A thesis submitted to the Department of Environmental Sciences and Policy of Central European University in part fulfilment of the Degree of Master of Science

Low power mode electricity consumption in Hungarian households: how big is the problem and what is the potential to mitigate it?

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July, 2007

Budapest

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ABSTRACT OF THESIS submitted by:
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for the degree of Master of Science and entitled: Low power mode electricity consumption in Hungarian households: how big is the problem and what is the potential to mitigate it?
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In the present thesis, the low power mode (lopomo) electricity consumption in Hungarian residential sector is analysed, based on spot and long-term measurements carried out in the sample of 95 households.

The average lopomo power in the households was found to be 30W. The average lopomo consumption was 0.65kWh per day, i.e. 236kWh per year. This represents 8.2% of the average electricity consumption in the survey sample.

The appliance categories with the highest share of lopomo consumption were audio-visual appliances and office equipment, representing together more than 80% of the average household lopomo consumption. Within the particular appliance type, set-top boxes, modems and routers were the appliances with the highest lopomo consumption. On the other side of the scale, cooking and cooling appliances formed only 4% of the lopomo consumption.

National lopomo consumption in the residential sector in Hungary was estimated to be 8 – 10% of the residential electricity consumption, which is comparable to the results from other OECD countries.

There were three policy options evaluated in terms of potential electricity savings. First, if all the appliances had lopomo power 1 Watt or less, more than 70% of the lopomo consumption could be saved, meaning decrease to only 3% of the electricity consumption. Very similar results were obtained in the case of behavioural potential (i.e. if all the appliances, where possible, were switched off or unplugged). Thirdly, economic feasibility of using standby killers was assessed. It was estimated, that by using two of these devices per household, the cost of the measure would be still two thirds less than electricity price.

To conclude, the lopomo consumption is an important, not negligible issue, which must be studied further. By the same token, the potential for savings is high and worth focusing on in designing energy efficiency measures.

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Keywords: energy, energy efficiency, standby, Hungary, demand side management

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1 Introduction

1.1 Background

In the European Union (EU), residential final energy consumption grew by 4.4% in the last decade[1], about 0.5% per year. Electricity consumption is growing even faster, by 2% per year (Mantzos *et al.* 2003). The household sector is (after transport) the second fastest growing sector in terms of final energy consumption in the EU (Mantzos *et al.* 2003). Residential electricity consumption now represents almost 30% of the European Union's[2] electricity consumption. From 1999 to 2004, residential electricity consumption grew by 10.8% (Bertoldi and Atanasiu 2007). The consequences for CO_2 emissions are significant as well, as household electrical appliances and equipment contribute 12% to energy related CO_2 emissions (IEA 2003).

A significant portion of residential electricity consumption can be attributed to losses caused by low power modes (lopomos). From the overall electricity consumption of a household, it is estimated that the losses caused by low power modes of electrical and electronic appliances make up for around 10% of this consumption, which means loss of 15 billion Euros per year (EC 2005). With expected higher penetration of electronic devices in the households in the near future, this share may grow even further.

The potential to reduce electricity consumption by addressing the lopomo consumption problem is therefore considerable - reducing the lopomo consumption in the world could decrease CO_2 emissions by 1% (Bertoldi *et al.* 2002). The potential for savings is apparently higher in the Central and Eastern European (CEE) region, where energy intensity is still above the EU-15 average.

Yet, the electricity saving and efficiency potentials in lopomos in CEE countries are still rarely mapped, so research is urgently needed in this area. This thesis will contribute to filling this gap by focusing on one country of this region – Hungary and analysing the electricity consumption from lopomos in Hungarian household. Detailed data on the actual magnitude and structure of

[1] In the EU-15 itself, it was 7.3%.

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the lopomo electricity consumption as well as estimates of potentials are needed in decision-making processes when developing energy efficiency policies, yet in Hungary there is almost no up-to-date information available in this field.

1.2 Aim and objectives

The aim of the thesis is to assess lopomo electricity consumption in Hungarian households from the point of view of its magnitude and structure. Special attention will be paid to evaluating the potential of technical and behavioural measures to decrease the lopomo electricity consumption in Hungarian households.

The objectives of this thesis are:

- To analyze the lopomo electricity consumption of appliances in a real life situation in Hungarian households
- To estimate the national level of lopomo electricity consumption in the Hungarian residential sector
- Based on the results, to determine the potential of technological improvement and behavioural contribution to decrease lopomo consumption in the analyzed households, as well as on national level

By providing up-to-date, concise data on lopomo electricity consumption in Hungarian residential sector, which are currently lacking in Hungary, this thesis will contribute to filling in this gap.

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[2] The data on former EU-25 are used, as the new member states – Bulgaria and Romania only entered the EU this year, 1st January 2007.

1.3 Organization of the chapters

The second chapter reviews current state of knowledge in the studied field. The controversial issues such as what is actually standby or low power mode and what is the likely development in this field are discussed, as well as the situation in standby measurements in other countries and mostly discussed policies to address this problem.

The following chapter then focuses on the actual study design of this survey. Both the long term and short term measurements, which were conducted during this survey, are described. Several limitations when developing and carrying out the survey occurred and are therefore discussed as well.

In the fourth chapter, the collected data on lopomo power and consumption are presented and analysed. The chapter is divided into two main parts, the household level and appliances type. The sample is presented and compared to national level statistics. Within each subchapter, the lopomo power and consumption results are presented and discussed. The analysis of correlations between household lopomo consumption and different household characteristics is included.

In the following two chapters, the results from chapter 4 are extrapolated in order to give a broader picture of the studied problem. In chapter 5, the national level estimate of lopomo consumption in Hungarian households is made. There are three different methods that were used to make these estimates. The results from using these three methods are presented and their advantages and drawbacks are discussed.

In chapter 6 three policy measures or solutions are evaluated, as to their potential of reducing the lopomo consumption in Hungarian residential sector. These measures are namely the 1 Watt policy, maximum behavioural potential and penetration of standby killers into households.

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2 Literature Review

The issue of standby power use was first brought to international attention in the early 1990s. Sandberg (1993) observed some electronic appliances drew power when in standby mode or even when completely switched off; he called this phenomenon “leaking electricity”. A similar experience was reported also by Meier *et al.* (1992). Since then, there has been significant development in this field, which will be dealt with hereinafter. Firstly, the definition of the standby mode will be discussed, as a common definition is a prerequisite for comparable assessment of standby electricity use. Review of methods to actually carry out such assessments will follow, together with standby measurements carried out throughout the world. Next, policy options and solutions to standby power use will be discussed, followed by an assessment of the situation in Hungary.

2.1 Definition of standby: rationale and possible drawbacks

In the early works on standby power use (Sandberg 1993, Meier *et al.* 1992, Nakagami *et al.* 1997), there were basically three modes examined – “on”, “off” and in standby position. Also, these early works only examined audiovisual appliances, like televisions (TV) or video-cassette-recorders (VCR), as these were the first appliances to be equipped with standby mode (IEA 2001). Since then, however, the situation has changed significantly. Firstly, more appliances now have standby mode (or several different modes that function as standby mode[3]) or have been identified to draw power in standby mode. Moreover, it has been discovered since then in the case of some appliances that even when they seem to be switched off, but remain plugged in, some electricity power is still being drawn (Meier 2005).

It has gradually become clear that a common definition of standby power is needed. There are several reasons for this. Firstly, as mentioned above, the situation has become more complicated since the beginning of 1990s. In the last decade, the number of types of appliances that have modes other than “on” and “off” has increased significantly. Harrington *et al.* (2006) found in their study performed in Australia that the number of appliances drawing power when

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not carrying out their major function actually rose by one third within five years (from 20 in 2000 to 27 in 2005). Moreover, this number is projected to continue growing in future, mainly due to the fact that appliances (a good example being "white goods"[4]) are getting more sophisticated and their functions more complex, and therefore need to be connected to the mains continuously (IEA 2001). To emphasize the complexity, Siderius *et al.* (2006) use the term "network" products indicating the shift from "simple" standby mode products to more complicated ones that are interconnected among themselves.

Secondly, a common definition is necessary to be able to make comparable estimations among countries. There have been many studies published[5], but the results can rarely be compared perfectly, as the studies differ in what definitions they use. This is then the major obstacle for evaluating standby consumption on the global scale (IEA 2001). Similarly, when developing a programme to address standby power use, the common definition is important to ensure complementarity and consistency "not only among programmes, but (…) within programmes" (Meier 2005).

Lastly, related to this, the producers need a common clear definition in order to know, "what to comply with". Without a common definition, the producers have to fulfil different requirements for different countries or regions (Gudbjerg and Gram-Hanssen 2006), which may put them in a difficult position.

Consequently, in order to tackle all the above mentioned needs, the International Energy Agency (IEA) formed a task force, which then in 2001 came up with a broad, common definition of standby mode, which reads as follows:

> Standby power use depends on the product being analysed. At a minimum, standby power includes power used while the product is performing no function. For many products, standby power is the lowest power used while performing at least one function. This definition covers electrical products that are typically connected to the mains all of the time.

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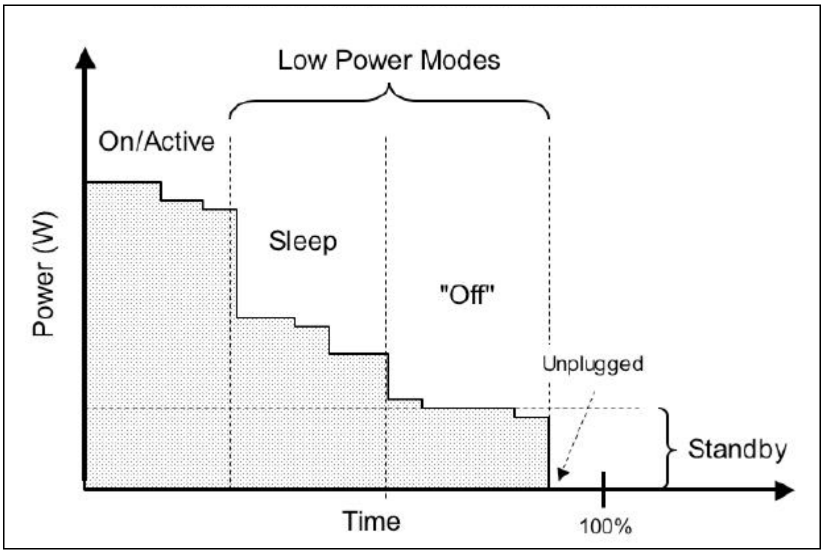
[3] Such as "ready mode", "sleep" or "deep sleep" modes. (Schlomann *et al.* 2005)
[4] Term "white goods" is used for major domestic appliances such as fridge, freezer, washing machine or dish washer. This is opposed to so-called "brown goods", which is usually the entertainment equipment such as TV, CD or DVD players or stereos.
[5] Detailed account is given e.g. by Meier (2005). Also see section 2.3.

Based on this definition, certain types of products generally do not have standby power consumption. This includes, for example, products that have only two distinct conditions: “on” and “off”, where the product does not consume power when it is switched off. (IEA 2001)

This definition is therefore based on the different functions of an appliance. This approach was adopted e.g. by Energy Star Programme[6]. However, as Nordman and McWhinney (2006) note, the limitation is that it may be sometimes difficult to tell what actually the main function of a device is. An obvious example the authors give is the one of clock radio, where it may be questionable which of the two uses is the main one and consequently what mode is the standby mode.

Some authors (Payne and Meier 2004, Nordmann and McWhinney 2006) suggest moving from the standby definition to so called “lopomos”, i.e. LOw POwer MOdeS. This classification should in their opinion better represent the complexity of appliances and their modes. Figure 1 shows the different power modes and also what their relation to power use is.

Figure 1 Graphical Depiction of Device Power Modes



Source: Payne and Meier 2004

Schlomann *et al.* (2005) further develop this idea, but choose different terminology. As can be

[6] Energy Star Programme was founded by the Environmental Protection Agency (EPA) in 1992 as voluntary labelling programme, focusing on computers and monitors primarily. The programme has gradually covered other appliances as well as lighting and has spread to countries all over the world. More information about the programme can be found at www.energystar.gov.

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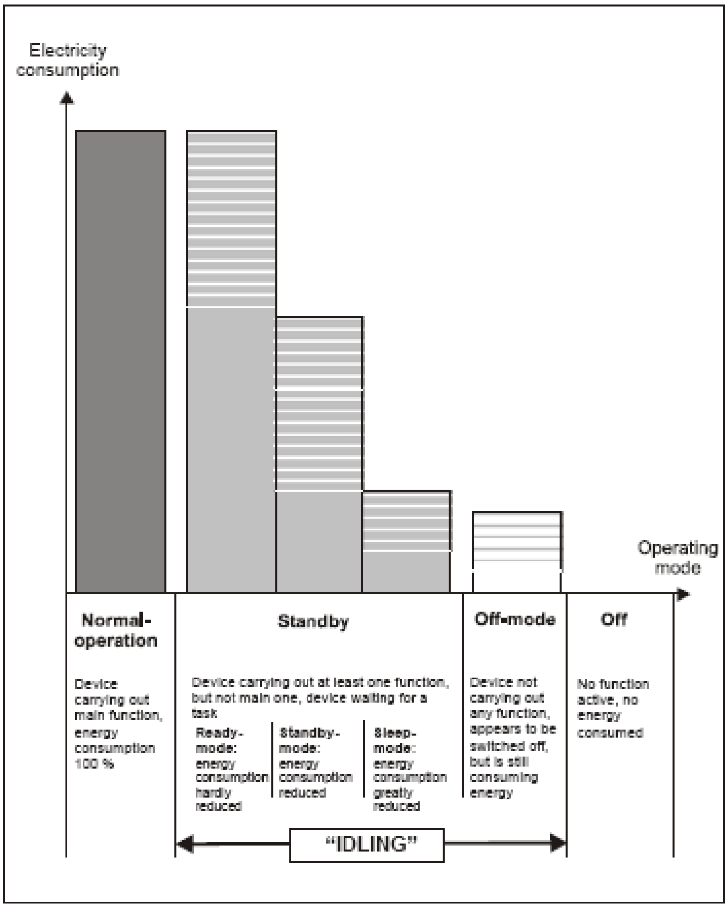
seen in Figure 2, they use the term standby according to the IEA definition. The term “idling” is then used as an equivalent to lopomo[7].

Figure 2 Low Power Modes



Source: Schlomann *et al.* 2005

Payne and Meier (2004) then go even further leaving the term standby mode as such and assigning the term standby only to a certain “power level” (Payne and Meier 2004)[8]. According to this approach, which is advocated by the International Electrotechnical Commission (IEC), the standby power is then only the “the minimum power draw of the device while connected to the mains” (Meier 2005). An ambiguity is still present as to the proper terminology. Schlomann *et al.* (2005) complain “the term "standby", in particular, is used inconsistently” (Schlomann *et al.* 2005).

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[7] It covers off-mode and different standby mode.
[8] Detailed explanation with examples of why it is better to use “standby” term only for power levels is given in Payne and Meier (2004).

2.2 Review of methods used for estimates[9]

There are two basic, mostly cited approaches to measure and estimate standby consumption. Both of them have their weak and strong sides.

The first approach used is called the "bottom-up estimate" (Bertoldi *et al.* 2002). In this method, the information on standby power use gained from the market is put together with the known saturation rate and estimated time of use of each appliance (Gudbjerg and Gram-Hanssen 2006). As Meier (2005) emphasizes, one disadvantage of this method is that it does not take into account the real life situation in the households, e.g. the fact that the households very often use the equipment which is no longer marketed. Moreover, very often only the main appliances are examined, therefore leading to underestimates of the actual standby consumption. This drawback can be partly overcome by surveying (through questioning) the existing stock (AGO 2004) or by adding information from repair shops, as done by Rosen and Meier (1999), which may provide at least partly the missing knowledge on the existing stock in households.

The other approach in use is the field measurement, which is sometimes called whole-house or building measurement (Bertoldi *et al.* 2002). In this case, each and every appliance that could possibly draw some standby power is measured in selected households. However, this method may also underestimate the actual standby consumption. The reason is, that it is very easy to overlook some appliances, or some are difficult (or impossible) to get to[10] (Lebot *et al.* 2000). This can be partly solved by measuring the overall minimum electricity consumption of the household, when all appliances are off, as it was done e.g. by Sidler (2002). Another limitation is that it is usually rather difficult to get the data from a representative sample of households. This would be very expensive and also time consuming. Even one of the biggest studies conducted so far (Sidler 2000), does not claim to have gathered a representative sample.

On the contrary, Meier (2005) points out that there is one important advantage of this method as opposed to the bottom-up approach. That is it can also grasp the behavioural aspect of standby use, which cannot be studied by bottom-up analysis, but which can play quite a significant role in the standby use.

[9] With respect to what was said above, in the rest of this chapter term

[10] For example built in appliances, doorbells or alarms.

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2.3 Previous standby consumption measurements

So far, the attention of residential standby use surveys has been mainly concentrated in the developed countries. The majority of the surveys have been conducted in Western Europe and North America, and some in New Zealand, Australia and Japan. The first measurements and estimates of standby power use were carried out by the bottom-up method. This method was used in the already mentioned early work of Sandberg (1993), in which 300 appliances were measured in stores in Sweden. A similar survey was conducted by Siderius (1995) or in California by Rosen and Meier (1999), who focused on standby use of TVs and VCRs.

Recently, the bottom up approach has been used in Australia (Energy Efficient Strategies and EnergyConsult 2006), where in the scope of the National appliance and equipment energy efficiency program, an extensive database of standby powers of all domestic appliances has been created. Since 2000, there have been surveys conducted every year in the stores that provide most up-to-date information on standby power use in the Australian residential sector.

Apart from the bottom-up surveys, the field, whole-house measurements have gradually been introduced, mainly towards the end of the last and the beginning of the present decade. In 2000, Ross and Meier (2000) made a whole-house measurement in ten Californian households, measuring almost 200 appliances. In the same year, a much more extensive study from France (Sidler 2000) was published. In this study, 178 French homes from all over the country were investigated. Two years later, an analogous study was conducted (Sidler 2002), where the measurements where extended to four additional European countries: Denmark, Greece, Italy and Portugal. In total, almost 400 additional households were surveyed.

More recently, Foster Porter *et al.* (2006) carried out field research in which 75 Californian homes were metered. The priority in measurements was given to audio and video appliances and office equipment and the devices were installed for one week. The data were combined with instantaneous measurements provided by Lawrence Berkeley Laboratory.

Cogan *et al.* (2006) conducted a study of standby power use in New Zealand. They examined 400 households, making a random sample of New Zealand households. The spot measurement

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was carried out in the entire sample and in 100 households also the long-term end-use measurement was conducted. The researchers needed six full years to complete the study.

Importantly, whichever of these methods is used in the above mentioned works, the results do not differ significantly. The residential standby consumption, based on the results of multiple campaigns, is estimated to be 4-11%, i.e. 60 – 110W per household (Meier 2005). The lower estimates usually belong to studies voluntarily focusing only on the major appliances or omitting to measure some appliances (IEA 2001). The higher estimates then sometimes indicate, as in the case of New Zealand (Cogan *et al.* 2006), that appliances, which may not fulfil the IEA standby power definition, were measured[11]. The results from the major studies are in the field summarized in Table 1.

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[11] Heated towel rails in this case.

Table 1 Measurements of standby power

Study	Country	Year(s)	Number of homes*	Number of appliances	Power (W)	Share in domestic electricity consumption (%)
Cogan *et al.*2006	New Zealand	2000 - 2006	400	11 891	58 (112 baseload)	N/A
Energy Efficient Strategies and EnergyConsult 2006	Australia	2005	X	946	92,2	10,7%**
Gudbjerg and Gram-Hanssen 2006	Denmark	2004-2005?	30	N/A	67	9%
Meyer and Schaltegger AG 1999	Switzerland	1999	X	N/A	37	3%
Foster Porter *et al.* 2006	USA (California)	2005	50	N/A	N/A	9-12%
Ross and Meier 2000	USA (California)	N/A	10	190	67	9%
Siderius 1995	Netherlands	1995	X	N/A	37	10%
Sidler 2000	France	1999	178	1 270	38	7%
Sidler 2002	Denmark	2001	100	N/A	60	14%
Sidler 2002	Greece	2001	96	N/A	50	13,5%
Sidler 2002	Italy	2001	102	N/A	57	15%
Sidler 2002	Portugal	2001	99	N/A	46	13,7%
Vowles *et al.*2001	United Kingdom	2000	32	287	36	6-10%

*if applicable
** share in Australia's total residential electricity consumption
N/A = not available
Source: Table compiled by author.

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Although there are current studies on standby power use, it seems the frequency of publishing these studies has been declining over past several years (Meier 2005). Yet, continuous data are needed to evaluate the dynamics of standby consumption and to be able to project the standby power use in future. Due to insufficient amount of such data (Meier 2005), uncertainty still remains about the probable evolution of standby consumption in the coming years.

On the one hand, some researchers (e.g. Bertoldi *et al.* 2002) believe that due to the increasing number of electric and electronic appliances in homes, which have some or several lopomos, standby power use in the residential sector will grow. The reason is that high saturation will exceed the possible savings from technological improvements.

On the other hand, Meier (2005) is more ambiguous about future development. He points out there are “several conflicting trends whose net effect is difficult to estimate” (Meier 2005). It may be expected that most appliances will decrease their standby power levels to under 1 Watt in near future, which would therefore imply a decrease in standby mode consumption. Yet, this reduction may only include standby as defined by IEC, whereas overall lopomo consumption is, according to Meier, likely to increase. Meier also stresses the impact of the growing number of appliances in homes and therefore advocates the need for long-term assessments to be able to predict the future development.

Schlomann *et al.* (2005) compared two studies which were made in 2001 and in 2004 in Germany and found out that the electricity demand in standby mode grew during this period only slightly. They also made a projection until 2015 in which they expect the standby consumption to be decreasing significantly till 2010 and then remain the same. Their estimations however focused only on ICT and audio-visual appliances.

To add some more incertitude, the future development of standby consumption depends to a large extent on policies that are or will be adopted (as discussed below). Gudbjerg and Gram-Hanssen (2006) evaluated the impacts of different program measures - “communication period” and “technology period” (Gudbjerg and Gram-Hanssen 2006) and found these may actually lower the standby consumption in households to one third of the original level. Yet, they did not find out what factors were determinant for high or low reaction of different homes.

To sum up, there have been quite a few studies concerning the standby consumption in households. Yet, there are still vacancies to be filled in as to the research method used or the sample size. Moreover, making such surveys is a continuous process which needs to be carried out periodically. This is a prerequisite for obtaining the most valid and up-to-date data.

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2.4 Solutions to standby

There are basically three ways to deal with the standby power use issue discussed. Firstly, the efficiency of the appliance in lopomo states may be improved. Secondly, some kind of power switch may be incorporated into the device or attached to it; and thirdly, the behaviour of the users may be influenced. Although these options are interconnected, they will be dealt with separately below.

2.4.1 Efficiency measures and related policies

The first option to tackle the problem of standby consumption is to focus on improving the efficiency of the appliances. The IEA (2001) suggests increasing the efficiency in the product components that operate in lopomo, or exchanging such components entirely.

The general idea, presented by Meier *et al.* (1998), is to reduce the standby consumption of all appliances to under 1 Watt. This vision, originally expressed by Alan Meier at the International Energy Efficiency Appliance Conference in Florence in 1997 has been adopted by the International Energy Agency and since then the IEA has tried to realise this target (IEA 2002).

The concept of a 1-Watt policy also gained more credibility as some countries began to incorporate it into their strategies and adopted binding regulations. Among the first ones, Australia has already adopted mandatory standby standards. In 2000, the Australian government launched so-called Minimum Energy Performance Standards (MEPS) and Energy Labelling Process. The government has set the target that all domestic appliances in Australia must have a standby power not higher than 1 Watt by 2012[12] (Harrington *et al.* 2006). A similar goal was adopted in 2005 in South Korea, with the target date 2010. Differing slightly, Japan has set the target on overall energy consumption from standby, not on individual appliances[13].

In the United States, the key document is the Executive Order 13211 on Energy Efficient Standby Power Devices issued by the president in 2001. In this order, the agencies are to purchase only products that "use no more than one watt in their standby power consuming mode" (Bush 2001).

However, in most countries, still only some form of voluntary agreements are in force. Probably the best known one is the Energy Star Programme. The Energy Star Programme[14]

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[12] "While a notional target of 1 Watt across the board has been adopted, actual targets vary by product and mode, depending on what is technically feasible based on good design practices." Harrington *et al.* (2006)
[13] For an extensive overview of current governmental and non-governmental programmes, see Meier (2005).
[14] Detailed information about the Energy Star programme can be found at their official website www.energystar.gov.

was originally developed by the U.S. Environmental Protection Agency (EPA) and joined by the U.S. Department of Energy (DOE) in 1995. The Energy Star Programme currently covers more than 50 categories of products, aiming at the 1 Watt consumption. The programme has been also adopted by other countries (such as Australia, Canada and Japan).

The European Union joined the Energy Star Programme in 2003. Besides this, the backbone of the EU standby regulations are the two Codes of Conduct. The first one, the Code of Conduct for Digital TV Service Systems has been in force since 2001. The agreement currently covers the major part of the products in question; and also the manufacturers that are not directly involved in it mostly comply with the targets (Bertoldi *et al.* 2006).

The second is the Code of Conduct for External Power Supplies, which was adopted in 2003. This has been rather successful in covering mobile phones and IT appliances, but concerning DECT telephones, answering machines, portable consumer electronics or kitchen tools, the results are far less convincing (Bertoldi *et al.* 2006). In the near future, a third Code of Conduct should be introduced and it should cover broadband equipment.

So far therefore, the EU has had no binding regulation on standby consumption. The situation may be changing, though. In 2005, the directive (2005/32/EC) establishing a framework for the setting of ecodesign requirements for energy-using products was adopted. This directive does not set any binding targets as to standby consumption; however, it may provide a framework for launching such action.

2.4.2 Switch-off using "standby killer"

Apart from increasing the efficiency of appliances, another option is to actually unplug the device completely, i.e. cut it from the electricity supplies. Schlomann *et al.* (2005) propose the switch can be integrated into the device - once the device does not have a power supply unit (PSU). The authors however note this only concerns a limited number of appliances. For the devices that have a PSU, the solution is either unplugging the appliance or integrating a primary side-switch (called "a switchable power socket" (Schlomann *et al.* 2005) by the authors), which make it more convenient to turn off the device.

With respect to the possibility to switch off the appliance, Siderius *et al.* (2006) point out that standby mode is defined as performing some function. Therefore, when the appliance is

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switched off (plugged off or using the so called "standby killer"[15]), this function disappears. They further add that "with a standby power consumption of 1 W or less, the rationale for having an on/off switch is less clear." (Siderius *et al.* 2006)

The question also is how much the option of introducing "standby killers" would influence standby consumption. Gudbjerg and Gram-Hanssen (2006) evaluated the impact of using this device in the surveyed households. The "standby killers" were found to be used for TV sets, computers or for the power boards. The authors found out that thanks to using these devices, the standby consumption was reduced by 50% compared to the original situation, therefore justifying its use in the surveyed households.

2.4.3 Behavioural change

The potential of behavioural change has been rather underdeveloped compared to the other two options. Only a few of the works reviewed by the author actually tried to take behaviour into account. Vowles *et al.* (2001) examined the potential behavioural change through a series of questionnaires and also by following the households' behaviour after they were informed about standby consumption and options to change it. After this three week period, the authors found standby consumption decreased by one fourth compared to the original level.

Similarly, in the first part of their research, Gudbjerg and Gram-Hanssen (2006) informed the families about the possibilities to reduce standby consumption. An advisor also visited the surveyed households, tailoring the measures for them. After this "communication period" (Gudbjerg and Gram-Hanssen 2006) standby consumption declined by one third.

Conversely, Siderius *et al.* (2006) think behavioural changes are far less effective than the technical solutions. In the same way, IEA (2001) believes the potential savings from behavioural change are rather limited in scale, at least in the short-term. However, neither of these studies gives any quantitative support for their statement.

The impact of behavioural change is rarely included in surveys. Although being acknowledged as influential, behaviour has rarely been incorporated into quantitative research (Weber and Perrels 2000). Moreover, as to policy implications, as Gudbjerg and Gram-Hanssen (2006)

[15] The standby killer basically cuts the electricity supply of devices that are in standby mode, but are not used. It can depend on switching off one main appliance (e.g. with switching off the computer, the monitor and printer

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note, it was rather difficult to determine in their study, what type of households are susceptible to change and therefore, at which target group to aim communication.

2.5 Previous standby monitoring in Hungary

Final electricity consumption in the residential sector in Hungary is growing continuously (CSO 2007). The analysis of residential electricity consumption has already been quite satisfactorily described; a quite detailed information database is available in the Hungarian Central Statistical Office (CSO 2006a).

On the other hand, to the author's knowledge, the standby consumption (in the residential sector, but also in other sectors) has received much less attention. Elek (2004) presented the average standby power 52W per household (data from 1997). In its general overview, the IEA (2001) has estimated the Hungarian standby consumption to be 700 GWh/year, meaning 181 kWh per household per year. To make such estimate, the IEA assumed the standby power to be 20W per household, i.e. much (2.5 times) less than Elek's estimate.

In her study, monitoring 30 Hungarian households, Strukanska (2001) produced a different number. She estimated the average household standby power to be 37W, i.e. almost two times more than the IEA estimate, but closer to the estimate from 1997.

She also made a first attempt to analyse the standby consumption in households in more detail. The limitations to this analysis were the quite low number of households examined. Similarly, using only the instantaneous measurements in her study, there was only limited scope for analysis. Moreover, the devices used for metering could measure only power that is higher than 1.5W, therefore possibly omitting quite a few appliances.

The area of evaluating the potential savings rising from different technical and behavioural options seems even more underdeveloped. Strukanska (2001) estimated the potential of adopting the 1 Watt policy. To the knowledge of the author, no other estimates are available.

Therefore, it seems important to provide a more accurate estimate of the standby consumption in Hungarian households, as the available estimates differ a lot and are also quite outdated

connected to it will switch off as well), or there may be one main switch for all appliances in the room.

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now. Despite the previous research, more detailed, precise and up-to-date analysis is needed, because as was shown above, significant changes can be expected. Using new metering devices, a larger sample of households and more precise methods, this thesis should contribute to filling in these gaps.

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3 Methodology

The objective of this thesis is to monitor and assess the standby electricity consumption in Hungarian households. To this end, a survey of a sample of 95 households was carried out. The research was mainly conducted in the framework of the REMODECE (Residential Monitoring to Decrease Energy Use and Carbon Emissions in Europe) project, in which the Department of Environmental Sciences and Policy of Central European University (CEU) participates. Under this project, electricity end-use measurements are conducted in households in European Union countries[16].

In addition to this, data from a survey conducted by Smith (2006) were used, to take advantage of having a larger sample of households and therefore a larger pool of data for the analysis.

The method used for the survey was the field, whole-house measurement, in which all the appliances in the households were measured. The data were gathered through short term, instantaneous measurements, and long term, time-series measurements.

3.1 Definition of standby

For each appliance the situations when the appliance is "on", in standby mode[17] and "off" mode were examined. With respect to the above mentioned difficulties concerning the common definition of standby consumption, the following terminology was applied for the purposes of this study and is used in this thesis.

The term "standby" was used with the meaning of all lopomos except the off mode (following Schlomann *et al.* 2005). The term lopomo was then used according to the above mentioned definition (e.g. used in Payne and Meier 2004), i.e. including the "standby" mode *and* off mode.

[16] Detailed information about the project can be found at http://www.ceu.hu/envsci/projects/REMODECE/index.htm (consulted 26 July 2007)

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The method to calculate the lopomos was adopted from Cogan *et al.* (2006). According to the authors, it "is the mode of the distribution, which is defined as the value that occurs most often." In other words, for each set of appliances, the most used mode was identified among the households and used for further analysis and for the estimations.

3.2 Data collection

A total of 95 households from Budapest and surrounding villages was examined. Given the limited amount of time and resources, as well as given the pioneering character of the study, it was not feasible to use random sampling in this study. Instead, non-probability, convenience sampling was utilized. The major limitation of this method is the lack of representativeness of the sample, but within the sample chosen, different types of households with respect to type of housing (type and area of dwelling) and socio-demographical characteristics (number of family members, age, education or income) were selected to participate in the survey. In other words, an effort was made to make the sample as varied as possible.

The representativeness of the sample was examined through a questionnaire, which was distributed to be filled out by all the surveyed households. Having the information about number, age, education and income of the members of the household, as well as information about the housing, the representativeness of the sample in relation to the demographic features of the general population was evaluated.

All 95 households were surveyed by the spot, instantaneous measurement, which was carried out from May 2006 till June 2007. 71 household data were taken from the REMODECE project. From these, the author's own measurements consisted of 50 households and the remaining 21 measurements were carried out by other members of the REMODECE project. Data from 24 households were taken from Smith (2006), who carried out the whole-house, spot measurement in Hungarian households in spring 2006.

[17] Following the definition of Schlomann *et al.* (2005) the standby mode then represents ready mode, standby mode and sleep mode.

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Consistency in conducting the measurement within the REMODECE project was ensured by the project rules. As to Smith's data, given his attendance at the CEU, he followed the same procedures as under the project.

During this instantaneous measurement, each and every appliance, which could possibly draw some lopomo power, was metered in all the above mentioned modes by Sparometer. The Sparometer (Figure 3) is a device, which is able to record the power of the appliance, ranging from 0.2W to 2300W. It has maximum 2% failure. Thanks to such accuracy, the lopomo power can be metered very precisely.

Figure 3 Sparometer

Source: Kofod (2007)

The questionnaire was distributed in each household to get the demographic data about the respective household and also to find out the patterns of usage of each measured appliance. The questionnaire was administered by the surveyor him/herself; therefore the return rate was almost 100%. In Smith's survey a slightly different questionnaire was administered, important questions about the demographic features of the households however were the same.

In addition to this, in 39 households out of the 95 long-term measurements under the REMODECE project were carried out[18]. The author's own measurements consisted of 20 households; the other 21 were carried out by other members of the project. As the project has a rather well developed and precise methodology of carrying out the metering, consistency in measurement was ensured.

[18] This method has been used e.g. in Foster Porter et al. (2006), where the long-term consumption measurements were combined with a set of data from instantaneous measurements.

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This long-term metering was carried out by serial wattmeters developed by ENERTECH (in Figure 4). These devices are plugged in serial between the appliance measured and the standard socket and record the electricity consumption every 10 minutes. The maximum power level of the wattmeters is 2600 W and their resolution is 0.1Wh.

Figure 4 Wattmeter

Source: Kofod (2007)

In each household a set of 10 wattmeters was installed. In the framework of the REMODECE project, the choice of appliances to meter was prioritized as follows (Kofod 2007):

1. Washing machine
2. Tumble dryer
3. Entertainment appliances - a group of appliances in living room: TV, DVD, CD, etc.
4. Computer and peripherals as a group for home office appliances
5. Refrigerator
6. Freezer
7. Ten most used lamps individually or the sum of lighting by groups in the installation
8. All kinds of standby consumptions recorded at the time of installation by Sparometer including satellite amplifier, Internet connection, chargers, etc.

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Given the limited number of the metering devices, the appliances sometimes had to be measured in groups (such as e.g. the office equipment or TV/Video appliances). In this case, the instantaneous spot measurements of the appliances (carried out by Sparometers) were used to identify the lopomo consumption of each appliance in the group.

In addition to the wattmeters, a set of wattmeter and so called *pulsemeter* were connected to the mains. These devices served for recording the overall baseload of the households for the given period.

The wattmeters and pulsemeters were installed for 15 days in each household. After the end of the metering period, the data were read by Oscar software[19], which is designed to facilitate the transfer of the information from data loggers to computer. Subsequently the data were transformed into Microsoft Office Excel files for further analysis.

The advantage of the method of whole-house measurement is that it allows one to see exactly for how long the appliance stays in each mode, therefore fitting the purposes of the present study. The drawback of the method is that some of the appliances might have been overlooked during the measurement or simply could not be metered. This was mainly the case of built-in appliances (usually the cooking appliances), but sometimes also due to technical problems, such as bad state of the socket. For such reasons, the pulsemeters were installed to show the overall electricity consumption. In other words, the "residue" consumption of appliances, which have not been measured or might have been overlooked, could be identified.

3.3 Data analysis

The appliances measured in households were categorized according to the REMODECE project guidelines as follows (Figure 5):

[19] OSCAR 1.01, ENERTECH

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Figure 5 Categorization of appliances

Category	Appliance	Category	Appliance
Cooling	Refrigerator	TV/Video	Antenna
	Freezer		Digital Optical Out
Cooking	Coffee machine		DVD player
	Water kettle		DVD/CD/VCD
	Microwave		Game console
	Toaster		VCR
	Digester		Satellite/Cable Set top box
	Bread maker		TV (CRT,LCD, Plasma, Rear projection)
Hi-Fi	Amplifier		VCR
	CD player	Various	Air conditioning system
	Clock-radio		Alarm clock
	Hi-Fi System		Battery charger
	Receiver		Bread slicer
	Subwoofer		Dish washer
Office	Desktop		Gas boiler
	Laptop		Hair dryer
	Modem		Halogen lamp
	Monitor (CRT,LCD)		Iron
	Printer		Irrigation system
	Multifunctional device*		Kitchen Cordless Vacuum Cleaner
	Router		Space Heater
	Scanner		Toothbrush
	Speakers		Tumble drier
Telephony	Cordless phone		Vacuum cleaner
	Phone-Fax, Answering machine		Washing machine
	Mobile Phone Charger		Water boiler

* Printer-Scanner-Copier
Source: Compiled by the author on the basis of Kofod (2007)

As the measurements took sometimes longer than 15 days, the data had to be normalized (as done by Foster Porter *et al.* 2006). This means that the data were recalculated for daily values (or 365 days for yearly estimates).

The data were analyzed using Microsoft Office Excel[20] for making tables and graphs and Statgraphics[21] for statistical analysis.

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[20] Microsoft® Office Excel 2003. Microsoft Corporation
[21] Statgraphics ® Plus, version 5.1. Statistical Graphics Corporation.

3.4 Extrapolation of the data

3.4.1 National level standby (lopomo) consumption

The method used for metering the lopomo consumption allowed for the development of several different equations to estimate the overall lopomo electricity consumption in Hungarian households. Three different ways to estimate the national lopomo electricity consumption in Hungarian households are therefore described below.

Apart from the data obtained during the metering, the data from Hungarian Central Statistical Office (CSO) have been used (CSO 2005).

1. The **first estimate** was based on the overall electricity consumption in the households. According to the REMODECE project criteria, the lopomo consumption is considered to be the total electricity consumption, measured during the night, when all the appliances are supposed to be in their low power mode. Therefore, one option to calculate the overall lopomo electricity consumption is simply to take the data from 2:00 am to 3:00 am for each household.

   Adopting a slightly different approach, Sidler (2002) in his study measured the electricity consumption when all the appliances were off, therefore identifying the lowest electricity consumption, attributable then to lopomos. The disadvantage of this approach may be that it does not take into account the behaviour of the households, i.e. the mode, in which the appliance is actually typically kept.

   Similarly, Cogan *et al.* (2006) defined the baseload as the "the typical lowest power consumption when there is no occupant demand" (Cogan *et al.* 2006). The baseload in this sense therefore includes both the lopomo of the appliances and the devices that draw power continuously (such as alarm systems). This may also have disadvantages, because appliances are measured which are not in their low power mode.

   Nevertheless, the approach followed by Cogan *et al.* (2006) has been chosen for the purposes of this study, as the data obtained from the metering allow for construction of the baseload. Moreover, it also seems more reasonable than the approach advocated in

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the REMODECE project, as it is hard to ensure that exactly between 2:00 am and 3:00 am all the appliances are in their lopomo.

The overall lopomo consumption in Hungarian households was calculated as an average of these data and then multiplied by the number of households in Hungary (for a year).

For lopomo consumption

$$\overline{BC_{hh}}(kWh/day) = \frac{\sum Baseload_{hh}}{n_{hh}}, \quad BC(kWh/year) = N_{hh} \cdot 24 \cdot 365 \cdot \overline{BC_{hh}},$$

where $\overline{BC_{hh}}$ = average baseload consumption of households in the sample

BC = yearly baseload consumption of Hungarian households

n_{hh} = number of households in the sample

N_{hh} = number of households in Hungary

For lopomo power

$$\overline{BP}_{hh}(W) = \frac{\sum baseloadpower_{hh}}{n_{hh}},$$

where $\overline{BP}_{hh}$ = average baseload power of households in the sample

In this case, only the data obtained during the REMODECE project could be used, therefore the original sample consisted only of 39 households in which the long term measurements were carried out and the pulsemeters were instaleed. In contrast, in the second and third estimates, all the data could be used.

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2. The **second estimate** was based on the sum of lopomo consumption of metered appliances in each household. Using the time series, the frequency distribution of the electricity consumption of each appliance was made. Based on this, the typical lopomo for each appliance was calculated. The electricity consumption of the appliances in their respective lopomo, which were measured in each household, was added up. The average from this number was then again multiplied by the total number of Hungarian households. The data from all 95 measurements were used. The typical lopomo and hours were drawn from the long-term measurements only and were combined with the results from the questionnaire distributed during the instantaneous measurements, in which the interviewed persons answered the question about how they keep their appliances when not using them.

For lopomo consumption

$$LC_{ap}(kWh/day) = LP_{ap} \cdot t_d \; ; \qquad LC_{hh\,n}(kWh/day) = \sum LC_{ap} \; ,$$

where LC_{ap} = lopomo consumption of appliance/day in a household

LC_{hh} = lopomo consumption of 1 household

LP_{ap} = typical lopomo of appliance (W)

t_d = average time per day spent in typical lopomo (h),

then as in 1.

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For lopomo power

$$LP_{hh}(W) = \sum LP_{ap} \; ; \quad \overline{LP}_{hh}(W) = \frac{\sum LP_{hh}}{n_{hh}}$$

3. The **third estimate** was based on the lopomo electricity consumption determined for each type of appliance. The typical lopomo electricity consumption was determined for each type of appliance, based on data from the households. Then, using the statistical

data on prevalence of the given appliance in Hungarian households – the penetration rate, the overall lopomo power and consumption were estimated.

For this estimate the data from the whole sample of 95 households were used, as for the second estimate. Similarly to the second estimate, the typical lopomo and hours were drawn from the long-term measurements only and were combined with the results from the questionnaire distributed during the instantaneous measurements.

Such estimate using the penetrations rates is widely used in the bottom-up approaches. The bottom-up approach however usually does not work with long-term measurements, therefore not taking in to account the real life situation, e.g. how the appliance is actually used. The advantage of this survey is that such the long-term whole house measurements were used, therefore revealing the real behaviour of the households and possibly making the estimate more accurate.

For lopomo consumption

$$LC_{ap}(kWh/day) = t_d \cdot LP_{ap} \cdot p \cdot N_{hh}; \qquad LC_y(kWh/year) = LC_{ap} \cdot 365;$$

$$LC_{HU} = \sum LC_y ,$$

where p = penetration rate in % of Hungarian households (data from CSO)

LC_y = yearly lopomo power of the appliance

For lopomo power

$$\overline{LP}_{ap}(W) = \frac{\sum LP_{ap}}{p \cdot N_{hh}}$$

The results obtained were then compared and the differences discussed. The estimates were also related to the average electricity consumption in Hungarian households and this percentage compared to the existing studies discussed in the literature review.

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3.4.2 *Estimates of saving potentials*

Different ways of reducing the standby electricity consumption in households have been examined through document review. Based on this research, three different measures/policies were then evaluated quantitatively for the Hungarian residential sector. These options are namely

- the potential of reducing the lopomos to under 1 Watt,
- maximum behavioural potential, i.e. having all appliances where possible switched off or unplugged, and related to this
- the cost-effectiveness of introducing the standby killer device into households.

As to the **1-Watt policy**, the estimated standby electricity consumption was compared to the proposed 1-Watt option. The longest lifetime of the appliances was assumed to be 15 years; therefore the year 2020 (to round up the number) was taken as the reference year for the purposes of this estimate. Number of households was estimated by making a forecast from the available time series from the Hungarian Central Statistical Office (CSO 2006b). Due lack of such time series for the penetration rates an assumption was made that Hungary will develop in the next 13 years and will reach the level of current average European country. Spain was found to be such country, whose economic level is currently exactly the average of the EU-25. Therefore, current penetration rates from Spanish Statistical Office (INE 2004) were used. For the set-top boxes and mobile phones, air condition and CD and cassette player, such statistics were not available, so the current Hungarian penetration rates had to be used instead. The potential savings in lopomo consumption were calculated assuming 1) the present realised values of standby power 2) all the appliances having their standby power less than 1 Watt. The saving potential was then received as the difference between these two numbers. The following equations were therefore used:

$$1)\ LC_{ap_1}(kWh/day) = t_d \cdot LP_{ap} \cdot p \cdot N_{hh}, \qquad LC_{y1}(kWh/year) = LC_{ap1} \cdot 365,$$

$$LC_{HU1} = \sum LC_y$$

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2) $LC_{ap2}(kWh/day) = t_d \cdot 1W \cdot p \cdot N_{hh}$, $LC_{y2}(kWh/year) = LC_{ap} \cdot 365$,

$$LC_{HU2} = \sum LC_y$$

3) Potential = $P(kWh/year) = LC_{HU1} - LC_{HU2}$

Where p = penetration rate of an appliance taken from INE (2004)

A second estimate was made for the option, when all the appliances were **switched off** or unplugged, when not used; i.e. the maximum behavioural potential was determined. Only the appliances, where switching off is possible or meaningful, were taken into account. As it would be practically impossible to generate a complete list of such appliances, it was assumed that switching off is feasible for the devices from the group Cooking, Hi-fi, Office and TV/Video and therefore only these were included in the calculations. The groups of Cold appliances or Telephony have not been included into this calculation, as they are supposed to be in their standby mode all the time to be able to perform their main functions.

Thirdly, the usage of **standby killer device** was assessed in terms of its economic feasibility. The costs of conserved energy (CCE) were calculated, using the following equation (Stoft 1995):

$$CCE(Ft/kWh) = \frac{AC}{\Delta E};\ AC = \frac{C \cdot d}{1-(1+d)^{-n}},$$

where AC = annualized costs

ΔE = energy saved/year

C = cost of equipment

d = consumer's annual discount rate

n = number of years of energy savings, e.g. duration of the conservation measure

It was assumed that there would be two standby killers in each household, one for the office equipment and one for the television/video appliances. Therefore appliances from these two

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categories were only included when making this calculation. The discount rate was taken from the Hungarian National Bank statistics (MNB 2007).

3.5 Limitations

The basic limitation of this survey was the impossibility to conduct a probability sampling. Moreover, the sample was mainly taken from Budapest and nearby villages and the households were chosen from acquaintances of acquaintances. This may have also influenced the willingness of the households to participate in the survey. It is very likely that given the intrusiveness of this survey, it might be more difficult to get the randomly selected households to participate.

Given also the final volume of the sample, consisting of 95 households, the statistical methods, mainly for the national level estimations, had to be used with caution. Statistical inference was used when extrapolating the results on national level to assess the accuracy of such calculations.

There is a high probability that the accuracy of such estimates will be rather low. Nevertheless, the final calculation may still be relevant in evaluating the trends within the country and making comparisons with studies from other countries.

Apart from the representativeness issue, there were several difficulties emerging during the data collection itself. First, during the long-term measurements, the major limitation was the necessity to group the appliances to one wattmeter. Consequently, it was sometimes impossible to determine exactly, in which mode some appliances in the group were. For instance in a group of TV, VCR and DVD, it was not possible to distinguish whether just the TV was on, or also the TV and VCR. Therefore, in such cases, once the consumption changed, it was assumed, all the appliances in such group changed their mode.

In the contrary, some appliances, although being in a group with some other, were just assumed to be in certain mode for 24 hours, as it resulted from their character and function. Example of such appliance would be the modem or fax machine. It can be assumed they are in standby mode the whole day in most of the households. There are just very short periods of

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time when these are in “on” mode, i.e. performing their main function - in this case sending or receiving data. Therefore, it could be assumed that they are kept in their lopomo for 24 hours a day.

As to filling out the questionnaires, the questions were distributed upon the measurement, ensuring almost 100% return rate. However, there were questions that remained unanswered by several households. Such questions concerned mainly the income level (one can assume the households were not comfortable with answering such question) or the electricity consumption (in this case, the households usually simply did not know the exact number). The question about energy class of different appliances remained usually unanswered because the respondents either did not know it or the appliances were too old. The limited amount of time for the research then did not allow for revisiting the households for gaining the missing information.

There were several limitations which influenced the estimations. First of all, due to technical problems, the pulsemeters could only be installed in a few households. Moreover, only some of the installed pulsemeters recorded the data correctly. Therefore the first estimation of the national lopomo consumption could not be used in the way that was presumed at first. Yet, the information from the households where the pulsemeters were installed properly may be still useful with respect to the methodological approach, i.e. to see what level of lopomo electricity consumption might be overlooked.

Major methodological limitation of the third estimation was that the penetration rates are known only for limited number of appliances, therefore some of the appliances measured could not be included into the calculation. On one hand, this is mainly the case for appliances where one can assume the penetration rates are still rather low, such as kitchen cordless vacuum cleaner or cordless phone. On the other hand though, there are appliances missing whose penetration rate is low now, but whose presence grows rather rapidly and that also have quite high lopomo power. This is mainly the case for most of the office equipment, such as modems, printers or routers. Therefore, the estimate is likely to be rather accurate now, when the penetration rate of these appliances is rather insignificant. However, in the future one may expect growing penetration of the above mentioned devices and therefore the accuracy may decrease, unless the penetration rates are provided.

Limitation of the 1 Watt potential estimate is the assumption of frozen efficiency, e.g. assumption that the energy efficiency does not improve over time. Energy efficiency of the

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appliances is likely to increase in future and potential savings arising from the 1-Watt policy may be therefore overestimated.

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4 Presentation and discussion of the data

In this chapter, the results from the survey on lopomo consumption in Hungarian households are presented. The chapter is divided into two main parts. In the first part, the data are analyzed at the household level; in the second part, the figures are presented by appliance category, in which the results for the appliances are discussed in detail. Each section is then divided into subsections on lopomo power and lopomo consumption.

4.1 Household level

4.1.1 Description of the sample

The sample consisted of 95 households, selected from Budapest and nearby villages. The average number of members in the households within the sample was 2.61. The average income of the households[22] was 294 688 HUF per month (1 179 euro[23]), or 3 536 256 HUF (14 145 euro) per year. This means that the average monthly income per person in the sample was 112 907 HUF.

As to the highest achieved level of education in the household, this question was answered only by two thirds (63) of the respondents. Within this sample, more than 70% (49) had the university degree as the highest reached education level in the household. Within the rest, 5 had high school or equivalent and 4 had no degree. The same number of households (4) stated the highest education level in the household was a vocational certificate without high-school graduation.

Concerning the type and characteristics of surveyed dwellings, both flats in multi-occupancy buildings and single family houses were selected into the sample, the proportion being about 1 family house for 2 flats. The average area of the dwellings was 86m^2 and the average number of rooms 3.16.

[22] 65 of the households out of 95 answered this question.
[23] The exchange rate from 7 July 2007, published by the Hungarian National Bank (www.mnb.hu), was used – 250HUF/EUR.

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The sampled household electricity consumption was on average 2869 kWh per year (median being at 2538 kWh). The sample data ranged from 504 kWh to 8080kWh per year. The mean proportion of household income that is spent on electricity bill is 3.22%, with the median being 2.79%.

To put the above described results into context, a comparison with the national statistics was made. Such a comparison is also important in order to be able to evaluate the representativeness of the given sample in relation to the socio-demographic characteristics of the whole nation. The comparison can be seen in Table 2.

Table 2 Comparison of the sample with national data

	Survey sample	Confidence interval (95%)	National statistics	Difference
Members of household (n)	2.61	2,36511;2,8606	2.67	-2.25%
Income per household (HUF)	294 688	250818,0;338557,0	285 978	3.05%
Income per person (HUF)	112 907		107 108	5.41%
Area (m2)	86	76,0896;95,9779	78.1	10.12%
Number of rooms (n)	3.16	2,86205;3,46652	2.63	20.15%
Electricity consumption (kWh)	2869	2530,24;3208,05	2741	4.67%
% of income spent on electricity	3.22	2,66606;3,78413	3.15	2.22%

Source of national estimates: CSO (2005), CSO (2006a)

The average number of members of a household is very similar to the national level estimate, which is just 2% lower than the sample average. The difference in average income per household is just slightly higher, about 3%. Significant differences however can be observed in the information about housing of the households. Both the average area of the dwelling and the number of rooms was much higher than at the national level. This is a rather surprising result, given the place where the sample comes from. In Budapest, the average area of a dwelling is well below the country's average (64 m^2 compared to 78 m^2), same for the number of rooms (2.33 rooms on average compared to 2.63) (CSO 2005). The reason for such differences will be most probably attributable to the method of sampling – in other words, people with higher education may be expected to live in bigger dwellings. By the same token, one may find the little difference in income level rather a surprising result.

The highest attained education in the sample is even more different from the nation's average. In Hungary, most people reach a basic education level or some type of secondary education, whereas in our sample, people with a university degree prevail. The reason for such high difference in these results may be explained by the method of sampling - convenience sampling,

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in which the acquaintances of acquaintances form the selected sample. Therefore people with higher education were more represented. The impact on the lopomo consumption is however not clear. One may expect the sampled households will have more electronic devices, e.g. more equipped computer area, but in the mean time, these households may be more environmentally careful.

To sum up, there are differences between the examined sample characteristics and the national statistics. On the one hand, important features of the households in relation to lopomo consumption which are members of the household, average income, and electricity consumption (4% difference) are very similar to the national level. The percentage difference between the sample and national level statistics is not higher than 5%. On the other hand, the mismatch is quite significant concerning the education level of the households and also in the characteristics of the dwellings. Despite these differences, the sample, although not selected randomly, shows similarities in most of the examined demographic features, which makes further analysis, and mainly the national level estimates more valid.

4.1.2 Lopomo power

The average lopomo power of the household in the sample is 30W, ranging from 0W in some households up to as high as 110W. The median level was 27.3W. With 95% confidence the mean lopomo power is in the interval between 25.4W and 34.6W. Standard skewness of the sample is 4.81 (Table 3). This is quite a high number indicating that there is a significant prevalence of lower values in the sample.

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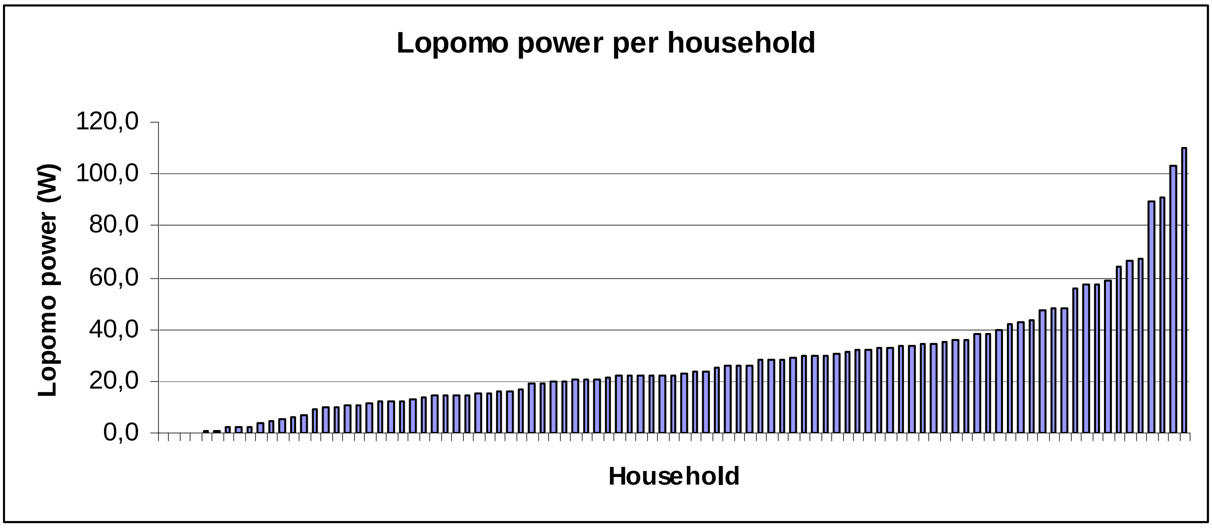
Table 3 Househołod lopomo power

Average	Maximum	Minimum	Median	95% confidence interval for average	Standard skewness
30W	110W	0W	27.3W	25,4W;34,6W	4.81

The actual distribution of the metered lopomo powers can be seen in Figure 6.

Figure 6 Lopomo power per household



There were several households with 0W lopomo power. This was not due to the fact that these households did not own any appliances with low power modes, but rather because they just switched all the appliances off or unplugged them. The presence of several of such households in the sample may again be the result of the method used for sampling, which probably led to a higher presence of environmentally careful households.

On the other side of the scale, in the household with the highest lopomo power, the main part of the lopomo load can be attributed to the set-top boxes. One household (HH48) had three of them, with average lopomo power of 12W each. This is particularly interesting, as the set top boxes have not played an important role so far, but their importance and presence is likely to grow (Bertoldi *et al*. 2002), increasing significantly the lopomo power and consumption in the residential sector.

4.1.3 Lopomo consumption

As for the lopomo electricity consumption in the surveyed households (Table 4), the values varied from 0 kWh up to 2.55kWh per day (which is 933kWh a year). The average household lopomo consumption in the sample was 0.65kWh per day (236kWh per year) with median 0.6kWh/day (219kWh/year). It means the lopomo consumption represents 8.2% of the average electricity consumption in the households. Standard skewness of the daily lopomo consumption is 4.62. This is very similar to the skewness in lopomo power distribution.

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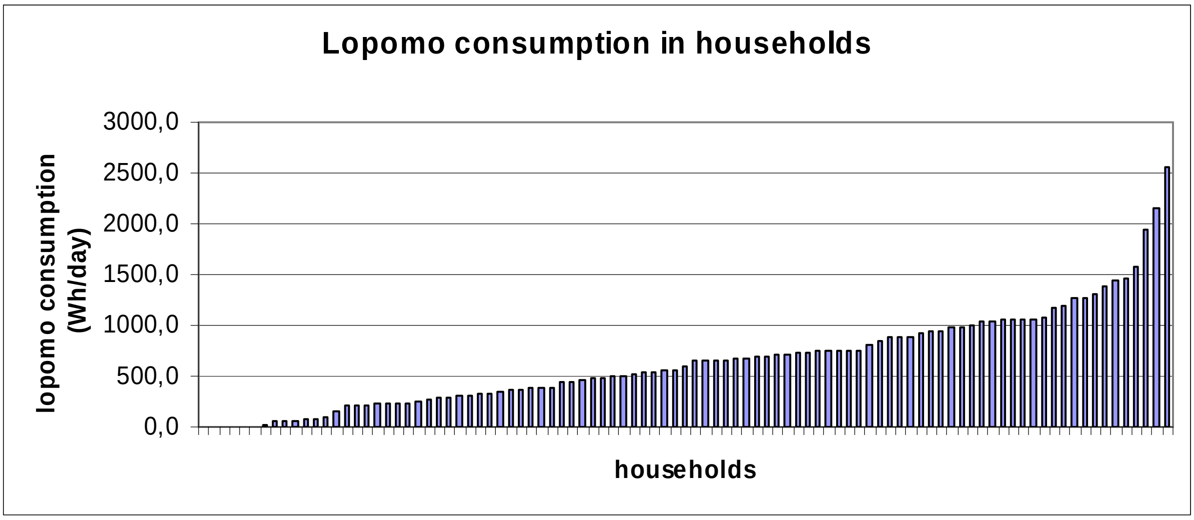
Table 4 Household lopomo consumption

Average (kWh/day)	Maximum (kWh/day)	Minimum (kWh/day)	Median (kWh/day)	95% confidence interval for average	Standard skewness
0.65	2.55	0	0.6	0.55 – 0.75	4.62

Distribution of the daily lopomo consumptions in the households is presented in Figure 7.

Figure 7 Lopomo consumption per household



The highest lopomo consumption belongs to the household with the highest lopomo power as well. This is however not a rule, as the household with the second highest lopomo consumption has overall lopomo power of “only” 90W. Therefore, one may conclude that behaviour, i.e. the time for which the appliances are actually kept in lopomo plays a significant role. Similarly, the household with 0kWh consumption is the one where the appliances are switched off or unplugged.

When looking closer at the data, major contributors to the lopomo consumption in the households are office equipment and the appliances from the TV/Video category (Figure 8). Together, these two categories represent more than 70% (149kWh/year) of the total average lopomo consumption in the household, 80% together with audio equipment (172kWh/year); audio-visual equipment alone contributes 50% of the lopomo consumption in an average household[24]. Quite far behind these two categories is then telephony with only 6% on average.

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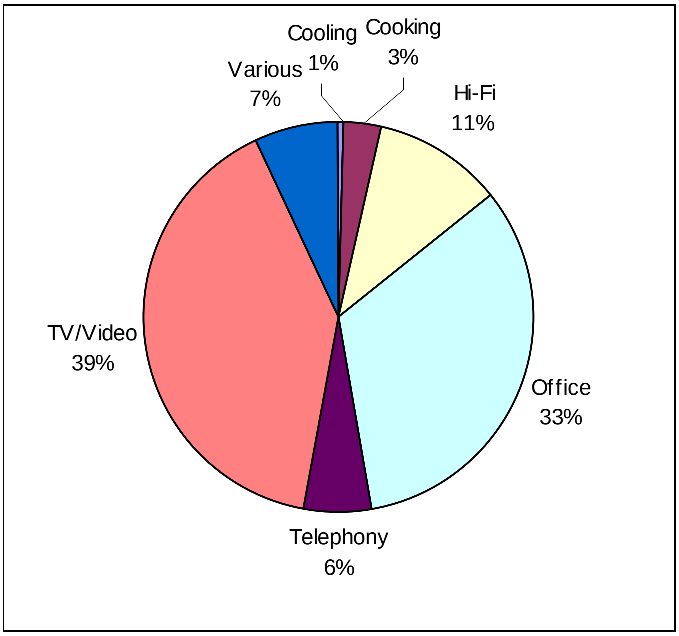
[24] These data come from just 76 households, as Smith (2006) did not divide the household data according to the categories, but just according to appliance types.

Cooking and cooling appliances have together around 3.5% on average of the lopomo consumption in the sampled households.

Figure 8 Share of appliance categories on the household lopomo consumption



In 39 households the pulsemeters were connected to the mains, metering the total electricity consumption. Due to technical problems, data from only 13 of them could be used afterwards. Nevertheless, it is useful to examine the results from these households, as it reveals how much lopomo consumption might have been overlooked and/or could not be metered (Table 5).

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Table 5 Baseload power and consumption

Household number	Baseload (W)	Metered (W)	Difference (W)*	Daily consumption (Wh)	Yearly (kWh)
14	54	47.4	6,6	1296	473.04
15	48	12	36	864	315.36
17	36	23.4	12,6	576	210.24
19	24	14.8	9,2	564	205.86
24	42	26	16	874	318.86
26	170	64	106	2873	1048.65
27	54	22	32	1269	463.19
28	72	5.7	66,3	900	328.50
29	68	58.7	9,3	1598	583.27
32	54	24.2	29,8	1053	384.35
33	246	103.2	142,8	3764	1373.79
34	120	66.8	53,2	1560	569.40
38	28	28	0	548	200.02
Average	**78.15**	**38.17**	**39.98**	**1364.49**	**498.04**

*****Difference between baseload and sum of metered lopomo powers of appliances

Average baseload, i.e. the typical minimum consumption, in the surveyed households was 78W (measured by the pulsemeters). Average lopomo power within these 13 households, when adding up the lopomo powers of the metered appliances, was however only 38W. Therefore on average 40W power was overlooked or could not be metered.

Another explanation of this large difference may however be that there was some appliance switched on; in other words, there may be some appliance running continuously and not qualifying as being in low power mode. This is also the main disadvantage of this method. When abstracting the two extreme cases (a difference of 142W and 106W), where it is almost certain that one or several appliances were in "on" mode, the average difference is only 25W. The conclusion could be made that these 25W represent the "hidden" lopomo power of a typical household.

4.1.4 Correlations

Following the analysis carried out by Sidler (2002), correlations between the lopomo consumption and different variables were examined. Namely, the possible correlation between lopomo consumption and the number of household members, area of a dwelling and electricity consumption were analyzed (Figures 9 to 11 and Table 6).

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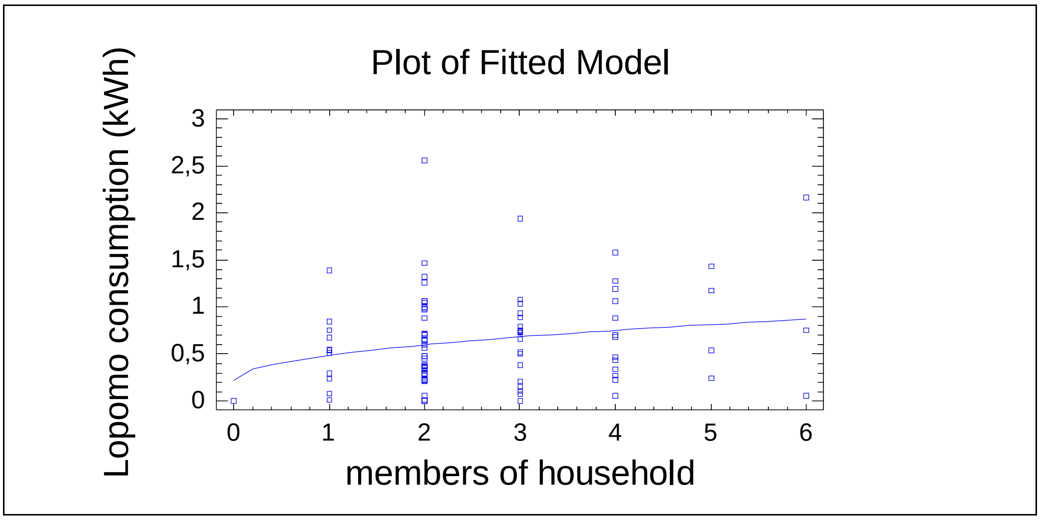
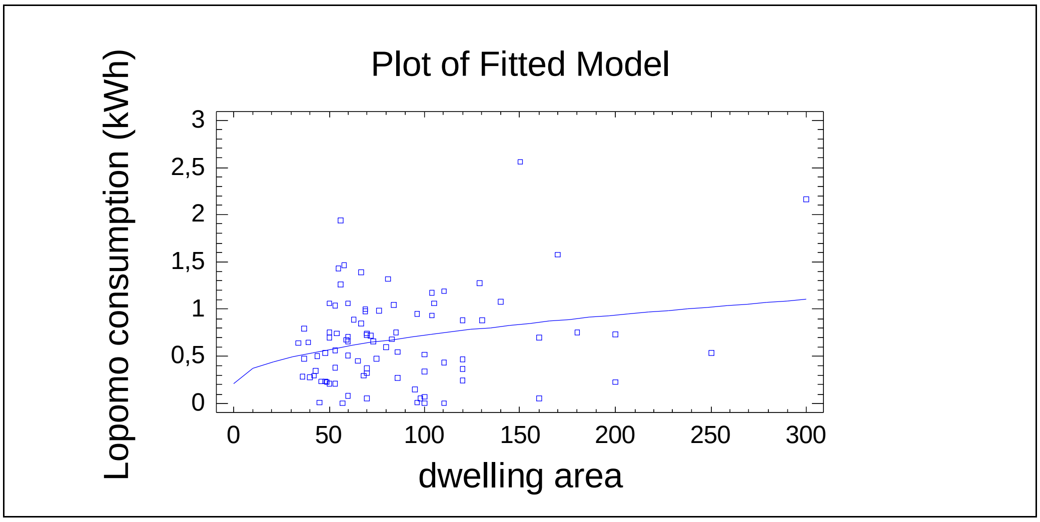
As to the correlation of number of members in households and daily lopomo consumption, the p-value is below 0.05 indicating there is a relationship between these two variables. However, the coefficient of determination (R^2) is only 3.44% and the correlation coefficient is 0.21, which shows that this relationship is rather weak.

Figure 9 Correlation of lopomo consumption (daily) and members in the household



The relationship is stronger for the lopomo consumption and the area of the dwelling. Still, however, the correlation coefficient is rather low (0.25), indicating a very weak relation as well.

Figure 10 Correlation of lopomo consumption (daily) and area of the dwelling



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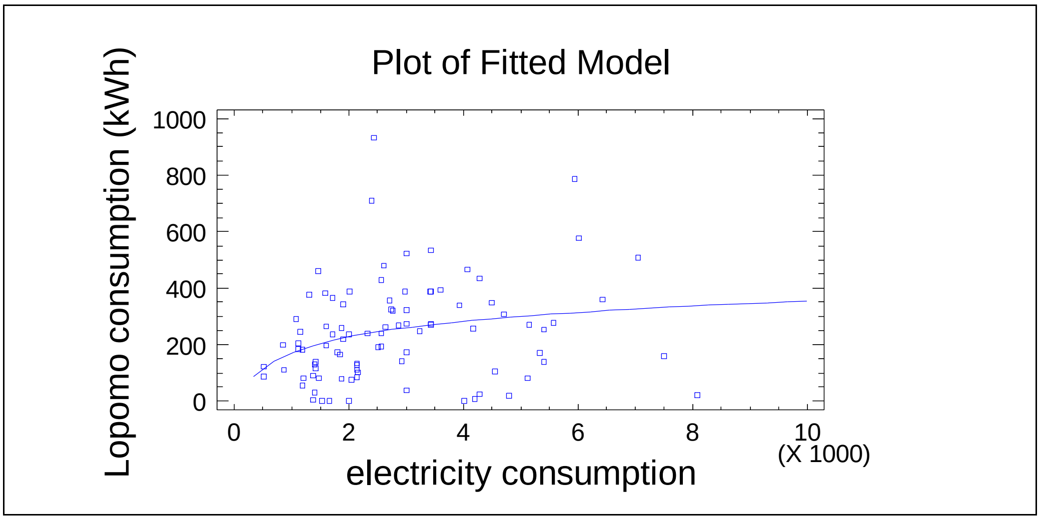
Interestingly, the correlation of the lopomo consumption and electricity consumption is very weak as well. The results for these two variables are slightly better than the previous two; still however, given the correlation coefficient (0.26), the relation between lopomo and total electricity consumption is far from being convincing.

Figure 11 Correlation of lopomo consumption (yearly) and total electricity consumption (yearly)



The statistical data described above concerning the correlations are summarized in the Table below.

Table 6 Correlation between lopomo consumption and number of household members, area and total electricity consumption

Correlation with	R-squared (adj.)	Correlation Coefficient	p-value	Equation of fitted model
Number of household members	3,44%	0,21	0,04	lopomo (kWh) = 0,22 + 0,27*sqrt(members)
Area (m2)	5,37%	0,25	0,02	lopomo (kWh) = 0,45 + 0,003*m2
Electricity consumption	5,71%	0,26	0,01	lopomo (kWh) = -1,03 + 0,22*ln(el cons)

None of the chosen variables explain the lopomo consumption sufficiently; the relations between the variables and lopomo consumption are very weak. Sidler (2002) in his study came to the same conclusion using the data from 400 households from four European countries. He explains the weak correlations by the fact that the actual lopomo powers of different appliances are very diverse, as well as the penetration of these appliances in the households. Therefore, he

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concludes the whole household lopomo consumption also differs a lot and no significant correlation can be traced. The same conclusion was found also with the data of the present survey.

4.2 Analysis by appliances

In this section, the lopomo power and consumption by appliance category are analyzed. First, the results in general are described and then the appliances are examined in detail by each category.

For the purposes of the analysis, the appliances measured were divided into 7 main categories according to their main function, i.e. cooling, cooking, hi-fi, office, telephony, TV/video and various, and then into 50 types according to their specific function. A total of 994 appliances were metered during the survey. Therefore on average, there were 10.5 appliances per household measured. The number of appliances per household however varied quite significantly from as low as 3 appliances (TV, microwave and fridge) to as high as 26 appliances in one household.

4.2.1 Lopomo power

The main characteristics of each appliance type are presented in Table 7, showing the minimum and maximum metered lopomo power of each appliance type, as well as the mean value[25]. In this table, only the values metered by spot measurements are only included, therefore the table provides information about the "technical" state of appliances in the households, disregarding the potential behavioural influence. The behavioural influence, e.g. when the household switches or plugs the appliance off is then included in the following table presenting the lopomo consumption.

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[25] Freezer, electric cooker, toaster, digester, mixer, dish washer, hair drier, tumble drier and vacuum cleaner are not included in this table, as none of the appliances measured was found to draw lopomo power.

Table 7 Appliance lopomo power

Category	Appliance	Count	Min (W)	Max (W)	Mean (W)
Cooling	Refrigerator	43	0	9	0.67
Cooking	Coffee machine	15	0	2.9	0.19
	Microwave	72	0	3.4	0.68
	Bread maker	2	1.6	2.2	1.9
	Bread slicer	4	0	6	1.58
Hi-Fi	Hi-Fi System	60	0	20.8	3.43
	Clock radio	22	0.6	3.2	1.49
	Radio	5	0	3	0.96
	CD player	26	0	5.7	1.7
	Cassette player	2	0	1.2	0.6
	Gramophone	5	0	2.1	0.7
	Subwoofer	1	10.4	10.4	10.4
	Amplifier	7	0	12.4	2.71
	Receiver	4	0.8	4.1	2.53
Office	Desktop	63	0	12	3.54
	Monitor	64	0.5	5.1	2.47
	Printer	43	0	10.7	2.92
	Multifunctional device	1	10.2	10.2	10.2
	Scanner	3	0	4.3	2.8
	Modem	42	2	9.4	6.8
	Router	23	3.5	9	5.89
	Speakers	21	0.8	6.5	2.38
Telephony	Cordless phone	32	0.3	4.5	2.41
	Phone-Fax	8	1.7	6.8	4.33
	Answering machine	3	3	3.3	3.17
	Mobile Phone Charger	27	0	6.6	0.37
TV/Video	TV	93	0.3	30.4	6.58
	DVD	49	0	11.6	1.44
	DVD/VCD/CD	3	0	3.1	1.3
	VCR	47	1.7	18.6	6.34
	Home cinema	3	0.5	4.2	1.77
	Satellite/Cable Set top box	16	0.7	18.5	9.31
	Game console	2	0.7	2.3	1.5
	Antenna	7	0.6	12	4
	Digital Optical Out	1	2.4	2.4	2.4
Various	Air conditioning system	4	1.5	4.7	2.68
	Alarm clock	2	1.8	2.4	2.1
	Battery charger/Adapter	10	0.3	16.4	3.51
	Electric piano	2	0	1.8	0.9
	Gas boiler	9	0	4.8	2.74
	Halogen lamp	2	1.7	2.4	2.05
	Iron	2	0	3	1.5
	Irrigation system	1	4	4	4
	Kitchen Cordless Vacuum Cleaner	3	1.4	1.6	1.5
	Toothbrush	8	1.1	4.2	2.32
	Washing machine	56	0	2.2	0.15
	Water heater	6	0	1.3	0.22

The highest lopomo power values can be found in the category TV/Video, in office equipment and hi-fi, within which the maximum levels fluctuate usually around 10W, but 20W lopomo power is not unusual either. Similarly, differences between the maximum and minimum

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metered values are rather significant within these categories. Within TV and video, the average difference between the highest and lowest value is 10W, the biggest difference being 30W.

The highest lopomo from all the appliances metered was found at one particular TV (30.4W) in standby mode. This is one third of the power when this particular TV is on (an average of around 80W). The power in on mode of the other metered TVs was sometimes even down to 60W, which means just twice the standby power of the “worst” TV.

The differences in lopomo power values are important even more when one realizes that the appliances are performing the same function (Sidler 2002). Taking the example of the TV once again, the lowest standby power is 0.3, while the function (i.e. preparedness to be switched on by remote controller) remains exactly the same.

4.2.2 Lopomo consumption

Table 8 shows the lopomo consumption of the appliances. The time-series data gained from the long-term measurement revealed exactly for how long the appliances are kept in a certain mode. Therefore, the overall standby consumption of the metered appliances can be calculated rather precisely. The average time for each appliance in the lopomo is shown in the first column of Table 8. In some cases, the time spent in lopomo is usually close to 24 hours, for example the microwave ovens or clock-radios, but in the case of appliances such as TV, hi-fi or computers, this time differs more significantly.

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Table 8 Appliance lopomo consumption

Category	Appliance	Hours	Consumption (Wh/day)	Consumption (kWh/year)
Cooling	Refrigerator	10.6	7.1	2.59
Cooking	Coffee machine	23.4	4.4	1.62
	Microwave	23.5	16.0	5.83
	Bread maker	24	45.6	16.64
	Bread slicer	23.9	37.8	13.78
Hi-Fi	Hi-Fi System	22.4	76.8	28.04
	Clock radio	23.5	35.0	12.78
	Radio	23.2	22.3	8.13
	CD player	22.6	38.4	14.02
	Cassette player	23.2	13.9	5.08
	Gramophone	24	16.8	6.13
	Subwoofer	24	249.6	91.10
	Amplifier	22.3	60.4	22.06
	Receiver	24	60.7	22.16
Office	Desktop	19	67.3	24.55
	Monitor	19.1	47.2	17.22
	Printer	22.5	65.7	23.98
	Multifunctional device	24	244.8	89.35
	Scanner	23.8	66.6	24.32
	Modem	24	163.2	59.57
	Router	24	141.4	51.60
	Speakers	21.6	51.4	18.76
Telephony	Cordless phone	24	57.8	21.11
	Phone-Fax	24	103.9	37.93
	Answering machine	24	76.1	27.77
	Mobile Phone Charger	24	8.9	3.24
TV/Video	TV	18.8	123.7	45.15
	DVD	20.8	30.0	10.93
	DVD/VCD/CD	17.9	23.3	8.49
	VCR	21	133.1	48.60
	Home cinema	15.8	28.0	10.21
	Satellite/Cable Set top box	21.8	203.0	74.08
	Game console	24	36.0	13.14
	Antenna	23	92.0	33.58
	Digital Optical Out	19.1	45.8	16.73
Various	Air conditioning system	24	64.3	23.48
	Alarm clock	23.8	50.0	18.24
	Battery charger/Adapter	20.6	72.3	26.39
	Electric piano	24	21.6	7.88
	Gas boiler	23.4	64.1	23.40
	Halogen lamp	24	49.2	17.96
	Iron	23.9	35.9	13.09
	Irrigation system	24	96.0	35.04
	Kitchen Cordless Vacuum Cleaner	24	36.0	13.14
	Toothbrush	24	55.7	20.32
	Washing machine	23.1	3.5	1.26
	Water heater	21.2	4.7	1.70

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The highest average lopomo consumption was found for set-top boxes[26], more than 0.2kWh a day (74kWh per year), which is almost a third of the average daily (yearly) lopomo consumption of the whole household. In the particular households in which the set-top boxes were found, their lopomo consumption represented on average 30% of the total lopomo electricity consumption (Table 9).

Table 9 Share of set-top box lopomo consumption on total electricity consumption in the households

Household number	Set top box consumption (Wh/day)	Lopomo consumptio n (Wh/day)	%
14	230.4	928.3	24.8%
29	201.6	1034.9	19.5%
33	282.2	1579.8	17.9%
34	223.3	878	25.4%
43	84	700.1	12.0%
48	885.6	2557.2	34.6%
61	333.6	1579.8	21.1%
65	479.6	787.9	60.9%

Similarly, routers and modems also form a large part of the lopomo consumption. This is because their lopomo power is quite significant (on average around 6 - 7W) and they are in their standby power mode basically 24 hours a day[27].

The same applies to the TV sets, which, if combined with VCR (in 47 cases in the 95 households), account for 0.257Wh a day, i.e. 94 kWh per year on average. This is almost 40% of the average household lopomo consumption.

Another important finding is that the combination of desktop computer with monitor and printer account for quite a significant amount of lopomo consumption as well (0.12Wh/day, 65kWh/year). This office set was found 43 times, i.e. almost one per two households on average in the sample.

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[26] The printer-scanner-copier and subwoofer had higher lopomo consumption, but there was only one case of each appliance type found in the whole sample. A larger pool of data would be necessary to support or displace this result.

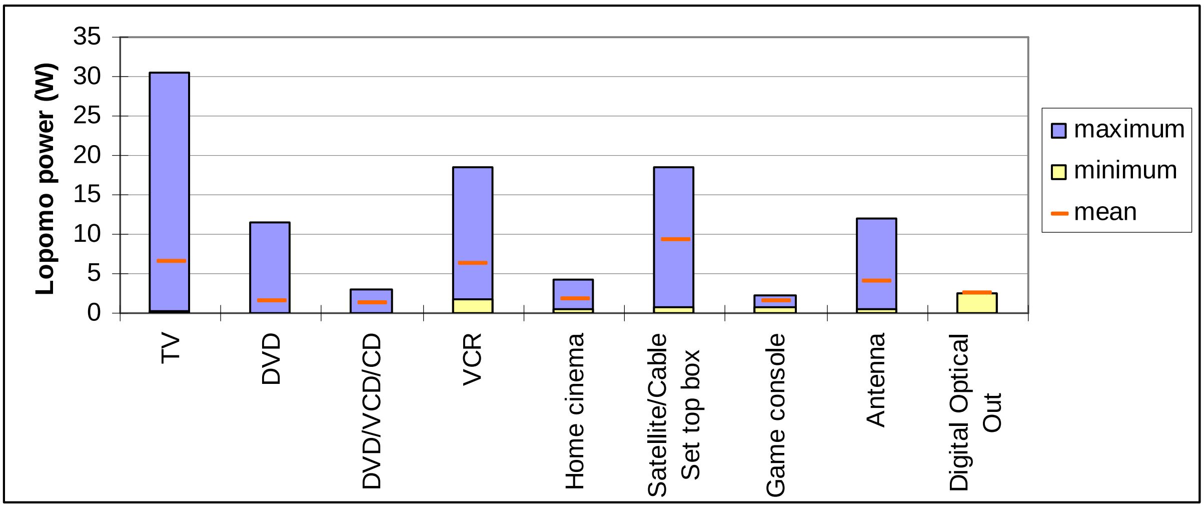
[27] Schlomann *et al.* 2005 determine the low power mode of the modems and routers as a mode when the unit is not processing any data, i.e. the internet is not used. However, from the experience in the household metering,

4.2.3 TV and Video

When looking closer at the biggest contributor to the household lopomo consumption, there are two striking features in it. First, the big difference between the metered values of the same appliance type and the overall high lopomo power of certain appliances, such as set top boxes or VCRs and second, the difficulty or inconvenience for the households to deal with the high lopomo consumption, as many of the appliances in this category cannot be switched off, i.e. have only "on" mode and "standby" mode, missing the "off" mode.

As to the magnitude of the lopomo power, the highest and the lowest values as well as the mean within the category are shown in Figure 12.

Figure 12 Lopomo power of TV/Video



The average lopomo power of the set-top boxes metered was more than 9W with the maximum level at almost 20W. The set top boxes were present only in about 10% of the metered households; however they are expected to penetrate fast on the market in the coming years (Bertoldi *et al.* 2002). It is therefore necessary to look at the results with this perspective in mind.

There were 93 televisions metered during the survey. As mentioned above, the highest standby power from all the appliances, as well as the biggest difference between the extremes was identified among this appliance type. However, the distribution of the metered values says

the consumption of the modems and routers stays the same and it is therefore not possible to detect when the modem or router is "on" and when on "standby".

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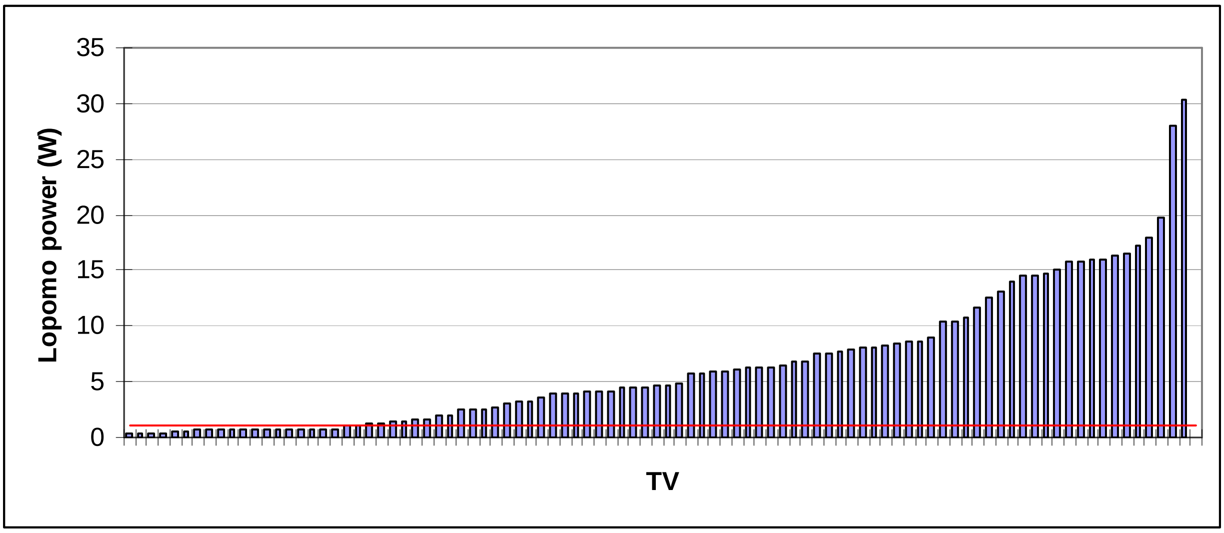
probably more about the situation in the households. There were only two televisions with such high standby power within the sample. Most of the values (as shown in Figure 13) can be found in the range between 0 to 5W (median of the sample is 4.6W). More than 20% of the TVs in the sample have standby power less than 1 Watt (the red line represents in Figure 13 the level of 1 Watt). The same proportion of the TVs still draws power between 10 to 20W. All the TVs measured had 0W lopomo power when switched off by the off button.

Figure 13 Distribution of standby power – TV



Note: The red line represents the level of 1W.

Within the survey conducted under the REMODECE project, the information about the type of TV (LCD, CRT, plasma or rear projector) was gathered, together with the size of the screen. Therefore, for the number of 66 televisions metered during this survey correlations between these characteristics and the standby power could be examined. However, within the sample, no significant relation was discovered either between standby power and size of the screen or the standby power and the type of the TV. Both correlation coefficients were very low (0.22 and 0.26 respectively).

As to the absence of an off switch, this was mainly the case of the DVDs and VCRs. The average standby power of the VCRs was more than 6W. Yet, in contrast to the TVs, in most cases there was no option to lower the standby power other than to unplug the device. Some of the DVDs had an “off” switch instead of a “standby” switch. The average lopomo power of this appliance type was lower compared to the VCR, as once there was an off switch in the DVD, the lopomo power of the DVD dropped to 0W when not used.

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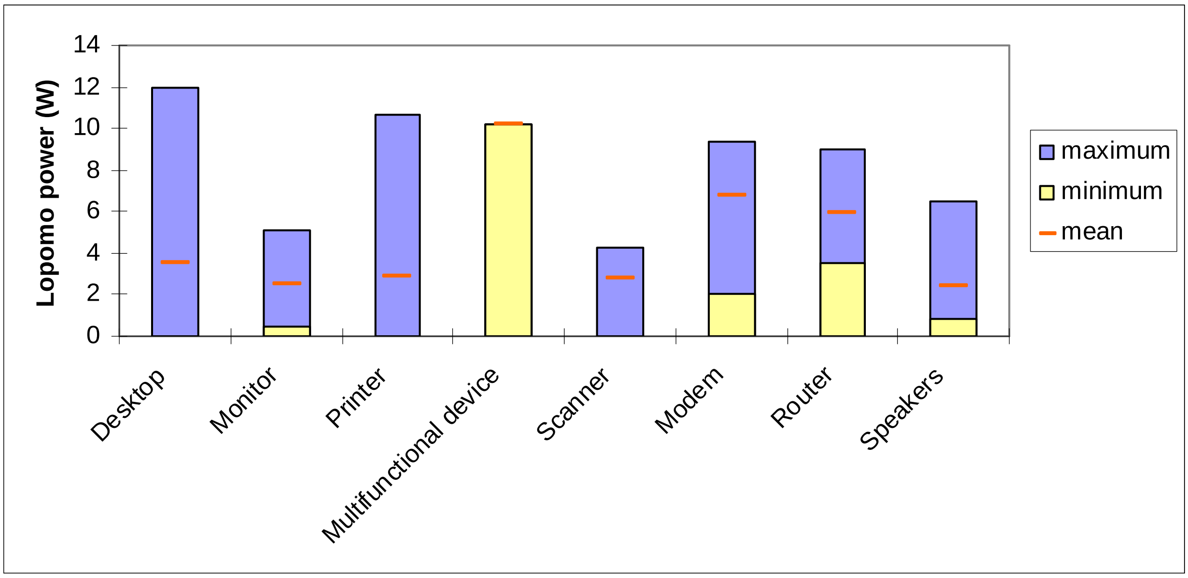
4.2.4 Office

The appliances from the category Office equipment were the second largest contributors to the household lopomo consumption. The penetration rate of office equipment was much higher in the sample than at the national level (66 compared to 36 computers per 100 households). But as in the case of set-top boxes, one may expect growing penetration of these appliances in Hungarian households. Therefore such data gathered by this survey still appears to be quite useful.

Figure 14 Lopomo power of office equipment



In Figure 14 the maximum, minimum and average values of each appliance type within this category are presented. Computers were metered in their "off" mode. Most of them drew power even when switched off. Only in two or three cases was the off mode power 0W. All the other 60 desktops did draw some power when switched off, mostly ranging between 3 and 5W, but in one case it was even 12W (distribution of the actual values is shown in Figure 15).

Due to the fact that computers are drawing power when switched off completely, the only way households can get rid of such electricity consumption is to unplug them, or by using the standby killer. This was however the case only in a few households, where the extension with a switch was used, and one may assume such "carefulness" will be again owing to the method of selecting the sample, but may be also due to other priorities, i.e. fire cautiousness.

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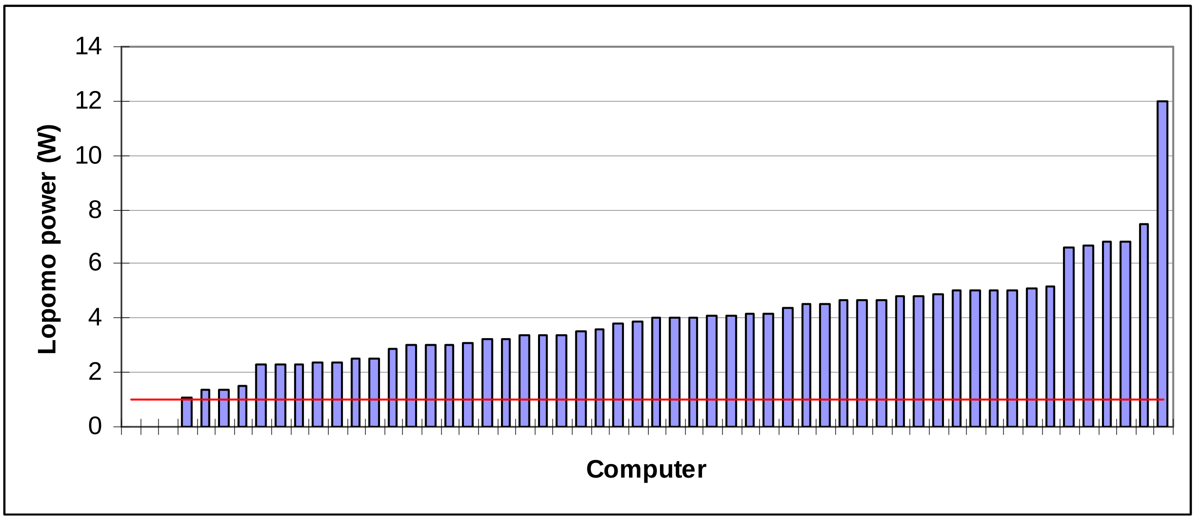
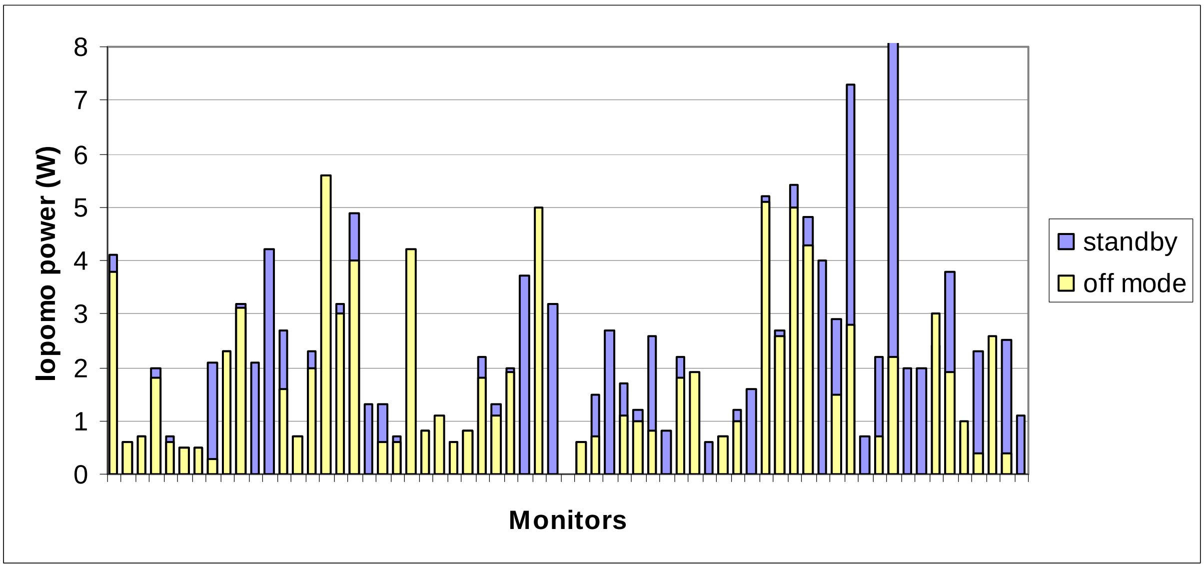
Figure 15 Distribution of lopomo power – computers



Note: The red line represents the level of 1W.

As to the monitors, the interesting characteristic was that the power they drew when switched off and when in standby mode was very similar. In many cases, the difference between these two modes was not more than 1W (Figure 16). The average lopomo of monitors was 2.5W with the median at 1.7W.

Figure 16 Standby and off mode — monitors



A similar pattern could be observed for speakers with an average standby power of 2.48W and average power when switched off just 0.5W lower – 2W. The highest average lopomo power was found for routers and modems (when not taking into account the printer-copier-scanner,

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as this appliances was found only once in the households), namely 5.9W and 6.8W respectively. There were modems found in about half of the metered households and routers in about one quarter. This is definitely a higher percentage than for all Hungarian households. Routers and modems represent quite a high share of the whole household lopomo consumption, when found together in one household, they made up to 80% of the lopomo consumption. Modems alone usually made up around 50% of the lopomo consumption on average in the sample.

4.2.5 Cooking and cooling appliances

There were 72 microwaves metered during the survey. As a general rule, only the microwaves with a clock drew some power in the lopomo. Microwaves without a clock always had 0W in their off mode. The average lopomo power of all microwaves was 0.7W. However, when looking only at microwaves with some standby power, the average was 2.3W (there were 21 of them from the total of 72 microwaves metered)[28].

Within the refrigerators, there were only a few appliances that drew power when not cooling. In such cases, however, the reason was not that the refrigerators would carry out some additional function (e.g. display with clock), but rather a technological problem, e.g. a resistance placed in the refrigeration compartment, which draws power even when the compressor is not working (Sidler 2002). In future however, this situation may change. Recently, the trend has been to have “intelligent” refrigerators and related to this one may expect growing lopomos within this category as well.

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4.2.6 Various

In the broad category of “various” appliances, which did not fit to any of the previous categories, there is without any doubt one appliance type which is worth mentioning - the halogen lamps. In the surveyed sample, there were just two lamps found to draw power when switched off. Nevertheless this case is interesting, because from the lopomo point of view, lamps in general are rather a neglected issue (Röing and Avasoo 2001). The power losses are

[28] In Table 4 and 5 both types of microwaves are included, therefore the lower average was used for calculations.

caused by the transformers that are plugged in and are used to power the lamp. The off mode power of the metered lamps was 1.7W and 2.4W, which is within the range Röing and Avasoo (2001) found in their study as well.

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5 National level estimates

There were three approaches used for the national level estimate of lopomo consumption. The first approach was based on the baseload, the second one was based on the metered appliances in the household and the third on individual appliance types combined with penetration rates. The results obtained by these three different methods to estimate the total Hungarian lopomo consumption are described below. The advantages and drawbacks of these methods are discussed.

The national level data, as well as the appliance penetration rates were taken from the Hungarian Central Statistical Office (CSO) and from International Energy Agency (IEA) statistics.

5.1 First estimate - baseload

The first estimate was based on the baseload, which was defined as "the typical lowest power consumption when there is no occupant demand" (Cogan *et al.* 2006). Cogan *et al.* (2006) refer to the baseload as to "the standby power load of the entire house" (Cogan *et al.* 2006).

The lopomo consumption of a household was measured by pulsemeters, which were connected to the mains. This was planned to be done in all 39 households participating in the long-term measurement. Unfortunately, due to technical problems during the installation of pulsemeters, only in 13 households did the pulsemeters work properly and produce data that could be used for further analysis. Nevertheless a national estimate using these data was made and the results are shown in Table 10.

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Table 10 First estimate of lopomo electricity consumption in Hungarian households

Average baseload - sample (W)	Daily lopomo consumptio n - sample (Wh)	Yearly lopomo consumpiton - sample (kWh)	Lopomo consumption national (GWh/year)	Electricity consumptio n in households (GWh/year)	% share of lopomo
78,15	1364,492	498,040	1993,143	11032	18,07

Source of national data: CSO (2005), IEA [2006?]

The average yearly lopomo consumption in the surveyed households was estimated to be 498kWh. When multiplied by the number of households in Hungary, the total lopomo consumption is estimated to be 1993GWh per year. Related to the residential electricity consumption, the share of lopomo on a national level is 18%.

Although the sample of households for this estimate was insufficient, some conclusions can be drawn from it. The percentage share of lopomo consumption seems to be rather high, compared to the results from other studies[29]. One reason is the average daily and yearly lopomo consumption within the sample is (coincidentally) almost twice as high compared to the average from all 95 households. Therefore the sample is not representative even within the surveyed households.

The second reason is that such estimates tend to be higher as there may be some appliances included which are not in their low power mode (Meier 2005). In the case of this survey, the average difference between the baseload and metered lopomo consumption was 39W per household, with median 29W[30]. This difference may still be explained by the appliances that might have been overlooked or could not be metered despite being in their lopomo. However, in some cases the difference was more than 60 or even 100W. In such cases, there must have been an appliance that was "on" and not metered by the wattmeters. Therefore, this approach to determine the total residential lopomo consumption is likely to be quite overestimated.

5.2 Second estimate – metered appliances in the household

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The second estimate was based on the overall metered lopomo consumption in the households. The average lopomo of the 95 households was multiplied by the total number of households in Hungary. Using this method, the yearly lopomo consumption in Hungarian households was estimated to be 945 GWh, which represents 8.5% of the total residential electricity consumption (Table 11).

[29] Summarized in Chapter 2, Table 1

[30] See Chapter 4, Table 5.

Table 11 Second estimate of lopomo electricity consumption in Hungarian households

Average metered lopomo (Wh)	Number of households in Hungary (2005)	Lopomo per day in Hungarian households (MWh)	Lopomo per year (GWh)	Electricity consumption in households 2004 (GWh)	% share of lopomo
647	4 001 976	2589.278	945.087	11032	8.57

Source of national data: CSO (2005), IEA [2006?]

It is difficult to assess this method as to its accuracy. There are two conflicting tendencies that may influence the result in two opposite ways. One is the possibility of overlooking or the impossibility of metering some of the appliances[31]. This would then lead to underestimation of the overall lopomo consumption. The second is based on the surveyed sample. One may expect higher rate of equipment in the households in the case of some appliances, such as office equipment, than the national average. This would cause overall overestimation of the lopomo consumption and share.

5.3 Third estimate – penetration rates

The third estimate is based on the penetration rates of the appliances in Hungarian households. Using the penetration rate and the average lopomo consumption of the appliances, the national consumption was calculated (Table 12).

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[31] Usually because they were in-built.

Table 12 Third estimate of lopomo electricity consumption in Hungarian households – penetration rates

	Penetration rate*	Average lopomo consumption (Wh/day)	Lopomo consumption - national (MWh/day)
Air conditioning	3	64.32	7.722
Casette player	71.2	13.92	39.664
CD player	25	38.42	38.439
DVD player	23	29.95	27.569
Hi-fi	34	76.83	104.543
Microwave	66.6	15.98	42.592
Mobile charger	131	8.88	46.554
Modem	15	163.20	97.968
Monitor	36	47.18	67.968
PC	36	67.26	96.902
Radio	104.6	22.27	93.232
Refrigerator	78.7	7.10	22.368
Router	5	141.36	28.286
Set top box	50	202.96	406.117
Speakers	18	51.41	37.032
TV	135	123.70	668.332
VCR	56	133.14	298.381
Washing machine	75	3.47	10.400

* Number of appliances per 100 households
Source of national data: CSO (2006b), CSO (2005), EC (2007), Elek (2004), CSO (2004)

The consumptions of all the appliances were then added up and the national estimate was calculated. The residential lopomo consumption determined by this method is 779 GWh per year, meaning 7.1% of the national residential electricity consumption (Table 13).

Table 13 Third estimate of lopomo electricity consumption in Hungarian households

Lopomo consumption of appliances (MWh/day)	Lopomo consumption of appliances (GWh/year)	Electricity consumption in households (GWh/year)	% share of lopomo
2134.070	778.936	11032	7.06

Source of national data: IEA (2006?)

The main disadvantage of this estimate is that not all penetration rates are known in Hungary. In other words, penetration rates only for the main appliances were available. Although several assumptions were made in order to include as many appliances as possible, some appliances had to be excluded from the calculation of the estimate. More precisely, 78% of the lopomo consumption of the sample was included in the estimate.

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As to the assumptions, there are some appliances in the table whose penetration rates are missing in the main source - the Statistical Yearbook of Hungary (CSO 2006b) - but where the penetration rate could still be taken from another source or was estimated. This was the case with set-top boxes, mobile chargers, routers, modems and speakers. The presentation of Elek (2004) was used for the penetration rate of set top boxes. As to mobile chargers, the only available information was about the ownership of mobile phones in households. Therefore, it was assumed that one mobile phone means one mobile charger. As to modems, there was data available on the broadband internet access in households (EC 2007). Therefore it was assumed that these households also have modems. Half of the households having a computer were assumed to have speakers and half of the households having a modem were assumed to have a router (the assumptions were based on the equipment of the surveyed households).

Yet, even when making all these assumptions, there were still a number of appliances missing in the estimate. Some of them had very low or zero average lopomo power (such as coffee machines or mixers), some are found rather rarely in the average household (bread maker, scanner, electric toothbrush), therefore do not distort the estimate significantly. On the other hand, appliances from the category Telephony are missing in the estimate, which make up for 6% of all the appliances' lopomo consumption in the sample (Figure 8 in Chapter 4).

Due to these above mentioned gaps in penetration rates, the extrapolation is expected to be rather underestimated, compared to the real value.

5.4 Comparison of the three methods

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Of the three methods used to estimate the lopomo consumption in Hungarian residential sector, the first one using the baseloads is clearly overestimated. One reason is the 13 households used for the assumption seemed to be "above average" even within the sample, second reason is the probable inclusion of non-lopomo consumption. However, from the methodological point of view, it is viewed as the most precise method in terms of whole household lopomo consumption (Cogan *et al.* 2006).

The second and the third estimates focus on particular appliances in the households. In contrast to the first estimate, these two give quite similar results, around 8%. The result from the second method may be slightly overestimated due to the higher share of office appliances in the surveyed sample, but also there may be some appliances overlooked or non-measurable. The third estimate would be the most precise if only all the penetration rates had been known. In our case, the lack of penetration rates may lead to underestimation of the number. A rough guide to what the magnitude of the underestimation may be the fact that 80% of the appliances' lopomo consumption in the sample is covered by the known penetration rates.

To sum up, the national estimate of the residential lopomo consumption may be expected to be between 8 – 10% of the residential electricity consumption. The accuracy of the estimate is influenced by the sampling method, as well as the above described methodological problems. Nevertheless, it still clearly shows the trend in and overall importance of lopomo electricity consumption.

5.5 Comparison with other studies

In the studies conducted in other countries[32] the estimates of standby (lopomo) consumption varied from as low as 3% to as high as 14% of the total residential electricity consumption. The results of the present study (8-10%) fall approximately in the middle.

The estimates are influenced by the method by which the data were collected. The lowest estimate comes from Swiss study (Meyer and Schaltegger 1999). In this study the bottom up approach using the penetration rates of appliances was used. Due to lack of data on penetration rates of smaller appliances (cordless phones, coffee machines) their calculation is likely to be an underestimate (Meier 2005). On the other side of the scale, the highest share can be found in the survey conducted in four European countries[33] by Silder (2002) – 14% as an average of these four countries. This survey was carried out by whole-house measurement and the percentage share was determined from the baseload electricity consumption. For Hungarian households, the standby consumption was estimated to be less than 4% of the residential electricity consumption (Strukanska 2001).

As mentioned earlier, the differences in the survey methods make it difficult to compare results from studies from different countries or even within a country. Despite the insufficiency of data

[32] Only the studies reviewed in the literature review are used for this comparison.

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and inconsistency in research methods, the lopomo consumption in Hungarian households represents the same order of magnitude as in other countries. Moreover, it seems the lopomo consumption in the Hungarian residential sector is growing and will continue to grow. In other words, the trend of a growing number of appliances in the households tends to prevail over the energy efficiency improvements of the appliances. As seen in the other European countries (mostly from Western Europe), there is a trend of growing penetration of set-top boxes, office equipment and other appliances with some kind of low power mode (Sidler 2002), which is likely to increase the lopomo consumption even more in future.

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[33] Denmark, Greece, Italy, Portugal

6 Potentials

6.1 1 Watt Policy

The 1 Watt policy has received a lot of attention since its first presentation[34] and has been incorporated into many energy efficiency policies all around the world[35]. The idea behind the concept is that the lopomo power of any appliance should not exceed 1W.

For the estimate of saving potential for Hungarian households, the year 2020 was taken as the reference year. The reason for this is that it takes time to exchange the appliance stock. Therefore the reference year has been chosen in the future and not in the present.

As to the concrete numbers, many appliances in the survey already had an average lopomo below 1 Watt (e.g. washing machines or microwaves). In such cases, the current consumption was included in the estimate instead of the proposed 1 Watt, because that would mean worsening of the situation.

As to the potential itself, by having all appliance lopomo power under 1 Watt the lopomo consumption could decrease by almost three quarters (72.5%). This would mean a reduction of 649 GWh per year for the whole country (Table 14). Relating this number to CO_2 emissions, it would mean 322 kt of CO_2 per year less, or 0.56% of current CO_2 emissions from energy. In terms of individual households, the almost three-quarter reduction would represent potential savings of 171 kWh per year, or translated to monetary terms 6327 HUF per year[36].

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Table 14 1 Watt policy

Expected number of households (2020)	Potential savings (GWh/day)	Potential savings (GWh/year)	CO2 emissions reduction (per year)	% of present CO2 emissions
4078023	1,779	649.204	321.8kt	0.56

* Source: data extrapolated from CSO (2005), CO_2 conversion factor calculated from HMEW (2005) and Zürn and Fall (2005)

[34] It was ten years ago that Meier (1998) first came with this idea.
[35] An up-to-date summary of such policies can be found in Meier (2005)
[36] At current price of electricity 37Ft/kWh.

The major limitation for this estimate is the assumption of frozen efficiency. It was assumed the efficiency of the appliances will not change over the years. However, this is not true in reality and the actual magnitude of the technological improvement can be clearly seen when comparing the present results with the results of Strukanska (2001). Strukanska made the 1 Watt estimate for the year of collecting the data – 2001. She estimated the potential reduction for Hungarian households would be more than 90% of the total standby consumption. When the same method was applied to the current results, the possible reduction would be only 66%. Even with regard to the limited samples of appliances in both surveys, the difference within 6 years is quite significant. Therefore, one may assume that if the technological improvement had been incorporated into the model, the final potential reduction would have been lower.

Another limitation of this estimate was, similarly to the national estimates, the unavailability of penetration rates of several appliances. In this sense, the potential reduction might be even higher, if penetration rates of all appliances were considered.

Similar impact could be assumed as well due to expected growth in the number of appliances having standby (Harrington *et al.* 2006). There are many appliances which now do not have any low power modes and if they draw power when switched off, it is mainly a technological problem. A typical example is for instance refrigerators (Gudbjerg and Gram-Hanssen 2006). However, in future these appliances are expected to be more and more equipped with additional functions (IEA 2001), e.g. computers in refrigerators. If this was the prevailing trend, the overall lopomo consumption in households would be increasing and the 1 Watt policy may become even more important.

6.2 Behavioural potential

Some researchers (Vowles *et al.* 2001, Gudbjerg and Gram-Hanssen 2006) believe that behaviour of the households can play an important role in reducing the electricity or lopomo consumption. It is however difficult to say to what extent such reduction may be expected. Moreover, some researchers (e.g. Siderius *et al.* 2006) argue that trying to change user's behaviour concerning the lopomo consumption is "less effective than technical solutions" (Siderius *et al.* 2006).

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Nevertheless, in this subsection a very rough estimate is made as to how much electricity consumption could be saved if the maximum behavioural change in the households was assumed. In other words, how much could be saved if all the appliances, which it makes sense to switch off, were included.

By switching off the TV/Video, office, cooking and hi-fi appliances in the surveyed households, a total of 100W lopomo out of 135W would disappear, meaning 74%. As to the lopomo consumption within the surveyed households, the maximum potential for savings would be 817kWh per year in total, which is almost three quarters (73 %) of the current lopomo consumption in the 95 households (Table 15). On average, each household would therefore save 173kWh per year (6401 HUF).

Table 15 Maximum behavioral potential

Potential savings in survey sample (kWh/year)	% reduction of the lopomo consumption	Potential savings on national level (GWh/year)	CO2 emissions reduction (per year)	% of present CO2 emissions
817.6	73%	642.4	318.5kt	0.55

When extrapolated to the national level[37], the saving potential would then be 642GWh per year, which means 6.3% of the total residential electricity consumption in Hungary or in terms of CO_2 318.5 kt per year. In 2003, the CO_2 emissions from energy were 57 592 kt in total (HMEW 2005). Therefore, this means that thanks to maximum behavioural change potentially more than 0.5% of the CO_2 emissions could be saved.

6.3 Standby killers

One may assume it is quite difficult to change people's behaviour. Some researchers are very sceptical about it (e.g. Siderius *et al.* 2006). Where ever the truth lies, there is little doubt it may be rather painful to switch off or even unplug separately each and every appliance in order to avoid the lopomo consumption. A partial solution is the so called standby killer. It is basically an extension with a special function. There is one main socket and if the appliance

[37] For this potential, the average of the second and third estimate was used, i.e. 880GWh per year.

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plugged into this socket is switched off, the standby killer cuts the electricity supply to all the other appliances plugged into it as well.

As a result, the most appropriate and useful way of using the standby killers is when there is one main appliance and several dependent appliances (or peripherals). In households, this is usually the case for the television site (TV is the main appliance and VCR, DVD and other are the peripherals) and computer area (computer and printer, scanner, modem, speakers and other). That is why two standby killers per household were chosen, one for the TV site and one for office equipment.

There are no statistics available to the author about the penetration of these devices in Hungarian households. Despite the lack of statistics one may assume that on a national level the usage of the standby killers will be still almost negligible.

However, in the households participating in the survey, the usage of the extensions with a switch, which can be considered as a less sophisticated standby killer, was examined. Households were asked if they have been using these extensions. 64 households actually filled out this question and 39 of these 64 households (61%) responded in the questionnaire they have already been using one or more of them.

As a supplementary question, the households that have not been using the extensions with a switch yet were asked under what conditions they would start using these devices. Of the 13 households that answered this question, 4 respondents said they would not use them, because they thought it was inconvenient. On the other hand, 9 household respondents stated they would start using them "if it was economical" or if "the appliances switched on and off automatically".

The concern about the inconvenience of using extensions with a switch is solved in the case of standby killer, because the user does not lose any of the comfort[38]. The appliances also do switch on and off automatically when connected to the standby killer. Here below the answer to the concern about the economic feasibility of standby killers is examined. The cost of conserved energy (CCE) was used to assess it, as this formula helps to compare the saving measure with the electricity (or in general energy) prices (Lung *et al.* 2005).

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[38] Television can still be switched on and off by the remote controller and the computer is just switched off and on as usual.

The rationale behind the formula is that the cost of the saving measure (here the standby killer) is annualised[39] and then divided by the electricity that is potentially saved by the measure.

The cost of currently available standby killers is 10 (for office equipment) to 12 Euros (for a TV site), i.e. 2500 – 3000 HUF[40] (Table 16). The average life time of the device is 5 years (SavePower n.d.). The annualised cost of the standby killer (taking into account the consumer rate) is then 1038 HUF for the TV/Video category and 865 HUF for the office equipment category.

Table 16 Standby killer - economic evaluation

	Cost of standby killer (HUF)	Consumer rate	Lifetime of the standby killer	Electricity savings (kWh/year)	CCE (Ft/kWh)
TV site	3000	0.2157	5	82.54	12.58
Office site	2500	0.2157	5	66.91	12.93

Source: SavePower (n.d.), MNB [2007]

The cost of conserved energy is therefore 25.51 HUF/kWh in total, being 12.58 HUF/kWh for the TV site and 12.93 HUF/kWh for the office equipment.

The current electricity price for Hungarian households[41] is 37 HUF/kWh (inc. VAT). Therefore, the resultant CCE, which is 25 HUF/kWh, shows that on average Hungarian household having two standby killers, one for the TV site and one for the office equipment, is advantageous in economic terms. In other words, the cost of conserved energy means how much it costs per 1 kWh to introduce the electricity saving measure. In the case of the survey sample, the cost of the measure is 25 forints per 1 saved kWh of electricity. If one was to buy this kWh, it would cost 50% more – 37 forints. Moreover, 72% of the lopomo electricity consumption would be saved[42].

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[39] See the formula on pp 29.
[40] The exchange rate from 7 July 2007, published by the Hungarian National Bank (www.mnb.hu), was used – 250HUF/EUR.
[41] Taken from ELMŰ [2007]
[42] There is no data available to the author about how much lopomo power the standby killers themselves draw. One can expect it will not be a high number; however it may slightly distort the results.

7 Conclusions

Although the standby or lopomo electricity consumption of electrical and electronic appliances has received a lot of attention among researchers as well as policy makers since the 1990s, this applies mostly only to the countries of the Western world. In the Central and Eastern European region, this issue has been rather underdeveloped. Therefore, the aim of the present thesis was to increase knowledge on the magnitude and structure of low power mode electricity consumption in the residential sector of Hungary. Spot measurements, combined with long-term metering of the lopomo consumption were carried out in 95 households from Budapest and surrounding villages.

Within the 95 households participating in the survey the average lopomo power was found to be 30W, the average lopomo electricity consumption reaching 236kWh per year, which is 8% of the households' average electricity consumption. This falls roughly within the range suggested by previous studies undertaken in Hungary. It is less compared to the results of Strukanska (2001) – the average lopomo power in her sample was 37W. On the other hand, it is also more than in the estimate of IEA (2001), which was 20W per household. When looking at the studies in more developed countries, the lopomo power in Hungarian households is about half that of households in developed countries.

There were 10 appliances per household on average, compared to only 4 in 2001 (Strukanska 2001). Growing number of appliances with low power modes is supported by the trend from the other surveyed countries[43]. The highest share in the total lopomo consumption of the households belongs to audio-visual equipment and office appliances (together more than 80%). Within particular appliance types, the devices with the highest lopomo electricity consumption were found to be the set top boxes, modems and routers. These devices have not been very prevalent in the Hungarian households yet, but the trend from other countries shows their penetration is likely to be growing in near future and therefore definitely deserve attention.

The category of cooking and cooling appliances together formed just 4% of the average lopomo consumption in the households. Nevertheless, more appliances within these categories are expected to have some kind of low power mode in future and therefore, their importance as to lopomo consumption will probably grow.

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Overall, there is an indication that the number of appliances with low power modes is likely to grow in future. This implies the lopomo consumption is likely to grow as well, unless the technology improvements reverse this development (Bertoldi *et al.* 2002).

Three policy options to mitigate the lopomo consumption were evaluated in terms of the potential savings. It was estimated that the lopomo electricity consumption represented 8-10% of the total Hungarian residential electricity consumption. If all appliances reduced their lopomo power to under 1 Watt, the lopomo electricity consumption could be reduced down to less than 3% of the electricity consumption. Very similar results (73% reduction meaning a decrease to 2.2%) are obtained when looking at the maximum behavioural potential, e.g. if the appliances were switched off or unplugged.

As a third policy option, the economic feasibility of purchasing standby killers in the households was examined. Based on the cost of conserved energy it was found out that in an average Hungarian household, the standby killer is profitable given the current prices of electricity (25 HUF/kWh compared to 37HUF/kWh). Moreover, similarly to the first and second option, on average 72% of the lopomo consumption would be saved.

There were several problems that occurred when designing and conducting the survey, which influenced the results of the study. Mainly, the limited resources did not allow for random sampling, which would have been most appropriate. Also the complexity of the issue, the growing number of low power modes in the appliances as well as the still unsolved problem of a unified method of measuring the lopomo consumption, added to the limitations one encounters when conducting this research.

Nevertheless, despite the difficulties in the course of the survey, it has been shown that low power mode electricity consumption in the residential sector is an important, not negligible issue, since it represents a significant portion of overall electricity consumption. It has also been shown that there is high potential for savings through energy efficiency measures. If implemented, they could reduce the lopomo consumption significantly and would moreover (in the case of standby killers) be cost effective.

Nonetheless, more data are still needed to refine our knowledge about the phenomenon of low power mode electricity consumption in Hungary – in residential sector, but there is also a lack in data from office or industrial buildings (Meier 2005). Only through regularly conducted

[43] Meier (2005), Harrington *et al.* (2006), Bertoldi *et al.* (2002)

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research using unified methods will it be possible to evaluate the exact magnitude, structure and, importantly, the trends in lopomo consumption. Consequently, having this information it will be possible to develop well targeted energy efficiency policy measures. The energy related issues are of increasing political interest nowadays and energy efficiency definitely belongs to high priority solutions. Influencing the low power mode electricity consumption represents a low hanging fruit and deserves policy makers' attention when designing the energy efficiency policies.

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