Residential monitoring to decrease energy use and carbon emissions in Europe

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Abstract
This paper presents the structure and methodology from the European EIE project REMODECE, whose overall objective is to contribute to an increased understanding of the energy consumption in the EU-27 households for the different types of equipment, including the consumers' behaviour and comfort levels, and to identify demand trends. In the project a large monitoring campaign is being carried out in 12 countries, accompanied by a consumer survey. Some preliminary results of monitoring campaigns are presented.

The European-wide residential energy monitoring being carried out is focused on electronic loads (entertainment, information and communication technologies, plus standby consumption) and lighting, as well as air conditioning in Southern European countries. In four Eastern European countries, because of lack of reliable data, white appliances are also being monitored.

From the measurements already carried out it can be concluded that electronic loads are a key contributor to the power demand and that there is wide range of performance levels in the models available in the market. Available technology, associated with responsible consumer behaviour, can dramatically reduce wasteful consumption of electronic loads. The project is also assessing the patterns of residential lighting use, in which an increasing penetration of CFLs is being partly compensated by an increasing penetration of halogen lighting. Residential air conditioning is growing fast and is already a major contributor to summer peak demand in Mediterranean countries, as the load curves from very hot days have shown in the past summer. The air conditioning market has been flooded with very low cost and very inefficient units, therefore needing urgent attention.

Overview of the project

The overall objective of the REMODECE project is to contribute to an increased understanding of the energy consumption in the EU-27 households for the different types of equipment, including the consumers' behaviour and comfort levels, and to identify demand trends. This project will evaluate the potential electricity savings that exist in the residential sector in Europe, and that can already be implemented by existing means, like the use of high efficient appliances or the elimination/mitigation of standby consumption. The availability of high quality data is an essential condition for the definition of policy recommendations to influence through a combination of measures the energy efficiency of the equipment to be sold in the EU-27 in the next decade, as well as to influence the user behaviour in the selection and operation of that equipment.

In this scope, the main objectives of this survey are:

- To contribute to an increased understanding of the energy consumption in the EU-27 households for the different types of equipment, including the consumers' behaviour and comfort levels;
- To identify demand trends;
- To evaluate the potential electricity savings that can already be implemented by existing means, like the use of very ef-

ficient appliances or the elimination/mitigation of standby consumption;

- To analyse the market transformation for different types of equipment;
- To recommend policies for each type of equipment.

In Western Europe the focus of investigation is on new electronic loads, whereas in Central and Eastern Europe the monitoring effort deals with both conventional and electronic loads. The idea is to take advantage of existing monitoring and surveys, by structuring the available data into a data base of the residential electricity measurements and consumptions (per country and appliances), which are being updated with the project results. The monitoring approach is the following:

- In most Western European countries the consumption of the main domestic appliances, namely the load curve, and the peak power, is roughly known. Conventional "main domestic appliances" include cold appliances, washing machines, dryers, fans and lighting.
- In Central and Eastern European countries there are no significant measurements on residential electricity consumption. Therefore it is essential for the policy makers to have relevant data on electrical consumption for domestic appliances in these new EU countries.
- In all countries, four types of consumption seem to be rising particularly fast, in particular: domestic computer and peripherals, new domestic entertainment, standby power, and some lighting technologies such as halogen lamps. The increasing number of CFLs is also being investigated. Residential air conditioner loads are also increasing significantly in Southern Europe and their use is also being assessed during the project.

Introduction

Although significant improvements in energy efficiency have been achieved in home appliances and lighting, the electricity consumption in the average EU-25 household has been increasing by about 2 % per year during the past 10 years. Some of the reasons for such increase in the residential sector electricity consumption are associated with a higher degree of basic comfort and level of amenities (particularly in the new EU member countries) and also with the widespread utilization of relatively new types of loads whose penetration and use has experienced a very significant growth in recent years.

The International Energy Agency (IEA) estimated that, even with a continuation of all existing appliance policy measures, the appliance electricity consumption will grow by 13 % from 2000 to 2010, and by 25 % by 2020 [IEA, 2003].

As it can be seen in the Figure 1, the fastest growing electricity demand is projected to be standby power consumption or the consumption of electricity by appliances that are turned "off" or, that are in a low power consumption mode. According to IEA, 15 % of the total appliance electricity consumption in Europe, by 2030, could be due to standby functionality. This also represents the largest potential saving as it is currently unregulated and efforts to introduce measures to reduce this wasteful consumption are only just beginning (last decade).

The introduction of energy labels, implemented with EU Directives for the last ten years, has produced a positive trend in the sales of more energy efficient appliances. Consumers have responded positively to this mandatory information scheme enabling comparison of respective energy-efficiency of various models in the same appliances family through the ranking of the appliance into the proper energy class (A to G). The introduction of even better energy classes (A+ and A++) and the broadening range of appliances labelled are thought to produce even greater electricity savings.

Space heating, also represents a great potential for electricity savings mainly by the installation of high efficiency heat pumps whose relatively small penetration is increasing fast.

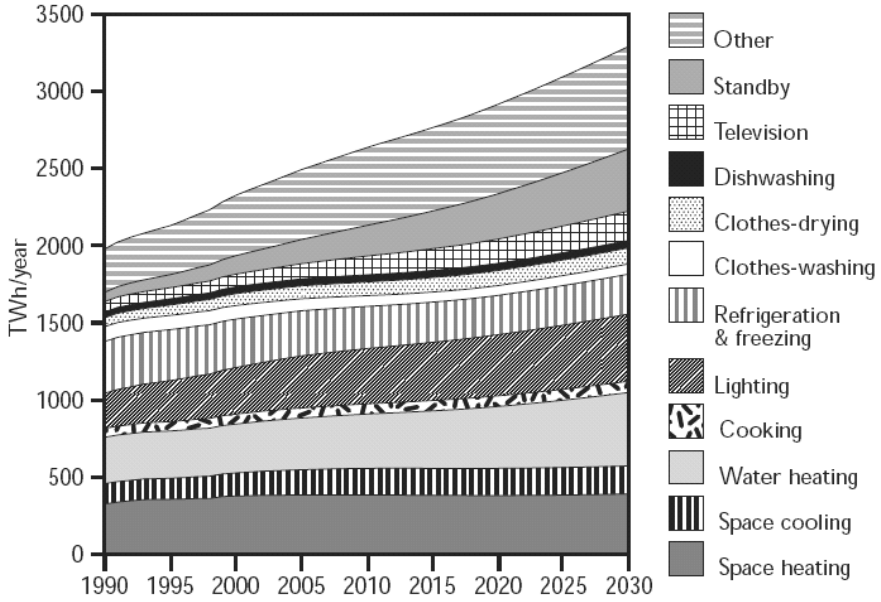


Figure 1. Projected IEA residential electricity consumption by end-use with current policies [IEA, 2003]

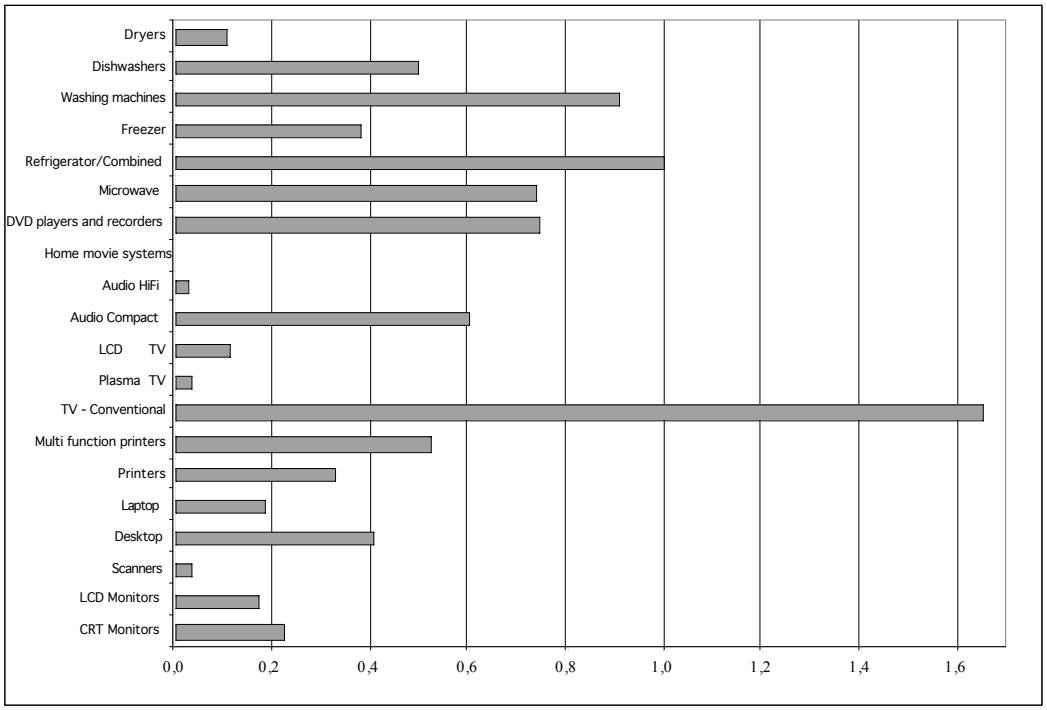


Figure 2. Estimated average ownership rate by the main end-use by 2005, [ISR-UC, 2006]

Based on the annual sales, on the number of households per country and on the lifetime of the equipment, the stock of appliances and the ownerships of the main domestic appliances and electronic loads in 2005 have been estimated, as shown in *Figure 2,* for the countries of the study. It is important to note that these are conservative figures, and in some cases the penetration rates are most likely much higher.

Data Collection Methodology

Within the project it was established a harmonised monitoring and survey methodology to combine the use of selective monitoring with a wider scale questionnaire based survey. This harmonised methodology will allow cross comparison of the energy efficiency and performance of similar equipment and households in the different countries involved.

The decision about what data to collect is very important for a cost-effective and reliable characterisation. Based on the already existing databases, enough data is being collected to update the existing information and gather new data. To estimate the disaggregation of electricity consumption by each major end use, the following methodology was selected:

- Analysis of already existing studies, surveys, metering campaigns, databases, statistics, manufacturer's information, market information, etc., on energy consumption in the residential sector, focusing end-use equipment, operating modes;
- Conducting households questionnaires (500 per country of the study). The questionnaires will be accompanied by expert interviews in most cases, and user behaviour will be addresses within this survey.
- Conducting detailed audits in 100 households per country, focusing demand load profiles in real situations.
- Conducting own measurements for a series of appliances/ end-uses, especially to determine consumption in the standby and off modes of operation, because the available data is still relatively poor in this area.

The starting point of this project was to elaborate a detailed list of all the main end-uses to be analysed, in Eastern European Countries and in the old EU Countries, as well as the definition of the main modes of operation to consider for the monitoring of the different appliances.

The list is divided into 4 main groups according to their main function: domestic computers and peripherals, new domestic entertainment, other standby loads and other loads, including lighting and air conditioning.

A number of determinants need to be known for the analysis and cross comparison of energy efficiency and level of comfort to be relevant. The relevant determinants to achieve cross comparison are:

- Yearly electricity consumption invoiced by the utility
- Size and structure of the household in terms of number of people by age category
- Highest education level in the household (no degree or certificate, secondary high school, vocational or trade certificate, university degree)
- Type of dwelling: apartment or house
- Location: rural vs. urban

Other specific data will be needed for consumption analysis and cross comparisons of air conditioning, such as the outdoor temperature during the monitoring, the indoor temperatures of the conditioned room and of non-conditioned rooms.

Due to budget limitation and the high cost of the monitoring campaign the conditions in which the campaign takes place,

the timing, the measurement method, the sampling method and sample representativeness can be different for each country. This has obviously consequences on how the data can be used and trusted for analysis. Therefore a common ground has been established to ensure a minimum consistency within the collected data.

Measurements are being carried out on at least 100 households per country. The measurement campaign is completed by a questionnaire based survey, which should target a minimum of 500 households per country. Monitoring period for the campaign is one month whenever possible, which will be extrapolated to determine the yearly consumption.

In relation to the number of end-uses to be monitored it is planned to dedicate on average 10 meters to major appliances or end-uses per household (cold, washing, consumer electronics…). In the case of lighting, at least the 10 main light sources are being monitored per household.

The measurement time step will depend on the equipment used, but is of the same order of magnitude for all partners. A time step of 10 minutes is commonly used for this type of monitoring to facilitate data analysis.

The total standby consumption cannot be directly measured, since even at night some appliances are necessarily on while fulfilling their primary function, such as cold appliances. In households where heating is not electric, the average total standby load is estimated by subtracting the average consumption of cold appliances, the lighting consumption and if relevant that of monitored loads likely to run at night (e.g. washing appliances when night fare is used) at the same period of night. The resulting value may be regarded as "active" standby consumption, which also takes into account all appliances left on at night but not actually used. The average standby consumption for a particular end use is estimated by taking the lowest consumption at night. The night period is taken, by default, as 3 am to 4 am. When meters are being installed, spot measurements are made on appliances, for off mode, standby and active standby mode

Air conditioning is being monitored over a longer period (summer period: 4 months). Therefore there is no need to carry out extrapolations and the exact conditions of use will be known. In countries where this end use is being investigated, 20 households are being monitored. In these households the temperature is monitored simultaneously with the electricity consumption in the conditioned room, outdoors and if possible in non conditioned rooms. The surface of the conditioned area is also recorded.

DEFINITION OF STANDBY CONSUMPTION WITHIN THIS PROJECT

There is not a uniform definition for the operating modes for electronic appliances, and several approaches have been developed worldwide (ACPI, Energy Star, GEEA, Ecolabel, etc.). However, taking this situation into consideration the Standby consumption in this survey will be based on the standard IEC62301.

The final draft of the international standard IEC 62301 "House electrical appliances – Measurement of standby power", published in June 2005, and its European on going transcription EN 62301, specifies methods of measurement of electrical power consumption in standby mode. It is applicable to mains powered electrical household appliances and to mains powered parts of appliances that use other fuels such as gas or oil. The objective of this standard is to provide a testing method to determine the power consumption of a range of appliances and equipment in standby mode, generally when the product is not performing its main function.

According to this international standard, the definitions for standby mode and standby power are as follows:

- The **standby mode** is the lowest power consumption mode which cannot be switched off (influenced) by the user and that may persist for an indefinite time when an appliance is connected to the main electricity supply and used in accordance with the manufacturer's instructions.
- The **standby power** is the average power in standby mode.

The standby mode is usually a non operational mode when compared to the intended use of the appliance's primary function. The measurement of energy consumption and performance of appliances during other operating modes or intended use are generally specified in the relevant product standards and are not intended to be covered by this standard.

Based on the experience from some partners in the project, it was found to be useful to measure two major standby modes for some appliances, like for example, TVs, DVDs, Power Supplies/Chargers , some domestic equipment, etc. Theses modes are: the Off-Mode and the Standby Active Mode. The first, the Off-Mode is when the device is totally switched off (i.e. the power button is off, but the mains plug is connected). The later, the Standby Active Mode, is the mode when the device is able to respond to outside commands, such as when it is possible to use the remote control to switch on the equipment (i.e. typically is when the LED or display is still on).

In addition to power monitoring, the project will also investigate the number of hours per day the appliances in each of the modes. This information is required, because it will give an insight about the people behaviour with equipment. In particular, regarding standby consumption, the two above mentioned modes can be assessed as behavioural standby vs. technological standby.

Electronic Appliances and Standby Loads

Based on *Figure 1* and taking into account the measurements carried out so far it can be concluded that electronic loads are a key contributor to the power demand and that there is wide range of performance levels in the models available in the market. Available technology, associated with responsible consumer behaviour, can dramatically reduce wasteful consumption of electronic loads. The present total EU consumption for home consumer electronics in standby is estimated to be about 36 TWh and is forecast to grow to 62 TWh by the year 2010.

Recent market surveys [CETELEM], [Schlomann, 05], have shown that the household electronic loads market has increased significantly in the EU countries in recent years, and the following tendencies emerge with regard to the development of the stock of ICT and electronic appliances in households up to 2015:

- Audio devices represent an almost saturated market so that only a slight increase in the stock of such appliances is expected.
- More than 75 % of the households own more than one TV. About 25 % of families have 3 conventional TVs in Home. The number of televisions will keep rising to 2015; this increase is due to the growth in second or third TV sets. CRT TVs are gradually replaced by LCDs, plasma TVs as well as front and rear-projection televisions.
- There will be a strong growth in the future in the number of setop-boxes (STB) which are increasingly necessary for digital television reception. In particular, the switch of television technology from analogue to digital services leads to a stock increase in setop-boxes since a STB is required for each television set, i.e. for second and third TVs as well. Taking into account the setop-boxes already needed today for pay TV reception, the total number of STBs (including SAT boxes) will increase several fold until 2015.
- Appliances for recording audio-visual data (video VCR recorders, DVD recorders) have become prevalent in households in the past few years. It can be expected that the stock of DVD players will increase tenfold in the next ten years and that a rapid displacement of conventional video VCR recorders will take place.
- The stock of video cameras or camcorders will increase by about two times, by 2015, and massive stock growth can be expected for digital photo cameras. However, a modest increase is anticipated for game consoles because market saturation is already becoming apparent in many EU countries.
- Households are already almost fully equipped with fixed network telephones. However, within the stock, a clear structural shift has begun away from simple telephones to so-called "smart phones", which are relevant for electricity consumption and feature many additional functions, as well as to cordless phones, consisting of a base station with message recording, and one or more handsets. This trend will continue in the future, especially for the households with higher incomes.
- The number of mobile phones in most EU countries has grown enormously over the last five years, reaching almost saturation levels. A slight increase in mobile phone users is expected for the near future. In spite of the currently uncertain development of the UMTS system, this technology will gradually spread in the years up to 2010 and that the simple GSM devices will be replaced by UMTS.
- The number of computers in households has been increasing significantly. A 40 % increase is expected up to 2015 with the strongest growth in the number of laptops. The often observed trend towards mobile IT and telecommunications support can also be seen in the growing number of PDAs (Personal Digital Assistants). The total number of computer monitors is growing in parallel to the number of desktop PCs. Up to 2015, the cathode ray tube screens still common today will be completely replaced by the TFT (LCD) screens. The number of ICT peripherals that can be connected to the computers has been increasing and becoming more complex. The majority of peripherals are the standard equipment like printers and loud speakers, but the digital era has been changing the household habits, and besides PDAs it is common to find digital cameras, pen drives, mp3, etc., in many households, as the second largest group of peripherals to be connected to the computer.
- Households with PCs now also feature printers as standard equipment so that the situation here is likely to evolve in the same way as for PCs. The sales of combined printer/scanner/copier devices (possibly with additional fax function) have also risen strongly recently. It is expected that the share of multifunctional devices will become largely dominant in 2015.

The future power demand is being influenced by the technical improvements introduced in the equipments by manufacturers, mainly caused by voluntary agreements and programmes (such as EACEM TV agreement and the VCR agreement, Code of conduct for Digital TV Services, Code of Conduct on Energy Consumption of Broadband Communication Equipment, Code of Conduct on Efficiency of External Power Supplies and IEA Stand by Power Initiative). The power consumption is also caused by equipment market demand, and by the behavioural changes resulting from the increasing awareness of consumers and the increasing number of electronic "gadgets" available in the market. Electrical and electronic equipment with standby losses is a fast growing load (e.g. entertainment including setop boxes-STB, information and communication technologies -ICT).

As it was already mentioned, the fastest growing residential electric end-use is projected to be standby power consumption. This is the consumption of electricity by appliances that are turned "off" or, that are in a low power consumption mode, (standby, hibernate; sleep modes, off, etc.). According to IEA, by 2030, 15 % of total appliance electricity consumption in Europe could be for standby functionality, which is currently unregulated.

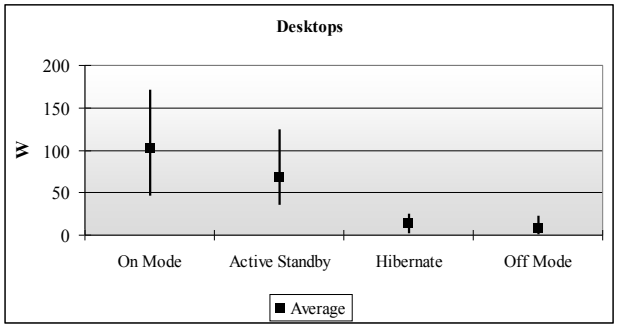
A recent market survey found that over 50 % of households had a personal or laptop computer in the home in the year 2005. The ownership of several computers and laptops is strongly related to the presence of young people in the homes. (*See Figures 3a and 3b overleaf.*)

The increasing number of personal computers and peripherals (e.g. printers, internet) in the homes will have implications in the residential electricity consumption, predominantly standby loads, because they are left on the standby mode during large periods of time.

The LCDs TVs and Plasma TVs market is booming as the prices have been decreasing significantly in the last few years. The electricity consumption of these appliances is related to the technology, the size of the screen and with the brightness.

Figure 4 (overleaf) shows the average power of domestic entertainment loads in the distinct operating modes and in more detail the average standby consumption.

There is a large number of small household electronic appliances with external power supplies (mobile phones, laptops, cordless phones, etc), most of which are always left on the socket. The average power input of these loads in the stand by mode



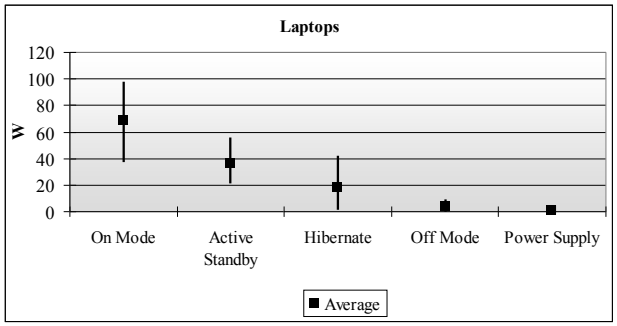


Figure 3a. Power consumption of desktop PCs, for each operating mode [ISR-UC, 2006]
Figure 3b. Power consumption of Laptops, for each operating mode, and for the power supply alone [ISR-UC, 2006]

Mode definition:
On mode: normal operation, the device is carrying out main function.
Active Standby Mode: Energy consumption is reduced; the device is able to awake very quickly.
Hibernate/Sleep Mode: Deep sleep mode, the device is suspend to disk; Energy consumption greatly reduced.
Off-mode: Device is not carrying out any function, seems to be off but is consuming energy.

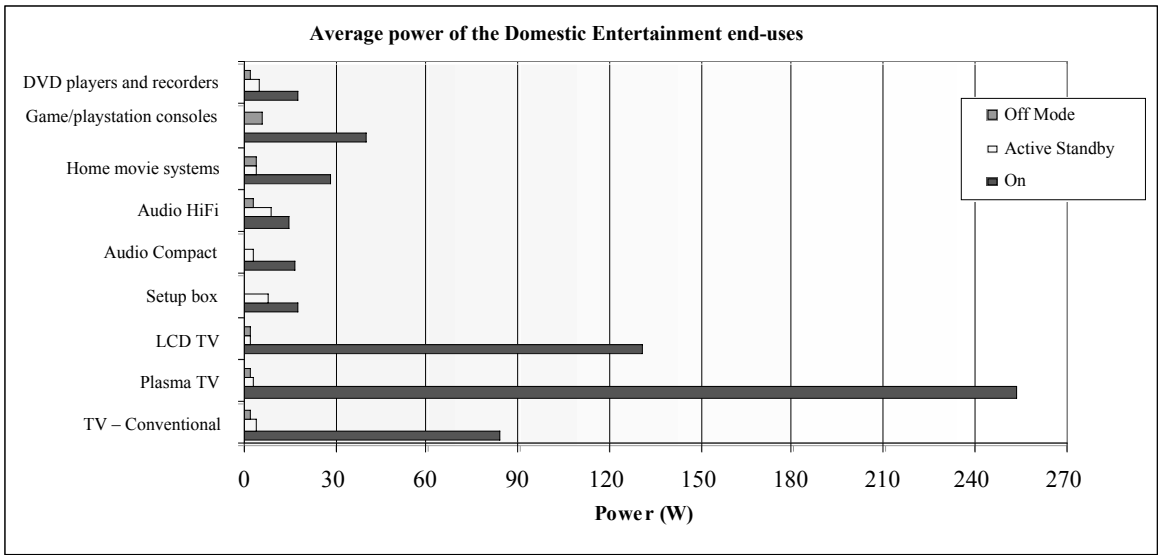


Figure 4. Average power of domestic entertainment loads in the distinct operating modes [ISR-UC, 2006]

Table 1. Average power and operating hours in the stand by, off and on mode [ISR-UC]

	On		Off		Standby	
	Average power W	operating hours per day h	Average power W	operating hours per day h	Average power W	operating hours per day h
Domestic computers and peripherals						
CRT Monitors	32,6	3,92	0,78	5,51	1,43	14,57
Desktop	119,6	5,98	0,28	8,4	36,9	9,62
Peripherals	3,32	6,38	1,29	7,2	0,42	10,42
Multi function printers	4,37	1,94	1,28	10,54	0,8	11,52
New electronic loads						
TV - Conventional	159,98	4,09	0,08	4,68	13,38	15,23
Setop box	4,5	4,5	-	-	4,51	19,5
Audio HiFi	17,92	1,35	1,25	4,14	4,53	18,51
Game/playstation consoles	2,7	1,43	0,01	10,14	0,21	12,43
DVD players and recorders	14,27	0,72	0,45	4,8	6,06	18,48
Other standby power						
Electronic alarm clocks	-	-	-	-	1,05	24
Chargers for cordless Phones and mobile phones	3,52	8,68	-	-	3,19	15,32
Microwave					0,92	23,91

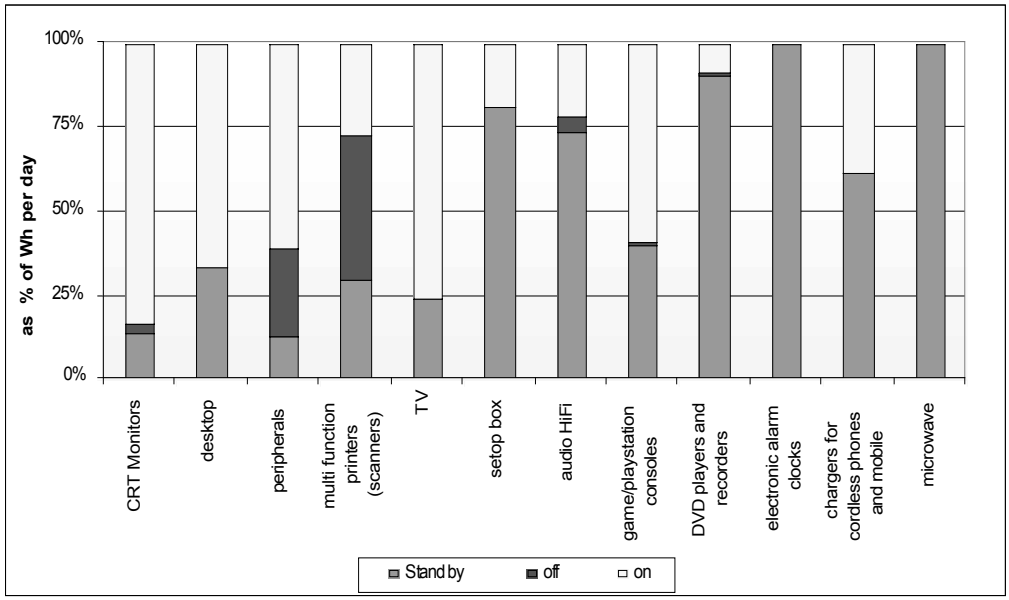


Figure 5. Stand by, off and on mode electricity consumption as % of their total consumption [ISR-UC]

can vary from 0,8 W to 4,8 W. In the near future, all domestic equipment (including white goods) is likely to be controlled by electronic equipment, and will have the capability to communicate with other equipment. This situation will potentially lead to an increase in the standby electricity consumption.

Based on the monitoring campaign and survey it was possible to carry out estimates for the standby energy consumption per household for the three different modes of operation. *Table 1* shows that alarm clocks, microwave, DVD players and recorders and Setop boxes represent the loads with the highest number of operating hours per day in the Standby mode, amounting to 18 and 19 hours.

New electronic loads and entertainment contribute to 72 % of the total energy consumption in stand by mode, being TVs the major contributor. *Figure 5* shows the share of electricity consumption for domestic computers and new electronic appliances in terms of electricity consumption in the on and off mode and stand by consumption per year.

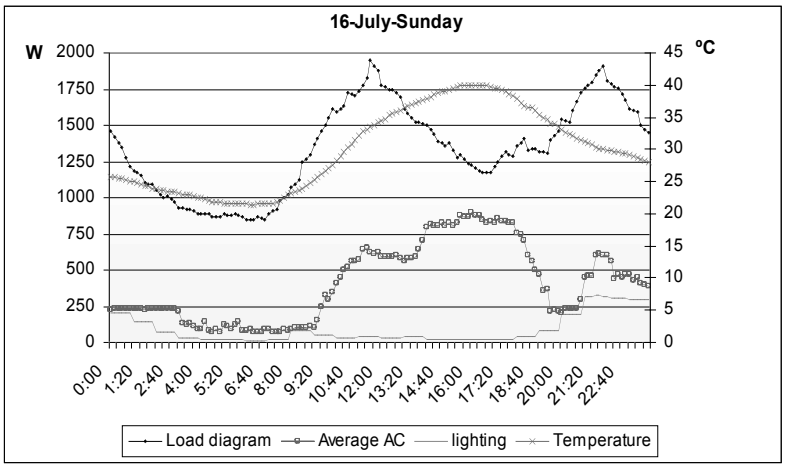


Figure 6. Daily Load profile of air conditioning and lighting in a weekend day [ISR-UC]

Air conditioning loads

Residential air conditioning is growing fast and is already a major contributor to summer peak demand in Mediterranean countries, as the load curves from very hot days of the last summer have shown (*Figures 6 and 7*).

As it can be seen in the above presented load profiles, air conditioning represents a significant share of the total electricity consumption of households. Its operation is directly related to the outside temperature, which has been increasing in the last decades, and therefore air conditioning loads are becoming increasingly widespread in the households all around Europe, but especially in France, Greece, Italy, Portugal and Spain.

The driving factors for air conditioning growth are:

- Increasing affordability;
- Shifts in comfort culture, behavioural patterns and consumer expectation;

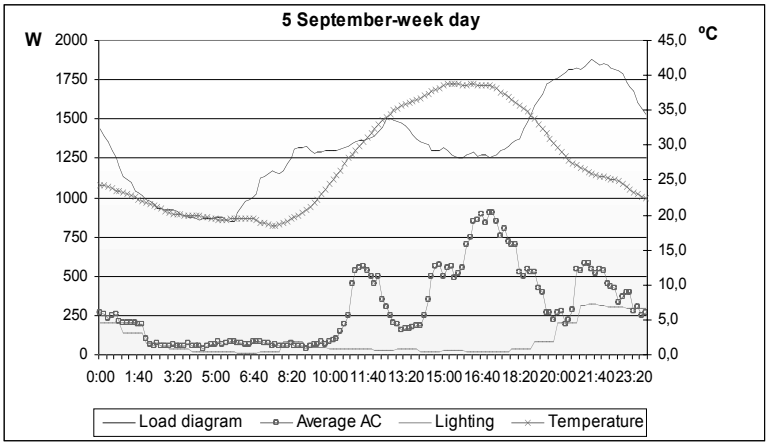


Figure 7. Daily Load profile of air conditioning and lighting in a normal working day [ISR-UC]

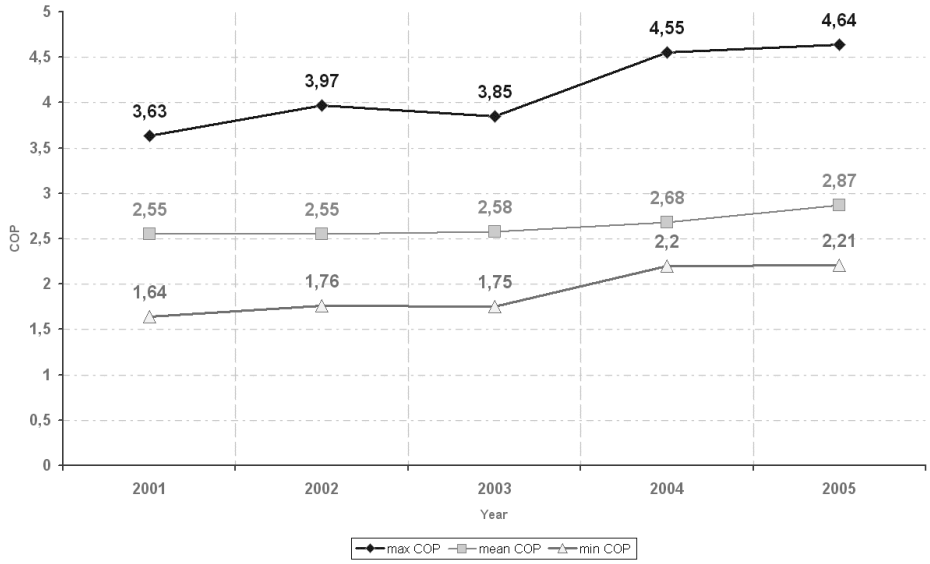


Figure 8. Evolution of energy efficiency of split, non ducted, air-cooled air conditioners up to 12kW in the EU [MEEUP]

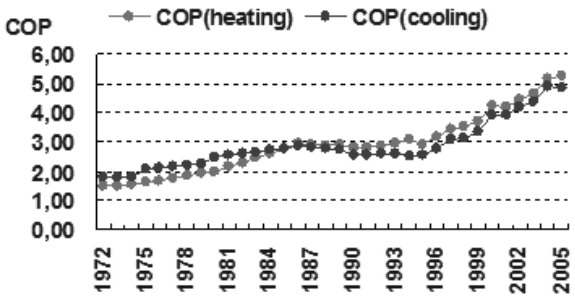


Figure 9. Average COP of Room AC in Japan (for residential use), [JRAIA]

- Increase in internal heat loads (computers etc.);
- Increase in urban heat island phenomenon and a general trend towards higher temperature;
- Perception that comfort cooling contribute to higher productivity.

The air conditioning EU market has been flooded with very low cost and very inefficient units, therefore needing urgent attention as seen in *Figure 8*.

The main electricity consumer in an RAC is the compressor. Inverter technology is one of the most important BAT for air conditioners. EuroVent greatly endorses the application of inverter technology, seeing both benefits for policy makers (reduces stress on energy supply) and end-users (lower energy bills, higher comfort). [MEEUP]

In Japan air conditioner efficiency is significantly better than in the EU. *Figure 9* shows the remarkable evolution of the efficiency in Japanese residential air conditioners over the last years.

The highest COP available in the market is even more impressive. The best COPs in Japan for residential heat pumps (AC) in 2005 are [Shibata, Yoshiaki]:

- Best COP for cooling 6.51 (2.8 kW/0.43 kW)
- Best COP for heating 6.85 (2.5 kW/0.365 kW)

Standby power consumption can be relevant for air conditioners. Most RAC have a power consumption in standby (0.2 to 10 W) to allow electronics to check for incoming operating signals (some have remote controls and/or a timer switch), but some models also have sump heaters installed. Sump heaters are small electric heating elements that prevent compressor wear during cold start-ups. These heaters may consume up to 20 to 70 Watts in 'off-mode', so without the end-user knowing it. It is believed that approximately 1 out of 10 models have a sump heater [MEEUP].

MARKET EVOLUTION FOR AIR CONDITIONING

The EERAC study presented the EU15 RAC stock and forecasts for 2010 and 2020. Interpolation of these figures results in a RAC stock in 2004 of approximately 17 million units. But comparing the EERAC stock forecast with a forecast based upon sales figures by The Japan Refrigeration and Air Conditioning Industry Association (JRAIA) and European Committee of Air Handling and Refrigeration Equipment Manufacturers (EuroVent) it can be seen that the actual sales are already more than the total stock in 2020 predicted in EERAC.

With all the progress made in the last years, the EERAC conclusions were right when saying that possibly the final results were "very conservative assumptions ... about future market growth". These is already been proved by the actual sales and conclusions presented in MEEUP study.

There is a big degree of uncertainty regarding future sales and consumptions around Europe, as shown in *Table 2*. One thing is certain, new technologies and materials allow for higher efficiency levels now than the predicted in EERAC. Also the prices are more accessible and with the climate change, a significant increase of the penetration of these equipments can be expected along the years to come.

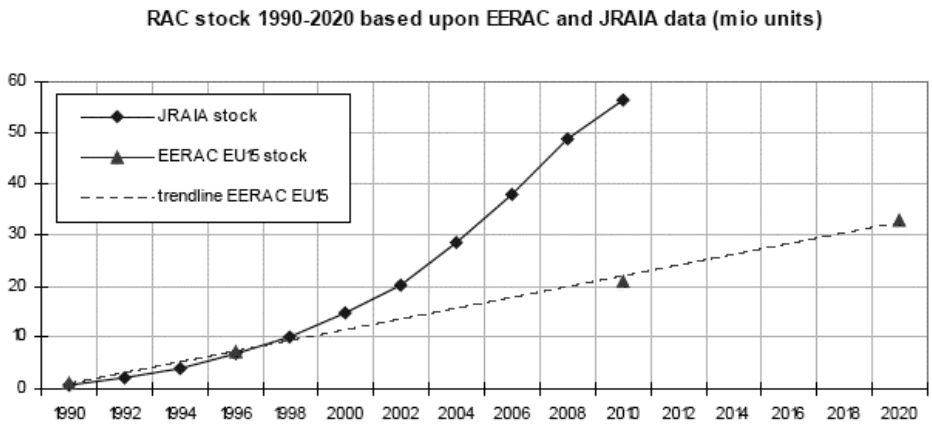


Figure 10. Development of RAC stock in EU-15, [MEEUP]

Table 2. Estimate of World Demand for Air Conditioners (2000-2008), [MEEUP]

	2000 Actual	2001 Actual	2002 Actual	2003 Actual	2004 Projected	2005 Forecast	2006 Forecast	2007 Forecast	2008 Forecast
(1) All air conditioners (in thousands of units)									
World Total	41,874	44,834	46,840	54,379	58,147	60,422	62,97	65,663	68,654
Europe	2,907	2,918	3,412	4,359	4,799	5,087	5,382	5,694	6,118
(2) Room air conditioners (for domestic use) (in thousands of units)									
World Total	31,538	34,695	36,212	43,352	46,559	48,655	50,967	53,409	56,126
Europe	2,48	2,477	2,958	3,93	4,324	4,592	4,861	5,149	5,543
(3) Packaged air conditioners (for commercial use) (in thousands of units)									
World Total	10,336	10,139	10,629	11,027	11,588	11,766	12,003	12,254	12,528
Europe	426	442	455	430	475	495	521	545	575

Lighting

The project is also assessing the patterns of residential lighting use, in which an increasing penetration of CFLs is being partly compensated by an increasing penetration of halogen lighting.

Based on the audits carried out in 50 households in Portugal (34 houses + 16 flats), it was possible to characterise the type of lighting in each room type [*Figure 11*]. Incandescent lamps are by far the most common type of lamps in living rooms (74 %), bedrooms (98 %), bathrooms (81 %), corridors (74 %) and warehouses (100 %). CFLs penetration has been increasing but they still are not widely used, unless in the exterior lighting, where they represent about 60 % of lighting. One reason for this largest share is the higher lifetime of these types of lamps. Tubular lamps are mostly used in the kitchen, offices and garages, where they represent about 73 %, 52 % and 77 %, respectively. Halogen lamps are mostly used in corridors (23 %) and in halls (33 %).

In terms of time of use, it was possible to conclude that the kitchen is the room with the highest number of hours of use of lighting per day. *Table 3* shows the average number of hours of use per day for each room:

A rough estimation of the daily lighting consumption per room type is presented in *Figure 12*. *Figure 13* presents the average daily lighting load diagram.

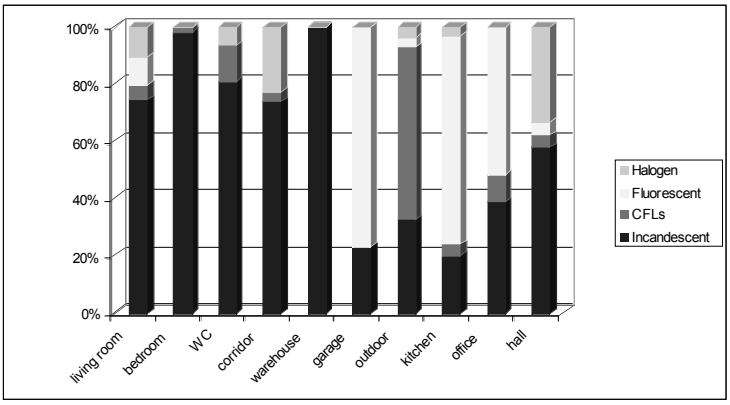


Figure 11. Percentage of the type of lighting per room type [ISR-UC]

Table 3. Average number of hours of use per day and average lighting power [ISR-UC]

Room type	Average time of use per day [h/day]	Average power [W]
living room	3,04	117,33
Bedroom	1,31	152,54
Bathroom	1,42	82,01
Corridor	1,03	66,43
Warehouse	0,44	66,77
Garage	0,72	80,44
Kitchen	4	59,92
Office	2,75	72,76
Hall	1,18	65,66
Exterior lights	3,56	59,10

It is important to mention that this is a conservative number because the survey/monitoring has been carried out in Spring and Summer time, in which the lighting needs are considerable less than in winter season. It should also be noted that most of the elements of the sample are houses, explaining the high share of outdoor lighting.

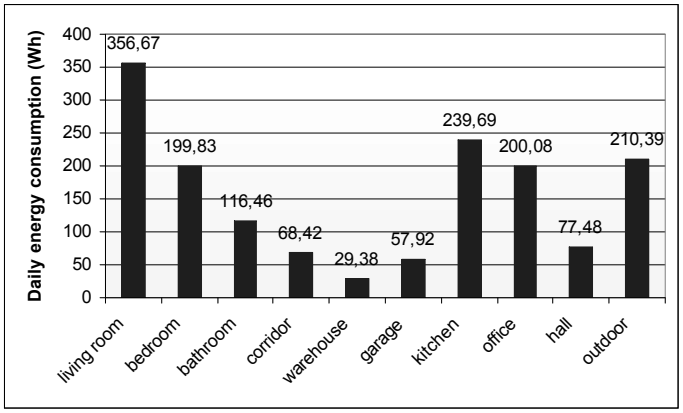


Figure 12. Daily lighting consumption per room type [ISR-UC]

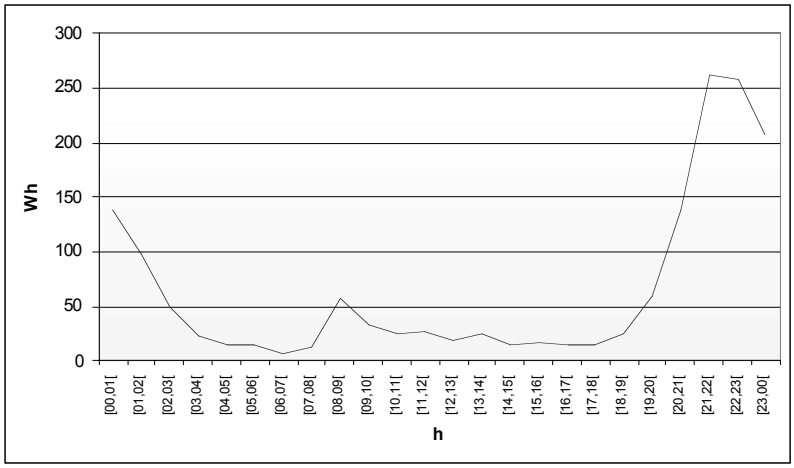


Figure 13. Average daily lighting load diagram [ISR-UC, 2006]

LIGHTING TRENDS

LEDs have already been used in traffic lighting and in information displays for a long time, but the increased commercial availability of high-luminous intensity white LEDs at cost effective prices allows the increased utilization of these devices in residential applications, in which they can replace small halogen lamps.

Some of the main advantages of using LEDs as light sources are their lifetime (usually more than 50.000 h) and their increased efficiency (current commercial white LEDs can provide up to 80 lm/W [Dialight] and this figure is rapidly increasing. Some experts predict that 200 lm/W will be possible to achieve in the next decade.

			LED		
	Incand.	Fluorescent	2003	2007	2012
Efficiency (LPW)	16	85	25	75	150
Flux (lm/lamp)	1,200	3,400	30	200	1,000
Lumens Cost ($/klm)	$0.40	$1.50	$200	$20	$4.5
Lifetime (khr)	1	10	50	75	100
	Target			Incand.	Fluorescent

Other potential advantages of these devices for specific applications are their monochromatic emission (for decoration lighting), the ability of easily dimming the light emission while maintaining the power efficiency and the small area of emission that allows to obtain special architectural lighting effects (e.g. like the ones obtained usually with optical fibbers).

Conclusions

The availability of high quality data is an essential condition for the definition of policy recommendations to influence through a combination of measures the energy efficiency of the equipment to be sold in the EU-27 in the next decade, as well as to influence the user behaviour in the selection and operation of that equipment. In the project a large monitoring campaign is being carried out in 12 countries, accompanied by a consumer

survey. From the measurements carried out it can be concluded that electronic loads and entertainment are key contributors to the power demand contributing up to 72 % of the total energy consumption in the stand by mode. In addition there is a wide range of performance levels in the models available in the market. Available technology, associated with responsible consumer behaviour, can dramatically reduce wasteful consumption of electronic loads.

Residential air conditioning load is also increasing fast and is already a major contributor to summer peak demand in Mediterranean countries. The air conditioning market has been flooded with very low cost and very inefficient units, therefore needing urgent attention.

Lighting loads are being influenced by conflicting trends. On one way the growing penetration of CFLs is reducing consumption, but on the other way the increasing penetration of halogen lighting is pushing up the lighting consumption. LEDs increasing available may replace some spot halogen applications with significant energy savings.

It is expected that based on the project results, to be conclude in June 2008, a better understanding of the residential electricity consumption will be achieved and strategies to achieve a desirable market transformations will be identified.

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Bibliography

[Adnot, J.], "Energy Efficiency and Certification of Central Air Conditioners", study for the D.G. Transportation-Energy (DGTREN) of the Commission of the E.U., Co-coordinator: J. ADNOT, September 2002.

[Adnot, J.], "Limiting the Impact of Increasing Cooling Demand in the European Union: Results from a Study on Room Air-Conditioner Energy Efficiency" Jérôme Adnot, Ecole des Mines de Paris, France; Matthieu Orphelin, Ecole des Mines de Paris, France; Carlos Lopes, Centro para a Conservação de Energia, Portugal; Paul Waide, PW Consulting, United Kingdom.

[Bertoldi, P. 2006], "European Polices for Energy Efficiency in residential appliances", European Commission, Directorate General JRC, Milan, March 30, 2006.

[Bertoldi, P.], "European Polices for Energy Efficiency in Residential appliances", European Commission, Directorate General JRC, Milan, March 30, 2006.

[Bistrup, N.] "High efficiency circulators for domestic central heating systems", Niels Bidstrup Chief Engineer, Ph. D. Grundfos Management A/S.

[Dialight], http://www.dialight.com

[EEA] – "Impacts of Europe's changing climate - An indicator-based assessment"; EEA Report No. 2/2004.

[EERAC], "Energy Efficiency of Room Air-Conditioners"; Contract DGXVII4.1031/D/97.026 Co-coordinator: Jérôme ADNOT, ARMINES, France

[EHPA], European Heat Pump Association.

[HEPTEI] "HEAT PUMPS – TECHNOLOGY AND ENVIRONMENTAL IMPACT July 2005: Part 1" prepared by Martin Forsén, Swedish Heat pump Association, SVEP, Member of the European Heat Pump Association EHPA.

[IEA, 2003]; "Cool Appliances, Policy strategies for Energy Efficient Homes", OECD/IEA 2003

[ISR-University of Coimbra, 2006], "Residential Monitoring to Decrease Energy Use and Carbon Emissions in Europe", Aníbal de Almeida, Paula Fonseca, Barbara Schlomann, Nicolai Feilberg, Carlos Ferreira, presented in "International Energy Efficiency in Domestic Appliances & Lighting Conference 2006".

[JRAIA], "The Japan Refrigeration and Air Conditioning Industry Association", http://www.jraia.or.jp/frameset_statistic.html.

[Mayer, R.], information shared by Rayner M MAYER, Chairman EHPA - European Heat Pump Association.

[MEEUP, 2005], "Methodology Study Eco-design of Energy-using Products, Final Report, MEEUP Product Cases Report", VhK for European Commission, 2005.

[MEEUP], "Methodology Study Eco-design of Energy-using Products, Final Report, MEEUP Product Cases Report", VhK for European Commission, 2005.

[Observador, 2006]; "O Observador – Grandes Mercados", CETELEM, 2006.

[Schlomann, 2005]; "Technical and legal application possibilities of the compulsory labelling of the standby consumption of electrical household and office appliances", Report Nº53/03, Schlomann B., et all, Fraunhofer ISI, June 2005.

[Schwitzer, J.], "Boiler Savelec – Characterization and reduction of electrical consumption of heating systems and components", August 2005.

[Shibata, Y.], Personal Communication, Jyukankyo Research Institute, August 2006.

[Siderius, H.], "Standby the next generation"; Siderius, Hans P., SenterNovem the Netherlands; presented in "International Energy Efficiency in Domestic Appliances & Lighting Conference 2006".

[TVESHB], "The Virginia Energy Servers Han Book", http://www.mme.state.va.us/De/hbchap5.html

[Yoshii, T.] "Heat Pumping Technologies in Asia and the Pacific: an overview", Heat Pump & Thermal Storage Technology Center of Japan, Tokyo

[Waide, P.], "Technical and economic potentials to raise energy efficiency among residential appliances in the EU"; JSWG on Energy Consumption in Products and Industrial Processes, 2000.