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Analysis of Monitoring Campaign in Europe

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TABLE OF CONTENTS

1	Introduction	2
2	Description of the Analysis Method	3
2.1	Overview of the Survey and Measurement Campaign.....	3
2.2	Ownership of Appliances.....	4
2.3	Key Results from the Measurement Campaign	5
2.4	Problematic Issues	6
2.5	Methodology	6
3	Analysis of Measurement Campaign.....	8
3.1	Energy Use per Appliance and per Household	8
3.2	Energy Demand per Use of the Appliances	10
3.3	Energy Demand in Standby Mode	12
3.4	Comparison between Countries and European average	14
3.5	Distribution during day.....	16
3.6	Aggregated Values, Present State	17
3.7	Best Available Technology – Technical Scenario	19
3.8	Energy Savings by Switching to Best Available Technology	20
3.9	Potential CO ₂ Savings by Switching to Best Available Technology	24
4	Discussion of Results	25
5	Summary	27
6	References	29
	Appendix I.....	30
	Appendix II.....	39
	Appendix III.....	44

1 Introduction

The objective of this study (WP5)¹ is to perform a common analysis of the measurement (and survey) campaigns (WP4) of electricity consumption in households in European countries. This report presents a summary of the analysis of the measurement campaign for all participating countries: Belgium, Bulgaria, Czech Republic, Denmark, France, Germany, Hellas, Hungary, Italy, Norway, Portugal and Romania. The measurement campaigns have been carried out as a “thorough” campaign in the new EU countries and Norway, focusing on appliances with a high consumption of electricity. In the old EU countries, having performed earlier measurement campaigns, the REMODECE measurement campaigns were carried out as a “light” measurement campaign, focusing on new electronic loads, standby consumption, air conditioning and light. Input from earlier measurement campaigns are also used in the analysis where applicable.

The measurement campaigns were performed in at least 100 households per country, using monitoring equipment capable to monitor the energy demand every 1 or 10 minutes in a varying number of appliances per household. The measurement period has been approximately two weeks per household. “Spot measurements” have also been carried out in the electronic loads in some countries.

Chapter 2 gives a summary of relevant results from WP4 and other input data from national statistics used in WP5. The analysis methods are shortly described in chapter 2.5. A more detailed description of the methods are given in Appendix II and III.

Energy demand is analyzed at per household level in chapter 3, estimating yearly energy demand from the two weeks measured. Details from the measurement campaign are given in Appendix I. Furthermore present energy demand on European² level (i.e. Present State) is estimated based on ownership level of the measured appliances. Ownership is found from national statistics and/or from the survey campaigns (WP4). Chapter 3 also gives an estimate of energy savings switching to “Best Available Technology” appliances.

Chapter 4 gives a discussion of the quality of the results and chapter 5 gives a summary of the report.

The organization of the project in work packages is:

WP1: Project Management

WP2: Database

WP3: Methodology

WP4: Measurement and Survey Campaigns

WP5: Analysis (this report)

WP6: Strategies

WP7: Dissemination

WP8: Common dissemination

¹ WP = Work Package (in the project)

² Only for countries participating in REMODECE. Later called “All” or similar

2 Description of the Analysis Method

2.1 Overview of the Survey and Measurement Campaign

This chapter shows some information from the survey and measurement campaign (WP4) relevant for the common analysis presented in this report (WP5). Table 2-1 show some key numbers from WP4 used in the analysis. The difference between number of appliances measured and number of appliances analyzed is due to poor quality on some of the measurements. The same was the situation for some of the received surveys. In addition, some measurements had to be omitted due to too few measurements or if the measurements were carried out in only one country. About 6 % of the measurements had to be omitted from the further analysis, due to meaningless high or low values.

Table 2-1. Key Numbers from Measurement Campaign

Number of households measured	1 300
Number of single appliances measured	12 189
Number of single appliances analyzed	11 459
Group of appliances analyzed	24

Table 2-2 shows the number of households in each participating country. The total number of households in participating countries is about 127 million. These numbers are used for aggregation and weighting later in this report.

Table 2-2. Number of Households in Participating Countries

Country	Abbreviation	Number of Households
Kingdom of Belgium	BE	4 439 652
Republic of Bulgaria	BG	3 066 809
Czech Republic	CZ	≈ 4 500 000
Federal Republic of Germany	DE	39 767 000
Kingdom of Denmark	DK	2 516 682
French Republic	FR	27 161 000
Hellenic Republic	GR	3 689 737
Republic of Hungary	HU	≈ 3 900 000
Italian Republic	IT	≈ 23 907 410
Kingdom of Norway	NO	2 214 770
Portuguese Republic	PT	3 839 300
Romania	RO	8 231 000
Total for all participating countries	ALL	127 233 360

≈ Estimated by SINTEF

2.2 Ownership of Appliances

Table 2-3 shows ownership level (percent) for different appliances in the participating countries. The source for these values is mainly the REMODECE survey. In a few cases, national statistics have been used. Both the information from the surveys and the national statistics has been supplied by the project partners. The ownerships are weighted by the number of households in the respective countries.

Table 2-3 Ownership for Electrical Appliances in 2007/2008

Nº	Appliance Groups	All Participating Countries Weighted Average
1	Chargers	-
2	Refrigerator without freezer	34,8 %
3	Refrigerator with freezer	78,9 %
4	Freezer	49,5 %
5	Washing machine	94,3 %
6	Clothes dryer	31,8 %
7	Dishwasher	60,8 %
8	Desktop PC incl. monitor	78,9 %
9	Laptop PC	41,9 %
10	Router for Internet	47,9 %
11	Wireless access point	51,0 %
12	Printer	66,9 %
13	TV CRT	92,6 %
14	TV LCD	22,5 %
15	TV Plasma	8,8 %
16	DVD recorder/player	66,6 %
17	Hi-Fi	71,5 %
18	Satellite/cable/air set top box	41,1 %
19	Air conditioner/Heat pump	16,8 %
20	Oven/cooker	80,1 %
21	Microwave oven	66,6 %
22	Water kettle	50,0 %
23	Vacuum cleaner	-
24	Lamps	-

2.3 Key Results from the Measurement Campaign

Some key results from the measurement and the analysis campaigns are shown in Table 2-4. The table shows “measured” yearly average energy consumption per appliance and yearly average energy consumption per household.

The values shown are based on data from all countries that have participated in the project. The average household values are corrected for appliance ownership (Table 2-3). Because all households do not own all appliances, or some households may have more than one of each appliance, these values will be different from the *appliance* values. These values are not weighted by the number of households in the respective countries.

The total household consumption is about 2 700 kWh per year for an average household. For comparison, the weighted average value from the survey campaign is 5 084 kWh per year.

Table 2-4. Main Results from the Measurement Campaign. Measured and Corrected for Ownership

Appliance	Average Yearly Appliance Consumption	Average Yearly Household Consumption
<i>Unit</i>	<i>kWh/appliance</i>	<i>kWh/household</i>
Chargers	13	13
Refrigerator without freezer	384	134
Refrigerator with freezer	451	355
Freezer	543	269
Washing machine	184	174
Clothes dryer	347	110
Dishwasher	234	142
Desktop PC incl. monitor	276	218
Laptop PC	56	23
Router for Internet	58	28
Wireless access point	72	24
Printer	33	22
TV CRT	124	114
TV LCD	186	42
TV Plasma	400	35
DVD recorder/player	23	15
Hi-Fi	46	33
Satellite/cable/air set top box	75	31
Air conditioner	372	63
Oven/cooker	301	241
Microwave oven	33	22
Water kettle	70	35
Vacuum cleaner	65	65
Lamps	487	487
<i>Total</i>	<i>4 833</i>	<i>2 695</i>

2.4 Problematic Issues

There were various problems in the measurement campaign in the different countries. Some of the problems have been caused by the metering equipment, like communication problems, lack of metering equipment and problems to recruit enough participants to the measurement campaign.

Hopefully these problems did not have a significant influence on the results. The software³ used to perform the analysis also performs an automatic error correction. This process rejects, as earlier mentioned, 6 % of the measurements due to poor quality. Some obvious measurement errors have also been manually removed. With more than 12 000 time series equal to more than 24 million data, SINTEF haven't had any possibility to manually check each measurement. It has been the responsibility of each project participant to check the values for each country, but we can't disregard there still may be some errors in a few measurement. One example of possible errors is erroneous classification - such as a mobile phone charger classified as a laptop.

It is probably a biased distribution in the household strata in most countries. There is probably a larger share of families with children in the measurement campaign than in the population. This is easy to correct, but due to an agreement in the project group, this correction is not performed in this analysis. The reader has to be aware that the calculated national and multinational averages in this project probably are higher than the real national and multinational averages.

2.5 Methodology

As it was mentioned above, the measurements are first roughly cleaned for errors. Then the consumption of two weeks of measurements is multiplied with a factor to account for the number of utilization days in the year to obtain the yearly consumption. This factor equals the number of weeks in the year minus two weeks for vacation etc. Refrigerators, freezers and water heaters are assumed to be switched on all the time. Air condition is defined to have a utilization period of 3 months. The resultant value is called yearly consumption per appliance [kWh].

The yearly consumption per appliance is multiplied with the appliance ownerships per country to obtain the average yearly consumption per household [kWh]. Finally the yearly consumption per household is multiplied with the number of households in the country to obtain the total national and multinational consumption [GWh]. This is also called the Present State or Present Values in this report. All participating countries have not performed measurements on all appliances because of shortage of appropriate monitoring devices and absence of appliances within the visited households. Where measurements and/or ownership information is missing, the European average values are used when aggregating to national and multinational levels.

When calculating national savings by replacing the appliances, it is first necessary to calculate the energy used by the "Best Available Technology" appliances. The power (Watt) used by the best technology of an appliance is mainly found from scanning and analysing the collected measurements. In some instances manufacturer specifications or similar information from other energy saving projects and databases are used. The BAT (Watt) per appliance is the same for all countries, but the aggregate values will depend on the country specific utilization hours of the appliance and of the ownership level. The annual energy demand of BAT appliances are found by multiplication of the BAT power (Watt) with the load factor (utilization hours) of the country. The Present State is country specific based on data from the monitoring and survey campaigns (WP4), and in some cases previous projects and measurement campaigns.

One of the REMODECE project targets is to identify the total savings (technical potential) by replacing the installed inefficient technologies (present values) with the best available technologies (BAT) present in the market. Structural effects as change of load patterns due to possible change of behaviour are not

³ The Useload software was developed at SINTEF in the period 1980-2000 to analyze and store hourly measurements of energy consumption

integrated in the calculations, as these would require additional efforts and it would be too difficult to evaluate with accuracy. Also, market transformation is not taken into account. It may take several decades to replace inefficient equipment with more efficient equipment. Old equipment may also be replaced with larger sized equipments using more energy. Such examples are TVs and refrigerators. Possible future development of even more efficient technologies is neither analysed within this project.

The BAT calculations are different for various appliances, mainly due to different use of the appliances. Manually operated appliances must be treated different from automatically operated appliances. A detailed description of the methods used to find the Best Available Technology is given in Appendix II and III for each group of appliances. In most instances the BAT power (in Watt) is found by scanning the metered appliances for the lowest power demand or the lowest 10 % percentile. Where appropriate information is available, BAT is obtained from other projects as [1] and [2], and from the Internet service "Topten" [3]. Annual energy demand using BAT is then found by multiplying the BAT power with the load factor of each country. In this way the load pattern of each country is applied. In addition the BAT calculations assume that the standby consumption is reduced to a minimum (0,5 W).

For most appliances, standby energy is calculated from an automatic inspection of the measurements, identifying the minimum power consumed and the hours this power is consumed. For some appliances, like routers and set-top boxes, it is difficult to identify standby using this method. For such appliances, standby is calculated as the consumption in the hours when the associated PC or TV is not in use.

After these calculations, which are performed per appliance, per household and per country, the average BAT [kWh/household] is calculated for all countries. This is multiplied with ownership and number of households in the countries to obtain aggregated values [GWh], using the same method to compensate for missing values as used for calculating the Present State. To calculate emission reductions, the same emission coefficient is used for all countries except Norway which is not included in today's EU mix.

3 Analysis of Measurement Campaign

3.1 Energy Use per Appliance and per Household

Table 3-1 shows estimates of yearly energy consumption in appliances: Average, minimum – and maximum consumption per appliance. The values in this table are not corrected for ownership level.

Table 3-1 Results from the Measurement Campaign. Annual Electric Energy in Appliances

Appliance	Total N° Analysed	Average Yearly Appliance Consumption	Minimum Yearly Appliance Consumption	Maximum Yearly Appliance Consumption
<i>Unit</i>	<i>N°</i>	<i>kWh/appliance</i>		
Chargers	14	13	1	80
Refrigerator without freezer	206	384	49	2883
Refrigerator with freezer	288	451	58	1519
Freezer	126	543	117	1262
Washing machine	506	184	4	3675
Clothes dryer	64	347	9	1179
Dishwasher	198	234	9	1673
Desktop PC incl. monitor	202	276	1	1188
Laptop PC	180	56	0	463
Router for Internet	33	58	4	165
Wireless access point	6	72	11	115
Printer	41	33	0	85
TV CRT	708	124	0	2665
TV LCD	145	186	3	975
TV Plasma	56	400	6	1021
DVD recorder/player	162	23	0	314
Hi-Fi	281	46	0	381
Satellite/cable/air set top box	108	75	2	232
Air conditioner	28	372	5	2692
Oven/cooker	23	301	15	943
Microwave oven	78	33	0	153
Water kettle	58	70	3	220
Vacuum cleaner	99	65	2	335
Lamps	7 849	487		
<i>Total</i>	<i>11 459</i>	<i>4 833</i>		

The total appliance consumption is about 4 800 kWh per year without correction for appliance ownership. If a household has installed one of each of the average appliances, and the appliances have an average usage pattern, the yearly consumption will be as high as 4 800 kWh per household. A more reasonable value (2 700 kWh per household) is calculated in Table 3-2.

The average energy demand in freezers is about 540 kWh per appliance and year. Refrigerators use about 380 kWh, while fridges with freezer use about 450 kWh. Electric cooker use about 300 kWh, washing machines use about 180 kWh, while clothes dryers use about 350 kWh.

Conventional televisions use about 125 kWh, and LCD TVs uses about 190 kWh. Plasma TVs use 400 kWh in average. In average plasma TVs are bigger than LCD TVs, and LCD TVs are bigger than CRT

TVs. Besides the different efficiency of the technology, a part of the differences in the consumption in table 3-1 can be explained by size of the appliance and different usage pattern as analyzed later. Lighting is calculated to about 487 kWh in average. Air conditioning uses about 370 kWh per year assuming a use of 3 months per year. A desktop PC uses about 276 kWh, while laptop PCs only use about 60 kWh per year. Much of the difference may be explained with the type of technology used in laptops, but also the usage pattern can explain this significant difference in the consumption.

Some of the differences between the minimum and maximum values can be explained by different usage pattern and different technologies. For appliances that are automatically operated, it is difficult to find a reasonable explanation for the great variations apart from some differences due to different sizes and technologies. In some cases it may be that the appliance has not been used in the measurement periods and/or that the estimated minimum values for yearly consumption is only the standby consumption.

Table 3-2 shows average appliance consumption and average household consumption for a multinational average household, where ownership is taken into account. Decimals are not shown due to uncertainty in the estimates, The multinational average is about 2 700 kWh per household and year for all measured appliances. This value seems to be more reasonable compared with national statistics.

Table 3-2 Results from the Measurement Campaign. Annual Electric Energy Demand in Appliances and Households

Appliance	Average Yearly Appliance Consumption	Ownership	Average Yearly Household Consumption
<i>Unit</i>	<i>kWh/appliance</i>	<i>Percent</i>	<i>kWh/household</i>
Chargers	13	100 %	13
Refrigerator without freezer	384	35 %	134
Refrigerator with freezer	451	79 %	355
Freezer	543	50 %	269
Washing machine	184	94 %	174
Clothes dryer	347	32 %	110
Dishwasher	234	61 %	142
Desktop PC incl. monitor	276	79 %	218
Laptop PC	56	42 %	23
Router for Internet	58	48 %	28
Wireless access point	72	33 %	24
Printer	33	67 %	22
TV CRT	124	93 %	114
TV LCD	186	22 %	42
TV Plasma	400	9 %	35
DVD recorder/player	23	67 %	15
Hi-Fi	46	72 %	33
Satellite/cable/air set top box	75	41 %	31
Air conditioner	372	17 %	63
Oven/cooker	301	80 %	241
Microwave oven	33	67 %	22
Water kettle	70	50 %	35
Vacuum cleaner	65	100 %	65
Lamps	487	100 %	487
<i>Total</i>	<i>4 833</i>	<i>-</i>	<i>2 695</i>

Figure 3-1 shows the distribution of yearly electricity consumption for a typical (average) European household. Cooling (refrigerators and freezers) is the group of appliances requiring the largest share of the electricity consumption within a household, representing about ¼ of the total electricity consumption. Lighting represents the second largest with 18 % of the total electricity consumption. Clothes washing and drying represents about 16 %, personal computers and accessories 12 %, cooking 11 % and television 9 %. Air conditioning loads requires about 2 % of the household electricity consumption, while other appliances such as vacuum cleaners, radios and chargers represents about 4%.

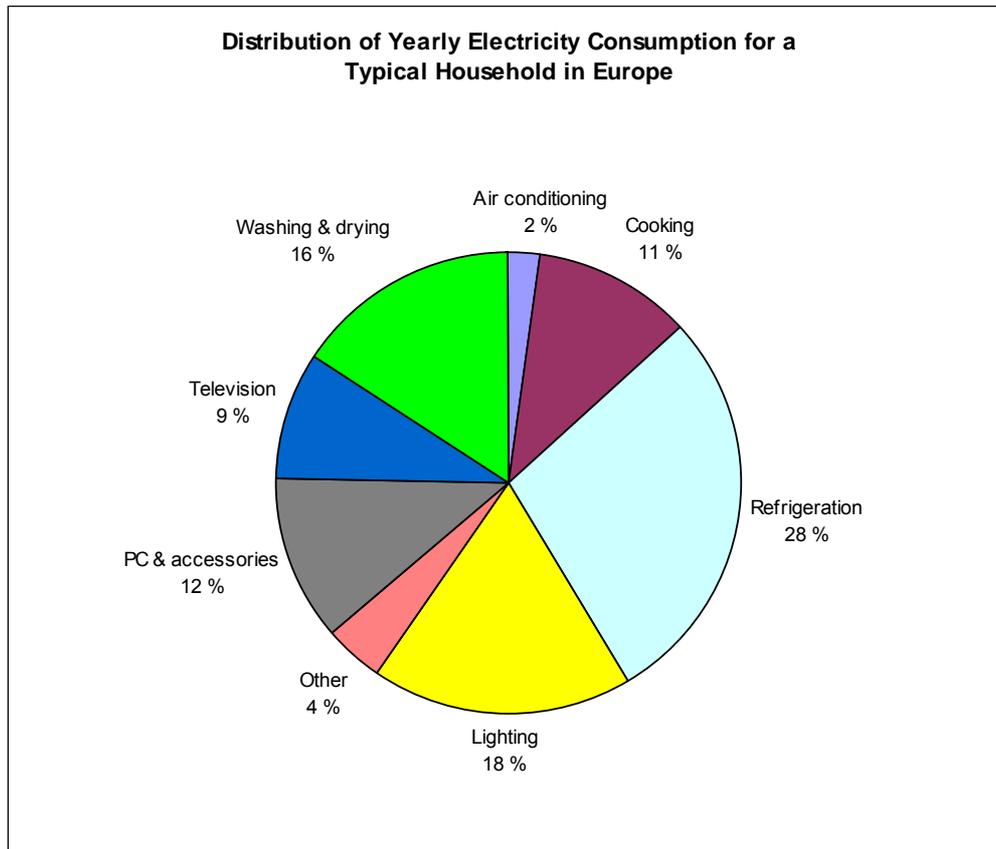


Figure 3-1 Percent Shares of Electrical End-Uses in Europe 2007/2008 from the REMODECE Measurement and Survey Campaigns (Excluding Electric Space and Water Heating)

3.2 Energy Demand per Use of the Appliances

Table 3-3 shows annual energy, energy consumption per single use of the appliance, number of times the appliance is used per year and number of times the appliance is used per week. The values in this table are not corrected for ownership. Appliances automatically operated (refrigerator and freezers) are omitted from this table. Only appliances that are manually operated (like washing machine, dishwashers and computers) are shown. Hours per single use is not analyzed in this report.

Energy per (single) use is calculated as the energy consumed between on-mode and off-mode or standby mode per appliance. The energy per use is found using this rule when scanning through the metered time series.

For washing machine and clothes dryer and dishwasher, it can be seen that such machines are used 4-5 times a week. A class A washing machine uses about 1 kWh for a 60 degree wash, and one should therefore expect a lower average, since most washes are carried out at lower temperatures. Our results

shows an average of about 0,7 kWh per wash. One use of clothes drying consumes about 1,7 kWh. A dishwasher consumes about 1,1 kWh per single use.

Plasma TV is very energy consuming due to non-efficient plasma technology and the larger size. Although the frequency of use of LCD TVs are about twice as high as plasma and CRT TVs, the LCD TVs use only 60 % of the energy per single use compared to the CRT TV. Compared with a plasma TV, the LCD TV uses only 24 % of the energy per single use. This may also be explained by hours of use, but this is not analyzed in this project.

A comparison of desktop PCs and laptop PCs shows that the energy per use for a laptop is 14 % of the energy per use for a desktop. This may be explained by different technologies, but it may also be explained by hours per single use. A printer consumes about 3 kWh per use. The explanation may be that the printer is rarely switched off.

An electrical oven/cooker uses about 0,5 kWh per single use and is used 11 times per week in average. A microwave uses about 0,07 kWh per use. This is explained by technology differences, but also by the fact that microwaves are mainly used to warm food that is prepared earlier, and to prepare smaller and quicker meals.

Table 3-3. Results from the Measurement Campaign. Annual Electric Energy, Energy per Use, Number of Uses per Year and Number of Uses per Week

Appliance	Average Yearly Appliance Consumption	Energy Per Use of Appliance	Number of Uses of Appliance per Year and per Appliance	Number of Uses per Week and per Appliance
<i>Unit</i>	<i>kWh/appliance</i>	<i>kWh/use</i>	<i>Nº</i>	
Chargers	13	0,59	23	-
Washing machine	184	0,68	272	5,2
Clothes dryer	347	1,72	202	3,9
Dishwasher	234	1,13	207	4,0
Desktop PC incl. monitor	276	1,62	170	3,3
Laptop PC	56	0,23	239	4,6
Printer	33	2,95	11	-
TV CRT	124	0,44	283	5,4
TV LCD	186	0,27	694	13,3
TV Plasma	400	1,14	352	6,8
DVD recorder/player	23	1,16	20	0,4
Hi-Fi	46	1,10	42	0,8
Air conditioner	372	3,18	117	2,2
Oven/cooker	301	0,51	586	11,3
Microwave oven	33	0,07	439	8,4
Water kettle	70	0,12	578	11,1
Vacuum cleaner	65	0,51	129	2,5
Lamps	472	-	-	-

For lighting a different methodology was used: In stead of calculating the number of uses per year or week, the load factor is used. The load factor is the total hours the lamps are used in percentage of the total number of hours per year. This is 4,5 % in average for all participating countries, meaning that the lamps are used 394 hours per year in average or about 1 hour per day in average.

3.3 Energy Demand in Standby Mode

Table 3-4 shows the standby electricity consumption for the appliances measured under the REMODECE project. These values are defined for the typical household, taking ownership level into consideration. *In the REMODECE project standby mode is defined as the electricity consumption of the appliances during the periods where the appliance is not used for its primary use.*

For most appliances the standby energy is relatively low, between 0 and 2 percent of the total yearly consumption. This is assumed to be caused by some displays and/or electronic circuits in the appliance that consume a little energy. Some of the new electronic appliances have a relatively high share of standby consumption, in the magnitude of 85 percent of total yearly consumption per appliance. In such appliances standby may be the electricity required⁴ to keep information (as storing TV stations) in the appliance memory.

In average the standby consumption is about 27 W or 179 kWh per household per year, which is about 6,6 % of the total annual energy per household. The standby energy aggregates up to about 23 TWh for all households in the participating countries, responsible for about 10 million ton CO₂ per year.

The values in Table 3-4 are multiplied with the “ownership level” to apply to the “typical household”. So appliances that might have a high share of standby energy compared to its annual energy demand, will have a lesser impact on the standby percentage to the total demand – if the appliance has a low ownership. Equally, an appliance that has a low energy demand also has a low impact on the standby share of the typical household.

⁴ Can be avoided by using “non-volatile” electronic components that can store information even if the power supply is disconnected

Table 3-4 Results from the Measurement Campaign. Standby Energy Consumption

Appliance	Measured Yearly Standby Consumption	Share of Total Yearly Consumption
<i>Unit</i>	<i>kWh/household</i>	<i>Percent</i>
Chargers	0,1	1,1 %
Refrigerator without freezer	1,2	0,9 %
Refrigerator with freezer	2,9	0,8 %
Freezer	0,9	0,3 %
Washing machine	1,8	1,0 %
Clothes dryer	0,6	0,6 %
Dishwasher	1,2	0,9 %
Desktop PC including monitor	20,1	9,2 %
Laptop PC	2,5	10,7 %
Router for Internet	23,7	85 %
Wireless access point	20,1	85 %
Printer	21,9	99,9 %
TV CRT	11,7	10,2 %
TV LCD	1,5	3,6 %
TV Plasma	0,4	1,2 %
DVD recorder/player	1,8	11,8 %
Hi-Fi	5,7	17,4 %
Satellite/cable/air set top box	26,3	85 %
Air conditioner	0,8	1,4 %
Oven/cooker	5,2	2,3 %
Microwave oven	4,2	19,5 %
Water kettle	0,1	0,2 %
Vacuum cleaner	0,5	0,7 %
Lamps	23,2	4,6 %
<i>Total</i>	<i>178,6</i>	<i>6,6 %</i>

3.4 Comparison between Countries and European average

A comparison between measured yearly appliance consumption for different countries is shown in Table 3-5. *The values are not corrected for ownership.* The values in the "ALL" column are averages of all participating countries, including the northern European countries. The inclusion of these countries may contribute to larger values for some appliance compared to a European average if those countries have been neglected. Some examples are light, air-conditioners/heat pumps and cooker/oven.

In the table, empty cells are due to missing metering of the appliance in the country. In later tables missing values are filled with the average for all countries.

Table 3-5. Annual Electric Energy in Appliances, kWh/year per Appliance

Country	ALL	BE	BG	CZ	DE	DK	FR	GR	HU	IT	NO	PT	RO
Appliance	kWh/appliance												
Chargers	13				24		11						
Refrigerator	384		367	497	258	287			284	586	307		361
Fridge freezer	451		471	512	451	379		575	344	359	374	484	388
Freezer	543		600	634	256	496			486		631		500
Washing	184	162	113	131	117	184	164		92	377	207	183	
Clothes dryer	347	393	239		211						267		
Dishwasher	234	288	132	231	146		250		157	330	206	188	
Desktop PC	276	182	239	368	233	303	247	320	80	361	97		229
Laptop PC	56	44	60	111	37	61	31	82	57	32	87	53	83
Router for	58				38	102	41				51		
Wireless	72												
Printer	33	51			30		30		51				
TV CRT	124	61	130	144	83	109	69	156	96	106	172	96	161
TV LCD	186	132	156	186	205	174	171	175		277	223	144	337
TV Plasma	400		310			427	456				325		
DVD	23		5		40	25	18	23	30	47	21		
Hi-Fi	46	48	42		21	51	38	55	53	77	103		
Set top box	75				47	83	78				84		
Air conditioner	372							473		107	1179		
Oven/cooker	301								138		287		
Microwave	33			32	54				24	43	30	16	
Water kettle	70			84	67				43		24		
Vacuum cleaner	65				11		62		45				70
Lamps	487	524	776	68	352	908	452	459	221	901	1013	233	143

Table 3-6 shows the average consumption per household per country where the average European value (ALL) is multiplied with the ownership per country. Where information about ownership is missing for some appliances and countries, the European average ownership is used. The table shows that the European average consumption is about 2 700 kWh per household per year for the electrical appliances measured in this project.

Table 3-6. Annual Electric Energy in European Households, kWh/year per Household

Country	ALL	BE	BG	CZ	DE	DK	FR	GR	HU	IT	NO	PT	RO
Appliance	kWh/household												
Chargers	13	13	13	13	13	13	13	13	13	13	13	13	13
Refrigerator	134	253	138	51	203	207	123	19	294	38	200	36	68
Fridge freezer	355	248	329	387	355	248	324	505	133	405	297	449	407
Freezer	269	405	179	150	380	394	244	137	258	152	397	261	174
Washing	174	164	177	163	177	161	175	173	165	182	177	172	149
Clothes dryer	110	232	14	7	149	205	173	28	13	31	163	97	17
Dishwasher	142	144	59	31	138	156	201	123	35	166	206	164	18
Desktop PC	218	207	141	95	331	249	122	171	157	229	193	243	91
Laptop PC	23	34	13	28	13	50	11	20	19	51	40	41	9
Router for	28	30	3	19	33	39	27	20	16	34	39	28	3
Wireless	24	24	24	24	24	24	24	24	30	24	53	24	24
Printer	22	23	10	24	25	28	17	22	14	27	20	26	13
TV CRT	114	12	114	120	152	114	65	157	114	120	86	126	114
TV LCD	42	136	10	42	28	42	48	35	42	42	93	33	42
TV Plasma	35	60	11	35	5	35	72	8	35	35	200	12	35
DVD	15	16	10	15	13	20	16	19	13	20	17	17	6
Hi-Fi	33	38	21	31	33	32	31	39	19	40	46	34	14
Set top box	31	5	11	29	47	26	20	21	10	36	29	35	8
Air conditioner	63	19	82	14	63	7	4	197	22	141	93	74	32
Oven/cooker	241	199	241	123	253	301	241	241	241	241	289	241	241
Microwave	22	22	22	23	22	22	22	22	26	22	3	24	22
Water kettle	35	35	35	35	35	35	35	35	35	35	35	35	35
Vacuum cleaner	65	65	65	65	65	65	65	65	65	65	65	65	65
Lamps	487	524	776	68	352	908	452	459	221	901	1 013	233	143
<i>Total</i>	2 695	2 908	2 498	1 592	2 909	3 381	2 525	2 553	1 990	3 050	3 767	2 483	1 743

3.5 Distribution during day

Figure 3-1 and Figure 3-2 shows load curves for a typical European household for a typical week day of the year in Watt. Figure 3-2 shows accumulated curves.

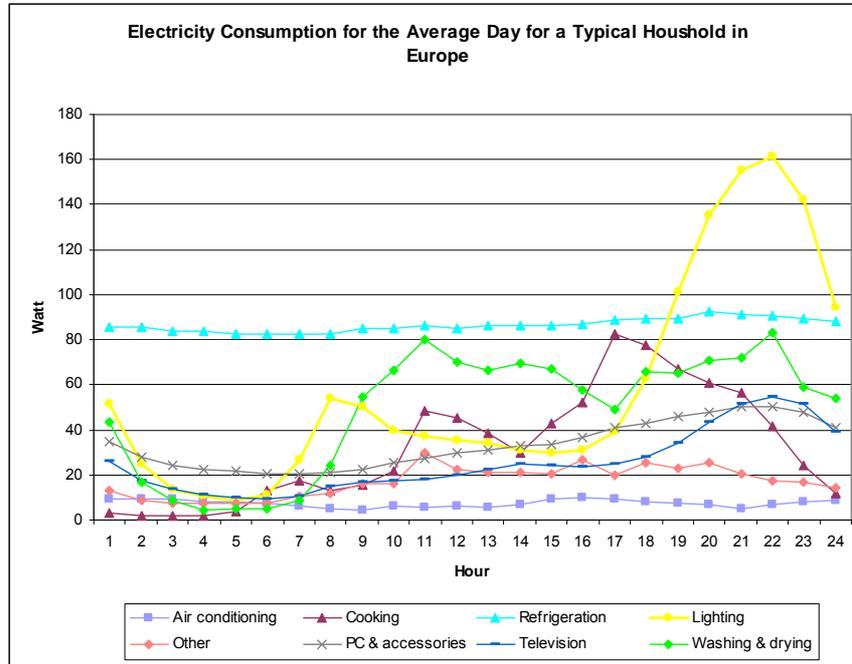


Figure 3-2 Electricity Consumption in Group of Appliances for A Typical Household on A Typical Day of the Year

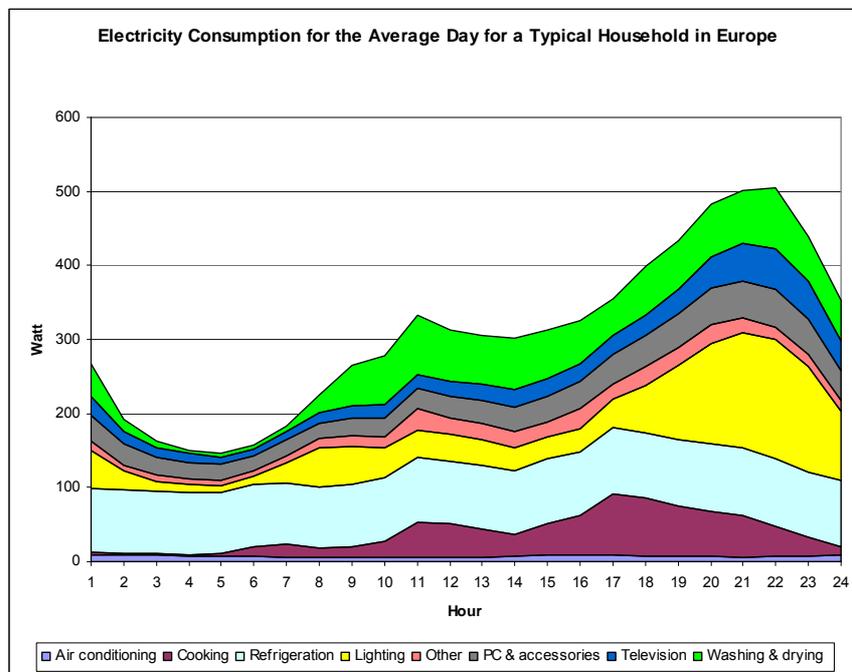


Figure 3-3 Electricity Consumption in Different Appliances for A Typical Household on A Typical Day of the Year.

3.6 Aggregated Values, Present State

Table 3-7 shows the average electricity consumption per household (taking into account the ownership of appliances) and the total electricity consumption aggregated to include all countries participating in REMODECE. The totals are only for the measured appliances, and the multinational values are calculated for a total of 127 mill households in the participating REMODECE countries. Based on this, the consumption of electricity for the electrical appliances where measurements have been performed is about 343 TWh per year.

Table 3-8 shows the aggregated values both on national level and the total for the participating countries. Both tables show the Present State.

Table 3-7 Present State. Values per Household and Aggregated to Multinational Level

Appliance	Average Yearly Household Consumption	Yearly Consumption for the REMODECE countries
<i>Unit</i>	<i>kWh/household</i>	<i>GWh</i>
Chargers	13	1 699
Refrigerator without freezer	134	16 990
Refrigerator with freezer	355	45 222
Freezer	269	34 241
Washing machine	174	22 099
Clothes dryer	110	14 027
Dishwasher	142	18 111
Desktop PC incl. monitor	218	27 721
Laptop PC	23	2 963
Router for Internet	28	3 554
Wireless access point	24	3 012
Printer	22	2 789
TV CRT	114	14 557
TV LCD	42	5 311
TV Plasma	35	4 474
DVD recorder/player	15	1 938
Hi-Fi	33	4 144
Satellite/cable/air set top box	31	3 933
Air conditioner	63	7 969
Oven/cooker	241	30 663
Microwave oven	22	2 768
Water kettle	35	4 436
Vacuum cleaner	65	8 333
Lamps	487	61 983
Total	2 695	342 936

Table 3-8. Present State. Aggregated Annual Electric Energy in European Households per Country and Total for Participating Countries

Country	ALL	BE	BG	CZ	DE	DK	FR	GR	HU	IT	NO	PT	RO
Appliance	GWh												
Chargers	1 699	59	41	60	531	34	363	49	52	319	30	51	110
Refrigerator	16 990	1 125	424	232	8 071	522	3 338	71	1 146	918	442	138	563
Fridge freezer	45 222	1 100	1 009	1 739	14 135	624	8 810	1 863	518	9 694	659	1 723	3 348
Freezer	34 241	1 797	550	675	15 124	991	6 640	505	1 006	3 637	878	1 001	1 435
Washing machine	22 099	727	542	732	7 028	405	4 750	638	643	4 357	391	659	1 224
Clothes dryer	14 027	1 031	43	30	5 929	515	4 709	103	51	746	361	373	138
Dishwasher	18 111	639	179	139	5 492	392	5 468	455	136	3 974	456	629	152
Desktop PC	27 721	920	432	428	13 180	626	3 301	630	614	5 480	428	932	752
Laptop PC	2 963	150	41	125	530	126	302	74	74	1 222	89	158	73
Router for Internet	3 554	132	11	84	1 322	98	744	74	60	808	87	109	25
Wireless access point	3 012	105	73	107	941	60	643	87	117	566	118	91	195
Printer	2 789	100	30	109	991	71	463	80	54	635	44	102	110
TV CRT	14 557	55	349	539	6 040	288	1 779	579	446	2 865	192	484	942
TV LCD	5 311	602	30	188	1 103	105	1 312	130	163	998	206	128	344
TV Plasma	4 474	267	33	158	183	88	1 957	30	137	841	443	46	289
DVD recorder/player	1 938	71	31	67	518	50	441	69	52	481	38	67	53
Hi-Fi	4 144	168	66	141	1 322	80	841	144	75	958	101	131	116
Set top box	3 933	23	35	129	1 880	66	551	79	40	863	65	134	68
Air conditioner	7 969	83	251	62	2 491	19	121	728	84	3 380	206	286	265
Oven/cooker	30 663	881	739	555	10 048	757	6 546	889	940	5 762	640	925	1 984
Microwave oven	2 768	97	67	105	875	55	591	80	102	520	7	91	179
Water kettle	4 436	155	107	157	1 386	88	947	129	136	833	77	134	287
Vacuum cleaner	8 333	291	201	295	2 605	165	1 779	242	255	1 566	145	251	539
Lamps	61 983	2 326	2 380	306	13 998	2 285	12 277	1 694	862	21 541	2 244	895	1 177
<i>Total</i>	342 936	12 905	7 661	7 161	115 722	8 509	68 672	9 422	7 765	72 963	8 346	9 536	14 366

3.7 Best Available Technology – Technical Scenario

Table 3-9 shows the energy consumption per appliance and per household by using the best available technology. The method for calculating yearly energy demand for best available technology is found as described in Appendix II. In short, the power (Watt) of BAT appliances is found from other relevant projects or in most instances by scanning the measurements for the lowest values.

Table 3-9 Best Available Technology. Values per Appliance and per Household

Appliance	Average Yearly Appliance BAT Consumption	Ownership	Average Yearly Household BAT Consumption
<i>Unit</i>	<i>kWh/appliance</i>	<i>%</i>	<i>kWh/household</i>
Chargers	6	100 %	6
Refrigerator without freezer	191	35 %	66
Refrigerator with freezer	219	79 %	173
Freezer	217	50 %	107
Washing machine	136	94 %	128
Clothes dryer	174	32 %	56
Dishwasher	163	61 %	99
Desktop PC incl. monitor	100	79 %	79
Laptop PC	25	42 %	11
Router for Internet	29	48 %	14
Wireless access point	13	33 %	4
Printer	17	67 %	11
TV CRT*	124	93 %	114
TV LCD	125	22 %	28
TV Plasma	337	9 %	30
DVD recorder/player	8	67 %	5
Hi-Fi	7	72 %	5
Satellite/cable/air set top box	43	41 %	18
Air conditioner	227	17 %	38
Oven/cooker	226	80 %	180
Microwave oven	28	67 %	19
Water kettle	33	50 %	17
Vacuum cleaner	18	100 %	18
Lamps	184	100 %	184
Total	2 650		1 367

By switching to best available technology the household consumption can be reduced with about 1 328 kWh per year, from 2 695 kWh to 1 367 kWh per year. It is assumed that the use of the best available technology will be the same as found in the measurement campaign. That means the same uses usage pattern as in the present scenario.

3.8 Energy Savings by Switching to Best Available Technology

Table 3-10 shows the savings per appliance (as if all households owns the appliance), and per typical household (ownership taken into account).

Table 3-10. Annual Electric Energy Savings by Switching to Best Available Technology (BAT) in European Households

Appliance	Per Appliance Consumption			Ownership	Per Household Consumption			
	Present Value	Best Available Technology	Savings		Present Value	Best Available Technology	Savings	% Savings
Unit	kWh			%	kWh			%
Chargers	13	6	7	100 %	13	6	7	51,4 %
Refrigerator	384	191	193	35 %	134	66	67	50,2 %
Refrigerator with freezer	451	219	231	79 %	355	173	182	51,3 %
Freezer	543	217	326	50 %	269	107	162	60,1 %
Washing machine	184	136	48	94 %	174	128	45	26,1 %
Clothes dryer	347	174	174	32 %	110	55	55	50,0 %
Dishwasher	234	163	71	61 %	142	99	43	30,5 %
Desktop PC inc. monitor	276	100	177	79 %	218	79	139	63,9 %
Laptop	56	25	30	42 %	23	11	13	54,3 %
Router for Internet	58	29	30	48 %	28	14	14	50,7 %
Wireless access point	72	13	59	33 %	24	4	19	82,0 %
Printer	33	17	16	67 %	22	11	11	49,5 %
TV CRT	124	124	0	93 %	114	114	0	0 %
TV LCD	186	125	61	22 %	42	28	14	32,8 %
TV Plasma	400	337	63	9 %	35	30	6	15,9 %
DVD recorder player	23	8	15	67 %	15	5	10	65,3 %
Hi-Fi	46	7	38	72 %	33	5	27	84,3 %
Satellite/cable TV box	75	43	32	41 %	31	18	13	42,2 %
Air conditioner	372	227	145	17 %	63	38	24	39,0 %
Oven/cooker	301	226	75	80 %	241	180	60	25,0 %
Microwave oven	33	28	5	67 %	22	19	3	15,0 %
Water kettle	70	33	36	50 %	35	17	18	52,3 %
Vacuum cleaner	65	18	47	100 %	65	18	47	72,5 %
Lamps	487	184	303	100 %	487	184	303	63-64 %
Sum	4833	2650	2182		2695	1409	1283	47,6 %

Table 3-11 shows the average yearly household savings per appliance by switching to best available technology and the total energy savings for the 12 European countries participating in REMODECE. By switching to best available technology the average European household can save about 1 300 kWh per year. We have not calculated BAT savings for CRT TVs, because it is most likely that CRT TVs will be replaced with either LCD TVs or plasma TVs. Aggregated to include all 12 REMODECE countries, the savings will be about 165 TWh per year.

Table 3-11 Energy Savings. Values per Household and Aggregated to Multinational level

Appliance	Average Yearly Household Savings	Yearly Savings In Total for the 12 REMODECE Countries
<i>Unit</i>	<i>kWh/household</i>	<i>GWh</i>
Chargers	7	873
Refrigerator without freezer	67	8 532
Refrigerator with freezer compartment	182	23 216
Freezer	162	20 564
Washing machine	45	5 757
Clothes dryer	55	7 019
Dishwasher	43	5 521
Desktop PC including monitor	139	17 721
Laptop PC	13	1 608
Router for Internet	14	1 803
Wireless access point	19	2 471
Printer	11	1 380
TV CRT	0	0
TV LCD	14	1 743
TV Plasma	6	709
DVD recorder/player	10	1 265
Hi-Fi	27	3 493
Satellite/cable/air set top box	13	1 661
Air conditioner	24	3 106
Oven/cooker	60	7670
Microwave oven	3	420
Water kettle	18	2 320
Vacuum cleaner	47	6 039
Lamps	303	40 689
Total	1 283	165 579

Table 3-12. Per Household Annual Electric Energy Savings by Switching to Best Available Technology (BAT) in European Households

Country	ALL	BE	BG	CZ	DE	DK	FR	GR	HU	IT	NO	PT	RO
Appliance	kWh												
Chargers	7	7	7	7	7	7	7	7	7	7	7	7	7
Refrigerator	67	127	69	26	102	104	62	10	148	19	100	18	34
Fridge freezer	182	127	169	198	182	127	167	259	68	208	153	230	209
Freezer	162	243	108	90	228	237	147	82	155	91	238	157	105
Washing	45	43	46	42	46	42	46	45	43	47	46	45	39
Clothes dryer	55	116	7	3	75	102	87	14	7	16	82	49	8
Dishwasher	43	44	18	9	42	47	61	38	11	51	63	50	6
Desktop PC	139	132	90	61	212	159	78	109	101	147	124	155	58
Laptop PC	13	18	7	15	7	27	6	11	10	28	22	22	5
Router for	14	15	2	9	17	20	14	10	8	17	20	14	2
Wireless access	19	19	19	19	19	19	19	19	25	19	44	19	19
Printer	11	11	5	12	12	14	8	11	7	13	10	13	7
TV CRT	0	0	0	0	0	0	0	0	0	0	0	0	0
TV LCD	14	45	3	14	9	14	16	12	14	14	30	11	14
TV Plasma	6	10	2	6	1	6	11	1	6	6	32	2	6
DVD	10	10	7	10	9	13	11	12	9	13	11	11	4
Hi-Fi	27	32	18	26	28	27	26	33	16	34	38	29	12
Set top box	13	2	5	12	20	11	9	9	4	15	12	15	3
Air conditioner	24	7	32	5	24	3	2	77	8	55	36	29	13
Oven/cooker	60	50	60	31	63	75	60	60	60	60	72	60	60
Microwave oven	3	3	3	4	3	3	3	3	4	3	0	4	3
Water kettle	18	18	18	18	18	18	18	18	18	18	18	18	18
Vacuum cleaner	47	47	47	47	47	47	47	47	47	47	47	47	47
Lamps	320	320	320	320	320	320	320	320	320	320	320	320	320
<i>Total</i>	1 301	1 448	1062	986	1493	1443	1224	1208	1095	1249	1526	1326	999

Table 3-13. Aggregated Annual Electric Energy Savings by Switching to Best Available Technology (BAT) in European Households

Country	ALL	BE	BG	CZ	DE	DK	FR	GR	HU	IT	NO	PT	RO
Appliance	GWh												
Chargers	873	30	21	31	273	17	186	25	27	164	15	26	56
Refrigerator	8 532	565	213	116	4 053	262	1 676	36	575	461	222	69	283
Fridge freezer	23 216	565	518	893	7 257	320	4 523	957	266	4 976	338	884	1 719
Freezer	20 564	1 079	330	405	9 083	595	3 988	303	604	2 184	528	601	862
Washing machine	5 757	190	141	191	1 831	106	1 238	166	168	1 135	102	172	319
Clothes dryer	7 019	516	21	15	2 967	258	2 356	52	26	373	181	187	48
Dishwasher	5 521	195	55	42	1 674	119	1 667	139	41	1 211	139	192	46
Desktop PC	17 721	588	276	273	8 425	400	2 110	403	392	3 503	274	596	481
Laptop PC	1 608	82	22	68	288	68	164	40	40	663	48	86	39
Router for Internet	1 803	67	5	43	671	50	378	37	31	410	44	55	13
Wireless access point	2 471	86	60	87	772	49	527	72	96	464	97	75	160
Printer	1 380	50	15	54	490	35	229	40	27	314	22	50	54
TV CRT	0	0	0	0	0	0	0	0	0	0	0	0	0
TV LCD	1 743	198	10	62	362	34	431	43	53	328	68	42	113
TV Plasma	709	42	5	25	29	14	310	5	22	133	70	7	46
DVD recorder/player	1 265	46	20	44	338	33	288	45	34	314	25	44	34
Hi-Fi	3 493	141	55	119	1 115	68	709	122	63	808	85	110	98
Set top box	1 661	10	15	54	794	28	233	33	17	364	27	57	29
Air conditioner	3 106	32	98	24	971	7	47	284	33	1 317	80	111	103
Oven/cooker	7670	220	185	139	2513	189	1637	222	235	1441	160	231	496
Microwave oven	420	15	10	16	133	8	90	12	15	79	1	14	27
Water kettle	2 320	81	56	82	725	46	495	67	71	436	40	70	150
Vacuum cleaner	6 039	211	146	214	1 888	119	1 289	175	185	1 135	105	182	391
Lamps	40 689	1 420	981	1 439	12 717	805	8 686	1 180	1 247	7 645	708	1 228	2 632
<i>Total</i>	165 580	6 429	3 258	4 436	59 368	3 631	33 257	4 457	4 270	29 861	3 379	5 089	8 220

3.9 Potential CO₂ Savings by Switching to Best Available Technology

Table 3-14 shows that there is a savings potential of 165 TWh and an emission savings potential of 72 million ton per year by switching from present technology (PV) to best available technology (BAT). For calculation of CO₂ emissions, a factor of 435 ton CO₂/GWh is used as a common value for Europe except Norway. The factor is calculated as the European average emission of electricity production under average generator efficiency using the average mix of fuel.

Table 3-14. Per Household and Aggregated Annual Energy Savings and Emission Savings by Switching to Best Available Technology (BAT) in the 12 Countries Participating in REMODECE

Appliance	Per Household Saving	Total Saving for the 12 Countries Participating in REMODECE	Total Saving of CO₂
Unit	kWh/year	GWh per year	kilo ton per year
Chargers	7	873	373
Refrigerator	67	8 532	3 615
Refrigerator with freezer	182	23 216	9 952
Freezer	162	20 564	8 716
Washing machine	45	5 757	2 460
Clothes dryer	55	7019	3 053
Dishwasher	43	5 521	2 341
Desktop PC	139	17 721	7 589
Laptop	13	1 608	678
Router for Internet	14	1 803	765
Wireless access point	19	2 471	1 033
Printer	11	1 380	591
TV CRT	0	0	0
TV LCD	14	1 743	729
TV Plasma	6	709	278
DVD recorder player	10	1 265	539
Hi-Fi	27	3 493	1 482
Satellite/cable/air TV box	13	1 661	710
Air conditioner	24	3 106	1 316
Oven/cooker	60	7 670	3 336
Microwave oven	3	420	182
Water kettle	18	2 320	992
Vacuum cleaner	47	6 039	2 581
Lamps	303	40 689	17 391
Sum	1 282	165 580	72 027

4 Discussion of Results

For verification of the quality of the estimated values for different appliances, the number of measurements per appliance and confidence intervals calculated with standard statistical methods are shown in Table 4-1. Generally a high number of measurements give a more significant and accurate estimate than few measurements. It is not performed an analysis on how many measurements that are necessary to obtain a significant estimate. In total we have many measurements of the appliances with high energy consumption, like washing machine, TVs etc., and we can state that we have significant estimates of the consumption in these appliances. Even if we have performed many measurements on lamps, lighting is one of the most uncertain estimates. Some countries have measured all lamps, some have measured the most frequently used lamp and some have measured a random selection of lamps. Depending on measurement method used, the distribution of uncertainty may be different. Because of that, we have not calculated standard deviation or confidence interval for lamps.

A small confidence interval indicates a significant estimate, which is due to a low standard deviation in the energy consumption. In general we must be aware that within each appliance, there are a lot of makes and models with different yearly consumption (e.g. energy efficiency classes). Also, the use of some appliances is varying a lot between different consumers. A high confidence interval indicates that there are too few measurements for this appliance type.

Table 4-1 Statistical Analysis of Measurements. Not corrected for Ownership

Appliance	Total N° Analyzed	Measured Yearly Consumption	Confidence Interval	Confidence Interval
<i>Unit</i>	<i>N°</i>	<i>kWh</i>	<i>kWh</i>	<i>%</i>
Chargers	14	13	18	136 %
Refrigerator without freezer	206	384	19	5 %
Refrigerator with freezer	288	451	20	4 %
Freezer	126	543	37	7 %
Washing machine	506	184	9	5 %
Clothes dryer	64	347	85	24 %
Dishwasher	198	234	16	7 %
Desktop PC including monitor	202	276	22	8 %
Laptop PC	180	56	7	12 %
Router for Internet	33	58	12	20 %
Wireless access point	6	72	44	61 %
Printer	41	33	9	28 %
TV CRT	708	124	8	7 %
TV LCD	145	186	17	9 %
TV Plasma	56	400	74	19 %
DVD recorder/player	162	23	4	16 %
Hi-Fi	281	46	4	8 %
Satellite/cable/air set top box	108	75	10	13 %
Air conditioner	28	372	322	87 %
Oven/cooker	23	301	90	30 %
Microwave oven	78	33	8	24 %
Water kettle	58	70	16	22 %
Vacuum cleaner	99	65	15	22 %
Lamps	7 849	487	-	-
<i>Total</i>	<i>11 459</i>	<i>4 833</i>	<i>-</i>	<i>-</i>

Based on the values in table 4-1, we can have confidence in our estimates of cooling and washing appliances, except clothes dryers. The estimates for PCs are also trustworthy, but not for other devices connected to the PCs. Our estimates for conventional (CRT) and LCD TV's are also good, but not for plasma TVs. Air conditioners have a very high confidence interval, because of too few measurements. Other devices have moderate or high confidence intervals.

To calculate the CO₂ emissions the standard emission coefficient of 435 ton/GWh for CO₂ emission from electricity production in EU today was used. If the demand for electricity is reduced by 40 - 50%, this factor will probably change. If the renewable share of electricity production is increased, the emissions will also decrease. It is possible to calculate such effects using, for example SINTEF's Multi-area Power market Simulator, but this is outside the scope of this project.

Our estimates of Best Available Technology are very uncertain. As we have seen, it is difficult to compare laboratory tests and manufacturer information with measured consumption for many appliances. We have mostly used the 10% lowest power (watt) consumed or lowest country average. In many cases we have found a consumption in the measurements that is even lower than different sources claim that the consumption using the Best Available Technology should be. Future improvements of best Available Technology have not been analyzed. There are under development a lot of appliances consuming much less energy than the consumption today.

The same is the situation for Standby Energy, where it is difficult to define exactly what standby is. Our estimates are somewhat lower than other estimates. One reason may be that we have taken ownership into consideration when calculating the household average. We have not been able to analyze the differences in standby estimates in detail.

As mentioned in chapter 2, all our estimates are probably too high due to biases in the measurement campaigns. As an example, some of the countries have reported that the share of families with children in the measurement campaign is about 50 %, while the country average may be about 30%. Families with children usually use more electricity than families with one or two persons. The same is probably the situation for most of the other participating countries. Hence both the energy savings and reductions of CO₂ emissions may be less than the values we have calculated.

5 Summary

This report describes the results of the analysis of the measurement campaign. The measurement campaign is performed in about 1 200 households. About 12 000 single appliances are measured and analyzed. The appliances are grouped into 24 appliance groups or “end-uses”. The time interval for the measurements is mainly 10 minutes and each measurement has a measurement period of about two weeks. Some tables show “measured” values, where the consumption has been extrapolated from two weeks to one year. The measured values are also called the consumption per appliance. Most of the tables are corrected for appliance ownership, obtaining the consumption per household. By multiplying the consumption per household with the number of households per county, we obtain the aggregated consumption per end-use and per country and for all participating countries. This is called the Present State. Best Available Technology has been identified mainly from the measurements. In some cases other sources for Best Available Technology have been used. The savings by replacing the existing appliance stock with the Best Available Technology have been estimated both in GWh and million ton CO₂ using the standard EU mix for CO₂ emissions from electricity production.

Freezer is the appliance using most energy, about 540 kWh per appliance and year in measured average. Refrigerator with freezer uses about 450 kWh, while refrigerators without freezer use about 300 kWh. Washing machine uses about 180 kWh, while clothes dryer uses about 350 kWh. Air condition uses about 370 kWh per year and electric cooker/oven use 300 kWh in average. A desktop PC uses about 276 kWh, while laptop PCs use about 60 kWh per year. Much of these differences may be explained with technology as well as usage pattern. A conventional (CRT) television uses about 125 kWh and a LCD TV about 190 kWh. It must be noted that LCD TVs are used about twice as many times per year as CRT or plasma TVs. A plasma TV uses 400 kWh in average. Some of the differences may be explained by technology, size and different use of the TVs.

Lighting is calculated to about 487 kWh in average. An analysis of the minimum and maximum consumption shows there are large differences from household to household.

When ownership is taken into account the total energy demand is about 2 700 kWh per household per year in average. Air condition and cooker/oven are then included, but electric space heating and hot water are excluded. Due to low ownership rates on some appliances, the multinational average consumption for these appliances is reduced. As an example, the consumption in air conditioners is reduced from about 370 kWh measured to about 60 kWh per household per year when ownership is taken into account. The Czech Republic has the lowest average consumption with about 1 600 kWh per household. Norway has the largest consumption with about 3 800 kWh even if electric space heating and hot water in Norway are excluded.

Because energy per use of an appliance may be an interesting indicator, these values are calculated together with the number of uses per year and week. These indicators are also used when calculating Best Available Technology and energy savings. Energy used per wash in a washing machine is about 0,7 kWh, which indicates that most of the washes are performed at temperatures below 60 °C.

Energy in standby mode is also calculated. For most appliances the standby consumption is low. Some of the new electronic appliances have a high standby consumption. For all appliances it summarizes up to about 179 kWh per household per year. For all participating countries it summarizes to about 23 TWh or 10 million ton CO₂ for all the REMODECE countries.

The total consumption in the measured appliances is estimated to about 343 TWh in the participating countries. By changing to Best Available Technology, the households can reduce the consumption more than 47 % to about 1 400 kWh per year. The aggregated savings are roughly estimated to about 165 TWh or 72 million ton CO₂ per year. It is necessary to perform model calculations to obtain a better estimate of the emission savings. It is also necessary to perform more measurements, especially of energy efficient equipment and lamps to get more knowledge about the use of – and energy consumption in such appliances. Such measurements will make us able to obtain better estimates of the potential savings by replacing old inefficient equipment.

Within this project we have not taken lifetime of equipment or penetration time of Best Available Technology into account. Some of the savings can be achieved within short time. Examples of equipment with short lifetimes are desktop and laptop PC. Other appliances, like electric cooker/oven, may have a

long lifetime, and it may take several decades to replace today's equipment with more energy efficient equipment.

Through this project a comprehensive database of measurements has been established. Hopefully this can serve as a base for future energy analysis and decision making. In some cases, more measurements are necessary where they have not yet been performed or where there are too few. It is also necessary to perform measurements to observe changes over time. One example is that more energy efficient appliances often are replaced with larger sized appliances or one lamp is replaced by several lighting points (that is the case of using halogen lamps might add up to a higher consumption), and the potential energy savings may be less than we have estimated. Forecasting the future consumption, it is also important to be aware that the comfort level per country is very different and countries in the lower end are expected to increase their comfort level.

6 References

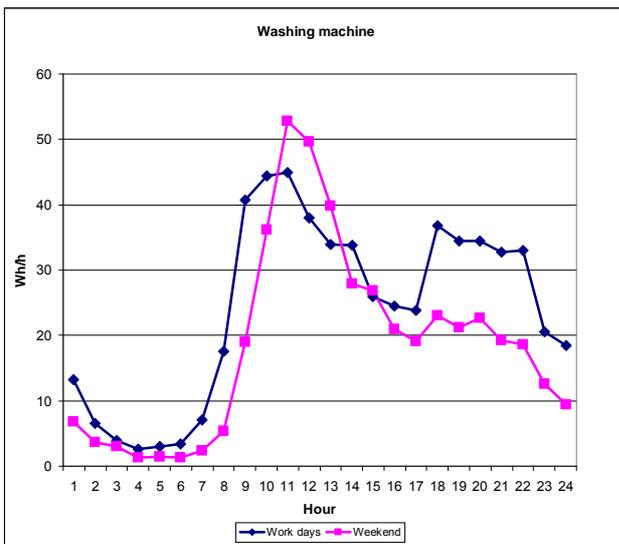
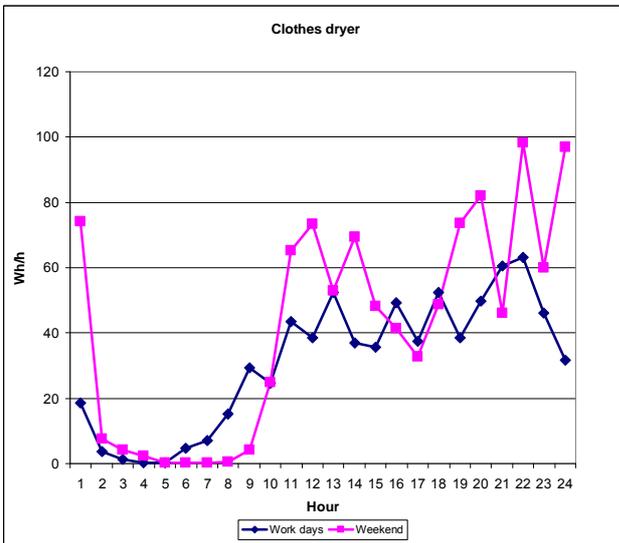
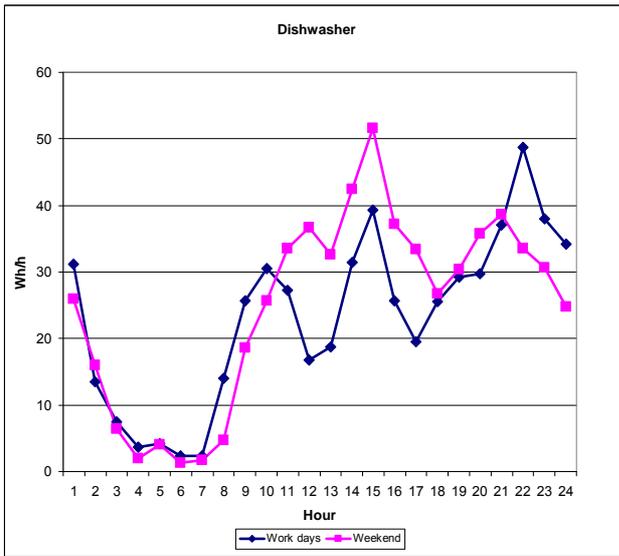
- [1] Barbara Schlomann, Fraunhofer ISI "Evaluation and Monitoring for the EU Directive on Energy En-Use Efficiency and Energy Services; Task 4.2: harmonised bottom-up evaluation methods.", 7 may 2008
- [2] "Final Report by Air Conditioner Evaluation Standard Subcommittee, Energy Efficiency Standards Subcommittee of the Advisory Committee for Natural Resources and Energy "
- [3] "Topten" www.topten.be

Appendix I

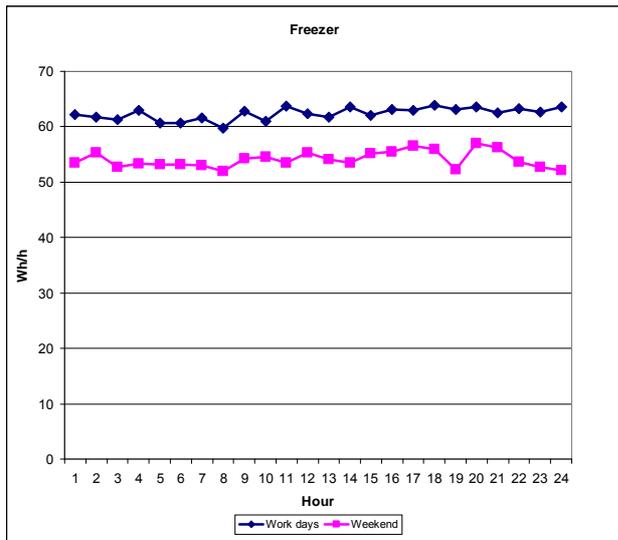
This appendix shows load curves for all groups of applications. The data shows average values based on metered data from all countries that have participated in the project. The values shown are split up in workdays (Monday – Friday) and weekends (Saturday and Sunday), and have the unit of Watt (Watt hour/hour – average consumption during hourly intervals).

Dishwashers, Washing machines and clothes dryers

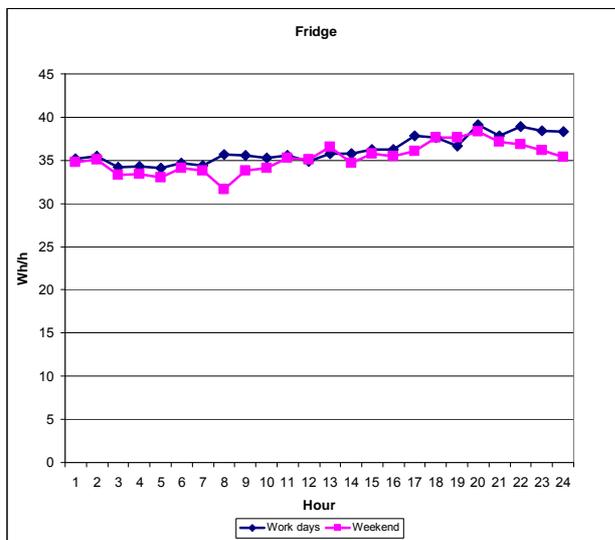
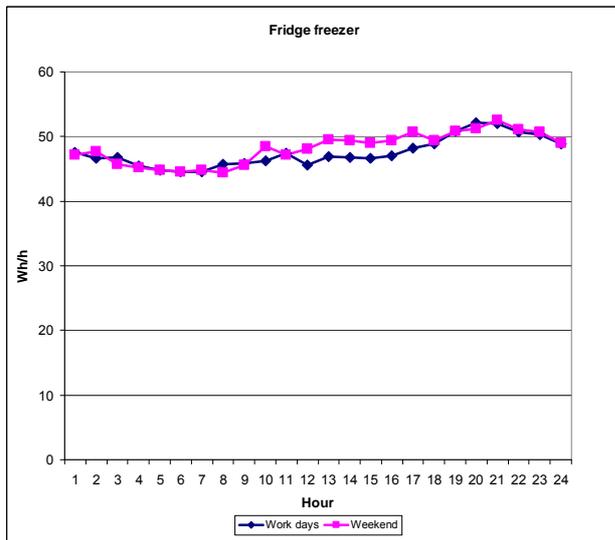
These types of applications are mainly used during afternoons. Peaks are at 15:00 hours and at 22:00 hours. There are different patterns for weekends and working days, there is more activity at weekends, at least for drying. Night-time consumption is low, although traceable.



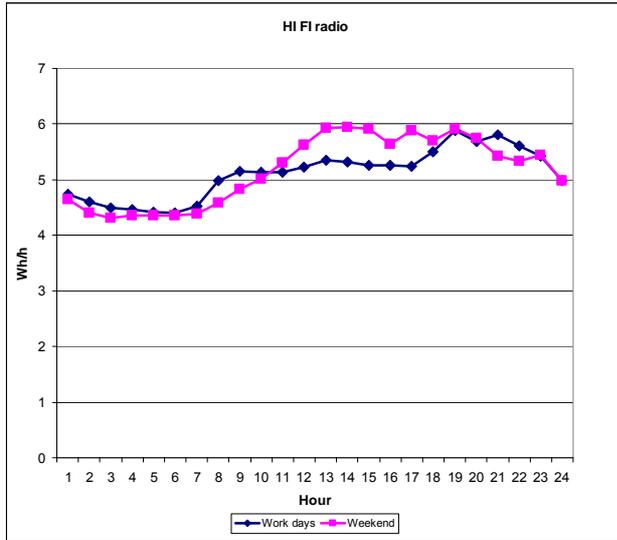
Refrigerators, freezers and combinations



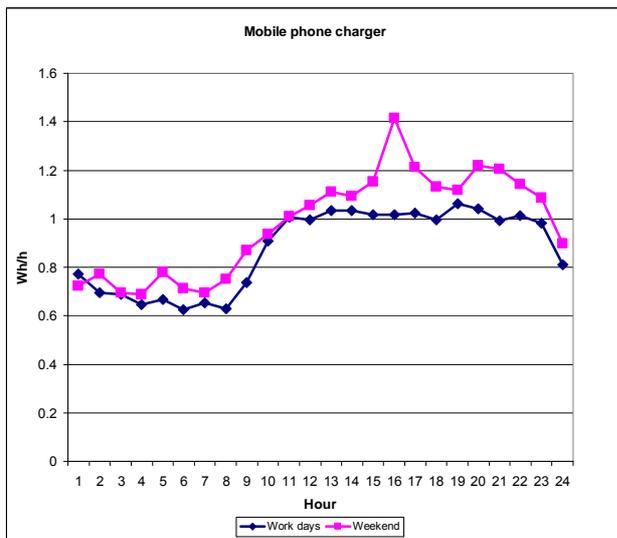
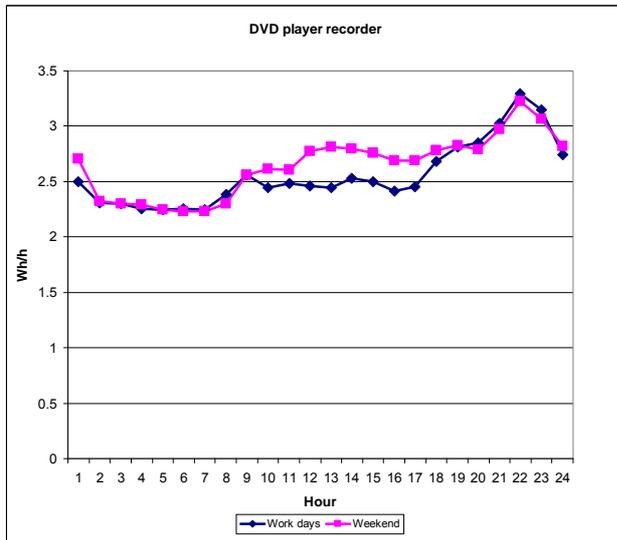
These types of applications are automatically turned on and off dependent on when the thermostat indicates too high temperature. Therefore the consumption is relatively flat. The fridge freezer (refrigerator with freezer compartment) has a greater distribution of energy demand during the day, maybe due to more use of this appliance (opening of the door).



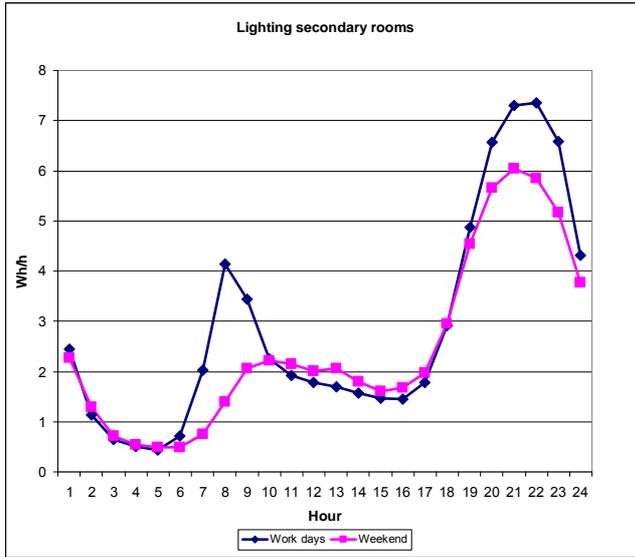
Electronic equipment



These types of applications are mainly used during afternoons, when people are home from work. There are clearly signs of standby energy, as a lot of the energy is used during off peak and nights.

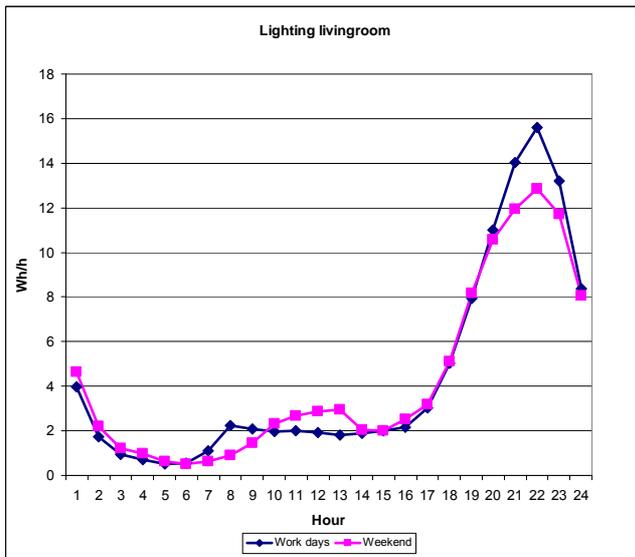


Lighting



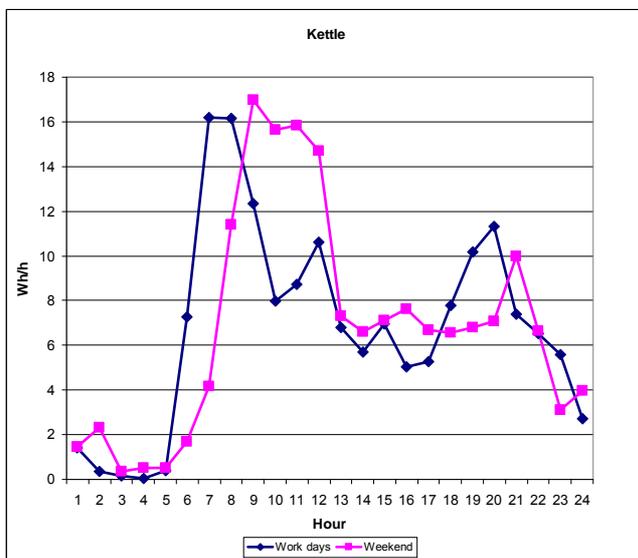
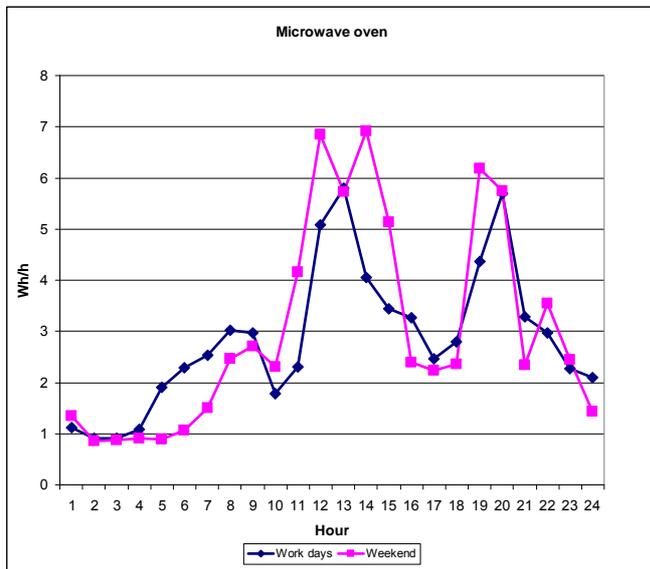
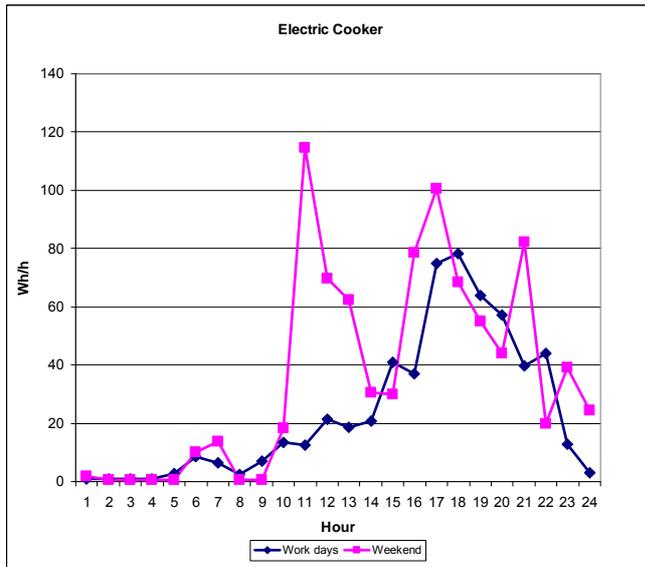
Lighting is clearly used during afternoon hours. Some lights are on during nights, but people tend to shut off lights when they leave a room unoccupied. Note the difference between living room and other rooms during week days. People do not turn on lights in the living room during morning hours.

The values shown are for the average bulb, this is the reason of the low power consumption.



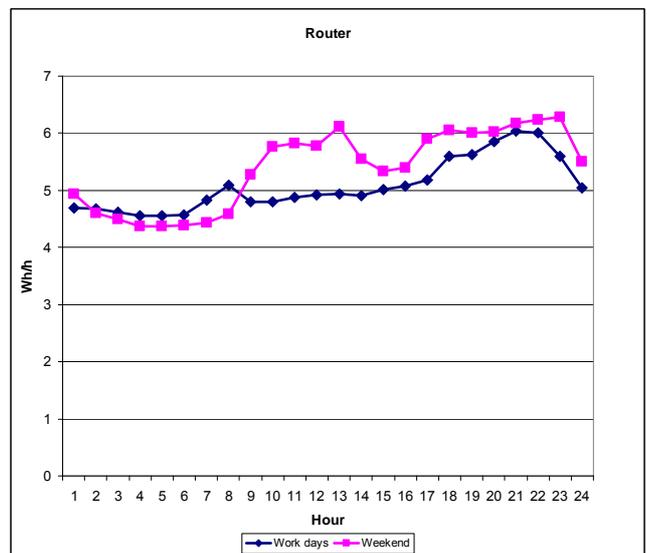
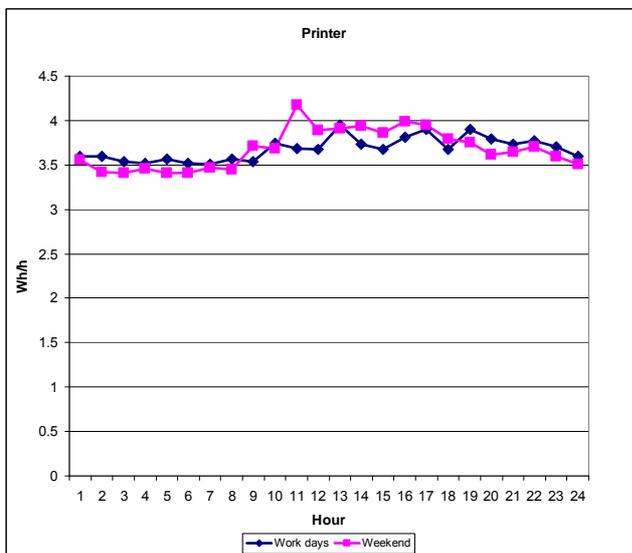
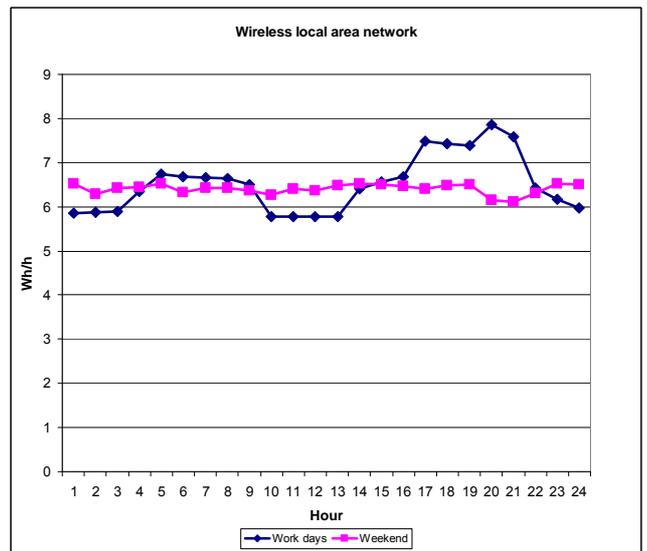
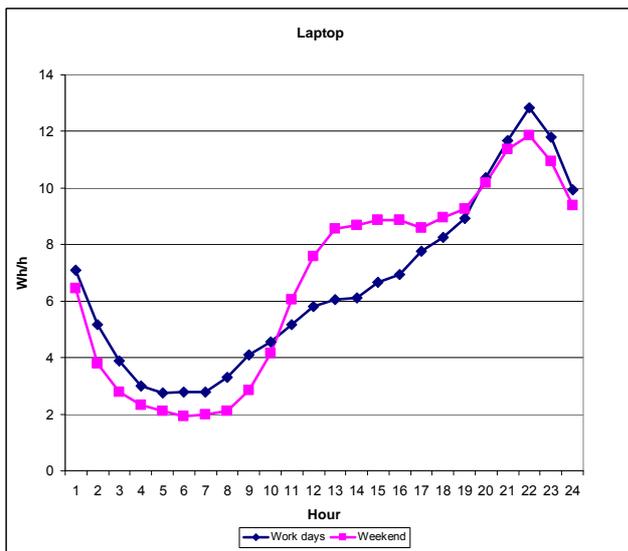
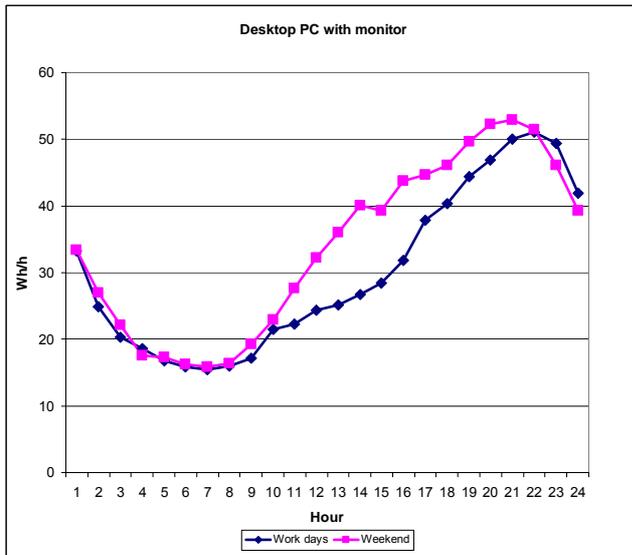
Cooker and other kitchen equipment

These types of equipment are used when people are preparing food for dinner and other meals. Dependent on country habits the time might vary a little. Note the difference between weekends and work days.

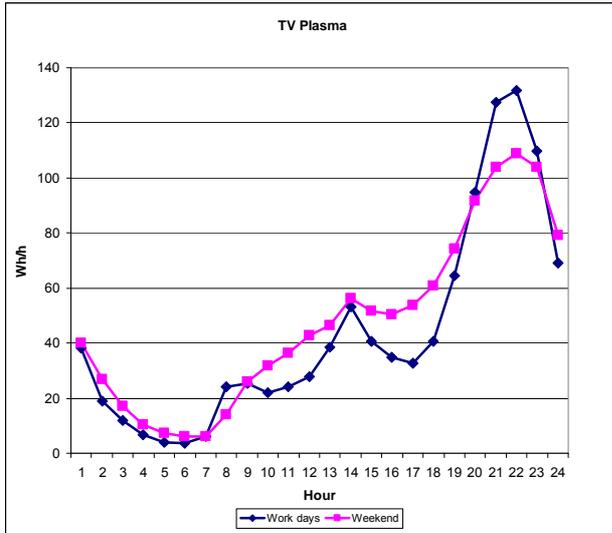


PCs and peripheral equipment

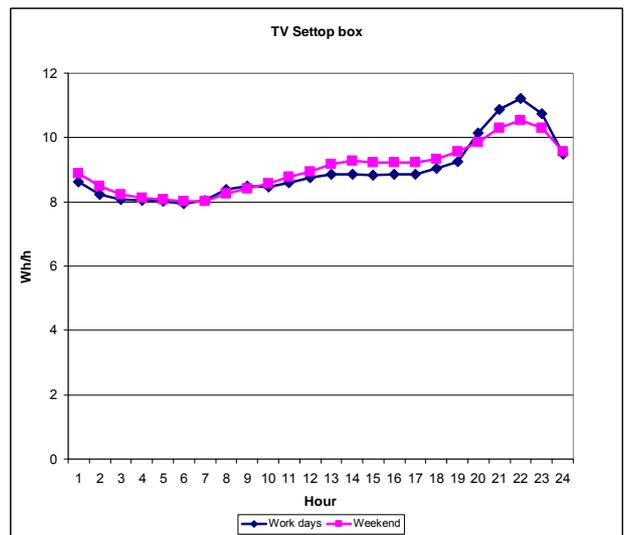
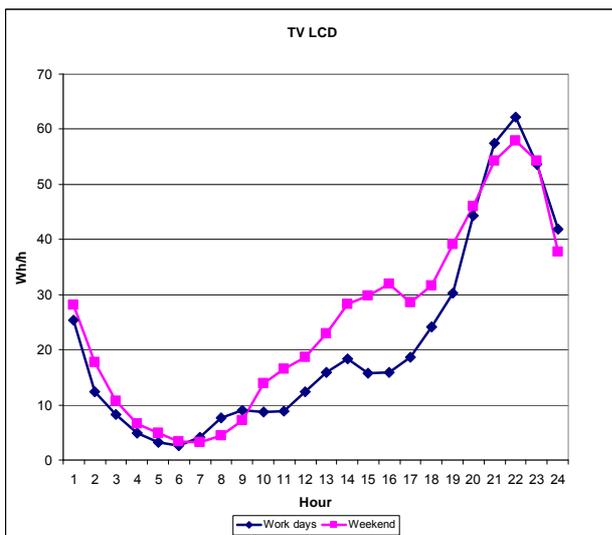
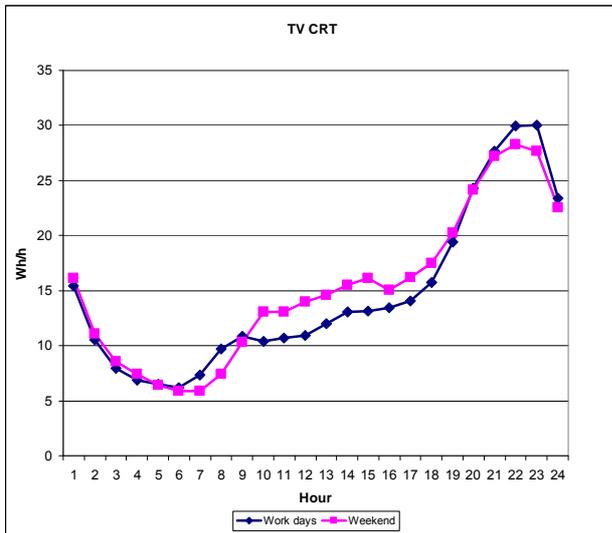
PCs (including monitor) and laptops are used during afternoons, peak hours are at 22:00 hours. Clearly these appliances are more used during early afternoons during weekends. Peripherals are on most of the time since they must be available for use by the PCs at any time.



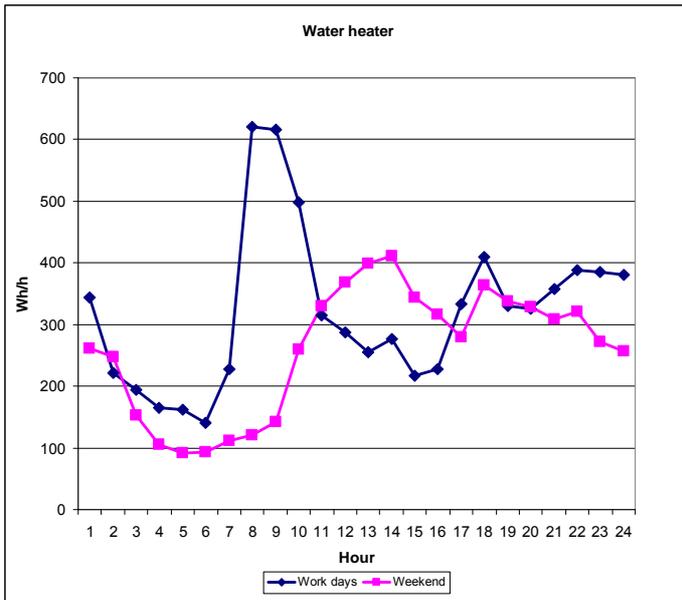
TVs and peripherals



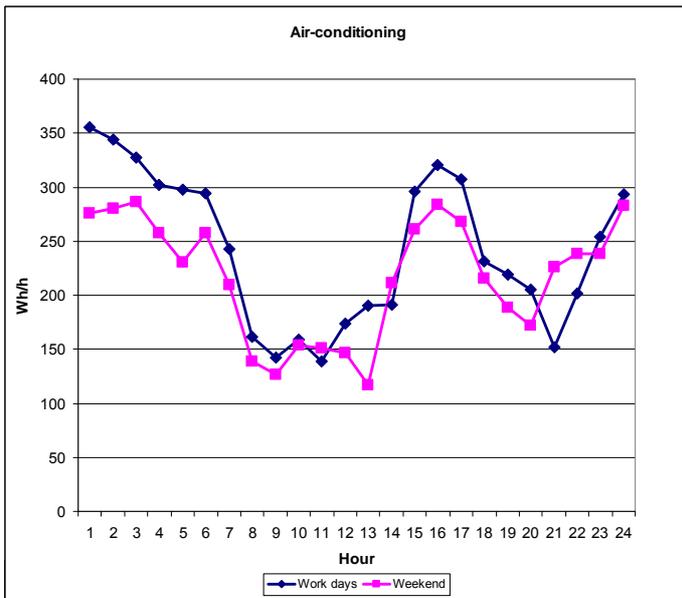
These applications are used most during afternoons. Some activity due to standby mode use is visible during night and mornings.



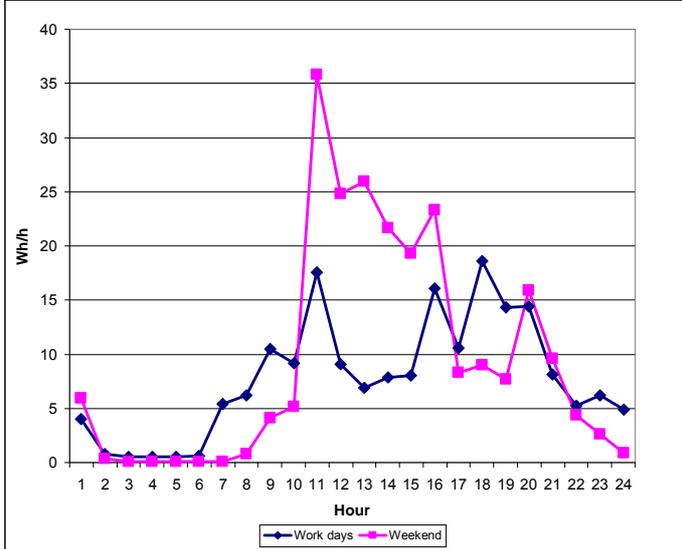
Miscellaneous applications



Electric water heaters are mostly used in Norway. During night hours energy losses are covered. These losses are higher than all other standby losses together. A significant energy demand could be avoided if the energy demand from use of hot water could be served instantaneous, so the need for storing of the hot water could be avoided. Better insulation would also help.



The use of air condition is a growing market in Europe the latest years. In colder countries as Norway heat-pumps have the effect of reducing the electric heating, as the efficiency of heat pumps are much higher than for resistance heating.



The energy used for vacuum cleaning is low. Clearly there is no standby consumption for these appliances.

Appendix II

This appendix gives a detailed description of the analysis methods used in this report to aggregate from measurements to national energy consumption and saving potentials.

For each end-use appliance the electricity consumption per year using “Present State” or “Present Values” (PV) and using “Best Available Technology” (BAT) is defined. The BAT is found by scanning and analysing the collected measurements, and is also found based on manufacturer specifications or similar information. The BAT per appliance is the same for all countries, but the aggregate values will depend on ownership level, and on the use pattern (load factor) of the individual countries. The Present State is country specific based on data from the monitoring campaigns and on previous campaigns.

The baseline to consider is stock replacement and not the market replacement. From the survey with questionnaires we have the distribution of appliances per efficiency level (stock) for some appliances. The idea of REMODECE is to identify the total savings (technical potential) by replacing installed inefficient technologies by BAT in the market. Structural effects are not integrated in the calculations.

Refrigerators, combinations (fridge/freezers) and freezers

These types of appliances are automatically operated, and are less influenced by manual use.

National Savings = $N \cdot (PV - BAT)$

Where

- Savings: TWh saved for a country per year
- N: Number of appliances in country
- BAT: Best available technology [kWh/year]
- PV : Present technology, common value for the appliance groups [kWh/year]

Details:

- PV : SINTEF has estimated these values for all countries provided that metered data (including “Household”⁵ files) are available
- For metered data older than 6 years, 20% has been subtracted – to handle improvements that have occurred the last 6 years.
- BAT : Common values provided by SINTEF Dependent on the mix of sizes which is unknown – but an expert estimate has been made
- The analysis are divided into 3 classes
 - Refrigerators without freezer compartment
 - Refrigerators with freezer compartment
 - Freezers

As the energy demand of cold appliances is dependent on the size of the individual metered unit, the country’s distribution share of the sizes are used to find the country specific values of consumption. The following types of refrigerators are used. The defined division into sizes in litres is used when estimating typical BAT for each country.

1. Volume less than 150 litres
2. Average volume (150-250 litres + “Unknown” in survey)
3. Volume more than 250 litres

When calculating BAT values for annual energy the following values are used [3]:

⁵ The “Household” files contains some information about the households and appliances monitored

Size	Unit	Refrigerator without freezer	Refrigerator with freezer compartment	Freezer
Small (<150 litres)	kWh/year	153,1	153,1	152,4
Average (150-250 litres)**	kWh/year	189,1	227,2	226,0
Large (≥250 litres)	kWh/year	224,5	257,2	249,0

Washing machines, clothes driers and dishwashers

These appliances are manually operated. The energy demand during single uses of the appliances are considered.

$$\text{National Savings} = N \cdot (PV - BAT) \cdot T$$

Where:

- Savings: TWh savings for a country per year
- N: Number of appliances in country
- BAT: Best available technology [kWh/use]
- PV : Present technology [kWh/use]
- T: Number of times of use per year

Details:

- In practice the households wash clothes at different temperatures, and lower temperature leads to lower energy demand. When BAT is calculated, the average mix of different wash temperatures and clothes fillings is considered. To simplify, the same average BAT are used for all countries.
- T: Number of times of use per year is determined by scanning the metered data.
- 10 minutes intervals are used when examining the metered data to find the per use consumption.

When calculating BAT values for annual energy the following energy per use values are used. The values are provided by SINTEF as the lowest country specific value for energy per use for all appliances in this category.

Appliance	Unit	Lowest country specific observation	Country
Dish washer	kWh/use	0,83	Hungary
Washing machines	kWh/use	0,51	Italy
Clothes dryer	kWh/use	1,53	Norway

Lighting

These appliances are manually operated, and have a seasonal variation.

$$\text{National Savings} = \text{SP} * \text{PV} * \text{N}$$

Where

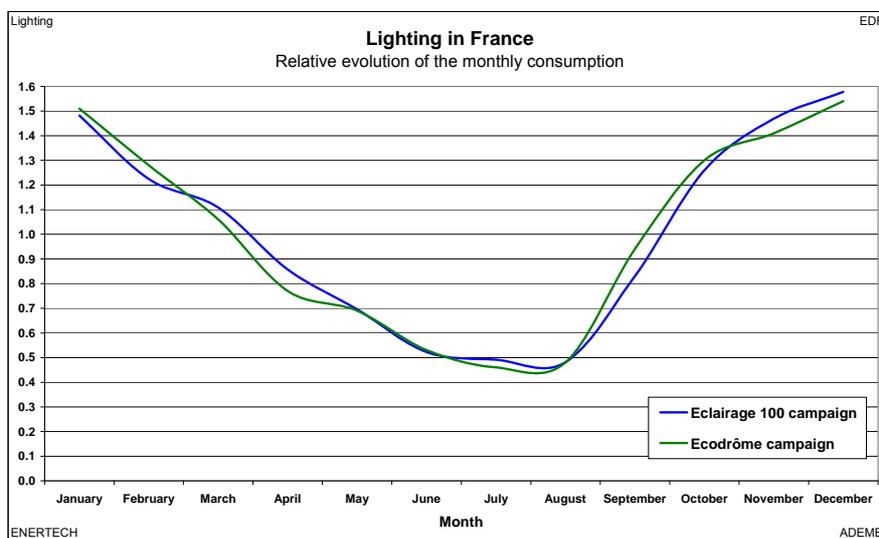
- Savings: TWh savings potential for a country per year
- N: Number of households in country
- SP: Savings potential [percentage]
- PV : Present technology [kWh/household/year]

Details:

- SP: Savings potential are provided by Energy Piano for GLS and halogen lighting sources. The breakdown of the total lighting consumption per country on different lighting sources are primarily based on the survey and secondary on the actually measurements in the 100 homes.
- PV: Present value is calculated as: Load factor * Installed Wattage* 8760 hours. The load factors are found by analysing the measurements and are adjusted for the fact that other lamps could be used less, and for the season where the measurements took place. The installed wattage is based on information from the different countries and the measurements per country.
- Load factors for the metered period, are found by SINTEF based on metered data
- Installed “Wattage” in typical household, are provided by participants – divided into 5 different lamp types and 2 types of rooms:
 - Living room
 - Other rooms
- Seasonal lighting distribution curves are provided by some of the countries and used for estimation of total year load factors.
- When calculating BAT, each type of lamp technology will be estimated separately.

An annual distribution of lighting is used so that metered data from a summer day will be corrected

upwards, and similarly, a winter metering will be corrected downwards.



The shown distribution is from France. This curve was used for correction of the lighting data for all countries that did not provide a national curve.

Savings potential for lighting is calculated dependent on a scenario that incandescent bulbs and halogen bulbs (high and low voltage) are changed to compact fluorescent light (CFL) that have improved light efficiency.

Saving potential

Lighting Technology	Multiplication Factor when Changing To Best Technology (Best technology is equal to CFL and fluorescent)
Halogen high voltage	44,8 %
Halogen low voltage (12 Volt)	32,6 %
Incandescent GSL:	25.4 %
CFL: 0%	100 %
Fluorescent tubes	100 %

Office installations, electronics, air conditioners etc.

These appliances are mainly manually operated. The annual energy demand is heavily dependent on behaviour, as the number of hours of use in individual households varies a lot. Behavioural aspects are treated by estimating the Load factor for each appliance type, the load factor materialises the behavioural aspect.

The energy demand in Standby mode can be reduced considerably, and should be treated separately from the energy demand in ON mode.

National Savings=N*(PV-BAT)

Where:

- Savings: TWh for total country
- N: Number of appliances in country
- BAT: Best available technology [kWh/year]
- PV : Present technology [kWh/year]

Details:

- BAT : Load Factor * 8760 * Power_{BAT} + StandbyEnergy_{BAT}
- PV : Load Factor * 8760 * Power + Standby Energy – the load factor was estimated for the ON mode only
- A PC was considered together with the monitor, this is the only cluster that will be analysed
- In the REMODECE project, the standby mode is assumed to be the state where the appliance is not doing the function for which it was designed.

When calculating BAT values for annual energy the following values for power [Watt] consumption in On mode, *when the appliances are in use in a household* - are used. The values are found based on the metered values of all countries in the project. For Air-conditioning, average energy consumption values from Greece are used, and target improvement of COP factor (5,2) is applied. 10 % percentiles are also shown based on data for all countries. The 10 % percentiles may be lower than the lowest values because they refer to different values. The 10 % percentile refers to all countries, while the lowest value refers to only one country.

Appliance	BIOS Watt [1]	10 % Percentile Watt	Lowest average value of all countries Power when used (Watt)	Country or reference for lowest average
AIRCOND		522	4,5/5,2*1363=1179 Watt [2]	Greece
Charger	3,2	2,6	6,3	France
COOKER		632	1207	Hungary
DVD	45,9	5	6	Bulgaria
HIFI-Radio		5	18,9	Hungary
Vacuum cleaner		594	455	Germany
Kettle		513	625	Hungary
Microwave oven		206	406	Portugal
PC Laptop	36,9	36	57	France
PC desktop incl. monitor	188	96	141	Germany
Printer	347	6	10	France
Router		6	7	Norway
TV (CRT)	74	45	72	Hungary
TV LCD	125	47	82	Bulgaria
TV Plasma	262	168	252	Bulgaria
TV-Set top		9	14	Norway
WHEATER		1775	2000	Norway
WLAN		4,5	25	ALL

In the table values denoted in red are used when calculating best available technology. The values shown are in Watt.

For standby under BAT a power consumption of 0.5 Watts is applied for all appliances. This is according to [1]. When calculating the energy consumption for BAT, the registered energy consumption in standby mode for the dimensioning appliance (the appliance with the lowest power consumption according to the shown table) is changed to the new standby energy. When estimating the new standby energy, the country specific hours in standby mode is used for each appliance type.

The values in the table are used to find the yearly energy consumption for each country, using the load factors of each appliance for each country. We will then find the future BAT energy consumption for the appliance in the country. When finding the BAT energy, reductions in standby consumptions are also found and applied.

Appendix III

The calculation of present value of energy for lighting is based on the following data, where all data are specified for two room types and for five different lamp types.

- Average number of lamps per household
- Average size in watts

These data are filled in by most of the countries. Where missing data, Sintef has used data that are equal to data from France (for average size). For

Room types

Data are defined for two different room types, "Living room" and for "Other rooms". The reason for dividing in these room types is that households tend to use the lighting different in living rooms as opposed to other rooms. The occupation of living rooms have a longer time duration than other rooms, and lamps in living rooms will be used more often. It is reason to expect that the load factors would be different dependent on room type, and the results from the metered data showed a significant difference, where the load factor for living room is higher than for other rooms.

Lamp types

Data are defined for 5 lamp types. The reason for dividing between lamp types are mainly that the savings potential are different for the 5 types. Incandescent and halogen lamps can be replaced with more efficient types as CFL (compact fluorescent lamps).

In the table is shown the lamp types along with the corresponding BAT value by replacing with CFL or fluorescent lamp.

LAMP TYPE	BAT PERCENT OF PRESENT VALUE
GLS (incandescent lamps excluding halogen)	25.4%
Halogen 12 V (low) wattage	32.6%
Halogen 230 Volt low wattage	29.1%
Halogen 230 Volt high wattage	44.8%
CFL	100%
Fluorescent	100%

The next table shows key values of installed watt per household, the average load factor and the average electricity demand per year for the different countries that have participated in the project.

Country	Installed Watt	Load factor	Annual energy kWh/year	Remarks
BE	1144	5.2 %	524	Number of lamps and watt per bulb given
BG	832	5.3 %	776	Total watt installed given
CZ	692	1.1 %	68	Very low factor specified by Seven (Czech)
DE	793	5.1 %	352	Energy estimated by Fraunhofer
DK	1425	7.3 %	908	Number of lamps given, watt per bulb is average
FR	1530	3.4 %	452	
GR	1094	4.8 %	459	
HU	569	4.4 %	221	Average size of lamps not given
IT	1703	6.0 %	901	Average size of lamps not given
NO	1346	8.6 %	1013	
PT	1116	2.4 %	233	
RO	476	3.4 %	143	
ALL	1060	4.8 %	504	Average

The graph shows an overview of the electricity demand and the installed watt per household.

