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# Evaluation of the energy impacts of the Energy Efficiency Law in Brazil

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ABSTRACT

Minimum energy performance standards (MEPSs) have been adopted in several countries to promote energy efficiency. This study evaluates the impacts of Law 10.295/2001 which regulates the efficiency of equipment in Brazil. This impact assessment was based on estimates of the amount of equipment in operation and the effect of MEPS on a representative model of equipment, in some cases considering efficiency degradation and operation conditions different than those assumed in efficiency measurement. Setting MEPS for refrigerators, air conditioners, and electric motors resulted in an estimated 182.8 GWh savings and 70 MW demand reduction in 2010, which is relatively low due to the limited number of models removed that are affected. The energy saved due to MEPS adoption for gas stoves and water heaters was estimated at 9575 toe (401.0 TJ)[1] in 2010. The projections for 2030 indicate a more substantial impact.



## Introduction

Since the eighties, actions have been implemented in Brazil to reduce energy losses and promote efficiency in the end use of energy. Some programmes, including adjustments in the legal framework, were created to foster energy efficiency and were mainly oriented towards the residential and industrial sectors. Among these programmes are the efficiency labelling programmes, which have been implemented to inform consumers about the energy performance of equipment, and the Energy Efficiency Law, which establishes the minimum levels of efficiency for appliances and energy equipment (e.g., motors and lamps), in both cases promoting the introduction of efficient equipment to the market and reducing energy losses.

In 1984, the Brazilian Labelling Program (PBE in Portuguese) was created, founded by an agreement between the Ministries of the Industry and Trade, Minas and Energy and the Brazilian Association of the Electric and Electronic Industry (ABINEE in Portuguese). This programme is coordinated by the National Institute of Metrology, Normalisation and Industrial Quality (INMETRO in Portuguese) and managed in cooperation with two other programmes: the National Program of Electric Energy Conservation (PROCEL in Portuguese), for equipment that uses or substitutes the use (as solar collectors) of electric energy, and the National Program of Rational Use of Oil Products and Natural Gas (CONPET in Portuguese), for equipment that uses fuels. Depending on its energy performance, equipment is classified by the National Label of Energy Efficiency (ENCE in Portuguese), usually into five classes of efficiency (A to E), with the A class attributed to the most efficient models, adding value to better technology and driving the market towards more efficient models. The information available on the label varies according to the labelled product, but it always includes the energy consumption and its layout is similar to those adopted in many other countries. Fig. 1 presents the label used on roof fans. Currently, this labelling programme covers approximately 48 different types of equipment marketed in Brazil, from hydromassage bathtubs to solar collectors.

In 1993, the PROCEL Label of Energy Economy, or simply the PROCEL label, was introduced with the objective of informing the consumer about better equipment and reinforcing the value of more efficient products. Complementary to the qualifying labels of PBE, this endorsement label emphasises the most efficient products which means class A equipment, according to the efficiency label and presents additional quality attributes, such as safety, low noise, and lower water consumption.

The concession of this label is the responsibility of PROCEL, which essentially uses the same equipment performance database as PBE. According to the Catalogue of the PROCEL Label 2011, this label covers 31 different categories of products and has been granted to more than 2400 equipment models that provide most of the energy savings associated with the PROCEL Label programme (PROCEL, 2011). Adopting the PROCEL Label as a model, in 2005, the CONPET Label was created,

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[1] 1 toe = 41.9 GJ.

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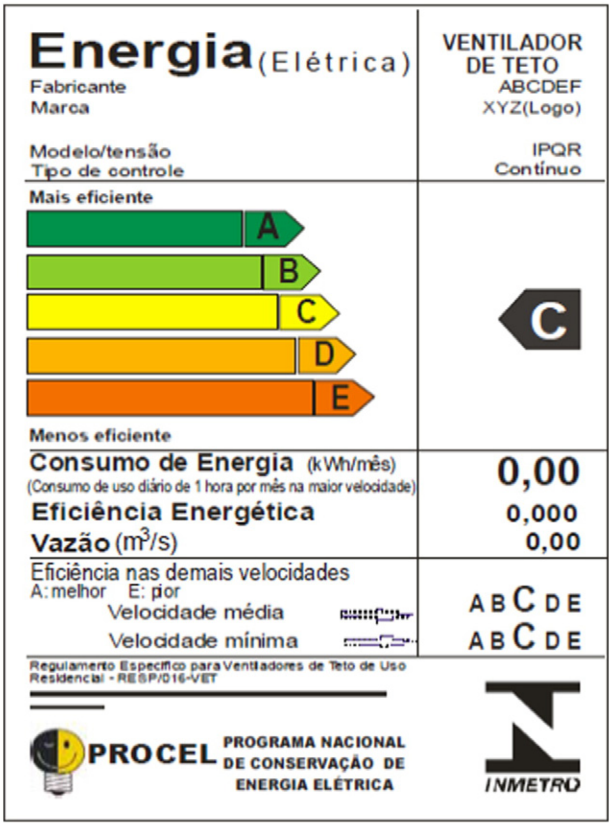


**Fig. 1.** National Label of Energy Efficiency for roof fans.

which is now granted to gas water heaters and stoves of several types. Fig. 2 presents the PROCEL and CONPET Labels.

The ENCE Label, which is more informative, and the PROCEL and CONPET Labels, which are more direct and easy to understand, were applied initially on a voluntary basis under the manufacturer's and importer's criteria. However, the regulation has been progressively adjusted, and now, applying these labels is largely mandatory.


**Fig. 2.** PROCEL and CONPET Labels of Energy Saving.

In 2001, Federal Law 10.295, known as the Energy Efficiency Law, was approved to reinforce those programmes, allowing the Brazilian government to establish minimum energy performance standards (MEPSs) for energy using equipment to prohibit the commercialisation of low-efficiency models and promote the progressive withdrawal of low-efficiency models from the market. The MEPS implementation, in the framework of this law, was recognised as one important measure to foster energy efficiency in Brazil (Volpi et al., 2006).

Considering this gradual evolution of instruments of public policy to promote energy efficiency in Brazil by market improvement through the awareness of equipment performance of consumers and traders, this study evaluates the energy impacts of the Energy Efficiency Law in terms of energy savings and peak demand reduction by considering the equipment currently regulated by the law: refrigerators, air conditioners, electric motors, compact fluorescent lamps, gas stoves, and gas water heaters. These impacts were assessed in the period from 2001 to 2010, corresponding to the first ten years of implementation, and projections for the impacts up to 2030 were made.

In several countries, studies have been developed to evaluate MEPS's impacts and results, such as those developed by Nadel (2002) for the United States, Lockerbie and Ryan (2005) for Canada, Fridley et al. (2007) for China, Lane and Harrington (2010) for Australia, and Tathagat et al. (2011) for India. In exploring the Brazilian reality, the present work has a similar aim and is part of a broad study undertaken by the Center for Strategic Studies and Management, an agency of the Ministry of Science and Technology to assess the quantitative and qualitative results of the Energy Efficiency Law.

## Basic concepts on the evaluation of the energy impact of energy efficiency measures

In essence, assessment of the energy saving from measures of energy efficiency is based on the comparison of the market previous to implementation (baseline) and the subsequent condition after the implementation of those measures, in terms of their impact on the system of energy supply. Therefore, the energy impact of the mandatory adoption of efficiency limits in appliances can be estimated by the difference between the original consumption of the stock of equipment with lower efficiency that is replaced by more efficient products and the consumption of this portion after the introduction of more efficient products.

In the case of MEPS applied to electric appliances, the impact to be evaluated involves the energy that was not consumed in the equipment over a period (for instance, the energy saved over one year, in GWh) and the capacity installed that was not required in the peak of the load curve of the system (capacity saved, in MW) as a direct consequence of the substitution of the less efficient products with more efficient ones.

A conceptual model of equipment sales involving the introduction of measures to increase consumer awareness about equipment efficiency and the establishment of efficiency standards is represented in Fig. 3, as suggested by the Collaborative Labelling and Appliance Standards

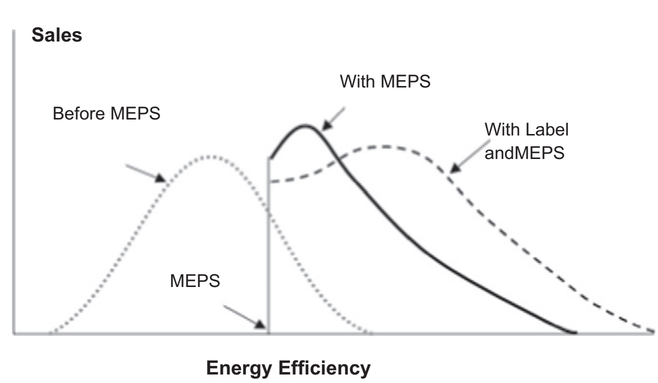


**Fig. 3.** Impact of efficiency standards and labels on the market of energy equipment.

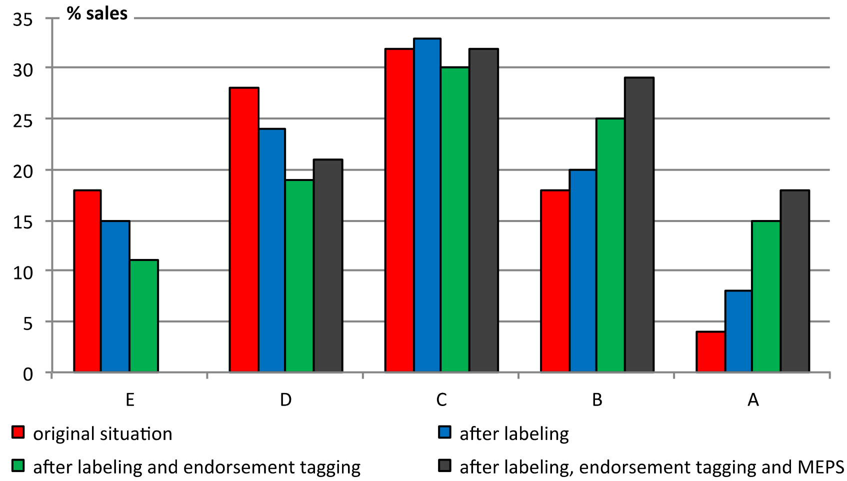


**Fig. 4.** Distribution of the annual sales of an equipment according to efficiency class in the original situation and with the introduction of efficiency label, endorsement tag and MEPS.

Program (CLASP, 2007). This figure indicates the original situation or baseline and the improved situations in two configurations: only with the limits of the minimum efficiency (MEPS) and with both these limits and the efficiency labelling programmes.

Considering the Brazilian context, which includes qualifying labels (ENCE), endorsement labels (PROCEL and CONPET Labels), and finally, through the Energy Efficiency Law, compulsory minimum levels of efficiency were successively introduced. Fig. 4 illustrates the distribution of sales among efficiency classes in different cases using the same base for performance evaluation. While efficiency labelling drives the entire market towards more efficient products, the Energy Efficiency Law removes from the market the portion of products with efficiencies lower than the minimum legal limit. In the absence of detailed sales data before and after the MEPS adoption, the sales of models removed from the market can be assumed to be distributed among the efficiency classes according to their initial share in the market, before MEPS.

## General model for evaluation of the energy impact of MEPS

The energy consumption associated with a particular final use, such as illumination or cooling, can be estimated by the product between the number of equipment in operation to meet that use and the unitary consumption of a representative unit of that equipment. These two parameters constitute the starting point for the modelling of the energy impact of the labelling programmes and the minimum limits of efficiency.

However, the application of this model is not immediate. Frequently, the necessary data are not immediately available in statistical series sufficiently long and detailed. In addition, the standardised conditions of equipment tests for the nominal energy consumption evaluation do not always reproduce the effective conditions of operation (e.g., ambient temperature or consumer behaviour) of that equipment. For instance, in Brazil, the refrigerator standard consumption is evaluated at 32 °C, a temperature that is higher than the average observed in most Brazilian cities. Thus, for more consistent values of energy consumption, some adjustments should be introduced in certain cases.

Fig. 5 displays the average annual consumption of new refrigerators (300 l models) available in the Brazilian market given the nominal values and the values corrected for the average temperature of operation, which is estimated to be 22.2 °C (Cardoso et al., 2010).

Another important effect in some cases is the degradation of the efficiency during the useful life of the equipment. Thus, it was assumed that the consumption of the refrigerators increases by 60% more than the consumption of new equipment after 16 years of use and that the consumption of air conditioners increases by 10% after 12 years of use, linearly with passing of the years. These values came from actual equipment studies and were adopted in Brazil (PROCEL, 2010).

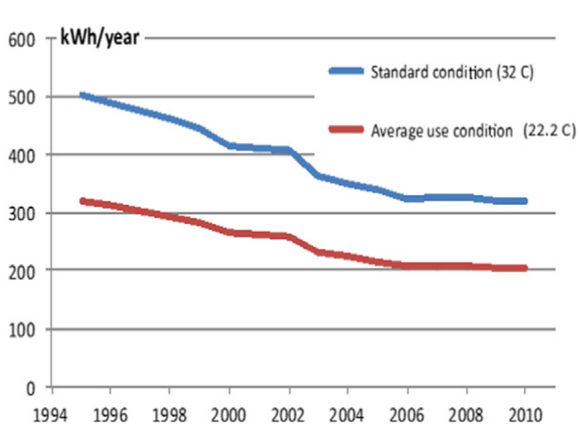


**Fig. 5.** Annual consumption of refrigerators of 300 l in Brazil.

**Table 1**
Refrigerator sales in Brazil (millions of units).

| Year | Models | | |
|---|---|---|---|
| | One door, 300 l | Combined, 400 l | Combined FF, 400 l |
| 2000 | 2.00 | 0.26 | 0.31 |
| 2001 | 2.20 | 0.29 | 0.34 |
| 2002 | 2.57 | 0.33 | 0.40 |
| 2003 | 3.01 | 0.39 | 0.47 |
| 2004 | 3.33 | 0.43 | 0.52 |
| 2005 | 3.40 | 0.44 | 0.53 |
| 2006 | 3.59 | 0.47 | 0.56 |
| 2007 | 3.71 | 0.48 | 0.58 |
| 2008 | 3.87 | 0.50 | 0.60 |
| 2009 | 3.99 | 0.52 | 0.62 |
| 2010[a] | 4.20 | 0.55 | 0.65 |

[a] Estimate.

**Table 2**
Division adopted in the market of air conditioners.

| Technology | Capacity range | Representative model |
|---|---|---|
| Window | 6 to 12 kBTU/h | 9 kBTU/h (2.64 kW) |
| | 12 to 36 kBTU/h | 21 kBTU/h (6.15 kW) |
| Split | 6 to 12 kBTU/h | 9 kBTU/h (2.64 kW) |
| | 12 to 36 kBTU/h | 21 kBTU/h (6.15 kW) |

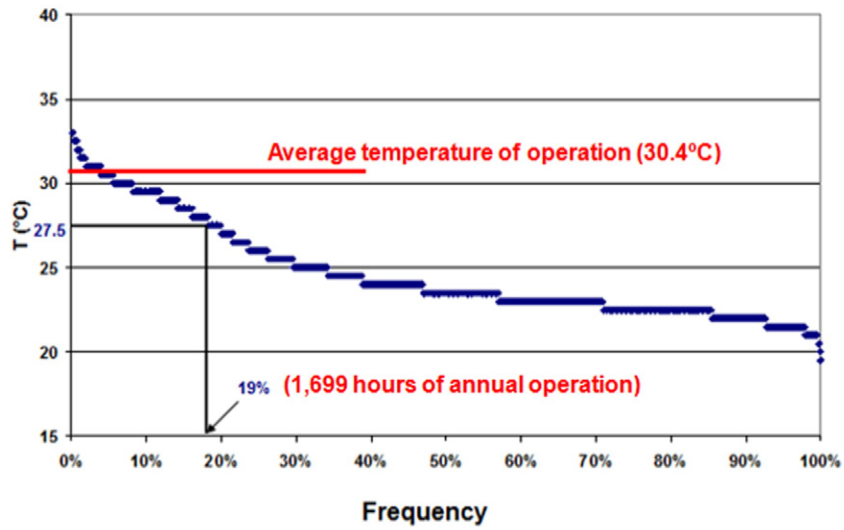


**Fig. 6.** Outside temperature frequency in Manaus (North region) and average temperature for a given operation time.

To improve the analysis and reduce the variability of operational conditions, the market for some equipment was divided into groups according to their capacity, and a representative unit of equipment and its operational conditions were defined for each group. The levels of disaggregation account for regional, sector, and efficiency classes whenever the necessary data are available. When the data are not available, these models are simplified by assuming a representative unit of equipment for the entire market.

Therefore, estimating the energy impacts associated with the adoption of minimum levels of efficiency requires consistent data and solid information at the level of the representative units on the following:

a) energy consumption of the equipment (nominal and real performance, efficiency degradation),
b) equipment (marketed products, in operation), and
c) actual operational conditions (e.g., time of operation, load and temperature).

The general equations used to estimate the impacts of the Energy Efficiency Law are presented below. These equations are functions of the evaluated equipment and available data and can be simplified. In these equations, the electric energy use is assumed, but it can be adjusted for the units typically used with other energy vectors, such as toe or GJ.

a) *Energy saving*: For a chosen period (typically one year), the energy economised is the difference between the consumption under the baseline conditions and the consumption after the adoption of a more-efficient equipment:

$$ES = EC_B - EC_E \tag{1}$$

where: ES — energy saving (GWh); $EC_B$ — energy consumption of the stock of equipment in the baseline (GWh); and $EC_E$ — energy consumption of the stock of equipment with efficient units (GWh). The line base is considered to be the average level of consumption of the less-efficient equipment at the beginning of the implementation of the law. That premise was assumed for the evaluation of each year.

b) *Energy consumption of the stock of equipment*: For both hypotheses of the composition of the stock of equipment, the energy consumption is the sum of the estimated partial consumption for several regions, sectors, and efficiency classes in the evaluated context for a given year. As mentioned above, the disaggregation adopted depends on the homogeneity criteria and the availability of data. The partial consumptions are estimated by the product between the number of units of equipment and the consumption of a representative unit:

$$EC_K = \sum_{\text{Region, sector or class}} ECS_K \tag{2}$$

$$ECS_K = AC_{jK} \cdot S_j \tag{3}$$

where: $ECS_K$ — annual energy consumption of the stock of equipment in the condition K (GWh); $AC_{jK}$ — average annual unitary consumption of the equipment of the region/sector/efficiency class in the condition K for the year j (kWh); $S_j$ — stock of equipment in the region/sector/class in the year j (millions of units); and K — a variable that refers to the scenario of the composition of the stock of equipment (baseline or after the regulation of the minimum levels of efficiency).

c) *Equipment in use*: The amount of equipment in a given region/sector/class in a certain year can be estimated by the sum of the sales during a period equal to the useful life and the equipment discarded after reaching the end of their useful life:

$$S = \sum_{i=j-UL}^{j} V_i - D_i \tag{4}$$

**Table 3**
Estimated operating conditions for air conditioners in Brazil.

| Region | Reference city and state | Annual operation time (PROCEL., 2007) | Average outside temperature when operating |
|---|---|---|---|
| North | Manaus AM | 1699 h | 30.4 °C |
| Northeast | Recife PE | 1699 h | 29.8 °C |
| Centre-west | Cuiabá MT | 695 h | 35.8 °C |
| Southeast | Belo Horizonte MG | 695 h | 33.1 °C |
| South | Porto Alegre RS | 695 h | 29.6 °C |

**Table 4**
Coefficients of performance of the representative models of air conditioners. Window type.

| Year | Baseline | | Improved | |
|---|---|---|---|---|
| | 9000 BTU/h | 21,000 BTU/h | 9000 BTU/h | 21,000 BTU/h |
| 1999 | 2.92 | 2.89 | 2.92 | 2.89 |
| 2000 | 3.06 | 2.90 | 3.06 | 2.90 |
| 2001 | 2.88 | 2.99 | 2.88 | 2.99 |
| 2002 | 2.98 | 2.90 | 2.98 | 2.90 |
| 2003 | 3.04 | 2.87 | 3.04 | 2.87 |
| 2004 | 3.01 | 2.88 | 3.01 | 2.88 |
| 2005 | 3.02 | 2.90 | 3.02 | 2.90 |
| 2006 | 3.00 | 2.87 | 3.00 | 2.87 |
| 2007 | 3.01 | 2.85 | 3.01 | 2.85 |
| 2008 | 3.00 | 2.85 | 3.00 | 2.85 |
| 2009 | 3.00 | 2.90 | 3.00 | 2.90 |
| 2010 | 3.00 | 2.92 | 3.07 | 3.00 |

where: S — equipment in use (millions of units); V — annual sales of equipment (millions of units/year); D — discarded equipment (millions of units); i — index related to the age of the equipment (year); j — index related to the year of analysis (year); and UL — useful life of the equipment (year).

The variable D, a function of discarding, can be assumed to be the amount of equipment coming to the end of its useful life, and presumes a complete and simultaneous withdrawal of these products in that year or distributed over the period at the end of the useful life, according to the discarding functions arbitrated as a function of sale reports and the stock of equipment in operation. For instance, studies performed by PROCEL indicate that the average useful life of a refrigerator in Brazil is 16 years but that approximately 50% of the products are discarded after 15 years, 40% within 16 years and 10% within 17 years after acquisition (PROCEL, 2010).

d) *Average unitary consumption*: Given the operational conditions of the region/sector, the average annual consumption of a representative unit of equipment in a given year can be estimated by weighing the unitary consumptions of the models marketed as a function of their sales during the period and considering the useful lifetime of the equipment. Thus, the representative unit of equipment represents several models with the same or different ages.

To simplify this procedure, the next two equations can be used. These initially consider models sold in the same year and then consider the consumption over several years. This approach assumes that the use patterns are preserved across the different models under the supposition of homogeneity of consumer behaviour. Further considerations can be introduced if the equipment operates at conditions different from those conditions used for nominal efficiency evaluation.

$$\mathrm{AC_i} = \frac{\sum_{\mathrm{j-UL}}^{\mathrm{j}} \mathrm{C_i} \cdot \mathrm{V_i}}{\sum_{\mathrm{j-UL}}^{\mathrm{j}} \mathrm{V_i}} \tag{5}$$

$$C_K = \frac{\sum_{i=\mathrm{mod\,els}} \mathrm{CP}_{iK} \cdot V_i}{\sum_{\mathrm{i=mod\,els}} \cdot V_i} \tag{6}$$

where: C — annual consumption of a representative unit of equipment for a given region/sector/efficiency class in the year j (kWh); and CP — annual consumption of the model, in the standard conditions, for a given region/sector/efficiency class in the year j (kWh).

**Table 5**
Coefficients of performance of the representative models of air conditioners. Split type.

| Year | Baseline | | Improved | |
|---|---|---|---|---|
| | 9000 BTU/h | 21,000 BTU/h | 9000 BTU/h | 21,000 BTU/h |
| 1999 | 3.15 | 3.01 | 3.15 | 3.01 |
| 2000 | 3.08 | 3.01 | 3.08 | 3.01 |
| 2001 | 3.05 | 3.01 | 3.05 | 3.01 |
| 2002 | 3.15 | 3.08 | 3.15 | 3.08 |
| 2003 | 3.08 | 3.02 | 3.08 | 3.02 |
| 2004 | 3.05 | 3.03 | 3.05 | 3.03 |
| 2005 | 3.07 | 3.04 | 3.07 | 3.04 |
| 2006 | 3.00 | 3.03 | 3.00 | 3.03 |
| 2007 | 3.05 | 3.06 | 3.05 | 3.06 |
| 2008 | 2.98 | 3.05 | 2.98 | 3.05 |
| 2009 | 3.04 | 3.06 | 3.04 | 3.06 |
| 2010 | 3.00 | 3.02 | 3.10 | 3.11 |

**Table 6**
Air conditioner sales in Brazil (millions of units).

| Year | Type | | Total |
|---|---|---|---|
| | Window | Split | |
| 2000 | 0.67 | 0.44 | 1.11 |
| 2001 | 0.67 | 0.44 | 1.11 |
| 2002 | 0.69 | 0.46 | 1.15 |
| 2003 | 0.76 | 0.51 | 1.27 |
| 2004 | 0.71 | 0.48 | 1.19 |
| 2005 | 0.76 | 0.51 | 1.27 |
| 2006 | 0.94 | 0.62 | 1.56 |
| 2007 | 0.85 | 0.57 | 1.42 |
| 2008 | 0.85 | 0.56 | 1.41 |
| 2009 | 0.77 | 0.77 | 1.54 |
| 2010 | 0.81 | 0.81 | 1.62 |

## Data and information for the evaluated equipment

Given the specificities of the markets, the use conditions, the available data and the regulations adopted in Brazil for a given equipment, the model developed in the previous section was adjusted and applied in refrigerators, air conditioners, gas stoves, water heaters, electric motors, and efficient lamps. This section presents the data used for estimating the energy impact of MEPS.

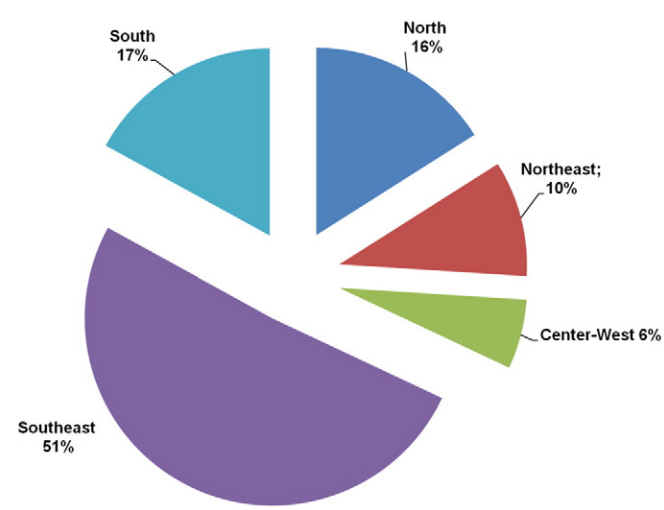


**Fig. 7.** Stock of air conditioner distribution in Brazilian regions.

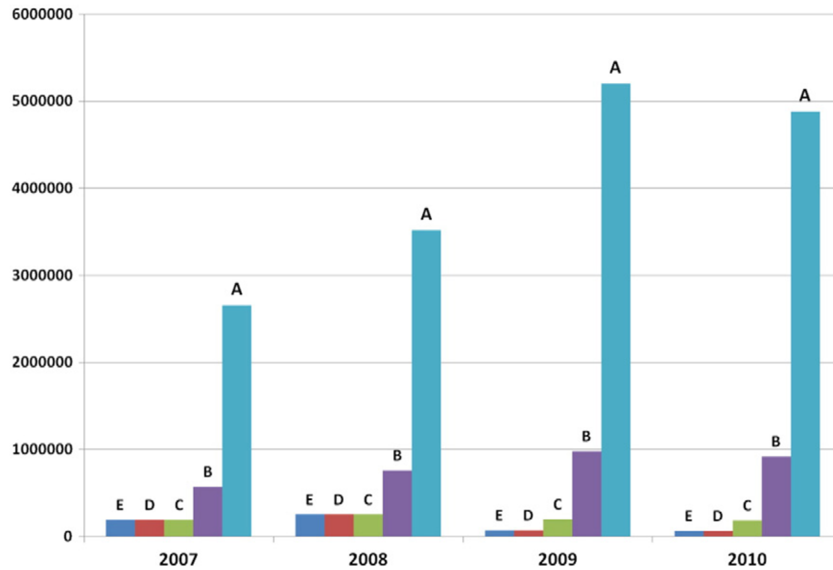


**Fig. 8.** Sales of gas stoves by efficiency class.

### Refrigerators

Refrigerators are responsible for a relevant fraction of the residential consumption of electricity, and details on the methodology for the evaluation of the annual consumption and the data regarding regionalisation and the adjustment of the ambient temperature effect were presented in a previous study (Cardoso et al., 2010). Particularly fostered by the labelling programme, improvements have been introduced in Brazilian refrigerators during the last few decades with a good outcome (Geller et al., 2000). Also, methodologies have been developed for setting the MEPS value based on life cycle analysis, considering the Brazilian conditions, as well as a methodology for estimating MEPS energy impacts has been put forward (Melo and Jannuzzi, 2010).

In the present work, refrigerators were categorised into three groups:

1) one-door refrigerators, represented by a refrigerator with an adjusted volume of 300 l,
2) combined refrigerators (refrigerator/freezer), represented by a refrigerator of 400 l of adjusted volume, and
3) refrigerators combined with frost-free freezers, represented by a refrigerator of 400 l of adjusted volume,

where the adjusted volume corresponds to the total volume of the refrigerator plus the freezer adjusted as a function of the thermal classification of each unit of equipment, according to a standardised procedure (MME/MCT/MDIC, 2007a).

Table 1 presents the values of the historical annual sales of refrigerators (ABRAVA, 2011). For 2010, the sales in this table were estimated assuming a growth rate of 5% over the previous year accompanying the growth of the GDP in that year.

**Table 7**
Data for the calculation of the energy consumption of electric motors.

| Power range (cv) | Representative motor (cv) | Annual operation time[1] (hour) | Load factor[2] (%) | Useful life[3] (years) |
|---|---|---|---|---|
| 1–10 | 5 | 800 | 55 | 13 |
| 10–40 | 25 | 1000 | 61 | 20 |
| 40–100 | 75 | 1200 | 70 | 25 |
| 100–250 | 175 | 2000 | 74 | 29 |

References: (1) PROCEL (2009); (2) PPE/COPPE (2005); and (3) Andreas (1982).

### Air conditioners

In recent years, the market for air conditioners has expanded significantly in Brazil, and they have become more important in the demand for energy. An assessment of air conditioners labelling in Brazil has been developed (Cardoso et al., 2012), and a comparison of MEPS values and impacts for this appliance in different countries, including Brazil, is available (Nogueira, 2013).

In the current study, air conditioners were classified into four groups as a function of the technology (window or split models) and capacity, as indicated in Table 2. In Brazil, the capacity of air conditioners is typically presented in BTU/h, with 1 BTU/h equivalent to 0.293 kW.

The annual energy consumption of an air conditioner depends on the total cooling load during one year, or the power required and time of operation. The cooling load varies over a large range as a function of several variables, which are difficult to determine in a generic manner, such as the thermal load, sensible/latent heat load ratio, and real operation temperatures, among others.

In seeking a simplified approach and approximating the actual use conditions, the expression below was adopted to estimate the annual energy consumption of air conditioners (in kWh), assuming: a) use under ambient (outside) temperatures different than the value adopted

**Table 8**
Electric motor sales in Brazil (thousands of units).

| Power range (cv) | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|
| 1–10 | 915 | 911 | 1035 | 1015 | 1181 |
| 10–40 | 182 | 188 | 233 | 254 | 297 |
| 40–100 | 38 | 42 | 55 | 56 | 63 |
| 100–250 | 15 | 17 | 20 | 20 | 24 |
| Total | 1150 | 1159 | 1343 | 1345 | 1565 |

**Table 9**
Data for evaluation of energy impact associated to the substitution of incandescent lamps in the residential sector.

| Parameter | Value |
|---|---|
| Typical incandescent bulb substituted (base line) | 60 W |
| Typical efficient lamp introduced (after regulation) | 15 W |
| Total lamps per household | 8.1 |
| Current fluorescent penetration in the residential sector | 50% |
| Annual operation time | 1000 h |

**Table 10**
Products regulated by the Energy Efficiency Law up to 2010.

| Product | Regulatory legal act | Entrance in force | Representative model(s) for energy impact evaluation | Stock in 2010 | Sales in 2010 |
|---|---|---|---|---|---|
| | | | | (million units) | |
| Three-phase electric motors | Decree 4.508/2002 and Interministerial Orders 553/2005 and 238/2009 | Aug/2003 Jan/2010 | Motor 5 hp | 10.1 | 1.18 |
| | | | Motor 25 hp | 2.6 | 0.3 |
| | | | Motor 75 hp | 0.6 | 0.06 |
| | | | Motor 175 hp | 0.2 | 0.02 |
| Compact fluorescent lamps | Interministerial Orders 132/2006 and 1008/2010 | Jan/2008 Jan/2013 | Efficient lamp of 15 W | 514.9 | 47.6 |
| Refrigerators and freezers | Interministerial Order 362/2007 | Oct/2008 | Refrigerator 300 l. One door | 43.5 | 3.99 |
| | | | Refrigerator 400 l. Combined | 5.96 | 0.55 |
| | | | Refrigerator 400 l. Combined. Frost-free | 7.13 | 0.65 |
| Gas stoves | Interministerial Order 363/2007 | Jan/2009 | Four burners stove. With oven. Without automatic firing | 54.4 | 7.43 |
| Air conditioners | Interministerial Order 364/2007 | Jan/2009 | Window air conditioner. 9 kBTU/h | 6.56 | 0.62 |
| | | | Window air conditioner. 21 kBTU/h | 2.65 | 0.28 |
| | | | Split air conditioner. 9 kBTU/h | 4.66 | 0.62 |
| | | | Split air conditioner. 21 kBTU/h | 1.13 | 0.15 |
| Gas water heaters | Interministerial Order 298/2008 | Oct/2009 | Fast water heater. Natural draft. 5 l/min capacity | 2.85 | 0.35 |

in standard performance tests (T = 35 °C, dry bulb) and b) operation at 70% of the nominal capacity (as suggested in the PBE rules).

$$C = 0.7.P_N.t_{oper}.\left(\frac{T_{amb}-10}{25}\right)/COP \quad (7)$$

where: C — annual energy consumption of an air conditioner; $P_N$ — nominal capacity of the equipment (kW); $t_{oper}$ — annual time of operation (hours); $T_{amb}$ — ambient (outside) temperature (°C); and COP — coefficient of performance, the ratio between the capacity of cooling and the required electric power (W/W).

For an analysis disaggregated at the regional level, the values of the outside temperature and time of operation were required for the Brazilian regions. In all cases, an internal temperature (in the conditioned room) of 26.7 °C (dry bulb) was assumed, as defined in the PBE rules. Although ambient temperature data are available for different sites in the country from meteorological records, the information necessary for this study was the average ambient (outdoors) temperature when the air conditioners were in use.

To estimate a regional baseline for the outside temperatures and the time of operation for the representative air conditioners, the following hypotheses were adopted:

- The operation time was determined from surveys of ownership and habits of the use of electric appliances in the residential sector (PROCEL, 2007).
- The air conditioners were used in the periods of higher temperature.
- The temperatures recorded closer to the most important cities of each region were considered representative of the area (CPTEC, 2009).

The recorded values of the ambient temperature were ordered and plotted in an accumulated frequency curve to estimate the average temperature when air conditioners are operating for a given operation time, previously known. This procedure is exemplified in Fig. 6 with values for Manaus City, which is representative of Northern Brazil. Table 3 summarises the results of the average outside temperature and operation time for the Brazilian regions.

The coefficient of performance for the original situation (baseline) and after the Energy Efficiency Law regulations was estimated based on the actual efficiency tests of air conditioners for PBE (MME/MCT/MDIC, 2007b) as presented in Tables 4 and 5 for window and split air conditioners, respectively. These values correspond to the supply voltage of 220 V, which is most frequent in air conditioning installations in Brazilian households.

The sales of air conditioners, by type, are presented in Table 6 (ABRAVA, 2010). For the regional disaggregation of the market, it was assumed that the sales are distributed as observed in the national census completed in 2003, as displayed in Fig. 7 (POF/IBGE, 2003).

*Gas stoves*

Liquefied petroleum gas (LPG) is largely adopted as fuel in Brazilian household, and gas stoves are used for the preparation of food in the majority of household. Fuel consumption varies as a function of family

**Table 11**
Values in the evaluation of energy impacts of the Energy Efficiency Law on regulated electric appliances in 2010.

| Product | Representative model(s) for energy impact evaluation | Average unit consumption (kWh/year) | Average unit consumption of excluded models (kWh/year) | Unit consumption reduction |
|---|---|---|---|---|
| Three-phase electric motors | Motor 5 hp | 3493 | 3528 | 0.98% |
| | Motor 25 hp | 20,355 | 20,620 | 1.29% |
| | Motor 75 hp | 66,377 | 71,657 | 7.4% |
| | Motor 175 hp | 271,346 | 273,944 | 1.0% |
| Refrigerators and freezers | Refrigerator 300 l. One door | 208 | 329 | 36.7% |
| | Refrigerator 400 l. Combined | 398 | 518 | 23.2% |
| | Refrigerator 400 l. Combined. Frost-free | 399 | 520 | 23.3% |
| Air conditioners | Window air conditioner. 9 kBTU/h | 654 | 900 | 27.3% |
| | Window air conditioner. 21 kBTU/h | 1946 | 2600 | 25.2% |
| | Split air conditioner. 9 kBTU/h | 607 | 830 | 26.8% |
| | Split air conditioner. 21 kBTU/h | 1830 | 2300 | 20.4% |

**Table 12**
Impacts of the Energy Efficiency Law on the electric power consumption in 2010.

| Product | Representative model(s) for energy impact evaluation | Sales fraction affected by efficiency regulation | Energy saved (GWh) | Peak demand reduction (MW) |
|---|---|---|---|---|
| Three-phase electric motors | Motor 5 hp | <7% | 43.1 | 17.7 |
| | Motor 25 hp | <7% | 3.1 | 1.3 |
| | Motor 75 hp | <7% | 3.6 | 1.5 |
| | Motor 175 hp | <7% | 16.7 | 9.1 |
| Refrigerators and freezers | Refrigerator 300 l. One door | <5% | 20.5 | 8.3 |
| | Refrigerator 400 l. Combined | <3% | 13.2 | 7.2 |
| | Refrigerator 400 l. Combined. Frost-free | <3% | 4.6 | 1.8 |
| Air conditioners | Window air conditioner. 9 kBTU/h | <6% | 14.0 | 6.1 |
| | Window air conditioner. 21 kBTU/h | <6% | 27.4 | 9.6 |
| | Split air conditioner. 9 kBTU/h | <6% | 12.0 | 3.5 |
| | Split air conditioner. 21 kBTU/h | <4% | 24.6 | 4.3 |
| Total | | | 182.8 | 70.4 |

income and home location. In fact, the spreading use of this fuel is important to reduce the fuelwood demand and improve the overall energy sector sustainability (Lucon et al., 2004).

There is also a temporal variation, depending on the adoption of new dietary habits (e.g., diet composition, cooking forms, and the use of prepared foods). However, given the data available, the average values for Brazilian homes can be considered satisfactory for the purposes of this study.

In the Brazilian standard, the efficiency values were defined separately for the cooking top burners and ovens. The efficiency of the top burners is defined by the ratio of the amount of thermal energy absorbed by the container positioned on the burner to the amount of thermal energy supplied by the combustion of gas, according to the classic definition of efficiency (MME/MCT/MDIC, 2007c). For the oven, the performance parameter is the gas consumption (kg/h) required to maintain the oven temperature at a standard value, which is hardly applicable for estimating the energy consumption because it depends on the frequency of oven use.

In this context, the energy savings associated with the adoption of efficient stoves was estimated for one stove based on the average household gas consumption, and the increase in efficiency observed in the burners of the cooking range, according to Eq. (8).

This procedure is justified because stove models with efficient top burners also have efficient ovens. The baseline efficiency adopted in the present study was the value presented by CONPET when the CONPET label for stoves was proposed, which is 52% (CONPET, 2010).

$$\Delta C = C_{med}\left(\frac{E_S-52}{52}\right) \tag{8}$$

where: $C_{med}$ — annual average gas consumption of the stove (J); and $E_s$ — efficiency of the stove top burners (%).

This equation was adopted as a representative model for a stove of four top burners with an oven without automatic firing, the model with the most sales. Assuming a useful life of 10 years, it was possible to compose the stock of equipment breakdown with the stove sale data (ABRAVA, 2010), and using Eq. (4). It is interesting to verify how the implementation of the minimum efficiency levels, valid since 2008, modified the distribution of sales towards more efficient stoves, as shown in Fig. 8 for the period from 2007 to 2010.

The average annual energy consumption (as liquefied gas of petroleum, LPG) of gas stoves was estimated in two ways, and both cases considered 2009 data:

— From the National Energy Balance (EPE, 2012), the residential consumption of LPG in 2009 corresponded to 6115 ktoe (256,032 TJ), where 99% was used for cooking (Schaeffer et al., 2003). With the number of households with gas stoves estimated to be 57.64 million based on the National Household Survey (IBGE, 2010), the annual consumption by stove was 105 kgoe (4392 MJ). This hypothesis does not consider the consumption of other types of fuel gases, which are much less important than LPG.
— According to the National Survey of Domestic Budget 2008/2009 (POF/IBGE, 2010), in 2009, the average Brazilian family spent R$247.56 annually on gas for domestic uses. Assuming a retail price of R$2.74 for LPG (the national average, June 2009) (ANP, 2011), it is possible to estimate an annual consumption of approximately 90 kgoe (3769 MJ).

Both results are relatively close, and annual average consumption of 100 kgoe (4187 TJ) was adopted for stoves in this study.

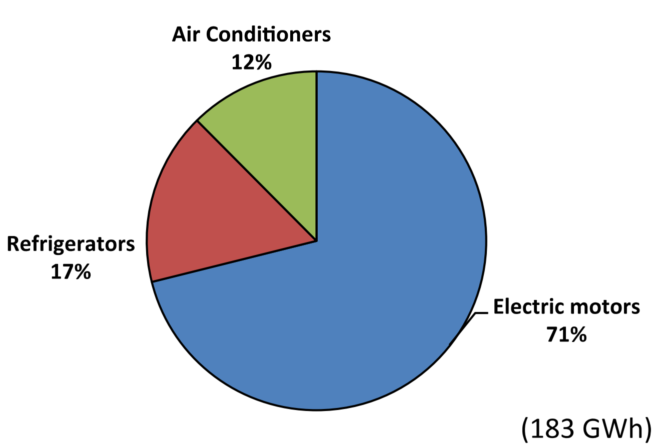


**Fig. 9.** Energy saving promoted by Energy Efficiency Law in 2010.

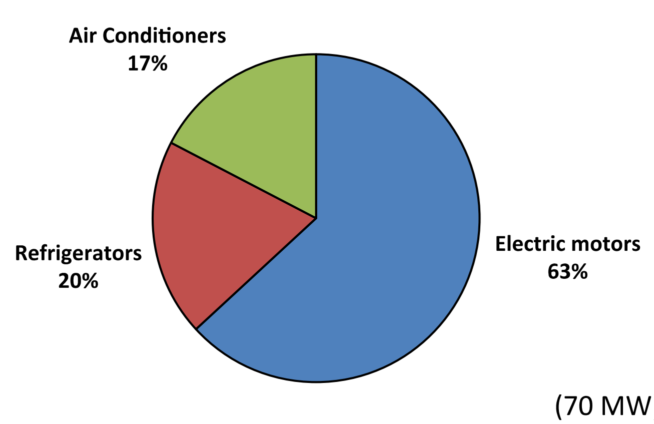


**Fig. 10.** Reduction in the peak demand promoted by Energy Efficiency Law in 2010.

**Table 13**
Values in the evaluation of energy impacts of the Energy Efficiency Law on LPG fueled appliances in 2010.

| Product | Representative model(s) for energy impact evaluation | Unit consumption (kep/year) | Base line efficiency | Regulated minimum efficiency |
|---|---|---|---|---|
| Gas stoves | Four burners stove. With oven. Without automatic firing | 100 | 52% | 56% |
| Gas water heaters | Instant water heater. Natural draft. 5 l/min capacity | 332 | 65% | 72% |

*Water heaters*

The electric shower largely dominates water heating in Brazilian homes, and showers lead to high demand that typically occurs at the peak of the load curve and clearly represents an inefficient form of electricity use. In this context, the diffusion of systems using fuel for water heating can improve the Brazilian energy system.

The Brazilian standard for performance evaluation of gas water heaters, using LPG or natural gas, defines the efficiency as the ratio of the amount of thermal energy absorbed by water to the amount of thermal energy produced by gas combustion. It prescribes a 20 °C elevation of the temperature for the water during the test (MME/MCT/MDIC, 2008).

Adopting a procedure similar to that implemented for gas stoves, the economy of energy associated with the adoption of efficient equipment can be estimated for a unit based on the average consumption and efficiency gain of a regulated heater in relation to conventional equipment, for which the efficiency of 65% was assumed.

$$\Delta C_{heater} = C_{average} \cdot \left(\frac{E_{heater} - 65}{65}\right) \quad (9)$$

where: $\Delta C_{heater}$ — energy savings associated with more efficient heater; $C_{average}$ — annual average gas consumption of the heater (J); and $E_{heater}$ — improved heater efficiency (%).

In addition to the lack of detailed information on household energy consumption, the evaluation of the annual average consumption of heaters presented additional difficulties because natural gas and manufactured gas are of greater importance than LPG in water heating. Thus, a heater with a nominal capacity of 5.0 l/min was adopted as a representative model, which corresponds to the capacity of approximately 10 kW in the standardised conditions. Operation for 360 h per year (approximately four daily baths of 15 min) was assumed, and thus, the annual consumption was approximately 332 kep. A useful life of ten years was adopted.

*Electric motors*

Electric motors are used extensively, mainly in the industrial sector, and constitute important electricity loads. A recent paper estimated the impact of the labelling programme in this equipment in Brazil (Bortoni et al., 2013). Their performance was the object of the first regulation in the framework of the Energy Efficiency Law 10.295/2001, which established minimum levels of efficiency for three-phase induction motor sup to 250 cv (MME/MCT/MDIC, 2005).

In this study, this equipment was evaluated in four capacity ranges with a representative capacity selected for each range and assuming that the energy consumed by electric motors can be estimated by the following equation:

$$C_{mot} = \frac{0.735.P.t_{op}.F_c}{\eta} \quad (10)$$

where: $P_{ot}$ — capacity of the representative model (cv); $t_{op}$ — annual operation time of a representative model (hours); $F_c$ — load factor (–); $\eta$ — electric motor efficiency, the ratio of the mechanical power production to the electrical power consumption (–); and 0.735 — conversion factor of cv for kW.

According to different references, the values for the operation time, load factor and useful life of each representative capacity are presented in Table 7. The load factor information was obtained from a survey of different manufacturers, which was available in the PROCEL MOTOR BD software database (PPE/COPPE, 2005). More details on the adopted methodology are available in the impact assessment of the PROCEL Label for electric motors (PROCEL, 2009).

Due to the typical operation regime, with subsequent departures and stops, expressive temperature variations, the effect of alterations to the magnetic characteristics, wear, maintenance activities and repairs, the efficiency of electric motors can be reduced during their useful life. However, the studies performed by Bortoni et al. (2007) verified that electric motors typically lose less than 2% of their efficiency during their life, even after repair.

The stock of electric motors in operation (number and age of motors) was estimated according to Eq. (4) and considered the sales of motors in different capacity ranges over recent years as presented in Table 8 (ABINEE, 2011).

*Efficient lamps*

Compact fluorescent lamps have diffused quickly in the Brazilian market during the past decade, with a significant volume of annual sales and substantial potential energy impact (Moreira, 1996). Due to relevant differences in the implementation process, the impact of establishing a minimum efficiency for these appliances was estimated differently than those for the other products.

The efficiency of lamps was regulated in Brazil in two stages initially, with the establishment in June 2006 of minimum efficiency levels (in lumens/W) and minimum useful life for compact fluorescent lamps and, later, in December 2010 by the definition of efficiency levels at values that led to the progressive compulsory withdrawal of incandescent lamps from the market.

It is difficult to estimate the energy impact of the first stage because lamps are typically bought by their power (real or equivalent, in the case of efficient lamps) and not by considering lighting intensity (luminance). In addition, it seems incorrect to attribute the adoption of more efficient lamps in Brazil in recent years to the Energy Efficiency Law alone because other factors have fostered their use, such as programmes for the subsidised substitution of incandescent bulbs. Under these conditions, no energy impact was attributed up to 2012,

**Table 14**
Energy saved due to the Energy Efficiency Law for LPG fueled appliances in 2010.

| Product | Representative model | Saved energy (toe) |
|---|---|---|
| Gas stoves | Four burners stove. With oven. Without automatic firing | 2858 |
| Gas water heaters | Instant water heater. Natural draft. 5 l/min capacity | 626 |
| Total | | 3483 |

**Table 15**
Annual growth rates adopted for households and GNP.

| Variable | 2010–2020 | 2020–2030 |
|---|---|---|
| Household | 0.68% | 0.60% |
| Gross national product | 3.2% | 3.2% |

**Table 16**
Projection of the annual sales of equipment (thousands of units).

| Equipment | 2010 | 2020 | 2030 |
|---|---|---|---|
| Refrigerators one door | 4017 | 4381 | 4623 |
| Refrigerators combined | 567 | 579 | 615 |
| Refrigerators combined frost-free | 670 | 693 | 736 |
| Air conditioners window (6 to 12 kBTU/h) | 639 | 1020 | 1460 |
| Air conditioners (12 to 36 kBTU/h) | 300 | 480 | 660 |
| Air conditioners split (6 to 12 kBTU/h) | 639 | 1025 | 1452 |
| Air conditioners split (12 to 36 kBTU/h) | 155 | 240 | 336 |
| Electric motors (1 to 10 hp) | 1219 | 1776 | 2333 |
| Electric motors (10 to 40 hp) | 300 | 436 | 573 |
| Electric motors (40 to 100 hp) | 64 | 94 | 123 |
| Electric motors (100 to 250 hp) | 25 | 36 | 47 |
| Gas and oven stoves | 7430 | 8103 | 8550 |
| Gas water heaters | 350 | 382 | 402 |

**Table 18**
Projections of the unit consumptions or efficiency in the base line.

| Product | 2010 | 2020 | 2030 | Unit |
|---|---|---|---|---|
| Refrigerators one door | 327 | 299.2 | 287.2 | kWh/year |
| Refrigerators combined | 623 | 570.0 | 547.2 | kWh/year |
| Refrigerators combined frost-free | 624 | 571.0 | 548.1 | kWh/year |
| Air conditioners window (6 to 12 kBTU/h) | 3.0 | 3.2 | 3.4 | W/W |
| Air conditioners (12 to 36 kBTU/h) | 2.9 | 3.2 | 3.3 | W/W |
| Air conditioners split (6 to 12 kBTU/h) | 3.0 | 3.2 | 3.4 | W/W |
| Air conditioners split (12 to 36 kBTU/h) | 3.0 | 3.3 | 3.4 | W/W |
| Electric motors (1 to 10 hp) | 85.7 | 85.7 | 85.7 | % |
| Electric motors (10 to 40 hp) | 91.0 | 91.0 | 91.0 | % |
| Electric motors (40 to 100 hp) | 93.2 | 93.2 | 93.2 | % |
| Electric motors (100 to 250 hp) | 94.9 | 94.9 | 94.9 | % |
| Gas and oven stoves | 52 | 52 | 52 | % |
| Gas water heaters | 65 | 65 | 65 | % |

when the progressive banning of inefficient lamps began. According to the regulation issued in the framework of the Energy Efficiency Law, starting in July 2012, incandescent lamps with more than 150 W will not be allowed to be produced and sold in Brazil, beginning the process of the gradual banning of these lamps and their substitution by more efficient models.

In July 2014, 60 W incandescent lamps, which are more widely used, will be included, ending the withdrawal process of incandescent bulbs in Brazil. In these conditions, the transformation of the market will occur essentially due to the Energy Efficiency Law, justifying the estimate of the energy impact in this context.

Currently, incandescent lamps are used mainly in the residential sector, and the studies of the effects of their substitution typically focus on that sector alone (Bastos, 2011). To estimate the energy impacts up to 2030, Table 9 presents basic information on the market of lamps in the residential sector (PROCEL, 2007) and data regarding the energy consumption adopted in the baseline condition with incandescent bulbs and after the replacement of these bulbs by efficient lamps.

## Energy impact for the period 2001–2010

For the first decade that the Energy Efficiency Law was in force, the energy impacts were studied for a) refrigerators and freezers, b) air conditioners, c) gas stoves, d) gas water heaters, e) electric motors and f) compact fluorescent lamps. In Table 10, general information about the regulation introduced by that law for those products is presented, particularly for electric equipment. Table 11 introduces the intermediate results of the appliance consumption in the baseline and the excluded portion, indicating a decrease in the annual consumption in each case.

The relative reduction in the consumption of refrigerators and air conditioners is more significant than the reduction in the consumption of electric motors; however, the energy impact of the motors is higher due to the large number of motors involved and greater operation time.

In Table 12, the final results are summarised, indicating the fraction of the sales substituted by more efficient models, which corresponds to the portion of the products affected by the definition of a minimum limit of efficiency. According to this study, the Energy Efficiency Law promoted a total economy of 182.8 GWh (less than 0.4% of the electricity consumed at the country in 2011, 481 TWh (EPE, 2012)), distributed among the three regulated electric appliances, as shown in Figs. 9 and 10.

The demand reduction was estimated based on the values of the energy saved and equivalent capacity factors (York et al., 2007), a procedure adopted in the PROCEL Label results assessment (PROCEL, 2010). As justified previously, the impact of the efficiency regulation of compact fluorescent lamps was not considered.

The demand reduction promoted by the Energy Efficiency Law in 2010, estimated as approximately 70 MW, is almost irrelevant face to the total generation capacity installed in Brazil, approximately 110 GWh. However, it should be noted that the impacts of the Energy Efficiency Law are still relatively reduced due to the limited number of models replaced in the market and the relatively recent introduction of efficiency regulation for refrigerators (2008) and air conditioners (2009).

For equipment using fuels, Table 13 presents the values of annual energy consumption in the original condition and the efficiency values before and after the introduction of the Energy Efficiency Law. It was assumed that 5% of the sales were altered by this law, according to the manufacturer information for gas stoves (ELETROS, 2011), and this value was also assumed for the heaters.

As indicated in Table 14, the fuel savings induced by the Energy Efficiency Law in 2010 were 9575 toe, a small amount (0.1%) in relation to the Brazilian LPG consumption. However, it corresponds to more than 736 thousand LPG bottles (13 kg), which were saved without modifying the availability of useful energy, only reducing losses and improving the equipment efficiency.

## Projections of the energy impact in 2030

For the products regulated by the Energy Efficiency Law as studied in the previous section, the projections of the energy impacts up to 2030 are presented below. Projections in equipment stock and estimates in the evolution of efficiency were made in order to adopt the same model used in the preceding sections.

Except for electric motors, whose sales present a good correlation with the national gross domestic product (EPE, 2009), the other

**Table 17**
Efficiency increase assumed in the period.

| Equipment | 2010–2020 | 2020–2030 |
|---|---|---|
| Refrigerators | 8.5% | 4.0% |
| Air conditioners | 8.3% | 3.5% |

**Table 19**
Projections of the unitary consumptions or efficiency of the equipment in the improved scenario (with the efficiency regulation).

| Product | 2010 | 2020 | 2030 | Unit |
|---|---|---|---|---|
| Refrigerators one door | 327 | 292.8 | 281.1 | kWh/year |
| Refrigerators combined | 623 | 566.4 | 543.7 | kWh/year |
| Refrigerators combined frost-free | 624 | 567.3 | 544.6 | kWh/year |
| Air conditioners window (6 to 12 kBTU/h) | 3.0 | 3.3 | 3.4 | W/W |
| Air conditioners (12 to 36 kBTU/h) | 2.9 | 3.2 | 3.4 | W/W |
| Air conditioners split (6 to 12 kBTU/h) | 3.0 | 3.4 | 3.5 | W/W |
| Air conditioners split (12 to 36 kBTU/h) | 3.0 | 3.4 | 3.5 | W/W |
| Electric motors (1 to 10 hp) | 85.7 | 86.0 | 86.0 | % |
| Electric motors (10 to 40 hp) | 91.0 | 91.3 | 91.3 | % |
| Electric motors (40 to 100 hp) | 93.2 | 93.5 | 93.5 | % |
| Electric motors (100 to 250 hp) | 94.9 | 95.1 | 95.1 | % |
| Gas and oven stoves | 52 | 56 | 56 | % |
| Gas water heaters | 65 | 72 | 72 | % |

**Table 20**
Projection of energy impacts for equipment using electricity in 2030.

| Equipment | Energy saving (GWh) | Peak demand reduction (MW) |
|---|---|---|
| Refrigerators one door | 356 | 146 |
| Refrigerators combined | 28 | 12 |
| Refrigerators combined frost-free | 34 | 14 |
| Air conditioners window (6 to 12 kBTU/h) | 337 | 184 |
| Air conditioners (12 to 36 kBTU/h) | 225 | 97 |
| Air conditioners split (6 to 12 kBTU/h) | 234 | 128 |
| Air conditioners split (12 to 36 kBTU/h) | 63 | 27 |
| Electric motors (1 to 10 hp) | 160 | 70 |
| Electric motors (10 to 40 hp) | 341 | 119 |
| Electric motors (40 to 100 hp) | 314 | 92 |
| Electric motors (100 to 250 hp) | 369 | 65 |
| Efficient lamps | 11,864 | 8300 |
| Total | 14,325 | 9254 |

projections were accomplished based on the forecast of homes and by evaluating a possible increment in appliance penetration in the residential sector. As the presence of refrigerators and gas stoves is almost absolute in Brazilian homes, an increase in penetration was not considered. Likewise, it appears likely that there are no significant reasons to increase the number of gas heaters or lamps significantly in Brazilian households. However, because the use of air conditioning is expanding, it was assumed that the penetration of this appliance in Brazilian homes will grow from 18% in 2010 to 35% in 2030. That penetration level at the end of the period reflects the expectations presented in the National Energy Plan 2030 (EPE, 2009).

Table 15 presents a synthesis of the hypotheses adopted in these projections, and Table 16 presents the expected evolution of the volume of equipment sold in 2020 and 2030.

Projections of efficiency gains for the equipment studied, either for the baseline or regulated cases, were made based on market forecasts available in energy planning studies (EPE, 2009), with the results summarised in Table 17. In the case of electric motors and gas appliances, the process of "technological saturation" was assumed to maintain the efficiency assumed for 2010.

Based on the consumption values calculated in the previous topic and the estimates of the evolution of efficiency, projections were made for two scenarios (baseline and improved, that is, after the introduction of MEPS regulations), as presented in Tables 18 and 19.

With the projections of equipment sales and unit consumptions made in these two situations, it was possible to forecast the energy impacts for 2030 by applying the model previously developed. Table 20 presents the prospective results of the economy of energy and the reduction of peak demand for each equipment.

According to the projections, the energy impacts of the Energy Efficiency Law will be increasingly significant in the future. It is expected that the energy savings will reach 14,325 GWh in 2030 (about 3% of the total current consumption of energy of the country), and the demand reduction will be approximately 9254 MW (9% of the currently installed generation capacity in Brazil). These prospective impacts were strongly based on the ban of incandescent bulbs, which is currently happening and will account for 82% of the foreseen total economy.

For equipment that consumes fuel, Table 21 presents the annual energy savings foreseen for 2020 and 2030 by considering the progressive adoption of more efficient models at a proportion of 5% of the market every year. As already observed, the expansion of gas appliances for residential heating systems was not considered, but it will certainly elevate these results if it occurs. However, it is possible that as a consequence of the Energy Efficiency Law, more than 6.1 million bottles of LPG will not be consumed in Brazil in 2030 due to a reduction in energy losses.

**Table 21**
Projection of energy impacts for gas appliances.

| Equipment | Energy saving (toe) | |
|---|---|---|
| | 2020 | 2030 |
| Gas stoves | 32,545 | 64,656 |
| Gas water heaters | 7819 | 14,845 |
| Total | 40,364 | 79,501 |

## Conclusions

Developing an evaluation of the energy impacts of the Energy Efficiency Law, based on data of the stock of equipment and the values of unitary consumption in the configurations with and without the efficiency regulation, it was possible to estimate the energy savings and demand reduction associated with the establishment of MEPS for the equipment regulated by the law. The useful life of the equipment and, when reasonable, the influence of the ambient temperature and efficiency degradation were also considered.

It was estimated that improvements in refrigerators, air conditioners, and electric motors driven by the Energy Efficiency Law generated energy savings of 182.8 GWh and a reduction of 70 MW in the peak demand in 2010. The impact of the regulation of the efficiency of stoves, gas ovens and gas water heaters was estimated at 3483 toe (145.9 TJ).

The impacts of Energy Efficiency Law are still relatively limited due to the reduced number of models displaced by the market due to this law regulation. However, in agreement with the projections made, the future impacts of the Energy Efficiency Law can be relevant, mainly due to the ban of incandescent lamps, which is a direct outcome of this law. According to the estimates, the energy savings will be 14,325 GWh in 2030 (sufficient energy to supply approximately 6 million residences, about 3% of the total current consumption of energy of the country), and the power demand will decrease by approximately 9254 MW, which is approximately 9% of the current capacity installed for the electric power generation in Brazil.

In a similar manner, the projections for fuel savings in gas stoves and heaters increase significantly as the amount of more efficient equipment in the market expands, reaching more than 79 thousand toe (3308 TJ) in 2030.

The overall results of this study indicate that the Energy Efficiency Law can play a significant role in reducing energy loss in Brazil. This law would be even more effective if marketing campaigns were introduced to inform consumers about the new regulation measures. Additionally, permanent efforts to review efficiency limits and expand the amount of regulated equipment should be undertaken and supported by efficiency monitoring programmes for traded products and the reinforcement of the new regulation. In a developing country like Brazil, performance standards should be established to reinforce the goals of supporting economic activity, reducing environmental impacts, achieving social goals, and finally, improving the rationality of energy use in the country.

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