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# The impacts of technical standards for incandescent lamp manufacture in Brazil

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**Abstract**

In 1996, a new standard for incandescent lamps was put into practice in Brazil, regulating the manufacture of lamp bulbs to be used by customers connected to the low-tension grid. In spite of having five different tension levels throughout the country, the new standard does not include specifications for incandescent lamps designed to operate at 127 V. Regions served by 127 V, which currently include about 20 million households (about half of the present population), now have to use a lamp designed to operate at the 120 V level according to the new standard. We demonstrate that this leads to significant economic and energy losses in households, the electrical sector and the society as a whole. We propose to return to the previous standard which included specifications for incandescent lamps operated at 127 V. 

## 1. Introduction

Incandescent lamps consume about 93% of electrical energy use for lighting in the Brazilian residential sector and about 50% of lighting electricity used in the commercial sector [1]. They are still the predominant source of light in homes, as is the case in many other countries. Nevertheless, the penetration of more efficient technology — compact fluorescent and regular fluorescent — is increasing as a result of some utility sponsored programs and more advertisements [2].

Brazil has a total of about 35 millions households connected to the electrical grid at the nominal

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voltages of 110, 115, 120, 127 and 220 V. Table 1 shows the geographical regions of the country served by each voltage and the corresponding share of households. About 60% of households live in areas using 110–127 V (the 127 voltage alone serves 85% of these households) and the remaining 40% are located in areas connected at 220 V. The existence of several voltage grid levels in the interval 110–127 V poses several difficulties to manufacturers of lamps and other electrical equipment since they need to operate in a wide range of tension.

Data on lamp sales up to 1997 also shows that 60% of the 300 million lamps sold annually in the country are used in areas served by the 110–127 V grid [3].

Besides the problem of voltage diversity, some areas of the country present significant voltage fluctuations, which are harmful to the operation and lifespan of electrical equipment.[1]

The new standard enforced in 1996 by the Brazilian Association of Technical Standards (Associação Brasileira de Normas Técnicas — ANBT) for incandescent lamp manufacture, known as norm NBR IEC-64 [6], set standards for lamps with nominal voltages of 100, 110 and 120 V to be used in areas currently served by 115 and 127 V, the predominant voltage levels for the low tension grid in Brazil. The previous norm (NBR 5 121: 1982) [7] included particular specifications for other tensions: 115, 125, 127 and 130 V. Therefore, before norm NBR IEC-64 was implemented, households served by the 127 V grid, for example, could purchase lamps manufactured to operate at this tension with similar lifespan, energy consumption and lumen output as other households from other voltage areas. Before 1997 nearly all lamps produced in the country were designed to have determined nominal features, such as 1000 h of burning life, when operated

Table 1
The distribution of households according to nominal grid voltage[a]

| Nominal grid voltage | Geographical areas | Estimated % of total Brazilian households |
|---|---|---|
| 110 | Some areas in São Paulo City and Manaus. | 1 |
| 115 | About half of São Paulo Metropolitan area and some areas in São Paulo and Rio de Janeiro States. | 7 |
| 120 | About 20% of São Paulo City and cities/towns in Minas Gerais, Tocantins, and Pará States | 2 |
| 127 | Most of Southeast, Center–West, and North Brazilian regions, cities/towns in Bahia, Paraná, Mato Grosso, Mato Grosso do Sul, and Rio Grande do Sul. | 50 |
| 220 | Northeast region (most of Bahia State), Federal District (Brasilia), Tocantins, Goiás, Rio Grande do Sul, and Santa Catarina States. | 40 |

[a] Source: authors' compilation based on [4,5].

[1] This is more critical for the low tension 110–127 V. The areas served by the 220 voltage have a better performance.

at 127 V (see Fig. 1 for more information). From this year onwards, manufacturers decided to change this value to 120 V, decreasing lamp lifespan. Shortly after, a new technical standard was put in place by the Brazilian Bureau of Standards (ABNT) without any technical specification for lamps designed to operate at 127 V.

It is very common to discuss the potential advantages of modern technologies to improve energy use in developing countries. However, sometimes old and obsolete technologies, such as incandescent lamps, which have widespread use need to be paid more attention, as in the case presented here. In this paper we will demonstrate that the change in the standards triggered significant alterations in the lighting load of the regions served at the 127 voltage level, which represents more than half of the households in the country. The new standard caused different economic impacts on the various stakeholders: customers, utilities, lamp manufacturers and the society as a whole.

In our view, the case presented here illustrates the need to constantly cross examine norms and standards from a public perspective. Although existing institutional arrangement of establishment of technical standards are conceived to reveal transparency and consensus building among all interested parties, they can have unbalanced effects on the society, with cost and benefits distributed unevenly. Sometimes, consumers — especially in developing countries — are not well represented in technical standards committees.

We first evaluate the changes in electrical consumption, lifespan and lumen output of incandescent lamps as function of nominal operating voltages. Based on the technical performance of the lamps produced in accordance to the new standard in areas served by the 127 voltage, we estimate the economic impacts to the customer, to the utility, and to the society as a whole.

## 2. The performance of incandescent lamps according to voltage

In this section we derive the relationship between the key lighting parameters (luminous flux, effective power and lifespan) and the operating voltages encompassed by the two mentioned

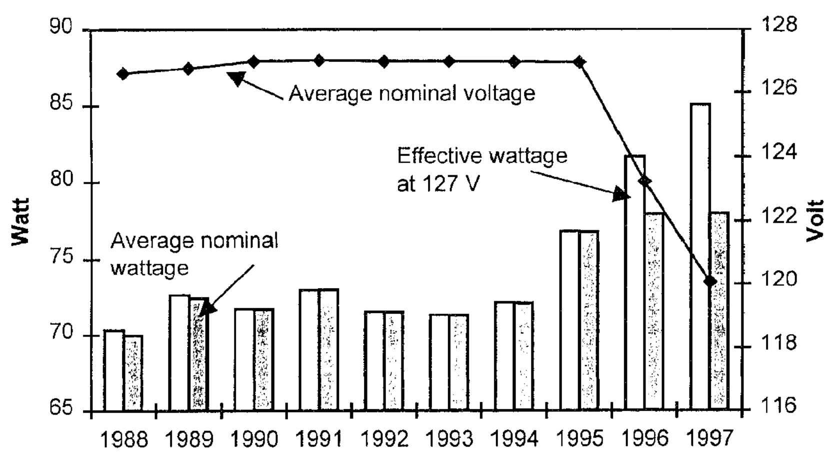


Fig. 1. The evolution of the average wattage and average (nominal and effective) voltage of incandescent lamps sold in areas of 110–115–120 and 127 V. Source: [1] and authors calculations (see Table 3).

standards. The incandescent lamp produces light by heating a tungsten element that rests inside the glass bulb filled with a mixture of gases such as nitrogen and argon at low pressure. Higher temperatures will yield more light, but this will accelerate the evaporation of the tungsten element, and therefore will limit the lamp lifespan. The incandescent lamp has to provide a certain amount of light output during a specified lifespan and under determined electrical conditions (Voltage), as stated by a technical standard. It can be operated under several different voltages; however, the amount of light and the lifespan of the lamp will vary greatly, since the temperature of the tungsten element will vary accordingly to the electrical tension applied.

When subjected to the same electrical tension $V$; incandescent lamps projected to operate at voltage $V_0$, have their real wattage (effective power) $P_{V_0}^{V}$ expressed by Eq. (1) [8]:

$$P_{V_0}^{V}=P_{V_0}^{V_0}\left(\frac{V}{V_0}\right)^{1.54}. \tag{1}$$

Similar expressions for light flux $\phi_{V_0}^{V}$ and lifespan $L_{V_0}^{V}$ are:

$$\phi_{V_0}^{V}=\phi_{V_0}^{V_0}\left(\frac{V}{V_0}\right)^{3.38} \tag{2}$$

$$L_{V_0}^{V}=L_{V_0}^{V_0}\left(\frac{V}{V_0}\right)^{-14}. \tag{3}$$

In order to represent the effects of different electrical tension on an incandescent lamp, let us consider two lamps with the same nominal wattage, one projected to operate at 120 V and the other at 127 V. From Eqs. (1)–(3), we can find the relationship between the effective power for a lamp projected for 120 V submitted to a probe voltage $V(P_{120}^{V})$ and another similar lamp, projected to 127 V, submitted to the same voltage $V(P_{127}^{V})$:

$$P_{120}^{V}=1.091P_{127}^{V}. \tag{4}$$

This means that a lamp designed to operate at 120 V will have energy consumption 9.1% greater than a lamp projected to operate in 127 V, when both are submitted to the same voltage level. As predicted by the literature [8], $V$ should not be more than 10% different of $V_0$.

Similarly, these two lamps, which were designed to have the same lifespan $L$ when operated at their nominal voltage ($V_0$), will experience a significant change on $L$ when a different tension is applied. The lamp designed to operate at 120 V will have a 55% decrease in its lifespan [8] when used in 127 V.

Using the same notation as before, we have:

$$L_{120}^{V}=0.452L_{127}^{V}. \tag{5}$$

On the other hand, a lamp designed to operate at 120 V will give more lumen output ($\phi$) than their similar designed to operate at 127 V:

$$\phi_{120}^{V}=1.211\phi_{127}^{V}. \quad (6)$$

(Considering $\phi_{120}^{120}$ equal to $\phi_{127}^{127}$. Actually, $\phi_{120}^{120}$ can be around 1.4% greater than $\phi_{127}^{127}$ depending on lamp power.)

In practice, there are fluctuations in tension ($V$) in the electrical grid, as mentioned earlier. The permitted variation in Brazil ranges from 106 V to 121 V for the areas served at 115 V, and from 116 to 132 V for the areas served at 127 V [9]. Lamps designed to operate normally at 127 V should not be used in the 115 V grid, due to an important decrease in their performance. In the extreme case when the voltage is allowed to drop to 106 V, the luminous flux of a 100 W lamp is less than the nominal value of the 60 W lamp. In this case, the number of lumens-per-watt decreases approx. 28% from its nominal value.

Table 2 shows the evaluation of luminous flux, effective power and lifespan for 60 and 100 W lamps according the permitted levels of tension variation for 115 and 127 electrical grids. We evaluated these parameters according to the two incandescent lamp standards that we are considering in this paper: the NBR IEC 64 (1996) (new standard) and the NBR 5 121: 1982 (old standard).

Data on residential voltage levels became almost unavailable for all regions in Brazil after power sector privatization, and are at the moment hard to access via the national regulatory agency. For the purposes of this work we relied on information on voltage grid fluctuations only for four big cities in Brazil [10]:

1. São Paulo, 10,300,000 inhabitants, nominal grids are: 110, 115, 120 and 127 V; Average voltage: 122.0 V (all grids), SD=3.5 V.
2. Belo Horizonte, 2,090,000 inhabitants, nominal grid is 127 V; average voltage: 125.5; SD=2.05 V.
3. Rio de Janeiro, 5,550,000 inhabitants, nominal grid is 127 V;average voltage: 124.2 V; SD=3.1 V.
4. Salvador, 2,21,000 inhabitants, nominal grid is 127 V; average voltage: 123.25; SD=5.03 V.

As stated earlier, this paper is devoted to analyzing the effects of the 120 V lamps when used in a 127 V electrical grid, which is in fact the nominal voltage for 90% of customers connected to the 110–127 V. grid. Therefore, we have estimated power, lifespan and lighting performance for incandescent lamps in use at the 127 V Brazilian grid, considering data for three cities (Belo Horizonte, Rio de Janeiro and Salvador). According to [8], in spite of these cities being served by 127 V, measurements showed a weighted average voltage of $V$=124.25 V and a standard deviation of $\sigma$=5.1 V.

In order to estimate incandescent lamps' power, luminous flux and lifespan, we assumed a statistical normal distribution as a function of the voltage as $f(V)$ :

$$f(V)=\frac{1}{\sigma\sqrt{\pi}}\exp\left[-\left(\frac{(V-\bar{V})}{\sigma}\right)^{2}\right], \text{ where } \int_{\infty}^{\infty} \mathrm{d}Vf(V)=1 \quad (7)$$

considering that $\bar{V}$=124.25 V and a standard deviation of $\sigma$=5.1 V. This statement is valid, in spite of the fact that negative values of $V$ have no meaning (it is an RMS value), since the negative part of the integral in Eq. (7) for typical values of $\bar{V}$ and $\sigma$ has no effect.

Table 2
The performance of incandescent lamps (60 and 100 W) according to the range of permitted voltages for areas served at 115 and 127 V under NBR IEC 64 (1996) and NBR 5121: 1982[a]

| National Standard | Characteristic | Nominal value | Tension (V) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 115 V electrical grid | | | 127 V electrical grid | | |
| | | | Lower limit 106 | Nominal value 115 | Upper limit 121 | Lower limit 116 | Nominal value 127 | Upper limit 132 |
| 120 V/60 W | Luminous flux (lm) | 760 | 500 | 658 | 782 | 678 | 920 | 1049 |
| 64 NBR IEC-5055-1 | Power (W) | 60 | 50 | 56 | 61 | 57 | 65 | 69 |
| *(new standard)* | Lifespan (h) | 1000 | >3800 | 1814 | 890 | 1607 | 452 | 263 |
| 127 V/60 W | Luminous flux[b] (lm) | 750 | 407 | 536 | 637 | 552 | 750 | 855 |
| NBR 5121:1982 | Power (W) | 60 | 45 | 51 | 56 | 52 | 60 | 64 |
| *(old standard)* | Lifespan (h) | 1000 | >3800 | >3800 | 1969 | 3555 | 1000 | 582 |
| 120 V/100 W | Luminous flux (lm) | 1400 | 921 | 1212 | 1440 | 1248 | 1695 | 1932 |
| 64 NBR IEC-5075-1 | Power (W) | 100 | 83 | 94 | 101 | 95 | 109 | 116 |
| *(new standard)* | Lifespan (h) | 1000 | >3800 | 1814 | 890 | 1607 | 452 | 263 |
| 127 V/100 W | Luminous flux (lm) | 1380 | 749 | 987 | 1172 | 1016 | 1380 | 1572 |
| NBR 5121:1982 | Power (W) | 100 | 76 | 86 | 93 | 87 | 100 | 106 |
| *(old standard)* | Lifespan (h) | 1000 | >3800 | >3800 | 1969 | 3555 | 1000 | 582 |

[a] Notes: values underlined are estimates made, since the voltage range lies out of the limits of validity of Eqs. (1)–(3) given by [8]. The limits are according to the existing norm [9]. For the 115 V tension the permitted range variation is 106–121, and for the 127 V tension the permitted interval is 116–132 V. These are estimated values according to the literature, variations may occur as result of operation conditions.

[b] We considered "normal flux" lamps. Lamps currently found in the market are "high flux", but those were not available before 1996 (when the "old standard" was in effect). Current 120 V lamps have high luminous flux 840 lumens (60 W), and 1540 lumens (100 W).

Taking into account the positive part of the domain, the average power $\bar{P}_{V_0}$ for a lamp designed to operate at tension $V_0$ is given by numerical integration of:

$$\bar{P}_{V_0}=P_0\int_0^\infty dV f(V)\left(\frac{V}{V_0}\right)^{1.54}. \tag{8}$$

As a result, we obtained $\bar{P}_{120}=1.056P_0$ and $\bar{P}_{127}=0.968P_0$ where $P_0=P_{V_0}^{V_0}$ is the nominal wattage. Similarly, luminous flux (*lumens*) can be found by integrating:

$$\bar{\phi}_{V_0}=\phi_0\int_0^\infty dV f(V)\left(\frac{V}{V_0}\right)^{3.38}, \tag{9}$$

resulting in $\bar{\phi}_{120}=1.140\phi_0$ and $\bar{\phi}_{127}=0.941\phi_0$. Here, $\phi_0=\phi_{V_0}^{V_0}$ is the nominal luminous flux.

Lifespan is also affected by the tension applied to the lamp. As when calculating the average power, the effective lifespan of the lamp is:

$$\bar{L}_{V_0}=\frac{L_0}{\int_0^\infty f(V)\left(\frac{V}{V_0}\right)^{14} dV}. \tag{10}$$

This equation gives a lifespan $\bar{L}_{120}=529$ h for lamps projected to operate at 120 V and $\bar{L}_{127}$ =1170 h for lamps designed for the 127 V. Here, we assumed that $L_0=L_{120}^{120}=L_{127}^{127}=1000$ h. Table 3 shows these results.

## 3. The impacts of the new norm

The following calculations assume as baseline case the situation prevailing when the old standard was in effect, i.e. when 60 and 100 W lamps projected to operate at the 127 V were available to households in these areas. We compare them with the corresponding lamps produced according to the new standard. We want to determine the impacts in the annual electricity consumption and the additional costs incurred by households in the 127 V areas. We use the values presented in Eqs. (8)–(10) to represent the effects of both standards on lamps of same nominal wattage (60 or 100 W), luminous flux ($\phi_0$ values from Table 2) and lifespan (1000 h) used by households served by 127 V grid.

We follow a method developed in previous work [11] to estimate the physical and economical impacts of the new norm. We assume a coincidence rate of 65% [12] of the lighting load with the electrical system evening peak, a 90% availability factor of the generation system (hydroelectric system), and transmission and distribution losses calculated at the generation point as 17.6% of the electricity consumed [9]. We also assume that each lamp socket is used 1300 h per year [9].

Table 3
The performance of incandescent lamps (60 and 100 W) designed according to standards NBR 5121: 1982 and NBR IEC 64 (1996) when operated in 127 V areas[a]

| Lamp | Effective power (W) | Peak capacity required at generation point (W) | Annual consumption at generation point (kWh) | Lamp lifespan (h) | Lamps per year per socket | Cost per $10^3$ lumen-year[b] (US$/lm-yr) |
|---|---|---|---|---|---|---|
| 60 W/120 V (NBR IEC 64: 1997) (*new standard*) | 63.4 | 53.8 | 108 | 529 | 2.46 | 9.00 |
| 60 W/127 V (NBR 5121: 1982) (*old standard*) | 58.1 | 49.3 | 99 | 1170 | 1.11 | 9.49 |
| 100 W/120 V (NBR IEC 64: 1997) (*new standard*) | 105.6 | 89.7 | 179 | 529 | 2.46 | 7.97 |
| 100 W/127 V (NBR 5121: 1982) (*old standard*) | 96.8 | 82.2 | 164 | 1170 | 1.11 | 8.51 |

[a] Notes: the peak coincidence factor is assumed to be 65%, system availability factor 90%, T&D losses of 17.6%, and lamp use of 1300 h/yr (as in [15]).

[b] Here, 1 lumen-year=1300 lumen-hour. Includes expenditure on lamp purchases and electricity costs (with consumer taxes).

Table 3 presents the results calculated with the above assumptions for 60 and 100 W lamps under both standards. The use of an incandescent lamp according to the new norm will not only increases the electricity consumption but also requires more peak capacity. Using the data from Table 3 and assuming that 80 million of lamp sockets use 60 W bulbs, and 40 million use 100 W in the 127 V areas, this implies that an additional peak demand capacity of 658 MW is required and that 1.32 TWh per year more energy for lighting will be consumed. Compared to the baseline case, more 162 millions lamps will be bought annually by households.

### *3.1. The social perspective*

Most of the lamps sold in the country are 60 W lamps, which cost on average US$0.39 each; 100 W lamps cost US$0.54. The lamp produced according to the new norm will burn out more quickly when operated at tension 127 V, implying an additional cost of US$0.53/0.73 per year for each 60/100 W lamp-socket, assuming an annual usage of 1300 h per lamp-socket.

If we assume that this situation persists for 50 years, the useful lifespan of a hydroelectric power plant,[2] we will have an additional expenditure in net present value of US$8.28/11.46 in 60/100 W lamps (per lamp socket), considering a 6% annual discount rate over this period. This implies that each additional peak kW that is now required to operate the lamp produced under

[2] Hydroelectricity accounts for about 95% of total electricity production. We are assuming the situation that incandescent lamps are bought continuously during the same period of an hydroelectric plant lifespan.

the specifications of the new standard (see Table 3) costs US$1846, just considering the 60 W lamp purchases over this time period, or US$1533 in the case of the 100 W lamp (Table 4). We should also add the cost to the society to build the additional kW that is required to operate these lamps, about US$2000/kW (hydroelectricity).

We can also estimate the impacts on energy costs by dividing the incremental annual cost of lamp purchases by the increment in energy consumption. The additional purchases will increase the cost to provide for lighting services by US$58.54 and US$48.64 for each MWh used by a 60 and 100 W lamp, respectively, in areas served by the 127 V grid (Table 4).

Therefore, from the societal viewpoint, not only more resources will be spent in the production of lamps, but also more electricity will need to be produced to service the incandescent lamp manufactured according to the new standards.

### 3.2. *Consumer perspective*

In the case of the consumer perspective it is necessary to include the effects of electricity tariffs, in addition to the lamp cost. We consider the three tariffs as prevailing in Brazil as of October 1999: US$0.081/kWh plus US$0.027 taxes (highest residential tariff), US$0.073/kWh plus US$0.010/kWh taxes (residential average tariff), and US$0.028/kWh, no applicable taxes (low residential tariff) [13].

Table 4
Economic impacts of standards (NBR IEC-64, 1996) and (NBR 5121: 1982) according to the social perspective

| Lamp | Lamp cost (US$/unit) | Annual lamp purchase per socket (US$/year)[a] | Additional cost per additional MWh (US$/MWh)[b] | Additional cost per additional kW (US$/kW)[c] |
|---|---|---|---|---|
| 60 W/120 V (NBR IEC 64: 1997) (*new standard*) | 0.39 | 0.96 | 58.54 | 1845.52 |
| 60 W/127 V (NBR 5121: 1982) (*old standard*) | 0.39 | 0.43 | | |
| 100 W/120 V (NBR IEC 64: 1997) (*new standard*) | 0.54 | 1.33 | 48.64 | 1533.21 |
| 100 W/127 V (NBR 5121: 1982) (*old standard*) | 0.54 | 0.60 | | |

[a] Takes into account the different lifespans, from Table 2 and an annual use of 1300 h.

[b] Includes additional costs with new lamp purchases divided by the additional annual electricity consumption at generation point.

[c] Includes additional lamp costs over a 50 year period (net present value) divided by the additional kW demanded on peak (see Table 3, the additional peak capacity required per lamp under standard NBR IEC 64 compared to NBR 5121). This simulates incandescent lamps purchase over the lifespan of a hydroelectric plant, which is assumed to supply the additional capacity.

Table 5
Additional annual costs per lamp-socket to the consumer with the new norm (NBR IEC 64) as compared to the previous norm (NBR 5121)[a]

| Consumer class | Nominal wattage (W) | Additional annual expenditure with lamps per socket (US$/yr) | Additional annual electricity consumption per socket (kWh/yr) | Additional annual expenditure with electricity per socket (US$/yr) | Total annual expenditure per socket (US$/yr) |
|---|---|---|---|---|---|
| Low tariff | 60 | 0.53 | 6.86 | 0.19 | 0.72 |
| Low tariff | 100 | 0.73 | 11.44 | 0.32 | 1.05 |
| Average tariff | 60 | 0.53 | 6.86 | 0.57 | 1.09 |
| Average tariff | 100 | 0.73 | 11.44 | 0.95 | 1.68 |
| High tariff | 60 | 0.53 | 6.86 | 0.74 | 1.27 |
| High tariff | 100 | 0.73 | 11.44 | 1.24 | 1.96 |

[a] Note: high tariff=US0.108/kWh; average tariff=US$0.097/kWh; low tariff=US$0.028 for low tariff (consumer taxes were added where applicable). It should be noted that lamps under the new standard are brighter (see Table 2) when used in 127 V areas.

The results are presented in Table 5 and consider the electricity consumption at the customer's point of use. As these results demonstrate the new norm represents additional costs to households, which vary from US$0.72 to US$1.96, per year and per lamp-socket, depending on tariffs and lamp wattage. It should be noted, however, that lamps made under the new standard became brighter (more lumen output) when compared to the case with the old norm (see Table 2). This fact may be considered as an advantage to the customers. It is interesting also to compare the costs of proving lumens by each of the lamps considered here. Lamps projected to operate at 120 V present a cost-per-lumen-year lower than the ones projected to operate at 127 V, however is the amount of increased lumen output (22%) really perceivable by the customer? According to [14] which reports experiment results of perceived luminous sensations, we believe that the increased 22% of lumen output is not enough to be claimed as an advantage to the customer. The human capability to perceive light intensity is not a linear function of luminous flux, and therefore we can not conclude that increase 22% in lumens means the same amount benefit for vision. According to [14], to double the apparent brightness of an object we must increase its illuminance by a factor of 6.5 (22% more lumens means 7.6% more apparent brightness in such scale).

### *3.3. The perspective of the power sector*

In the case of the power sector we include the electricity production costs and also the revenues resulting from the sales of electricity. We assume that 70% [15] of the electrical energy used for lighting is consumed during peak hours at a cost of US$150/MWh[3] and the remaining 30% during off-peak period at the cost of US$20/MWh to the power sector.

[3] We are assuming this value as the average cost for supplying electricity during peak hours. Some utilities have higher costs than that, i.e. the São Paulo Light and Power Co. paid US$0.38/kWh during peak and US$0.02/kWh during off-peak hours [12].

The use of lamps produced by the new norm has the effect of raising utilities' electricity sales. In the case of lamps being used by consumers paying the high tariffs for each 60 W lamp socket the power sector will have an increase in its revenues of US$0.56 per year (see Tables 5 and 6). This value is even higher for the 100 W, US$0.93. In the case of consumers paying the average residential rate, the values are US$0.50 and US$0.84 for the 60 and 2OO W lamp, respectively. The increase in electricity revenues, however, is not enough to compensate higher production costs during peak period, when most of these lamps are used. Assuming the marginal electricity production and T&D costs for peak period as US$150/MWh, as mentioned above, the power sector has higher costs to produce and deliver to the household the additional kWh demanded, in spite of increased sales as can be seen from Table 6.

### *3.4. The perspective of the lighting manufacturers*

Sales of incandescent lamps must have increased in the areas served at the 110–127 V, as our results from the previous sections indicate. Also, probably economies of scale were achieved by the simplification of production lines, stock and distribution costs for the manufacturers. We were not able to have data on lamp sales or industrial production costs of the average lamp sold today and compare with the data before the enforcement of the new norm. However, there are indications, as we tried to demonstrate in this paper, that significant resources are being transferred from customers, the utility sector and the society to lamp manufacturers.

The Brazilian Association of Lighting Manufact&ers (ABILUX) supports the new norm [3], and emphasize that customers at 127 V benefit now from the higher lumen output of their lamps. They say that customers' purchases have shifted in the past towards lamps of higher wattage as result of the poor performance of the electrical system. The data presented by ABILUX show indeed that there has been an increase of 8 W in the average nominal power of the lamps sold

Table 6
Evaluation of the economic impacts of standard (NBR IEC-64) ascompared to the previous norm (NBR 5121) to the power sector (US$ per lamp socket per year)[a]

| Consumer class | Nominal wattage (W) | Additional annual revenues per socket (US$/yr) | Additional annual electricity production cost per socket (US$/yr) | Net annual benefit per socket (US$/yr) |
|---|---|---|---|---|
| Low tariff | 60 | 0.19 | 1.00 | −0.80 |
| Low tariff | 100 | 0.32 | 1.66 | −1.34 |
| Average tariff | 60 | 0.50 | 1.00 | −0.49 |
| Average tariff | 100 | 0.84 | 1.66 | −0.82 |
| High tariff | 60 | 0.56 | 1.00 | −0.44 |
| High tariff | 100 | 0.93 | 1.65 | −0.73 |

[a] Note: the values were calculated assuming an annual use of 1300 h/yr, US$0.81/kWh as the high tariff, US$0.73/kWh for the average residential tariff and US$0.028/kWh for low tariff (consumer State taxes are not included). Utilities electricity costs were estimated assuming that 70% of the lighting load occurs during the peak period and costs US$150/MWh during this period. For off-peak hours we assumed the cost US$20/MWh. These values include T&D to the low tension household grid.

in the areas with tension 110–115–120–127 V, during the period 1988–97 [3], and this migration towards lamps of higher nominal wattage has not occurred in the areas of 220 V, which have a more reliable service. However, this trend apparently has not been altered after the enforcement of the new norm, as shown in Fig. 1. So, if customers were not satisfied with the luminous levels of the incandescent lamps manufactured, the new standard has not modified the trend.

From Fig. 1 it is also possible to see that before 1996 the average nominal voltage of the lamps sold was very close to 127 V, showing the weight of the 127 V market. As the new norm became in effect the average lamp voltage dropped to 120 V, but there is no sign that customers are buying lamps with less wattage. We also plot the evolution of the effective power of the average incandescent lamp when operated at the 127 V. Since 1996 there is in fact an increase in the power drawn by the incandescent lamps, due to their operation in the 127 V tension, as pointed before.

## 4. Conclusions

Technical standards represent important instruments for public policies in energy-related activities and this case illustrates the different impacts that they can produce in different segments of the society. Standards that do not lead to improvement of energy use in a society are not protecting the so-called *public goods* such as energy efficiency [16,17]. Even though the process of creating new standards observes a ritual of consensus building amongst the main stakeholders and public transparency, in many cases not all interested parties have time and resources to devote to a more thorough analysis of the matter, as this appears to the be the case.

The incandescent lamps currently manufactured under the new standard and sold in a significant part of the country are consuming 9.1% more electricity and having 55% less burning hours, compared to the ones available 3 years ago. Assuming no significant changes in consumer behavior with regards to lamp use, these lamps have added an amount equivalent to about 0.44% of the total electricity consumed in the country. This value is comparable to the amount of savings achieved by the daylight savings during the summer months in the southern part of the country or the amount of savings claimed by the National Electricity Conservation Agency in 1997, and resulted from the change in the technical specifications of the incandescent lamp sold in the country.

The economic impacts estimated here are significant and do not benefit customers, the society as a whole, and utilities, as we have demonstrated. Apparently only the lamp manufacturers experience benefits from simplifying production lines and very likely increasing lamp sales. The use of the newly produced lamps in the 127 V tension grid give more lumen output, which can be seen as an increased benefit, but this has an additional cost to consumers.

The Brazilian Association of Lighting Manufacturers — ABILUX, as well as other electrical appliance manufacturers, rightly points the diversity of tensions and their fluctuation as impediment for producing more efficient equipment. However, the arguments that the new norm will prevent households from shifting towards higher wattage lamps seem to us unsubstantiated and we hold the view that the mentioned problems of the electricity distribution system deserve the merit to be solved independently and directly with electricity utilities, and should not serve as basis for revisions of technical norms.

Based on the analysis performed in this paper we sustain that the previous standard presents more advantages to consumers, the power sector and also from the societal perspective.

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