

Lessons learnt from monitoring a sample of TVs and entertainment systems in Northern Italy

Gianluca Ruggieri & Mattia Bulgarelli
Department of Theoretical and Applied Sciences
Università degli Studi dell'Insubria
Via G. B. Vico 46
21100 Varese
Italy

Patrizia Pistochini
ENEA Energy Efficiency Department
Via E. Fermi, 2749
21027 Ispra (VA)
Italy
patrizia.pistochini@enea.it

Paolo Zangheri
European Commission, Joint Research Centre (JRC)
Via E. Fermi, 2749
21027 Ispra (VA)
Italy
paolo.zangheri@ec.europa.eu

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Abstract

The use of entertainment devices is changing quickly. A number of different devices are normally connected to the main television set, and these devices change rapidly, and at the same time new behaviours are emerging. Indeed, people are willing to prefer the use of computers, tablets and smartphones instead of the television for their audio-visual entertainment. In order to better identify the number of entertainment devices that is actually used and their energy consumption, in 2017 the measurement campaign HESCA (Home Entertainment System Consumption Analysis) was promoted and developed in some households in Northern Italy. The consumption of 28 main televisions and 14 entertainment systems was measured on a daily basis for at least two weeks. Standby consumption was measured as well. On the basis of outcomes evaluated it results that these devices are responsible for 9.3 % of the total electricity consumption as an average of 5.6 % for televisions and 3.7 % of the attached devices. Standby consumption is still considerable high (3.6 % of the total electricity consumption) especially for satellite decoders. Some interesting correlations were studied highlighting the effect of the introduction of the energy labels or the increasing size of the TVs over time. The main results obtained are compared to those of the previous monitoring campaigns launched in Italy.

Introduction

In 2016 final energy consumption in the residential sector in the EU-28 still accounted for 26.4% of total energy consumption although in absolute terms it has slightly decreased from 3,384 to 3,315 TWh (-2 %) between 2000 and 2016. In the same period the final residential electricity consumption has increased from 718 to 808 TWh (+12.5 %) (Tsemekidi-Tzeiranaki et al. 2018). In Italy the electricity consumption of the residential sector increased from 61.1 to 70.1 TWh between 2000 and 2011 and subsequently decreased to 65.5 TWh in 2017, for a total increase of +7 % compared to the 2000 level (EUROSTAT database).

These statistics appear to be counterintuitive, given the wide effort made by EU in trying to boost energy efficiency of domestic electric appliances. In particular, the energy label system was designed to improve and reward the performances in terms of energy efficiency of the best available appliances, while the Ecodesign process was aimed at eliminating the appliances with worst performance from the market. At the same time, other consumption driver factors have worked at swelling the residential electricity expenditure: increase in the number of households, increase in the number of electrical devices per home, increase in the final performance of the electrical devices (i.e. devices in the same energy class but with different size will have different consumption). Consumer behavior may also lead an important influence over consumption trends but it is more difficult to monitor.

In 2007, electricity consumed by TVs in the member states of the EU-27 was estimated at 60 TWh: 54 TWh in on-mode and 6 TWh in stand-by/off-mode (IEA, 2009). Between 2007 and 2009 the increase in consumption was estimated at around 2–3 % reaching 56 TWh in 2009 (Bertoldi et al., 2012) despite

an expected increase in energy efficiency. These figures show the increasing importance of TV and of entertainment devices in the households' electricity consumption. This trend has influenced deeply important policy actions. When Energy Labels for domestic appliances were introduced in the European Union in the '90s, the main focus was on white appliances. Cold appliances, washing (and drying) machines and dishwashers were the most consuming appliances and therefore the first ones that needed to be regulated. The implementation of the Energy labels directives on white appliances was effective in changing the market and, on the long run, the stock and total consumption. At the same time it was necessary to define and adopt energy efficiency policy measures covering further energy used appliances. For this reason in the second wave of energy labelling launched by the Energy Labelling Directive (EU 2010a) the scope was enlarged to other energy-related products, such as lamps, TV, air conditioners. Televisions were also included in the EU Ecodesign process. A comprehensive study (Stobbe, 2007) was developed between 2005 and 2007 in order to identify the minimum requirements for TV to be placed on the market. The legislative framework in the EU 27 was completed with the Commission Regulation (EU 2009b) implementing the recast of the Ecodesign Directive (EU 2009a) and the Commission Delegated Regulation (EU 2010b) supplementing the recast of Energy Labelling Directive (EU 2010a) with regard to energy labelling of televisions. Televisions are also subject to Commission Regulation concerning Ecodesign requirements for standby, off mode electric power consumption of electrical and electronic equipment (EU 2013).

The work on standards and labels was aimed at changing the framework of televisions' market and (on a longer perspective) stock in the EU27. But the implementation of these instruments occurred in a time when two technology driven market transformations happened: first the end of the Cathode Ray Tube (CRT) era, when CRTs on the market were completely substituted by flat panel screens; secondly the success of the second generation flat screen Liquid Crystal Display (LCD) technology using Light Emitting Diodes (LED) that overperformed and replaced LCD with Cold Cathode Fluorescent Lamps backlight. In 2004 CRT accounted for 89 % of the EU-sales and LCD TVs did only account for 8 % of the sales (Stobbe 2007). In 2007 more than two thirds of the sold TVs were LCD-TVs and the last few CRT TVs were sold out in 2011. In 2009 the CCFL-backlit LCD- TVs market share reached its peak with 87 % of the sales. Within four years the second market transformation was completed and in 2013 LCD-TVs with CCFL-backlight accounted only for 4 % of the sales while LED screen dominated the market (Michel et al. 2014).

The main effect of these two transformations was the impressive 65 % reduction of the On mode power. In 2008 the average TV sold in the EU had an On mode power of 156 W, in 2013 the average On mode power was 55 W although the average TV sold size increased over the same period. Between 2007 and 2013 the average screen diagonal increased by 20 % from 29.3" to 35" (i. e. from 74.4 cm to 89 cm) (Michel et al. 2014). However the effect of the power reduction on the actual electricity consumption by televisions is not clear. First of all the declared On mode power is normally measured at the lowest possible power, corresponding to the minimum of 65 % of the maximum brightness which is defined by the Ecodesign regula-

tion. But the user may adapt the brightness to his requirements increasing the actual power demand. Furthermore, the peak in sales of new televisions occurred during the first market transformation when the on-mode power demand was higher than before. The stock of televisions is therefore much more energy demanding than the market average.

Concerning users' behaviour, technology evolution has constantly radically changed the way we watch TV. From the '50s to the '80s the only way to use a television set was to watch the broadcasts on VHF and UHF frequencies (or via cable, if available). Later the development of satellite transmissions and the switch to the digital encoding of terrestrial broadcasts enlarged the portfolio of TV viewers. At the same time, since the late '70s a number of specific devices were developed to be used with television: videogames, magnetic tape videorecorders and, more recently, DVD/BluRay recorders and players. In the latest 20 years game consoles with higher performances have experienced a larger market success, and heavily energy intensive consumption behaviors seem to be encouraged by the design and marketing of new televisions and the services that support them (Crosbie 2008).

More recently the development of streaming contents and the proliferation of entertainment devices forced to quick evolution of TV use once more. Now a consumer can access content anytime and anywhere also from his smartphone. So this time the evolution may lead to two different and opposite results: from one side the television may be used as a hub that collects inputs from different sources (including streaming contents) and also for social networking (Pothitou 2017); on the other side television screens may be replaced by other screens (laptop, tablet and smartphone) that offer a larger flexibility of use. Actual changes in using TV must be analysed through specific on-site measurement campaigns.

In the past 20 years several monitoring campaigns were arranged. Projects Eureco (2000-2001), Micene (2003) and REMODECE (2008) are the most interesting Italian ones focused not only to TV but also on Entertainment Systems. The European project Eureco has monitored 102 Italian households. The individual electrical end uses have been monitored for a whole month, while the characteristics of the monitored sample and its load curves were reported for each type of end-use (Sidler 2003). Just after this experience the Italian project Micene has examined 110 dwellings selected to touch different geographical areas and urbanisation conditions. In the case of audio-visual equipment, overall measurements have been made for the main audio-visual site, usually consisting of a television set, a video recorder and other devices such as a decoder or a gaming console (Di Andrea 2004). More recently the European REMODECE project involved other 60 Italian households, carrying out a "light" measurement campaign for two weeks, focusing on new electronic loads, standby consumption, air conditioning and lighting (Grinden and Feilberg 2008).

Methodology

GENERAL STRATEGY

Although the electricity consumption patterns concerning entertainment devices are constantly evolving, the Insubria University and ENEA, with the scientific support of the JRC de-

cided to organise a measurement campaign (called HESCA for “Home Entertainment System Consumption Analysis”) based on a rather traditional approach: monitoring the main TV set and every device strictly connected to it. This approach used to be typical before the development of entertainment content linked with online services. Even though we are aware that we are probably losing a part of the picture, we think that a measurement campaign of TV electricity consumption could be useful because:

- At least in Italy, although new consumption behaviours are emerging, the majority of people (especially mature or old persons) are still using the TV as the main entertainment device in terms of time of use: tablets and smartphones have a marginal and additional role, they do not substitute TV (ISTAT, 2017; Auditel-CENSIS, 2018);
- TV is the only entertainment device with an EU energy label: it could be interesting and useful to analyse the effect of the introduction of energy label on the actual energy consumption especially by comparing the results to the previous campaigns;
- Previous monitoring campaigns show that the main TV causes a far higher energy consumption compared to secondary TV set: for example during the REMODECE project main TV had an average annual consumption of 307 kWh/year while secondary TV only 47 kWh/year (-85 %) (Energetech, 2008).

KEY QUESTIONS TO BE ADDRESSED BY THE CAMPAIGN

The measurement campaign should investigate in the following main issues:

- Total energy consumption: what is the average daily/annual consumption of TV and entertainment system? What is the percentage of their consumption compared to the total electric consumption?
- Standby energy consumption: what is the standby power demand for each of the entertainment device?
- Consumption driving forces: which are the main determinants influencing the total energy consumption (year of purchase, technology, energy class, screen size)?

MONITORING SYSTEM AND CAMPAIGN ORGANISATION

The HESCA campaign was launched by the use of the wattmeters RCE PM600, able to measure energy consumption (from 0.001 to 9,999 kWh \pm [1 % + 1 digit]) as well as power demand (from 0.400 to 3,999 W \pm [1 % + 100 mW]). The investigation did not include the daily demand curve. Twenty different wattmeters were distributed in different households in four successive campaigns during spring and fall 2017.

The measurements were proposed to architecture and engineering students as an applicative experience to do in their homes. In order to support the organisation of the monitoring campaign, some volunteers were recruited among the courses' students. The volunteers, who were constantly assisted by the measurement campaign team, were asked to monitor on a daily basis the consumption of their main television set as well of the Entertainment Systems, defined as all the devices

(VCR, DVD, decoder, HiFi, game consoles, etc.) attached to the television selected for the campaign. Two different wattmeter were handed out, one to measure TV consumption, the other one to measure the Entertainment System consumption. The volunteers were also asked to fill in a questionnaire aiming at helping the identification of the sample, including questions on the type and size of the dwelling, number of people living in the dwelling, annual total electricity consumption. A photograph of the rear label of the television set was also collected in order to precisely identify the model and to obtain manufacturing data and eventually energy labels from the producer's website.

SAMPLE IDENTIFICATION

The HESCA campaign has involved 44 households in Northern Italy. The first evaluation of the results has reported that only 28 measurements were assessed as sufficiently reliable for the purpose of the study. In these households, it was possible to collect consumption data for at least 14 consecutive days (excluding special periods e. g. Christmas holidays), standby power demand data and complete contextual information by questionnaire. The remaining 16 offered low quality or incomplete data that could not be used for the complete analysis of energy consumptions, even if 4 of them were included in the study on standby power.

Twenty-six out of twenty-eight participants lived with their family, the remaining two share the apartment with other students. Eleven lived in single family household, three in townhouses, six in small multifamily buildings (less than 10 dwellings), eight in large multifamily buildings (more than 10 dwellings). On average 3.2 persons lived in the apartment and a total of 2.6 television in each household.

The characteristics of the sample identify a particular set of household electric customers. The Italian Authority (AEEG-SI, 2016) has identified eight different benchmark customers: four including typical residents (from one to 4+ members) and four for particular users (non-residents, holiday houses, etc.). The sample involved in our measurement campaign is a good representation of benchmark classes C and D (families with 3 or more members). For this reason, the sample is not representative of the average domestic users, because it does not include singles or couples and it is located in a specific geographic area. It rather represents high consumption customers.

THE MONITORED TELEVISION SETS

The volunteers were asked to identify the main television (i.e. the one that is more frequently used by the occupiers) and to measure its consumption. The main television is 7.3 years old on average. The average diagonal screen size is 32.8 inches. As shown in Table 1, fifteen out of 28 have CCFL-backlight screens, eight have LED screens, one has plasma, one CRT (in three cases the technology has not been identified). Energy class was available only for eight televisions: two A+, four A and two B.

On average, the main television is connected to 1.2 peripherals: in 9 households the main television is not connected to any peripherals, in 10 household it is connected to one device, in five household to two devices, in three to three, in one to five.

Table 1. Main characteristics of the monitored households (SFH: Single Family House, AB: Apartment Block).

Household	Location (province)	Building type	Main TV monitored		Standby monitored		
			Technology	Energy label	TV	ES	Type of ES
HH04	Milan	SFH	unclear	–	1	1	Gaming console
HH05	Milan	AB	LED	A	1	0	–
HH06	Milan	AB	LCD	–	1	0	–
HH07	Milan	SFH	LCD	–	1	2	Decoder/Smartbox, Gaming console
HH10	Milan	AB	LCD	–	1	1	TV, Gaming console
HH11	Milan	AB	LCD	–	1	0	–
HH12	Milan	AB	LCD	–	1	1	Decoder/Smartbox
HH14	Milan	SFH	LCD	–	1	2	Decoder/Smartbox, Home theater
HH16	Milan	AB	LCD	B	1	1	DVD player
HH17	Milan	AB	LCD	–	1	0	–
HH18	Milan	AB	unclear	–	1	1	Decoder/Smartbox
HH20	Milan	AB	LED	A	1	1	Decoder/Smartbox
HH21	Varese	AB	LED	A	2	2	Speakers, Decoder/Smartbox
HH23	Varese	SFH	unclear	–	3	0	–
HH26	Varese	SFH	LCD	–	1	2	Gaming console, Radio
HH27	Varese	SFH	LCD	–	1	0	–
HH28	Varese	SFH	LCD	–	2	3	Decoder satellitare, Decoder/Smartbox, Home theater
HH29	Varese	SFH	PLASMA	–	2	2	Home theater, Video recorder
HH31	Varese	SFH	LED	A+	3	4	Home theater, Home theater, Decoder/Smartbox, Gaming console
HH32	Varese	SFH	LCD	–	1	0	–
HH33	Varese	AB	unclear	–	1	0	–
HH35	Varese	SFH	LCD	–	1	0	–
HH36	Varese	SFH	LCD	–	2	1	DVD player
HH37	Varese	AB	LED	A	1	0	–
HH38	Varese	AB	LED	–	1	1	Gaming console
HH39	Varese	SFH	LED	A+	4	6	Speakers, Home theater, Decoder/Smartbox, Gaming console, Decoder/Smartbox, Gaming console
HH42	Varese	AB	LCD	B		0	–
HH44	Varese	SFH	CRT	–	1	0	–
HH09	Milan	unclear	–	–	1	1	Decoder/Smartbox
HH24	Varese	SFH	–	–	1	1	Decoder/Smartbox
HH30	Varese	SFH	–	–	1	3	Hard disk, Decoder/Smartbox, Gaming console
HH43	Varese	unclear	–	–	1	1	Decoder/Smartbox

Results

ELECTRIC CONSUMPTION AND STANDBY POWER LEVELS

The analysis of data monitored for 28 main TV setups has allowed deriving the following key findings:

- The average daily consumption of the main television equals to 494 Wh (between a maximum of 1,862 Wh and a minimum of 7 Wh) and it represents the 5,9 % of the total electric consumptions.
- The average daily consumption of the entertaining systems (in the 13 households where they are present) equals to 257 Wh (between a maximum of 782 Wh and a minimum of 2 Wh) and it represents the 3,1 % of the total electric consumptions.
- The average daily consumption of the overall setup (main TV and connected devices) is 622 Wh (between a maximum

of 1,862 Wh and a minimum of 9 Wh). It represents the 9,0 % of the total electric consumptions.

Figure 1 provides the average daily energy consumptions registered in the 28 households, as well as their contribution to the total electric consumptions. In addition to the main audio-visual site the standby analysis was extended to other appliances available in the households. At the end 41 TVs and 37 entertaining systems were taken into account. The minimum, average and maximum power for each device category and the associated average annual consumption are shown in Figure 2.

In most cases standby power demand is far lower compared to the value measured in previous campaigns. Standby consumption appears to be still critical for at least two categories of devices:

- Older televisions: 22 % of the monitored devices have standby power demand higher than 5 W, with peak of 43 W;
- Satellite decoder (especially those with advanced features), with standby power greater than 13 W.

The 63 % of TVs have standby power demand lower than 1 W, which is the Ecodesign requirement in force for modes providing only information or status display, or providing only a combination of reactivation function and information or status display (EU 2009b).

DETERMINANTS INFLUENCING TV CONSUMPTIONS

As suggested by previous studies (Urban et al. 2017), the TV power depends above all on display type, screen size, and year of purchase (to which a specific energy regulation is associated).

The analysis of manufacturing data and available energy labels allowed associating the nominal On mode power to 20 main televisions (of which one plasma, 11 LCD and 8 LED). Excluding the Plasma TV (as a single appliance cannot be representative of the whole category), the nominal powers were grouped by display type (Figure 3) and correlated to the screen

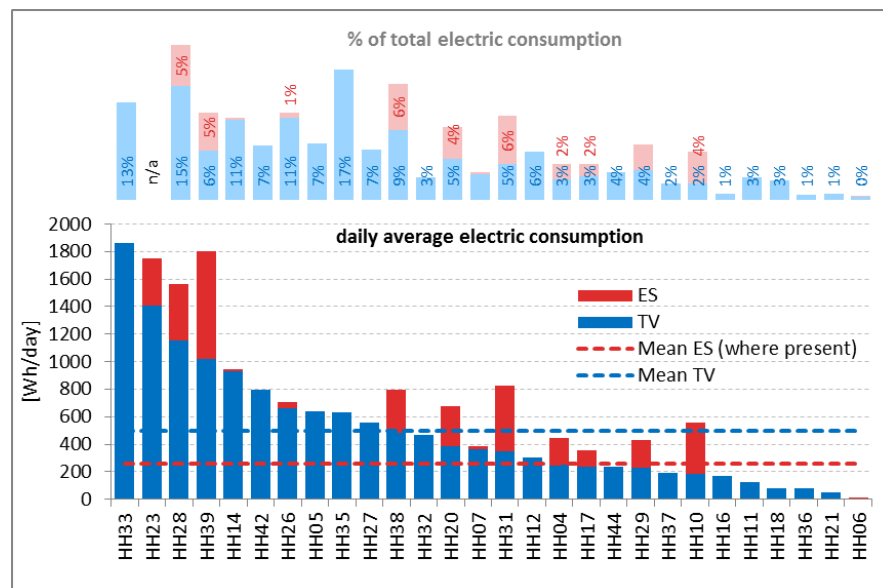


Figure 1. Energy consumption of televisions and entertainment systems in the different households (in Wh/day and as a % of the total electricity consumption).

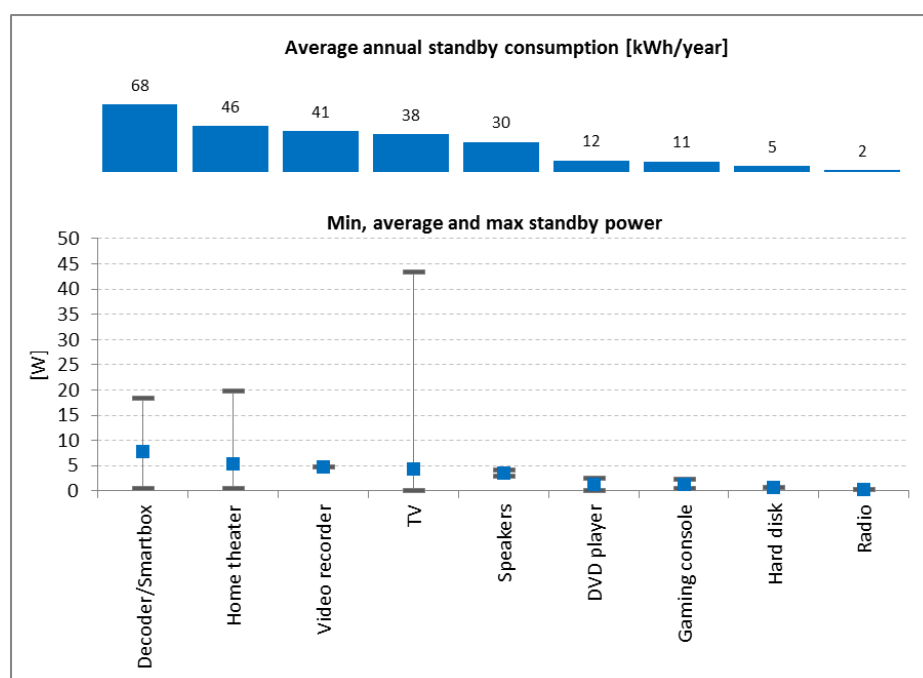


Figure 2. Average standby consumption (kWh/year). Minimum, average and maximum standby power demand for different classes of devices (TV and peripherals).

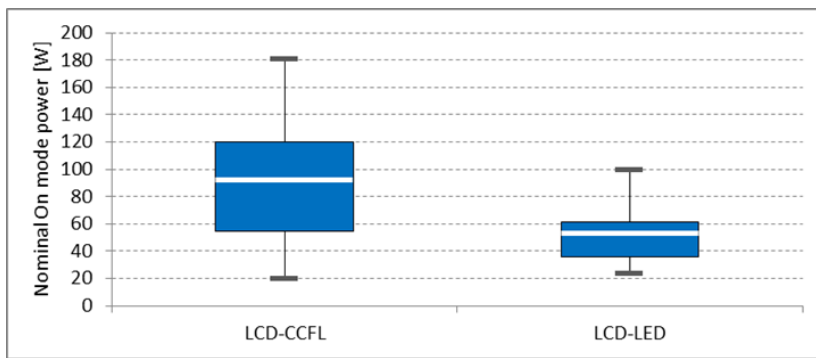


Figure 3. Statistical analysis of nominal On mode power for different LCD technologies: minimum, quartile Q1, quartile Q2 (median), quartile Q3 and maximum.

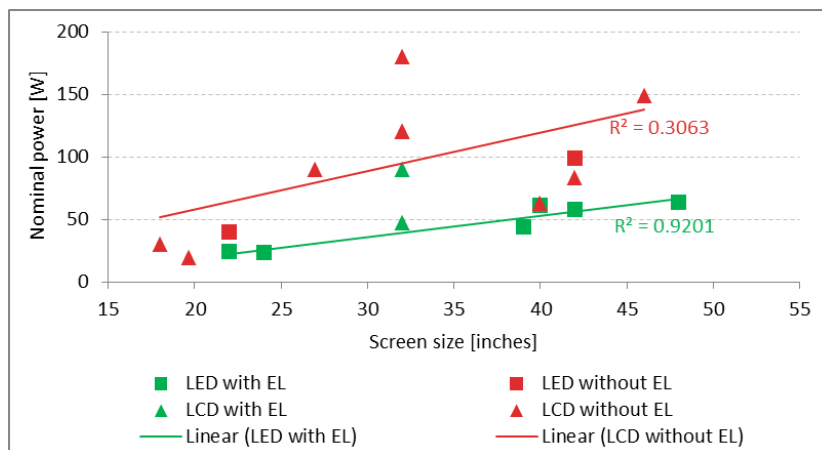


Figure 4. Relationship between nominal power and screen size for different technologies (EL: Energy label).

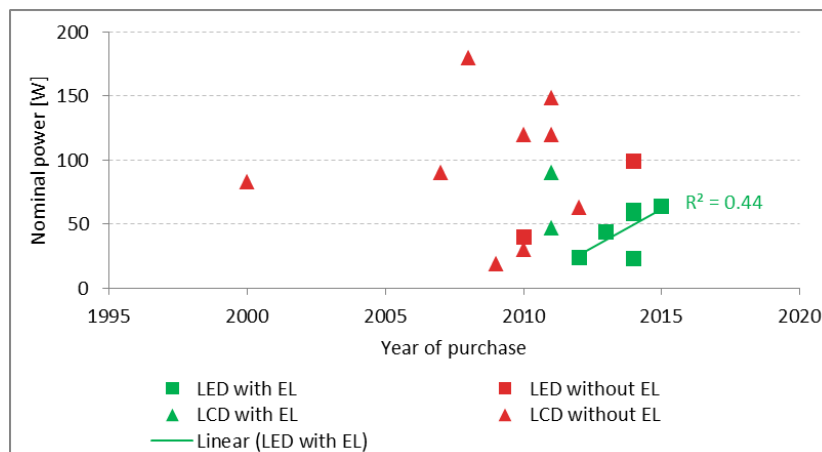


Figure 5. Relationship between nominal power and year of purchase for different technologies.

size (Figure 4) and the year of purchase (Figure 5). By this selection the devices with energy label were differentiated from the appliances not labelled.

Among other, it is evident that the power reduction imputable to the introduction of the energy labelling, since on average the nominal power of labelled LCD TVs is 43 % lower than the non-labelled LCD ones. Interesting is also the good correlation obtained between nominal power and screen size for LED TVs with energy label (Figure 4). Obviously the small

sample doesn't permit to derive definitive conclusions, but the comparison with the worse correlation of LCD TVs without label (R^2 -squared passes from 0.9 to 0.3) seems to indicate that the advent of energy labelling as well the switch to LED lights stabilised the On mode power density. However, due to the increase of screen size, also the LED segment increased the nominal On mode power in the latest years (Figure 5).

Moreover, it has to be noted that the comparison with the Ecodesign requirements (EU 2009b) reveals that only two main

Table 2. Comparison between annual consumptions derived from this and previous monitoring campaigns.

		EURECO (2001)	MICENE (2003–2004)	REMODECE (2007–2008)	HESCA (2017)
Sample size (number of households)		102	110	60	28
Annual electric consumption [kWh/year]	Average household	3,157	3,229	3,050	3,139
	Average TV	124	122	197	180
	Average Entertainment Devices	70	71	96	94

televisions exceeded the power limit in force. Specifically the plasma TV of 2007 and a LCD of 2008 (i.e. bought 3 years before the introduction of the requirement).

COMPARISON WITH PREVIOUS STUDIES

Table 1 shows a comparison of HESCA with the previous monitoring campaigns launched in Italy within the projects Eureco, Micene and REMODECE, in terms of annual electric consumptions (derived from the average daily consumptions).

In comparison with the first projects, HESCA has registered a slight reduction (about 3 %) of total electric consumptions and significant increases regarding TV (+48 %) and entertainment systems (+32 %). Contrariwise after ten years, the new data seem to confirm the REMODECE ones, with a small reduction (-9 %) of TVs' consumption.

Conclusions

Even if the energy consumption of the devices has become increasingly relevant on the typical energy bill of a household, very few new monitoring campaigns concerning TVs and entertainment systems were organised in the last ten years. This is true especially in Europe, where the Ecodesign and energy labelling requirements for television entered in force in 2011.

This study focuses on a small sample in a specific geographical area of Northern Italy, but provides new indicative references regarding:

- the characteristics of the current TV stock, which is characterized by a high inertia (less than 30 % of main TVs are labelled and almost 40 % of all TVs have a standby power higher than the Ecodesign requirement);
- the energy consumptions of different types of entertainment devices, which are assuming an increasing weight on the electricity bill of a household (on average 9,0 % in this case);
- the better energy performance of LCD with LED compared to LCD-CCFL (the average On mode power is reduced by 43 %), also in function of the screen size and the year of purchase;
- and the time of use of the main television, which results definitely higher than the reference used to calculate the annual consumption displayed on the energy label.

On one hand the analysis of monitored data highlights the technological development of latest years, which has been strongly catalysed by the international regulations that were introduced. On the other hand, significant reductions of real

energy consumptions respect previous monitoring campaigns are not observed.

The information obtained with this experience can serve as a base for future analysis of the real electricity consumption of home entertainment systems. To support the decision-making process, more measurements are necessary. It is necessary to observe carefully the changes over time and include new (numerous) appliances that are reaching now the market. It is also crucial to keep track of the influence of new purchase preferences, like choosing displays even larger and even more connected to decoders and streaming services, as well as the behavioural habits of users. Such measurements will permit to provide better indications about the energy impact of our home entertainment as well as to design suitable strategies to reach a saving potential that seems to still be consistent.

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