Increase in Equipments Efficiency Performance - The Brazilian Mandatory Standards Experience –

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Abstract. The use of public policies to improve energy efficiency is justified by the economic and environmental gains. The Brazilian experience begun during the 1990 decade with development of a voluntary labeling programs conducted by a an state energy company (Eletrobrás/PROCEL). The electrical energy crisis ocurred in beggining of this century changed the government priorities to the sector and an oficial mandatory standards program was initiated. This article analyzes this experience since the Energy Efficiency Law (Law 10295/2001), which gave to the Executive the means to set mandatory energy efficiency indexes for machinery and equipments used in the country, and details the methodology used during to achieve these goals, the regulation already approved and the first results.

Keywords

Regulation, efficiency, motor, energy, consumption, refrigerators.

1. Introduction

Brazil suffers an crisis in the supply of electrical energy in 2001. This fact alerted the government authorities for the necessity in investments in different sources of electrical energy (until then the suplí was almost exclusively from hidroelectricity) and for the urgency to put in practice programs to increase the electrical equipments efficiency. In the same year, the Congress approved the Energy Efficiency Law (Law 10295/2001), which allows the Federal Government to establish maximum levels of consumption, or minimum levels of efficiency for energy consumers machines and equipments used in the country. This Law gave a new dimension to the policy of improving the efficiency of electrical appliances, which until then consists of voluntary labeling systems and now includes regulations and procedures defining the energy performance of equipments consumed in the country. It also sets penalties for non compliance with the established indicators.

This paper reviews the methodology adopted while implementing the regulations, summarizes the standard indicators already approved, shows the first results alter the programs and analyzes the challenges remaining.

2. Methodology [1]

The Energy Efficiency Law created the Management Committee of Indicators and Levels of Energy Efficiency (CGIEE) formed by representatives of government agencies related to the energy sector and energy experts with the aims to develop specific rules for each type of electrical machines and apparatus, and to propose means to monitor their implementation and evaluate the results.

Initially, the Committee studied the international experience in the implementation of equipment standards and labels, evaluated the testing laboratories existing in the country, conducted market research about the main energy consumers machines and electrical equipment, determined the commercial implications of the adoption of the indicators of efficiency and defined which equipment should be subject to regulation and a set of goals for the manufacturers.

After these initial stages, the Committee defined the equipments which will be set mandatory minimum performance levels.

A GROUP 1: Electrical Equipments

1) Refrigerators
2) Freezers
3) Home Air Conditioners
4) Three phase electric motors
5) Transformers
6) Rural Electric Equipments
7) Lighting System
8) Electric Heaters

B *GROUP 2: Equipment employing other energy sources*

1) Solar Collectors
2) Gas Stoves
3) Gas Heaters
4) Automobiles

After these definitions, the regulations are established for each equipment, following a sequence defined by the Committee that takes into account the potential of energy saving equipment. The development of these regulations follows the phases:

1) Establishment of levels of efficiency (voluntary;
2) Meetings with manufacturers to determine the levels based on technical and economic values;
3) Initial version of the regulations for legal review;
4) Public Consultation with wide dissemination and acquisition of contributions during one month;
5) Public Hearing;
6) Presidential Act Promulgation.

3. Regulated Equipments [2]

The Three-phase induction motor was chosen to initiate the process of standards regulation. The choice of this equipment was due to the significant potential of energy consumption that represents in the total electrical energy consumption, which is about 30% of the total in the country and about 50% of the industrial sector. At the end of 2002, the regulation of minimum levels of efficiency for motors manufactured and sold in the country was approved, and in 2004 a new law was approved increasing the levels.

The regulations related to refrigerators, gas ovens and stoves, air-conditioning and water heaters were recently approved (2007-2008).

A. *Three-phase induction motor*

The three-phase induction motor regulation process occurs only one year after the Energy Efficiency Law was approved. This happened because a energy-efficiency label program has been applied to these equipments since 1992. This voluntary labeling program was conducted by PROCEL/Eletrobras (Energy Conservation National Program) and INMETRO (Metrology, Standardization and Industrial Quality National Institute) through the PBE (Brazilian Labeling Program)

The Three-phase induction motor efficiency is given by the ratio between the power delivered to the load (P_{out}) and the electric power supplied to the motor terminals (P_{in}). The mandatory minimum levels are set to nominal load operation. The method to determine this value is also established in the regulations throught the Technical Standarts Brazilian Association (ABNT) standarts.

$$\eta = \frac{P_{out}}{P_{in}} \tag{1}$$

The minimum levels of motor efficiency became mandatory since August 2003 (4508/2002 Decree). Initially, the regulation established two standards with mandatory minimum efficiency levels, one named Standard Motor and the other, with higher levels, named High Efficiency Motor. Figure 1 shows a comparison between the two levels. The High Efficiency Motor levels are compatible with those defined for the EPAct Motors (USA) and for Eff1 Motors (CEMEP).

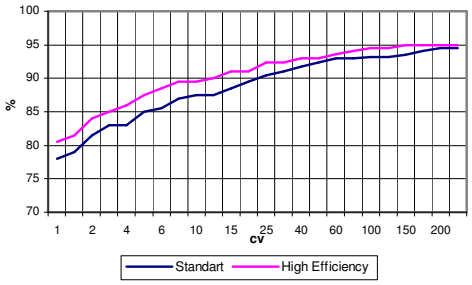

Fig. 1 - Minimum Efficiency Rates for 4 poles Induction Motors (Standard X High Efficiency)

This regulation was amended at the end of 2005 through [ ], which restricted the mandatory minimum efficiency levels to the High Efficiency one by the year of 2010.

B. *Refrigerators and Freezers*

In 2007, the 362/2007 Interministerial Act established mandatory maximum levels of energy consumption for refrigerators and freezers manufactured and sold in Brazil from May 2008. Also established the product test procedures and laboratories evaluation standarts, as well as the penalties and the facilities for the regulation monitoring compliance. Each equipment should indicate the monthly electrical energy consumption.

The maximum consumption level for each equipment depends on: its class of refrigerator (single, combined or combined *frost free*) and freezer (vertical, horizontal or vertical *frost free*); the element used for the insulating foam expansion (R141b or Ciclopentane); and the volume of each compartment and its temperature (*f*). The equipment Adjusted Volume (*AV*) calculation is given by:

$$VA = m\left[V_R + \sum\left(fV_C\right)\right] \tag{2}$$

Where V_R is the refrigerator volume, V_C is the volume of other compartments, the value of f is tabulated according to the maximum temperature of each compartment or section, and m is 1.2 for *frost free* technology and 1.0 for other cases. From this adjusted volume, the Maximum Level of Consumption (NMC) is obtained for each type of equipment from the expression:

$$NMC = p_1.VA + p_2 \quad (3)$$

The factors p_1 and p_2 are the parameters for each category and each element for the insulating foam expansion. The p_1 parameter varies from 0.0214 (Vertical Freezer *frost free* with Ciclopentane foam) to 0.1292 (frost free refrigerator combined with R14b foam) and p_2 parameter varies from 8.8936 (*frost free* refrigerator combined with Ciclopentane foam) to 71.6286 (Vertical Freezer frost free with R14b foam). These factors indicate that the Ciclopentane foam tends to be more efficient, and that the compartments volume has more influence in the freezers consumption.

For example, a refrigerator with internal storage capacity of 300 should have a maximum consumption of 36 kWh/month, while a vertical frost free freezer with the same storage capacity should consume no more than 82 kWh/month.

C. Gas Ovens and Stoves

In this item the actions of the Energy Efficiency Law turn to another source of energy, the Liquefied Petroleum Gas (GLP) and the Natural Gas (GN). The 363/2007 Interministerial Act defined the mandatory minimum energy efficiency levels of the gas ovens and stoves, manufactured and sold in Brazil from May 2008.

These minimum efficiency levels differs the values and test methods for the cooking table and the oven.

1) *Cooking Table.* The Cooking Table Burner efficiency (η_{Queim}) is given by the relation between the Thermal energy (U_{Queim}) absorbed by the contents of a standard container on the burner filled with a mass of water during the interval of time required to raise the water temperature from 20 ºC to 90º C, and the Thermal Energy (U_{Gas}) available by complete gas combustion due to its calorific power.

$$\eta_{Queim} = \frac{U_{Queim}}{U_{Gás}} \times 100 \quad (4)$$

The minimum energy efficiency level for the cooking table (η_{Mesa}) is calculated from the arithmetic average of j burners whose rated power is bigger than 1.16 kW (1,000 kcal / h).

$$\eta_{Mesa} = \frac{\sum_{1}^{j} \eta_{Queim}}{j} \geq 56\% \quad (5)$$

2) *Oven.* The oven consumption level (I_C) is given by the relation between the value of its maintenance consumption (C_{Manut}), which is measured by the quantity of gas per time unit which is necessary to maintain, during the burner combustion, an elevation of 210 °C above the ambient temperature in the geometric center of the empty oven, and the value of this maximum consumption (C_{Max}) calculated in an oven of identical volume according to the standard test (item 3.2 - NBR 13723-2 / 99).

$$I_C = \frac{C_{Manut}}{C_{Máx}} \times 100 \quad (6)$$

The oven energy efficiency level (I_E) is given by the percentage complement of the oven consumption level (I_C).

$$I_E = 100\% - I_C \geq 33\% \quad (7)$$

D. Air Conditioners

The 364/2007 Interministerial Act established mandatory minimum energy efficiency levels for home Air Conditioners manufactured and sold in Brazil from May 2008. The levels are set to window/wall or split system equipments

The energy efficiency level for air conditioners is given by the ratio of its total cooling capacity (W) and the respective electric power demanded (W). The test methods are defined in the NBR-5858 and NBR-5882 Standards. Table 1 shows the window/wall air conditioners minimum energy efficiency levels related by equipment cooling capacity. To be noted that the levels provide a relation greater than 1.0 for the cooling capacity and the electric power delivered to the device. This happens because we are dealing with a thermodynamic system, whose operation cycles performance differ from another formo f energy conversión.

Table 1 - Minimum efficiency levels for window/wall air-conditioners.

Cooling Capacity - CR		**Minimum energy efficiency Level**
BTU/h	W	W/W
CR ≤ 9.000	CR ≤ 2.637	2,08
9.000 < CR < 14.000	2.637 < CR < 4.102	2,16
14.000 ≤ CR < 20.000	4.102 ≤ CR < 5.860	2,24
20.000 ≤ CR	5.860 ≤ CR	2,11

The minimum efficiency levels of the split air conditioners are superior to the window ones. The equipments with cooling capacity up to 36,000 BTU/h (10,548 W), the minimum level is 2.39, in other words, they have a cooling capacity about 7% higher than the most efficient window devices for the same electric power delivered.

E. Gas Water Heaters

Another equipment that uses GLP and GN have their energy efficiency levels defined. The 298/2008 Interministerial Act establishes that all equipments that use gas for water heating manufactured or sold in Brazil should obey defined levels from January 2009.

The procedures for determining the efficiency levels of water heaters are similar to the ones used for the gas stove cooking table. The heater performance is calculated in a similar way to the cooking table burner efficiency, as shown in (4), and the heater efficiency level is given by the arithmetic mean of three performance measurements for a single unit. The heater efficency levels are showed in Table 2.

Table 2 - Summary of mandatory minimum efficiency levels

Equipment	Type	Minimum Efficiency Level
Three-Phase Induction Motor	**Standard**	**77 – 94,5 %**
	High Efficiency	**80 - 95,4 %**
Gas Water Heater	**Instantaneo**	**72 – 74 %**
	Accumulation	**72 %**
Refrigerator	**Combined**	**30 – 70 kWh/mês**
	Frost-free	**45 – 78 kWh/mês**
Freezer	**Vertical/Horiz**	**60 – 90 kWh/mês**
	Frost-free	**82 – 89 kWh/mês**
Gas Stoven	**Table**	**56 %**
	Oven	**33 %**
Air-Conditioning	**Window**	$P_{OUT,W}$= **(2,08-2,24)**$P_{IN,W}$
	Split	$P_{OUT,W}$= **2,39**P_{in}

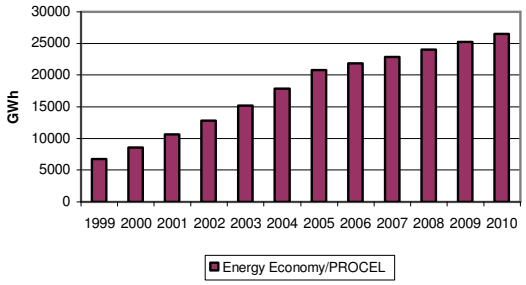

Fig. 2 – Electrical energy economy due to standads and labels programs

During the year of 2005, the economy in energy consumption and power demand due to these programs and resolutions results in 20.780 GWh and 271,3 MW, respectively. Figure 3 shows the distribution of this economy among the standartized equipments [4].

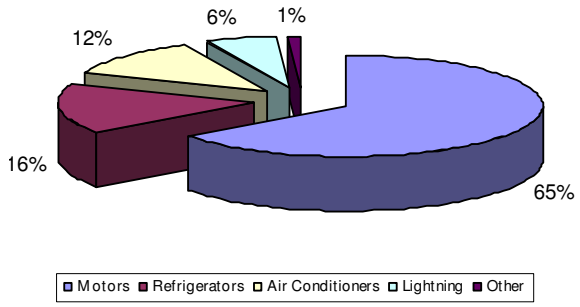

Fig. 3 – Energy economy results from the standartization Program

4. Results and Challenges

The process of creating and approving these regulations has been quickly put in practice due to the prior existence of a products certification organization (CONMETRO), a standardization agency (ABNT), a institute of compliance assessment (INMETRO) and a Label and Standard Program conducted by PROCEL, which conducted a successful voluntary label program [3].

The results of this voluntary programs showed the potencial of this kind of action and lead to the mandatory regulations established after the promulgation of the Energy Efficiency Law. Figure 2 shows the electrical energy economy due to the increase in the electrical equipments energy efficiency.

The principal equipments that contributes to the energy economy due to the standartization programs are the motors and the refrigerators. The Motors are expected to cause the larger economy because they are main electrical consumer in the country, but the refrigerators appears in focus due to the fact that they were one of the first equipments to have its energy consuption labeled (since 1995).

A. *Three-phase induction motor*

The regulation of the three-phase induction motors was approved only one year after the promulgation of the Energy Efficiency Law. The Figure 4 shows the that the response of manufacturers and consumers has been particularly slow, the High Efficiency Motor has increased its participation in the production from 10% to 15% within five years after the initial regulation and the expectation that this product will be the mandatory motor production from 2010 seems difficult to achieve [5].

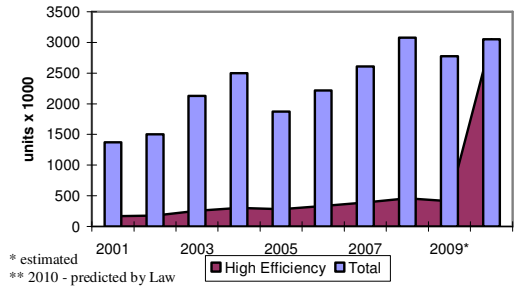

Figure 4 – Brazilian Production of Three-phase Induction Motors

This low demand for this product is due to the fact that the price is 40% higher than the Standard Motor and, apparently, the information that the cost of acquisition is less than 2% of the total cost of operation of the machine and that the increase in efficiency reduces these costs, is not adequately disclosed to the final consumer. However, the concept of standardization and labeling shows the impact on sales is positive [6]. Then, we have to wait this concept turns into reality in Brazil.

B. *Refrigerators and freezers*

In Brazil, these equipments are responsible for about 25% of the residential energy consumption and doing so, they were one of first loads to be included in the labeling programs. The results appear in Figure 4 where the consumption reduction in the equipments manufactured is bigger after the beginning of the programs (1995).

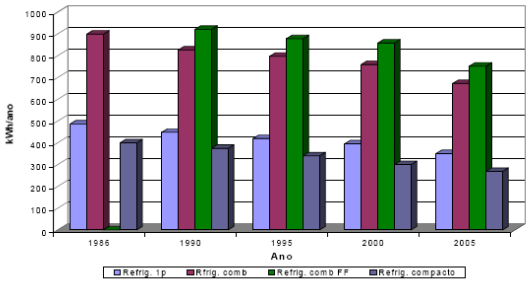

Fig. 4 – Refrigerators consumption evolution

The results achieved in Brazil are similar to those in the United States, where a similar program was adopted.

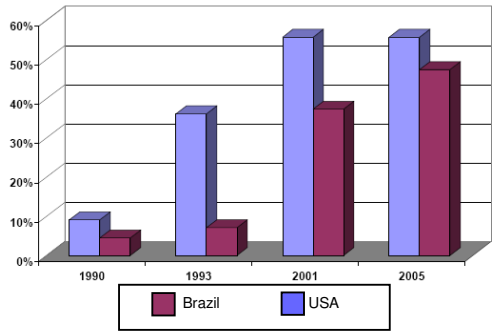

Fig. 5 – Refrigerators Consumption Reduction (%)

The evolution of the total electrical energy consumption related to refrigerators and freezers showed in Figure 7, reveal a constant increase but with less impact after the beginning of the label program conducted by PROCEL in 1995. This reduction should approach the lower curve with the approval of the mandatory resolution in 2008 and with the gradual exchange of the old models. In the same figure it can be seen the effects of the energy crisis in 2001.

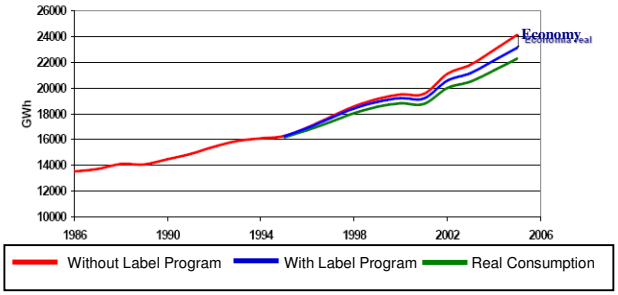

Fig. 7 – Freezers and Refrigerators energy consumption - Brazil

For the manufacturer, these mandatory high energy performance levels will require a strong change in the manufacturing process, including new machinery, tools and scheduling, which will affect mostly small producers. Mass production of high performance engines require significant increases in demand for some materials, especially sheets of iron-silicon and copper, whose prices have increased significantly in recent times.

The impact on prices of equipments can stimulate the import of cheaper products, hence the need for a greater control in monitoring this products by the government. Moreover, the regulation must expand its area of interest and includes the system to which the equipment is connected. In the case of motors, the study of the appropriate load and the correct use of the frequency inverters can generate even more savings than the increased in the efficiency levels itself.

5. Conclusions

With the approval of the Energy Efficiency Law, Brazil has become part of a select group of countries that have minimum energy performance standards for electrical equipment, aligning with the SEEEM (Standards for Energy Efficiency of Electric Motor Systems) initiative and going a little further with the regulations of equipment with other energy sources. The first step of this process was successfully achieved: the regulations were approved according to a careful process of research and consulting with manufacturers, experts and the public consumer. The three-phase induction motor, the first equipment to be regulated, is now being manufactured within the standards, but with a lower than expected production for the high efficiency motor and bringing doubts about the success of the new rules that requires only those engines to be produced from 2010.

The refrigerators and freezers efficiency improve reveals a case of success and these products manufactures are even better prepared to supply the demand according the new resolutions. The other equipment, which regulations were recently approved, the experience with the voluntary labeling will be very important to achieving the regulation goals. The residential consumer is already familiar with INMETRO and PROCEL labels, and the recent increase in the cost of electricity has improved the demand for equipment with low consumption.

The low demand, the high prices, the industrial limitations and an uncertainty brought with the recent worldwide crisis are obstacles to overcome for full implementation of these regulations. The monitoring and evaluation of products will be the great challenge of the government for the success of the legislation.

6. References

[1] Assumpção, M. G., Implementação da Lei de Eficiência Energética, CGIEE/MME, Brasil, 2002.

[2] MME – Ministério das Minas e Energia, .Energy Efficiency Laws and Reports, Disponível em www.mme.gov.br, Acesso em 10/09/2008.

[3] Geller H,, Roberto S, e Outros, Policies for advancing energy efficiency and renewable energy use in Brazil, pp. 1437-1450, Energy Policy, Vol. 32, Elsevier Science Ltd., EUA, 2004.

[4] Cardoso, R. B., "Avaliação da economia de Energia Atribuída ao Programa Selo PROCEL em freezers e Refrigeradores", Universidade Federal de Itajubá, Brasil, 2008;

[5] WEG, Relatórios Anuais de 2001 a 2008, Disponível em www.weg.com.br, Acesso em 20/12/2008.

[6] S. Wiel, J. E. Macmahon, "Energy Efficiency Labels and Standarts – A Guide Book for Appliances, Equipment and Lighting", CLASP, Washington, D.C., USA, February 2005;