

ANALYSIS OF TV SETS OPERATING IN *STANDBY* MODE: AN ENERGY EFFICIENCY APPROACH

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Abstract: Recently, devices operating in the *standby* power mode have gained official support and appropriate legislation. This article concerns television sets and analyzes the environmental and economic impact of their *standby* power consumption. The wide range of values obtained from experimental tests showed that *standby* losses could be reduced while maintaining performance. A brief discussion on technologies available to reduce *standby* losses is also presented. The economic analysis points to saving 8.53 millions of reais (R\$) on total consumers' electricity bill in 2005, if a 1W *standby* standard or less is enforced.

Keywords: Standby, energy efficiency, television sets, switching power supply, environmental pollution.

I. INTRODUCTION

The Brazilian law 10.295/2001 set the principles for the "National Energy Conservation Policy and Rational Use of Energy"[1]. All electric equipment commercialized in the country will be required to comply with energy efficiency regulations as long as this will be adopted. Energy standards are set up around the world through well-known ecolabeling and energy efficiency programs, such as Energy Star in the USA, Eco-Label in Europe and in Japan, the Top Runner. In Brazil, the Procel labeling program has been continuously updated and revised following the worldwide trends. However, only recently it had got into the hands of the Brazilian Congress for establishment of *standby* power standards [2]. In time of this research the North American and European standards have been borrowed for reference purpose.

The main intent of this work is to assess the televisions available in Brazilian market based on Energy Star and Eco-Label standards. Televisions (hereafter "TV") will be specifically evaluated for the *standby* power criteria in USA and Europe, which are shown in Table 1.

Additionally, Semiconductors Companies have launched technological improvements with impacts on energy efficiency issues, which are presented as reference for developers. Some new semiconductor devices have matured to the point of being currently available for switching mode power supply (SMPS) applications in order to increase the energy efficiency of TV sets. Finally, a summary of the economical and environmental impacts as consequence of cost-effective improvements in TV's is drawn based on the energy consumption drop and CO₂ reduction measures. It

takes into account information about production amount, energy consumption, lifetime and market share.

On July 2005, North American energy efficiency program celebrates the achievement of their first goal, i.e. the establishment of 1W *standby* limit for TVs. As seen in Table 1, from March 2005 advances in *standby* regulations on European community may yield even more strict limits on *standby* losses.

On the other hand, the electronic improvements lead to changes in the *standby* consumption regulations. In fact, the current *standby* definition may become inconsistent (see footnote) as a result of the establishment of new operating modes, such as "sleep" and "deep sleep". A worldwide agreement for household appliances operating on *standby* mode has been discussed on numerous occasions. So, the low power mode (LOPOMO) designation is under discussion in the *standby* power home page held by Lawrence Berkeley National Laboratory [6].

TABLE 1
Energy-Efficiency Specifications for Qualified TVs

Product	ENERGY STAR (USA)[4] (<i>standby</i> mode ¹)			ECO LABEL((Europe) [5]
	Phase I (effective 7/1/02)	Phase II (effective 7/1/04)	Phase III (effective 7/1/05)	Effective from 1 April 2002 until 31 March 2005.
TV	≤ 3W	≤ 1W (analog) and ≤ 3W (digital)	≤ 1W	< 1W (for passive <i>standby</i> consumption ²) and < 9W (for active <i>standby</i> consumption ³ of the televisions which have an integrated digital receiver/decoder)

II. TEST CRITERIA

The specifications to get energy efficiency endorsement are set up around the world "fitting" the local electrical distribution system and other peculiarities. For Energy Star labeling only the consumption in the *standby* mode is due

¹ *Standby* power is defined as the power being used when the product is connected to a power source, produces neither sound nor picture, does not transmit nor receive program information and/or data (excluding data transmitted to change the unit's condition from "*standby* mode" to "active mode"), and is waiting to be switched to "on" (active/play mode) by a direct or indirect signal from the consumer, e.g., with the remote control [1].

² Passive *standby* – the television is connected to a power source, produces neither sound or vision, and is waiting to be switched into the modes "off", "active *standby*" or "on" on receipt of a direct or indirect signal, e.g. from the remote control [2].

³ Active *standby* – the TV is connected to a power source, produces neither sound or vision, and is exchanging/receiving data with/from an external source [2].

whereas the consumption in “on mode”⁴ is also taken into account for Eco-label regulations.

Energy Star specifies a general criteria for voltage and total harmonic distortion (THD) lower than 3% and ambient temperature in range of $22^{\circ}\text{C} \pm 4^{\circ}\text{C}$. The nominal voltage is a market-specific criteria with values recommended in Table 2.

TABLE 2
Market-Specific Criteria for Energy Star

Market:	United States	Europe and Australia	Japan
Voltage	115 VRMS \pm 3 VRMS	230 VRMS \pm 10 VRMS	100 VRMS \pm 5 VRMS & 200 VRMS \pm 10 VRMS
Frequency	60 Hz \pm 3 Hz	50 Hz \pm 3 Hz	50 Hz \pm 3 Hz & 60 Hz \pm 3 Hz

The technical standard EN 50301 [7] is used to measure power consumption of appliances and equipment during normal operation (“on” mode) following Eco-label regulations. Regarded to the standby mode the working group 9, of IEC Technical Committee TC59 has specifically been prepared the international standard IEC 62301, i.e. “Household Electrical Appliances – Measurement of Standby Power”[8].

III. POWER CONSUMPTION TESTS

In order to better represent the TVs market, three leading Brazilian brands were purchased all with 20” of screen size to have the energy consumption measured according with the Energy Star criteria. Standard recommendations specifies that for testing purpose the voltage and frequency shall be within $\pm 1\%$ of the nominal and total harmonic distortion (THD) voltage shall not exceed 2% (Eco-Label) and 3% (Energy Star). Ambient temperature shall be within $22^{\circ}\text{C} \pm 4^{\circ}\text{C}$. So, a qualified AC Source model CI 4500iL manufactured by California Instruments had provided the power, as necessary. California voltage (rms) accuracy ($@25^{\circ}\text{C} \pm 5^{\circ}\text{C}$) is with $0.15\%+0.3\text{V}$ and frequency accuracy is $0.01\%+0.01\text{Hz}$ for the 45-100Hz range. The CI 4500iL model allows delivering 15Amps (45Hz-1kHz) while maintaining maximum 1% of THD voltage.

Figure 1 shows the voltage harmonic distortion in supplying a TV model HPS-2023 by CCE. A voltage distortion of 0.08% for the high THD current of 83.45% states the power performance specifications provided by California power supply. Voltage and current waveforms regard to these distortions are shown in Figure 2 such that supplied voltage and current are respectively 114.8V and 0.996A root-mean-square quantities, which performs 5.85W of active power.

For true power measurements of 10W or less the measurement instrument shall have resolution of 0.01W or less to match up to the Eco-label regulations. True standby power measurements request the use of a true power wattmeter. In such an exercise care should be taken to select appropriate power measurement equipment since TV sets

may draw current that is not sinusoidal, as shown in Figure 2. The high crest factor of the current may cause internal peak distortion on common wattmeter i.e. clipping off the top of the current wave.

As a matter of fact, to avoid low accuracy, resolution and peak distortion an oscilloscope with current probe was used in tests of standby operation.

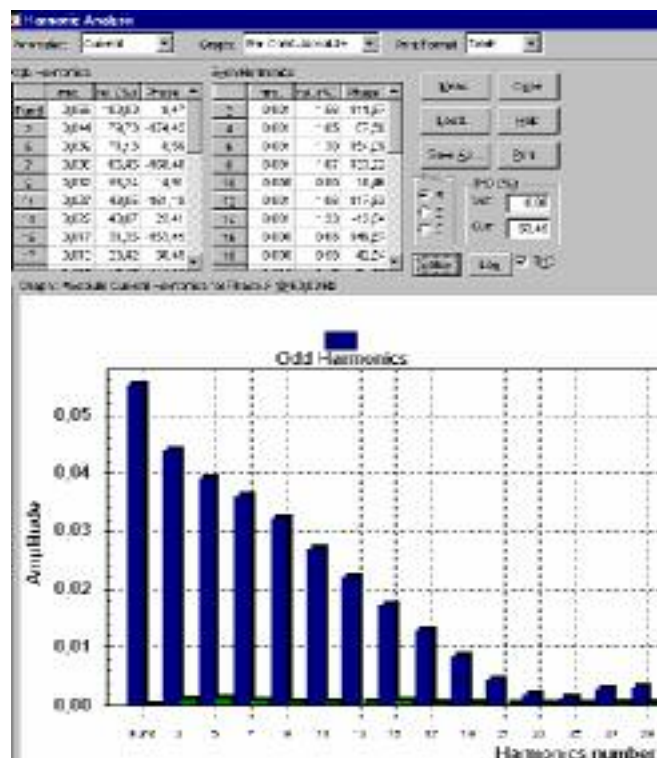


Fig. 1. AC Source measurement window. Current and voltage harmonic distortion (THD) and current spectrum.

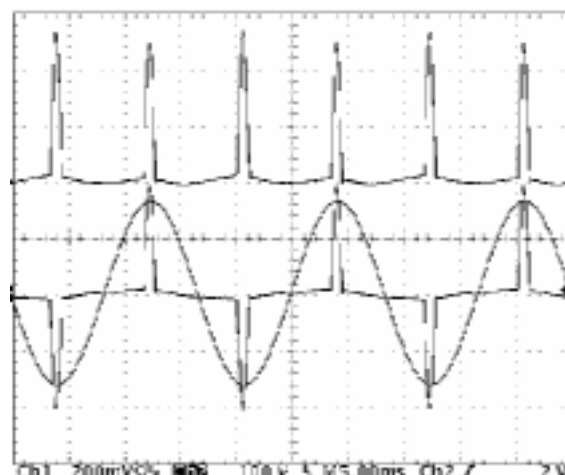


Fig. 2. Top: instantaneous active power in TV. Bottom: voltage and harmonic current waveforms for CCE HPS-2023 model.

A. Measurement Equipment

The digitizing oscilloscope TDS430A Tektronix addresses the needs of energy consumption measurements with the following features:

- 400MHz maximum analog bandwidth
- 100Megasamples/second maximum digitizing rate, on each channel simultaneously

⁴ “On mode” - the television is connected to a power source, and produces sound and vision.

- Up to 30,000-point record length per channel
- Each channel with 8-bit resolution⁵. Nevertheless, in High Resolution Mode up to 15 bits of digitized resolution is available. It is a nominal trait of high performance digitizing oscilloscopes.
- Minimum voltage setting is 1mV/div.

To avoid current distortions due to high crest factor a TCP202 50MHz current probe containing a Hall effect device was used. The TekProbe interface allows TCP202 probe to be directly connected to oscilloscope. The TCP202 probe has a maximum peak current of 50A with a pulse width $\leq 10\mu\text{s}$ (500 μA seconds). As the frequency decreases, the maximum current rating increases, limited to 15A (DC + peak AC).

IV. STANDBY POWER CONSUMPTION - EXPERIMENTAL RESULTS

Estimates of the number of the TV's in Brazil were taken from the CPqD Foundation's *Implementing Model of Digital TV in Brazil Project* [9], a statistical report prepared exclusively for Telecommunications National Agency (ANATEL) in 2002. Results indicate that at least one television unity is found in 87.7% of Brazilian homes. Nationally, residential TVs use 7.2 to 10.9TWh of electricity per year, or about of 10 to 15% of Brazil residential electricity consumption. The overall consumption in 2002 was 72.7TWh [10]. Therefore, concerned about standby consumption residential TVs seems like a good start point for researching.

Performing experimental tests to cover all TVs screen size is cost expensive. As a consequence, the 20" (twenty inches) screen size was chosen based on its 37% share of the Brazilian market on sales of 87.7%. Thus, models of the three more representative brands were purchased for testing purpose. Their respective features are listed in the Table 3.

Though neither brand has standby technology embedded in compliance with international standby regulations, it is evident these are able to suit worldwide market requirements. Further, from Table 3 is obvious the regulations lack for standby measurement in Brazil.

Experimental evaluation of Brazilian TVs sets was done according to the aforementioned international standby requirements. A summary of the experimental results for both rated voltages of 115 and 230V is shown in Table 4.

Only one model is currently complying with the North American energy efficiency program, at least until July 2005 from new rules will probably be established. Further, power consumption for both standby or "on mode" operation is quite discrepancy, respectively for Table 3 and Table 4.

Through measurements and tests of 321 TVs, results from previous work carried out by Alan Meier (from Lawrence Berkeley National Laboratory) showed that the TV active power draw ("on mode") is closely related to screen size and

manufacturer, while TV standby power draw is related only to manufacturer [11]. In spite of having few TV samples, results of Table 4 show same sparse *standby* power as verified in Figure 3 [11].

TABLE 3
TVs features of three major brands (according manufacturer specifications)

Brand/model	Voltage /frequency	Energy consumption in "on mode"	Standby consumption
PHILIPS /20PT3331	Universal (90 to 255)V/ 50 or 60 Hz	46W (approximated) Measurement conditions: not mentioned	< 3W Measurement conditions: Voltage at 220V
LG / RP 20CB20A	Universal (100 to 240)V/ 50 or 60 Hz	85W (maximum) Measurement conditions: not mentioned	10W Measurement conditions: not mentioned
CCE / HPS 2023	Universal (100 to 240)V / 50 or 60 Hz	54 W \pm 10% Measurement conditions: Voltage at 120V, "color bars" signal, volume=15, brightness/contrast and color = 50%	Not mentioned

TABLE 4
Standby consumption – 20 inches screen size Brazilian TV sets.

Brand/model	Standby Power [W]	
	115V	230V
PHILIPS /20PT3331	1,78	1,96
LG / RP 20CB20A	5,3	7,8
CCE / HPS 2023	5,85	8,1

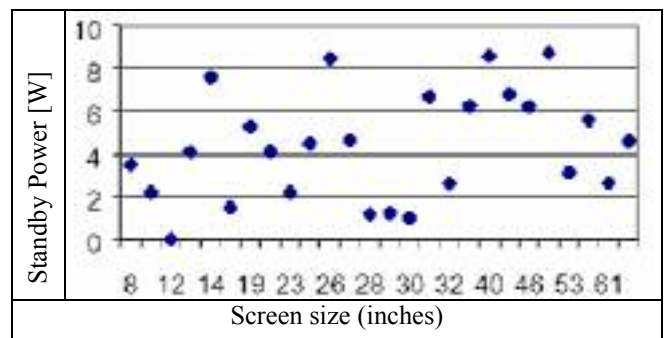


Fig. 3. Average standby power consumption values by screen size [11]

Consequently, it may be inferred that the standby power consumption depends basically on the switching mode power supply (SMPS) provided by the TV manufacturer's while the active consumption is mainly close to the vacuum tube technology.

Despite of the standby power concern of this work the active consumption must be taken into account when applying for European Ecolabel program. It happens due to

⁵ Displayed vertically with 25 digitization levels (DLs) per division. Expressed as a voltage, a DL is equal to 1/25 of a division times the volts/division setting.

the Eco-label environmental⁶ constraints rather than just energetic efficiency rules like Energy Star in North America. Applicants to Ecolabel for TVs need to consider passive *standby*, active *standby* and “on mode” consumption. Therefore Ecolabel additional requirements are introduced at this point.

V. ECOLABEL CRITERIA FOR TELEVISIONS

The main environmental impact for a television is energy consumption during use, and this includes both *standby* and “on modes”. The Ecolabel criteria set requirements for both passive and active *standby* modes (refer to Table 1), which are similar to those set by other organizations [12].

Active *standby* is becoming more significant as televisions use this mode for receiving electronic programme guides, and this may become a standard feature in new television sets. In addition, service providers of digital television transmissions may require an integrated receiver/decoder (IRD) to be in the active *standby* mode for significant periods of time. [12].

Consumption in the “on mode” is becoming more important as developments, which improve picture quality, increase the electricity consumption. The criterion set for “on mode” is based on energy efficiency and sets a requirement that televisions have to meet an **energy efficiency index (EEI_{on})** of < 65% which is between the proposed energy efficiencies for the A and B ratings in the energy label for televisions. [12].

A. Ecolabel “on mode” power consumption criterion

The “on mode” energy efficiency index EEI_{on} shall be derived from the equation:

$$EEI_{on} = P_{on} / P_{on,bc} \quad (1)$$

Where:

- P_{on} is the measured energy consumption in the “on mode”.
- $P_{on,bc}$ is the base case energy consumption of the television in the on mode. This is calculated using the following formula:

$$P_{on,bc} = 16 + 16 \cdot idd + \frac{0.75 \cdot format \cdot scrnsz + digit \cdot 0.33 + 0.38 \cdot scrnarea}{0.825} \quad (2)$$

Where:

- $digit$ is equal to 1 if the television has digital processing for picture scanning, 0 if it does not have such processing.
- $format$ is equal to 0.80 for a standard screen (4:3 aspect ratio), and 0.87 for a wide screen (16:9 aspect ratio).
- $scrnsz$ is the screen diagonal in cm.
- $scrnarea$ is the area of the screen in dm^2 , i.e. it is equal to $scrnsz \times scrnsz \times 0.48 / 100$ for a standard screen (4:3 aspect ratio), and $scrnsz \times scrnsz \times 0.427 / 100$ for a wide screen (16:9 aspect ratio).

• idd is equal to 1 if the TV has an Integrated Digital Decoder for digital broadcast signals, otherwise it is equal to 0.

In summary, the following assessment and verification must be ensured for applying to Ecolabel labeling [12]:

The applicant shall provide a test report stating that the level of power consumption in passive *standby*, active *standby* e “on mode” modes has been measured using the procedures shown in EN 50301 (Methods of measurement on receivers for TV broadcast transmission). The report shall state the measured power consumption in each mode, the calculated base-case “on mode” consumption, and the calculated percentage of base-case consumption in the “on mode”.

B. Experimental results for “on mode” power consumption

“On mode” power consumption measurements and base case power consumption, through (2), are shown in Table 5. Digital processing is not integrated in the evaluated three 20’ inches screen size TV models so that the following parameters were used to base case:

- $digit=0$;
- $format=0.8$;
- $scrnsz=48cm$;
- $scrnarea=11.06dm^2$;
- $idd=0$.

Brazilian standard NBR5258 sets to approximately 48cm the screen diagonal for 20’ inches television resulting the base case power $P_{on,bc}=58.18W$.

As seen, *standby* power (Table 4) and EEI_{on} (Table 5) make conclusive the non-conformity to Ecolabel requirements of the three national televisions analyzed. Philips model, $EEI_{on}=0.68$ and standby power of 1.96W (230V – European specific voltage), is the closest to Ecolabel standard. Regard to Energy Star the Philips standby power of 1.78W (115V North American specific voltage) satisfies the requirement limit of 3W, which is effective for July 2005.

TABLE 5
Ecolabel Energy Efficiency Index

Manufacturer/ Model	“On mode” power (P_{on}) [W]		Base case power ($P_{on,bc}$) [W]	Energy Efficiency Index (EEI_{on})	
	115V (rms)	230V (rms)		115V (rms)	230V (rms)
PHILIPS/ 20PT3331	39.6	--	58.18	0.68	--
LG/ RP 20CB20A	67	72		1.15	1.23
CCE/ HPS 2023	41	43.2		0.70	0.74

Considering the TVs overall performance, except Philips model, this paper succinctly addresses the technological enhancements with regard to switching mode power supplies in order to achieve the international standards.

⁶ Related to the use of energy, the Ecolabel criteria aim in particular at promoting:

– the reduction of environmental damage or risks related to the use of energy (global warming, acidification, depletion of non-renewable resources) by reducing energy consumption.

Observation: There are others criteria related to the use of natural resources and related to the use of hazardous substances.

VI. POWER SUPPLY LOSSES AND *STANDBY* EMERGING TECHNOLOGIES

Semiconductor manufacturers disseminate that 25% of total energy consumption is in low power/sleep/*standby* mode and around 75% of average total energy consumption is in active mode. Further, in active mode, changing efficiency from 60% to 75% can result in 15% energy savings [13].

Consequently, the losses are under analysis in *standby* and active mode, depicted as in Figure 4, to the prevalent topology (flyback) on driving TV sets and others audio devices [13]. Usually, highest losses are recorded in the bulk capacitor and the gate charge when in *standby* mode.

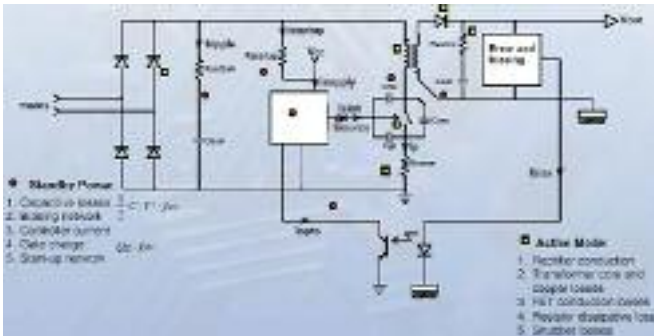


Fig. 4. Prevalent topology: losses in *standby* mode

The emergent energy efficiency regulations imply many semiconductors manufacturer on design of new SMPS controllers. The main features are as follow.

The *standby* controllers may supplies itself from the high-voltage rail, avoiding the need of an auxiliary winding. It is noticed in Figure 4 where $I_{startup}$ supplies the controller.

Even more important are the pins providing the following functionalities like “Peak Current Setpoint” and “Adjust” of the skipping peak current. Once the former is connected to an optocoupler, as seen in Figure 4, the peak current setpoint is adjusted accordingly to the output power demand. It means the peak current is proportional to load demand. As a result, the flyback slows down as fast as the load diminishes.

Additionally, the controller may automatically enter in the so-called “skip cycle” when SMPS works at light load or no-load conditions. It means that unnecessary switching cycles are completely skipped, so drastically reducing the power demand. Further, the tailor may adjust the level at which the cycle skipping process takes place, e. g., the designer can make sure that the skip operation only occurs at low peak current [14]. As may be noticed these are current-mode controllers. Furthermore, internal controller consumption (at no load) is extremely low.

VII. ENVIRONMENTAL AND ECONOMIC ANALYSIS

This analysis estimates the annual reduction on energy consumption and the CO₂ conservation accounted for the reduced emission in natural-gas power plants when taking more efficient TVs. Sales of 20” TV screen size for a year were considered. It means 2,251,080 units for retail sector (estimative for 2004) as stated in a recent Brazilian

government essay [15]. Many factors count to the environmental and economical outcome derived from energy efficiency improvement. Thus, it was considered following statements:

- *Standby* time: An average time of 6.6h in active mode was recorded for all social groups in Brazil [15]. Therefore, the televisions stay in *standby* mode for 17.4h.

- Market Share: Brand (%) sales, as detailed in Table 6.

- *Standby* power consumption: The brand weighted-average power is calculated from experimental data rather than that stated by manufacturer, otherwise the former cannot be evaluated. As a result, from Table 6 the average power is respectively 3.45W and 4.37W to the 115V and the 230V North American and European specific voltage.

A 1W mandatory *standby* would yield an average power reduction of 2.45W (115V) and 3.37 (230V) in 2005.

Table 6. Market share

Brand	Model	Standby – as stated by manufacturer in the technical manual [W]	Standby experimental results [W]		Market Share
			115V	230V	
Toshiba	TV 2090AV	3.0	assumed to be 3.0	assumed to be 10% higher than for 115V, i.e., 3.3	23%
Philips	20PT3331	< 3.0 (220V)	1.78	1.96	21%
CCE	HPS 2023	not declared	5.85	8.1	14%
LG	RP 20CB20A	10	5.3	7.8	13%
Philco	TP-2053	< 2.5	assumed to be 2.5	assumed to be 10% higher than for 115V, i.e., 2.75	13%
Panasonic		not available	(assumed to be <1W)		10%
Mitsubishi		not available			4%
Sony		not available			2%

- An increasing rate of 15% in sales is estimated to 2005 [16].

In conclusion, a mandatory 1W *standby* power requirement and from the aforementioned statements one could estimate a power reduction of 5.32MW (115V) and 7.32MW (230V) for 2005 current year. It is due to only 84% of TVs power improvement since the last three brands (Table 6) were assumed to be within the mandatory 1W standard.

Table 7 summarizes the all results for energy saving, power and CO₂ reduction. The 17.4h of estimated *standby* period was used in order to calculate the energy saving. As a result, the nation could save 16.25 GgCO₂ (115V) due to avoided emissions from natural gas fuelled thermolectric plants (it was assumed a coefficient of 0.48gCO₂/Wh [17]). Similar analysis may be done to 230V grid.

Table 7. Environmental and economic saving.

Voltage [V]	Technical/Economic data				Results		
	Real power [W]	Units sold in 2004	Retail rate increasing to 2005 [%]	Time in standby [h]	Power saving [MW]	Energy saving [GWh]	CO ₂ reduction [GgCO ₂]
115	3.45	2.251.080	15%	17,4	5,32	33,85	16,25
230	4.37	2.251.080	15%	17,4	7,32	46,56	22,35

VIII. CONCLUSIONS

The fairly recent discussion about energy efficiency standards in the national congress might require manufacturers, in the medium term, to improve the *standby* technology embedded in TV sets. It was theoretically shown that at least 84% of brands do not achieve actual energy savings. As a result, for example to the 115V grid, the establishment of a 1W *standby* standard for 2005 could save 8.53 millions of reais (R\$) on electricity bill (for 33.85GWh in Table 7 and the electricity price of 252 R\$/MWh, including the 18% of tax on the tariff of National Agency of Electric Energy - ANEEL). More societal benefits might be evident, for instance, avoiding 16.25Gg of CO₂ emissions.

Similar analysis may be done to 230V grid.

Nowadays, new SMPS controllers comply with the energy efficiency labels worldwide. Nevertheless, these controllers are developed for prevalent topologies and for limited power, for instance, flyback converters and 150W, respectively. As matter of fact, more effort from researchers on studying *standby* power losses should be encouraged.

As a final point, considering 50% of all 2,251,080 units sold in 2005 to be connected in the 115V and rest in 230V grid the average values from Table 7 are:

- Power saving = 6.32MW, energy saving = 40.2GWh and avoided CO₂ emission of 19.3 GgCO₂.

To serve as reference the estimated power saving is 30% of the total wind power capacity installed in Brazil, i.e. 20.3MW [18].

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