

# **Appliance Saturation and Energy Conservation Measures in Households in Brazil**

## *Results from Household Surveys in Rio de Janeiro, Brazil*

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### **Abstract**

Due to problems with electric sector restructuring, Brazil experienced a severe electricity shortage in 2001-2002. Most consumers in Brazil were required to reduce their electricity use by 20% over a nine month period. This resulted in fairly dramatic changes in consumer attitudes and behavior, including considerable adoption of energy conservation measures and practices.

This paper summarizes the result of a survey conducted in 400 households in Rio de Janeiro in 2004. Households were asked about: 1) appliance ownership including ownership of energy saving devices such as compact fluorescent lamps, 2) adoption of energy conservation practices such as unplugging or reducing use of appliances, and 3) awareness and use of the “selo PROCEL” energy efficiency label. Households were asked about what actions they took to conserve electricity during and after the electricity rationing in 2001-02, and which of these practices they are continuing to implement today. In addition, the data collected in 2004 are compared to data from previous household surveys in Rio de Janeiro.

### **Introduction**

Brazil is a middle-income developing country blessed with substantial hydroelectric resources. National electricity production reached the level of 392 TWh in 2000, with 90% of the electricity provided by hydropower. There is a high degree household electrification and considerable electricity-intensive industry in Brazil. Electricity use per capita grew 2.9% per year on average during 1990-2000.

Electricity consumption in Brazil breaks down by sector as follows: 28% residential, 43% industrial, 16% commercial, and 13% public sector, agriculture and other. For many years utilities were concerned primarily with their large commercial and industrial customers. Prior to the late 1990s, utilities showed little interest in understanding household appliance saturations and ownership trends, electricity consumption patterns, or consumer attitudes. Indeed, the only information available was based on a national survey conducted by Eletrobrás in the 1980s.

Utilities and others have increased their interest in household appliance trends and electricity consumption patterns in recent years for the following reasons:

a) There was significant growth in residential electricity consumption due in large part to the increase in appliance purchases following the economic stabilization program instituted in 1994. Residential electricity use increased 72% in Brazil between 1990 and 2000.

b) Electricity demand can be forecast more accurately if updated information on appliance ownership and ownership trends is available.

c) Utility demand-side management (DSM) programs can be improved if utilities understand what types of appliances and lighting devices consumers are buying, typical household load profiles, and the attitudes consumers have towards energy conservation measures and practices.

Furthermore, Brazil experienced a severe electricity shortage in 2001-2002. During the 1990s, Brazil attempted to privatize and restructure its electricity sector. But this was only partially successful. Flaws in this strategy led to relatively little investment in new generation and transmission facilities during the late 1990s. Combined with a few years of below-normal rainfall, this led to the power shortage (Geller 2003).

In response to the power shortage, the federal government implemented an electricity rationing strategy for nine months during 2001-02. Households consuming over 100 kWh per month were required to reduce their electricity use by 20% relative to consumption the previous year.<sup>1</sup> Those failing to comply with this requirement were first subject to stiff fines and then threatened with electricity supply curtailment.

This strategy was successful. Total electricity use in Brazil dropped by more than 20% soon after the strategy was implemented in mid-2001 (IEA 2005). Most consumers (households and businesses) cooperated and achieved their mandated reduction targets. The rationing was ended in early 2002 after strong summer rainfall and refilling of reservoirs.

Until now there was no systematic analysis of what households or businesses nationwide did to meet their reduction requirements. To address this shortcoming, PROCEL (Brazil's national electricity conservation program) and IEPUC (Energy Institute of the Catholic University of Rio de Janeiro) developed and implemented a nationwide survey of household appliance saturations, energy conservation measures and practices, and related issues in 2004.

The remainder of the paper is organized as follows. In section 2, we describe the national survey. In section 3, we present some survey results, concentrating on the city of Rio de Janeiro (the national data were not fully available at the time this paper was written). In section 4, we discuss the behavioral changes related to electricity use that took place in Rio de Janeiro during and subsequent to the 2001-02 rationing. Also, we briefly explain the policies and programs that helped households (and other consumers) comply with the rationing requirements. Finally, in section 5 we present the main conclusions.

## **Residential Survey Description**

The nationwide survey was implemented in cooperation with 20 distribution utilities in Brazil. For each utility, a sample of 400 to 600 customers was chosen randomly from the utility's residential consumers following a two-stage stratified sampling scheme developed especially for this survey. This sample size allows a maximum error of 4% for any estimate obtained from the sample.

In this first step, each utility's residential customers are distributed according to the following ranges of monthly consumption:

- range 1: 0 – 50 kWh
- range 2: 51 – 100 kWh
- range 3: 101 – 200 kWh
- range 4: 201 – 300 kWh
- range 5: 301 – 500 kWh
- range 6: > 500 kWh

Households were distributed in these six ranges of consumption for each city or town. We then made use of a neural network based algorithm to produce a cluster analysis that creates groups of cities

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<sup>1</sup> No reduction requirement was imposed on lower income households consuming less than 100 kWh/month. Businesses were required to reduce electricity use by 15-25% depending on the sector.

and towns with similar consumption distribution (Kohonen 2000). The cities and towns in each cluster are weighted according to their contribution to the total number of customers in the cluster they belong to. Also, the methodology points out the city or town which is the cluster representative, i.e., the one whose distribution is closest to the cluster distribution. The other cities and towns in the cluster are ranked according to their distance to the cluster representative.

Once the cluster analysis is concluded, a sample is randomly drawn within each consumption range from the cities and towns chosen within each cluster. The sample is representative of the utility's overall distribution of electricity usage. For each household selected, three others with the same characteristics (location and consumption range) are chosen as back-up households. The total sample size nationwide was 6,000 households.

For the survey, a standard 20-page-questionnaire was developed. It includes questions on:

- dwelling characteristics (location, size, number of inhabitants, type of construction, etc);
- household characteristics (average income, education level of family members, socio-economic class, etc.);
- ownership and estimated usage of electrical appliances;
- ownership and usage of different types of lighting devices;
- consumer awareness and attitudes concerning efficient appliances and the PROCEL energy efficiency label;
- consumer electricity conservation actions during and after the rationing period.

The energy efficiency label, known as the “selo PROCEL” in Brazil, is similar to the ENERGY STAR label in the U.S. Manufacturers place it on products that meet certain energy efficiency and product quality criteria established by PROCEL and the national standards agency. It is used on the following residential products: refrigerators, freezers, room air conditioners, and compact fluorescent lamps.

The survey interview was administered in person to the head of the household whenever possible. Completing the survey typically took about 30 to 40 minutes. The survey was administered by trained market research professionals, with graduate students acting as supervisors. The response rate, i.e., the fraction of households that completed the survey when asked, was about 60%. As noted above, an alternate household with similar characteristics was surveyed if the initial household selected declined to cooperate.

The main products of the survey include the following:

- databases with information and summary tables on appliance ownership and corresponding usage for each utility analyzed;
- a summary report for each utility meant for utility management;
- computer software with graphical facilities to estimate and draw the average residential load curves and the corresponding contribution of the main end-uses. The software, named “SINPHA” (Information System on Residential end-use Holding and Usages), is now being implemented on a web environment.

## **Rio de Janeiro Demographic and Appliance Saturation Results**

The 2004 survey has been completed and data analyzed for metropolitan Rio de Janeiro, one of the largest cities in Brazil. The population of this metropolitan area is around 6.0 million. The utility serving this city, known as LIGHT, is one of the largest distribution utilities in Brazil with a total of 3.4 million customers. The Rio de Janeiro results are interesting in part because IEPUC conducted

household surveys in the LIGHT service area in 1997 (sample size 635 households), 1999 (sample size 1,230 households), and 2002 (sample size 2,500 households). The 2004 sample size for LIGHT was 400 households.

The 1999 and 2002 surveys employed larger sample sizes in order to allow regional estimates within the utility's overall service area. Also interesting to note is that the first two surveys took place before the 2001-02 rationing, and the other two after. This allows an examination of changes in appliance ownership and consumer behavior provoked by the rationing.

The surveys indicated that approximately 80% of households in the metropolitan Rio de Janeiro area are middle or lower middle class (classes C and D under Brazil's income stratification system). As of 2004, about 15% of households were upper or upper middle class (classes A and B), and about 4% were lower class (class E). There has been a slight shift towards the middle class (i.e., away from both classes A and E) during 1997-2004.

The survey also indicated a decline in average household income during 1997-2004, as expressed in terms of the Brazilian monthly minimum salary (now approximately US\$110/month). In 2004, the self-reported average family income was 6 minimum salaries (approximately US\$660/month), compared to a self-reported average of nearly 8 minimum salaries in 1997-99.

Before presenting the survey results, a comment is in order on residential electricity prices during 1997-2004. In general, electricity prices were increasing during this period. Rising electricity prices, coupled with declining average incomes, no doubt increased consumer interest in energy efficiency during this period. However, we do not know how significant this factor was.

Table 1 shows the trends in average appliance and lighting saturation in Rio de Janeiro during 1997-2004. For more details see Souza, (1997, 1999, 2002 and 2004).

**Table 1.** Appliance and Lighting Saturation in Rio de Janeiro, 1997-2004

Product	Saturation			
	1997	1999	2002	2004
Elec. resistance water heater	0.60	0.61	0.75	0.78
Room air conditioner	0.32	0.38	0.41	0.42
Refrigerator	1.01	0.99	1.01	0.99
Freezer	0.22	0.22	0.24	0.24
Television	1.40	1.55	1.58	1.60
Fan	1.44	1.57	1.80	1.81
Microwave oven	0.18	0.23	0.24	0.25
Clothes washer	0.52	0.58	0.65	0.71
Personal computer	0.08	0.13	0.24	0.24
Printer	0.06	0.10	0.20	0.20
Incandescent lamps	6.80	6.20	4.40	4.47
Compact fluorescent lamps	0.01	0.03	2.30	2.31
Tubular fluorescent lamps	0.80	0.80	1.10	1.05

From this data, a number of observations can be made:

- 1) The penetration of electric resistance showers increased from 0.60 per household in 1997 to 0.78 in 2004. These are 4-5 kW devices that contribute a great deal to peak demand in the 5-9pm time period.
- 2) Refrigerators have clearly reached their saturation level of 1 per household, while freezers are still at the level of 0.24 per household without any significant upward trend. This can be

explained in part by the average size of the dwellings in Rio de Janeiro (75m<sup>2</sup>) which does not allow room for the freezers in many cases, as well as by the recommendations of energy authorities to switch off freezers during the rationing period.

- 3) Room air conditioner saturation is still rising, reaching the level of 0.42 per household in 2004. But air conditioner ownership increased much more slowly in the post-rationing period compared to the pre-rationing period. Air conditioner ownership is very income-dependent, with approximately 2 air conditioners per household in class A and B households.<sup>2</sup>
- 4) The average number of televisions and fans has increased moderately, reaching the values of 1.6 televisions and 1.81 fans per household, on average, in 2004. Fans are used by some households instead of air conditioners.
- 5) There has been a dramatic decline in the use of incandescent lighting in households in Rio de Janeiro. This was particularly seen between the 1999 and 2002 surveys, suggesting that many incandescent lamps were discarded or replaced with fluorescent lamps during the rationing. The use of incandescent lamps remained relatively constant during 2002-2004.
- 6) The penetration of compact fluorescent lamps (CFLs) increased dramatically between 1999 and 2002. Households in Rio de Janeiro now have nearly 2.3 CFLs, 3.4 fluorescent lamps of all types (tubular and compact), and 4.5 incandescent lamps on average. The ratio of fluorescent to incandescent lamps, 0.75, is very high compared to that in other countries.<sup>3</sup>
- 7) The saturation of microwave ovens and clothes washers also rose during the 1997-2004 time period. There are now 0.25 microwave ovens and 0.71 clothes washers per household in Rio de Janeiro. Neither has yet reached the expected saturation level.
- 8) The saturation of personal computers and printers increased at a high rate during 1997-2004. As of 2004, about 1 in 4 households had a personal computer and 1 in 5 a printer. However, the saturation of these products did not increase between 2002 and 2004, suggesting that they may be reaching saturation relative to the fraction of households with adequate income and desire to own these devices. On the other hand, rising income and declining equipment cost could alter this situation in the future.

Because of the high usage of CFLs in Rio de Janeiro (and in Brazil more generally), we present the breakdown of lamp use by household electricity consumption bin in Table 2. Electricity use increases as income rises, so this parameter is a reasonable proxy for income. Table 2 shows that the number of incandescent lamps does not vary according to consumption and income level, but the number of fluorescent lamps does. Higher consumption, higher income households have more fluorescent lamps than incandescent lamps.

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<sup>2</sup> Rio de Janeiro is a hot city with daytime highs often exceeding 35°C during the summer.

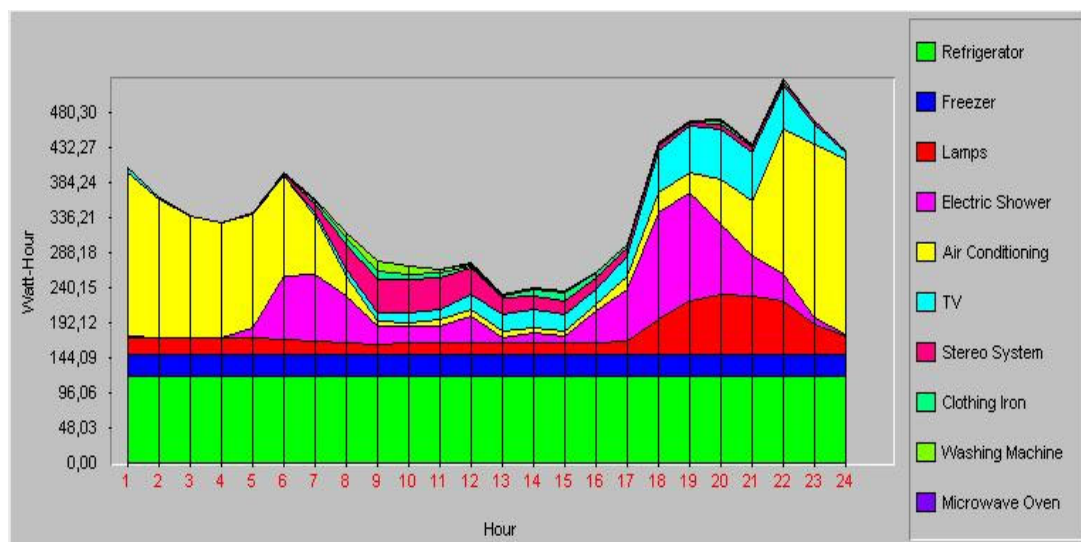
<sup>3</sup> In California, a state known for its strong energy efficiency efforts, there were close to 2 CFLs per household on average in 2003 (CEC 2004). Although the fluorescent-to-incandescent lamp ratio is not known, it is not likely to be greater than 0.10.

**Table 2.** Average Number of Incandescent and Fluorescent Bulbs per Household in Rio de Janeiro, 2004

Consumption range (kWh per month)	Number of Incandescents	Number of Tubular Fluorescents	Number of Compact Fluorescents
0 - 50 (kWh)	3.80	0.80	1.52
51 - 100 (kWh)	4.57	0.36	1.45
101 - 200 (kWh)	4.38	1.29	2.65
201 - 300 (kWh)	4.64	1.01	2.37
301 - 500 (kWh)	3.61	1.30	2.86
> 500 (kWh)	3.48	2.20	3.88
<b>Total</b>	<b>4.47</b>	<b>1.05</b>	<b>2.31</b>

Based on the appliance saturation data and on information regarding typical equipment wattages and usage levels, we can estimate the average daily load curve and the contribution of different appliances. Figure 1 shows this estimated load curve in 2004 during the “middle season” (spring or fall). Note in the figure that refrigerators are the lowest “slice”, freezers next highest, etc.

The diversified peak demand of about 500 watts during these months occurs around 10pm. It is strongly driven by air conditioning which is typically used in the evening and at night, often in the bedroom, in households in Rio de Janeiro. The high contribution of the electric resistance water heater to peak demand during the late afternoon and early evening is also seen in this curve. While each water heater draws 4 or 5 kW when on, there is only about a 5% probability that a randomly selected house will have an electric water heater operating at say 7 pm. Lights and televisions are other non-trivial contributors to the evening peak demand. Refrigerators and freezers provide a diversified baseload demand of about 145 watts on average.

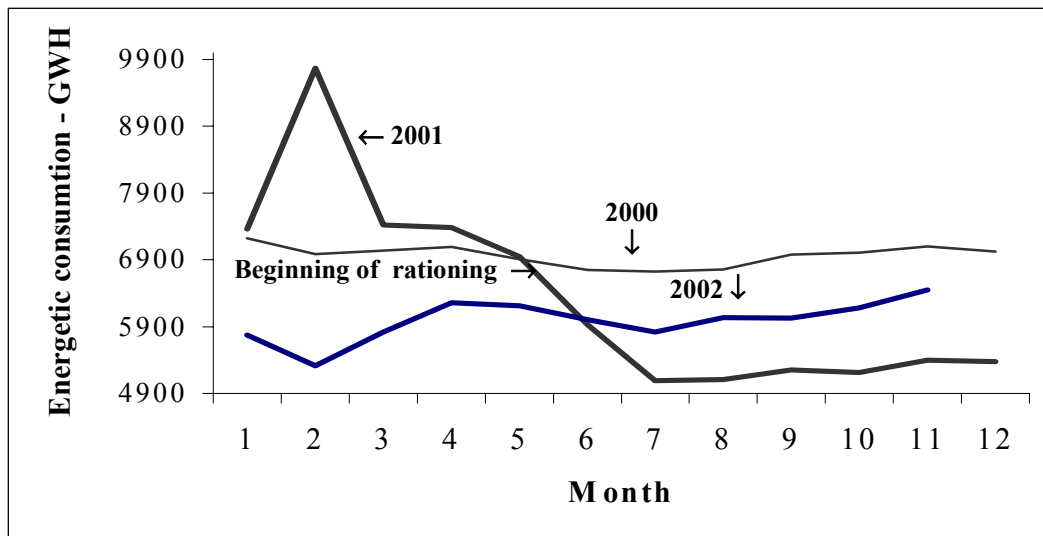


**Figure 1.** Estimated Load Curve in Rio de Janeiro in 2004

## Conservation Actions Taken During and Subsequent to the 2001/2002 Rationing

The rationing period lasted nine months from June 2001 through February 2002. As noted above, households consuming more than 100 kWh per month were required to reduce their electricity consumption by at least 20% relative to the same month the previous year. If this level of reduction was not attained, the consumer had to pay a fine and, if it happened again, the consumer had his/her electricity cut off for 3 to 6 days.

The electricity crisis was a daily “front page story” in Brazil and there was a high level of compliance with the rationing requirements. To illustrate, Figure 2 shows the monthly electricity consumption for all households in Brazil during 2000 (before rationing), 2001 (before and during rationing), and 2002 (the final two months of rationing and the post-rationing period). Electricity use spiked in February 2001 due to hot weather (during the summer in the southern hemisphere). One important observation is that residential electricity use did not increase very much after the rationing ended in early 2002.



**Figure 2.** Residential Energy Consumption Before, During and After Rationing

Concentrating now on the residential sector in Rio de Janeiro, we present the main actions taken to comply with the rationing. This information was obtained from both the 2002 survey (administered during the post-rationing period) and the 2004 survey.

First, as clearly indicated in the lighting saturation data, there was a significant shift from incandescent to fluorescent lighting during the rationing. Asked in 2002 about intention to permanently use CFLs, most households stated that they intended to do so. However, the penetration of CFLs did not increase in Rio de Janeiro between 2002 and 2004, due perhaps to the substantial first cost premium for the more efficient lamps.<sup>4</sup> Since CFLs should last four years or more when used 3-4 hours per day on average, it is still too early to tell if CFLs purchased during the rationing will be replaced with another CFL when they burn out.

Second, some households modified how they used their refrigerator. The surveys indicated that about 12% of households switched off their refrigerator for some portion of the day, in some cases as

<sup>4</sup> CFLs cost R\$10-15 in Brazil as of 2004-05, compared to about \$R1 for a 60-watt incandescent lamp (the exchange rate was approximately R\$2.70 per US\$ in early 2005).

much as 6 to 8 hours, during rationing. However, this measure was no longer practiced after the rationing concluded. But consumers learned and implemented other less drastic energy savings measures promoted in the media during the rationing such as reducing opening of the refrigerator door, not placing hot food in the refrigerator, and allowing proper air flow around the back of the refrigerator. The surveys indicated that most households continued to implement these basic conservation practices after the rationing concluded.

About one-third of households owning freezers in Rio de Janeiro unplugged their freezers and did not use them during the rationing period (and coincidentally increased the frequency of trips to the supermarket). The change in behavior with respect to use of freezers appears to be permanent. The saturation of freezers has not increased, and according to 2004 survey, about 30% of freezers are now only plugged in and used during special occasions, remaining off most of the time.

Many households modified their use of electric resistance shower water heaters during the rationing. The actions taken included: a) keeping the switch in the lower wattage “summer” position<sup>5</sup> at all times (55% of households with shower water heaters), b) keeping the heater unplugged (12% of households with shower water heaters), and reducing the average shower time from 12 to 8 minutes. The 2004 survey revealed that households no longer kept the shower unplugged or used the lower wattage setting year-round. However, the self-reported average shower time remained at 8 minutes.

Concerning clothes washers, consumers learned and implemented some basic measures to reduce electricity use during the rationing. In particular, the average household (four persons) reduced the frequency of clothes washer use from four times a week to twice a week during rationing. This action, involving accumulating dirty clothes to ensure the washer was used at full capacity, is still widely practiced according to the 2004 survey. Indeed, 77% of households interviewed in 2004 are still using their clothes washer twice a week and intend to do so in the future.

With respect to other domestic appliances, there were some temporary changes in behavior during the rationing. About 45% of households with microwave ovens unplugged and/or reduced their use of this device; 65% of households with air conditioners cut back on their use (air conditioners used only on very hot days, in some cases with the ceiling fans substituting on less hot days); 64% of households with dishwashers unplugged them or reduced their use; and 58% of households unplugged televisions and other electronic devices when not in use in order to reduce standby power consumption. All of these actions were recommended in consumer education programs and in mass media advertising campaigns during the electricity crisis.

The 2004 survey revealed that all of these appliances are now being used the same way they were before the rationing. It appears that the inconvenience or loss of amenity caused by these actions was too great for consumers to continue them when the rationing ended.

Last but not least, the awareness and understanding of the “selo PROCEL” label on efficient products increased significantly during the rationing and post-rationing period. In 1999, only 20% of households in Rio de Janeiro were aware of the “selo PROCEL”. This awareness increased to 33% in 2002 after the rationing ended, and, in 2004, it reached 42%. Also, the 2004 survey revealed that approximately 40% of consumers who purchased a refrigerator or air conditioner in Rio de Janeiro after the rationing ended sought and purchased a model with the “selo PROCEL” label.

Brazil implemented a number of energy conservation policies and programs that contributed to the success of the 2001-02 electricity rationing scheme. First, Brazil began a national electricity conservation program known as PROCEL in 1985 (Geller 2003). PROCEL instituted the “selo PROCEL” appliance testing and labeling program starting in the early 1990s. The selo PROCEL label was applied to higher quality CFLs starting in the late 1990s. Also, PROCEL prepared a large quantity

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<sup>5</sup> Most electric resistance shower water heaters have a lower wattage “summer” setting and a higher wattage “winter” setting.



of educational materials over the years. This enabled the federal government and electric utilities to quickly implement electricity savings educational campaigns once the rationing began.

Starting in the mid-1990s, utilities in Brazil were required to implement energy efficiency programs for their customers. Utilities expanded these efforts somewhat during the crisis, spending about US\$80 million (about 0.5% of revenues) on energy conservation programs during 2001 (Geller 2003). Utilities purchased and gave away over 5 million CFLs to low-income households during the crisis, for example. The Rio de Janeiro utility, LIGHT, implemented free CFL distribution, mailed out information brochures to all low voltage consumers, used radio and TV news programs to instruct customers on how to reduce their consumption in order to comply with the rationing requirements, and created a permanent customer information center to answer customers' queries. However, neither PROCEL nor individual utilities such as LIGHT implemented massive energy efficiency incentive programs during the crisis, as did the state government and utilities during the 2001 electricity shortfall in California (IEA 2005).

## **Conclusion**

The 2001-02 electricity crisis had some dramatic impacts on appliance and lighting purchases as well as consumer behavior with respect to electricity use in Brazil. In particular, the crisis and rationing significantly reduced the use of incandescent lighting and increased the use of fluorescent lighting (CFLs) at least in Rio de Janeiro. The crisis also may have limited growth in the ownership of discretionary products such as freezers and air conditioners to some degree.

A number of behavioral changes occurred during the rationing period that are still practiced in Rio de Janeiro today. These include reduced use of freezers, shorter showers (at least based on self-reported data), and less use of clothes washers. In addition, awareness and use of the "selo PROCEL" appliance efficiency label rose substantially during and subsequent to the rationing.

Households in Rio de Janeiro undertook other energy savings actions during the rationing such as lowering the amount of water heating, reducing use of microwave ovens, dishwashers and air conditioners, and unplugging televisions and other electronic products when not in use. But these practices were not continued by and large after the rationing ended.

It appears that national and utility efficiency programs helped to educate consumers on ways to conserve electricity during the crisis. But they played a much less active role than was the case in other regions experiencing electricity shortfalls, such as California. Moreover, the electricity crisis and rationing demonstrated the large potential for "saving electricity in a hurry" in urban households in Brazil.

## **Acknowledgement**

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