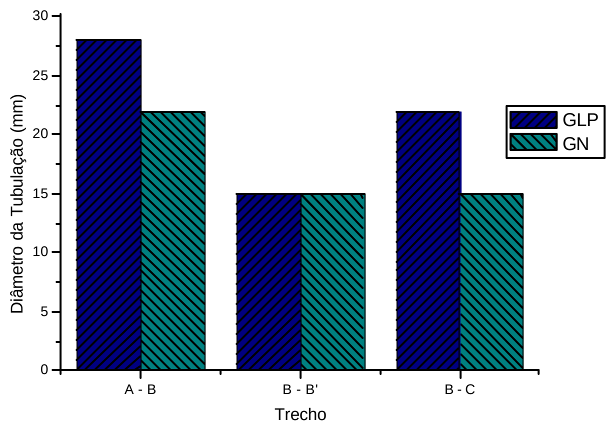


Figure 3 - Comparative Graph of pipes to diameters NG and LPG, in Each Studied Space.

Figure 4 - Main screen of the software EDIFICA 1.0.

4. Conclusions

With base in the presented results, it can be ended that installations sized initially for natural gas they are technique-economically viable that the same installations sized for LPG, presenting a percentile one approximate of 45% of economy in relation to these facilities (Fig. 2). Besides, it can be verified that if the sizing is made initially for exclusive use of a certain fuel, the use of that structure is made unfeasible technically for other fuels, could cart damages the physical structure of the equipments defective and/or in the provisioning (Fig. 3).

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6. Responsibility notice

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Agradecimentos

Os autores agradecem a FINEP/ CNPq/CT-PETRO, PETROBRAS/BAHIAGÁS pelo financiamento do projeto.