Characterization of the household electricity consumption in the EU, potential energy savings and specific policy recommendations

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Abstract

Although significant improvements in energy efficiency have been achieved in home appliances and lighting, the electricity consumption in the average EU-27 household has been increasing by about 2% per year during the past 10 years. Some reasons for such increase are associated with an increased 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. With the objective of contributing 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, a large energy monitoring campaign, co-funded by the IEE programme, was carried out in 12 countries, accompanied by a lifestyle consumer survey. From the measurements carried out it can be concluded that IT and entertainment loads, including standby, are a key contributor to the power demand. In basically all types of loads there is wide range of performance levels, including new emerging technologies, in the models available in the market. Available technology, associated with responsible consumer behaviour, can reduce wasteful consumption. 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 BAT (best available technology) efficient appliances or the elimination/mitigation of standby consumption, can reach up to 48% savings. Specific policy recommendations to promote market transformation and behavioural changes in the equipment selection and operation have been identified.

Setting the context

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 on average about 2% per year in the period 2000-2005 [ODYSSEE, 2008], despite the numerous energy efficiency policies and programmes at EU and national level. In the period 1999-2004, the total electricity consumption in the residential sector in the EU-25 has grown by 11% [Bertoldi and Atanasiu, 2007]. According to IEA projections [IEA, 2003], 15% of the total appliance electricity consumption in Europe, by 2030, could be due to standby functionality. This represents an important potential saving as it is currently unregulated and efforts to introduce measures to reduce this wasteful consumption are only just beginning (last decade). According to the EuP Lot 6, the business as usual standby consumption by 2020 will be around 100 TWh, and the recommended implementation leads to at least a 55% improvement against the business as usual by that time horizon. 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), increased penetration of traditional appliances which still did not achieve the saturation level, increased number of households due to an increasing part of the population is living alone, increased use of the equipments, increased
number of lamps and TVs per home, increased size of some appliances and also more single family houses and apartments, and the widespread utilization of relatively new types of loads whose penetration and use has experienced a very significant growth in recent years. These loads include personal computers, printers/fax/multipurpose machines, game consoles/ play stations, large-screen home theatre/DVDs, HVAC auxiliary equipment, air conditioners, chargers (phones, power tools), home security systems, garage door openers, etc. A wide variety of small appliances (bread makers, coffee makers) with electronic controls is also entering the market in an increasing scale. Households are becoming more and more dependent on electronic/electric devices and gadgets, with ubiquitous microcontrollers/digital controls being embedded into most apparatus, to improve the performance and the quality of the provided services. Unfortunately in many cases little or no attention is given to the energy consumption, particularly in the standby modes.

Despite the large increase in the use of electricity in the residential sector and the consequent impact in CO2 emissions, there is little reliable knowledge at European level on how the electricity is used. 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 in the next decade, as well as to influence the user behaviour in the selection and operation of that equipment. The REMODECE project, which results are herein presented, was targeted at bridging the existing lack of information, through a relatively large concerted effort.

Overview of the REMODECE project
The aim of the REMODECE project was to contribute to an increased understanding of current and impending electricity use by European households resulting from different types of equipment, consumers’ lifestyles, and comfort levels. The project evaluated how much electricity could be saved by the use of the most energy efficient appliances, by adopting a suitable behaviour and by the reduction of standby consumption.

The detailed characterization of residential electricity use and credible estimates of the huge potential energy savings are important results of this two and a half year long research project, carried out in 12 different countries: Belgium, Bulgaria, Czech Republic, Denmark, France, Germany, Greece, Hungary, Italy, Norway, Portugal and Romania, with the objective of contributing to an increased understanding of current and impending electricity use by European households resulting from different types of equipment including, consumers’ lifestyles and comfort levels. A large-scale monitoring campaign in 12 countries and a consumer survey have been carried out: 100 households have been audited per country and 500 detailed questionnaires have been collected in each country. The collected data is accessible from the project Database which is online from the project web-site [www.isr.uc.pt/~remodece]. 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 was also investigated. Residential air conditioner loads are also increasing significantly in Southern Europe. Therefore, in Western European countries (Belgium, Denmark, France, Germany, Greece, Italy, and Portugal) the research focused mainly on new electronic loads, lighting, as well as air conditioning. In Central and Eastern Europe and Norway white appliances have also been targeted because these countries have not earlier executed measurement campaigns (which was the case for the Western countries).

The electricity consumption in the residential sector in EU-27 could be reduced by about 268 TWh per year [REMODECE]. This energy savings potential can be achieved with the best technology available (BAT) in the market, coupled with responsible user behaviour, and would lead to an impressive reduction carbon emissions (116 Mton CO2) as well as save money for the consumers. A long list of steps and tips to save electricity, such as the adoption of compact fluorescent light bulbs and LEDs, the change to A+ and A++ appliances, reduced standby power requirements, use of the washings machines at full load and the coldest water as possible, prefer LCD TV’s instead of plasma TV’s, buy energy-star labelled equipment and check for the ECO label, in summer use night ventilation for free-cooling, the use of solar water heaters, etc., are among the key measures identified to save electricity at home.

The project also addressed the identification of policies and strategies for market transformation to promote electricity end-use efficiency in the residential sector. To take advantage of the energy-saving opportunities identified, some product standards need to be introduced and others have to be tightened, and some policy incentives have to be changed. Current regulations and fuel subsidies, for example, often favour consumption over efficiency. Many steps are not taken, because energy users lack information or do not value energy efficiency enough to change their buying habits. Regulation changes, information campaigns, with clear and simple messages targeting households, together with incentives seems to be the best effective way to stimulate market transformation towards more energy efficient appliances and behaviour in the residential sector.

Methodology
Besides the field collected data with the REMODECE monitoring campaigns and survey questionnaires, energy consumption data from previous campaigns has been collected and was considered for analysis whenever useful. All the collected data is stored in the developed European Residential Electricity Consumption Database, available at the project web-site: http://www.isr.uc.pt/~remodece/database/login.htm.

The measurement campaign was performed in about 1 300 households and the survey involved the collection of 6 000 questionnaires, addressing both quantitative and qualitative data. The starting point of the methodology 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. About 1 500 single appliances were analysed. The time interval for the measurements was 10 minutes, and the monitoring period for the campaign was two weeks, which enabled the extrapolation to determine the yearly consumption.
On average 5-10 meters have been used to monitor major appliances or end-uses per household (cold appliances, washing machines, consumer electronics...). In the case of lighting, at least the 10 light sources have been monitored per household including the lamps with highest burning hours. At the time of installation of end-use recording equipment additional information has been collected, such as:

- information about every end-use recorded - this was especially important when several appliances went in as a sum and only one end-use recording meter was used for recording of the load for the cluster.
- information from the appliance label.
- size of the family, type of home and area.
- spot metering on small appliances not included in the end-use recording including standby consumption measurement.

For the analysis of the huge amount of collected end-use data, the Useload software tool (Developed by Sintef) was employed. This powerful software analysis tool has been further developed adapting to needs in the REMODECE Project. Several features have been added, Useload has both been used for the data analysis and calculation of the potential electricity savings that can be implemented by existing means through replacing the old inefficient appliances (Present State) by the best available technology present in the market (BAT) and changing to best practice use of application (BP) including reduced standby consumption.

The measurements were cleaned for data errors, first manually by each partner and then automatically by the software. The consumption of two weeks of measurements was 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 in use the whole year, while air conditioning is defined to have a utilization period of 3 months per year. The resultant value is called yearly consumption per appliance [kWh/appliance/year]. This value per appliance is multiplied with the appliance ownership to obtain the average yearly consumption per household [kWh/household/year]. Finally the yearly consumption per household is multiplied with the number of households in the country in order to obtain the national and multinationa consumption per appliance [GWh/appliance]. This is the Present State (PS) of residential electricity consumption. The Present State is country specific, is based on data from the monitoring campaigns, and is also based on previous campaigns, for some appliances. Besides the PS, also the BAT and/or BP need to be established for the calculation of the potential national energy efficiency savings. The power (Watt) used by the best technology (BAT) of the appliance was found from scanning and analysing the collected measurements, manufacturer specifications, information from databases like TopTen1 and results from the Eco-design2 studies. The BAT (Watt) per appliance is the same for all countries. The aggregate saving potential through BAT/ BP depends on the country specific hours of utilization and ownership level per appliance. The annual energy demand of BAT appliances are found by multiplying the BAT power (Watt) with the load factor (utilization hours) of the 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).

Structural effects as change of load patterns due to possible change of behaviour were not integrated in the calculations. 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 equipment using more energy.

Figure 1 presents the ownership rate for electrical appliances in the EU-12.

The number of households with double or triple refrigerators has been increasing in recent years. The study showed that the number of households with more than one refrigerator in Belgium, Norway, France and Germany is quite high, representing about 71%, 60%, 28% and 32% respectively. One reason for this high share is because people keep the old refrigerator running in the garage to cool beer and other drinks instead of disposing it in a proper manner by calling the local waste management facility and ask about disposal of white goods. There is a very high internet penetration rate, as well as the ownership rate for desktops, laptops, monitors and printer.

Electricity end-use consumption in the residential sector in EU-12

Figure 2 shows the distribution of yearly electricity consumption for a typical (average) European household. Refrigeration, including refrigerators and freezers, is the group of appliances requiring the largest part of the total household electricity consumption, with a share of 28%. Lighting is the second largest electricity end-user with a share of 18%. Other appliances such as vacuum cleaners and chargers represent about 3% of the total household electricity consumption. Standby3 consumption which represents about 11% of the total consumption is embedded in all end-uses, but is mostly concentrated in office equipment (includes Internet plus communications) plus entertainment appliances.

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1. TopTen is a consumer-oriented online search tool, which presents the best appliances in various categories of products. The key criteria are energy efficiency, impact on the environment, health and quality (www.topten.info).

2. Eco-design aims the integration of environmental aspects into product design with the aim of improving the environmental performance of the energy-using product throughout its life cycle (http://ec.europa.eu/enterprise/eco_design).

3. The Standby definition in the REMODECE was based on the standard (IEC62301: “House electrical appliances — Measurement of standby power”, published in June 2005, and its European going transcription EN 62301”. 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.
Figure 3 a), b) and c) show estimates of yearly energy consumption for all the audited equipments: average, minimum and maximum consumption values per appliance are presented as well as the total number of equipments monitored, at the top of each bar. The values presented are not corrected for ownership levels.

Most of the differences between the minimum and maximum values can be explained by different usage pattern and by the different technologies. For appliances that are automatically operated, it is difficult to find a reasonable explanation for the large variations apart from some differences due to different sizes and technologies. In some cases it may be that the appliance has not been normally used in the measurement periods and/or that the estimated minimum values for the yearly consumption is only the standby consumption. Old appliances (e.g., refrigerators and freezers) can have a much poorer performance than “Up-to date” appliances.

Energy demand per appliance type

The load curves for a typical European-12 household for a typical week day of the year, based on the results from the monitoring campaigns, is presented in Figures 4 and 5.

Washing and drying are mainly used during the day, with peaks at 11:00 and 22:00. Night time consumption is low although it is recommended to load shifting these loads if cheap night tariff is available. The refrigeration consumption is relatively flat although it is possible to see a greater variation of the
Figure 3a): Annual electricity consumption range for several appliances [REMODECE campaign].

Figure 3b): Annual electricity consumption range for office equipment [REMODECE campaign].

Figure 3c): Annual electricity consumption range for entertainment equipment [REMODECE campaign].
consumption demand during the day, due to more use of these appliances and more door openings. Concerning electronic equipment, (PC & accessories and television and peripherals), these loads are mainly used during afternoons when people are back home from work, but in the case of PC & accessories, it is noticeable that many of these loads are being used 24 hours per day (an increasing amount of people work at home and others don’t turn the equipment off), and in the case of TVs and peripherals, some activity due to stand by mode is visible during night. Lighting is clearly more used during afternoon hours, after 17:00 and the peak is around 10:00. Some lights are on during nights, mostly outdoor lights and people tend to shut off lights in unoccupied rooms. The total average number of lamps per household is 27. On average there are 4 compact fluorescent lamps per household. Incandescent and halogen are the most widely used lamps, and there is a large potential for the application of CFLs in the households, for the replacement of incandescent lamps, which represent 50% of the total lamps installed.

The standby electricity consumption for the appliances measured under the REMODECE project is presented in Table 1. Measurements were taken both of load curves of equipment clusters (entertainment and office equipment), as well as spot measurements of the low power modes for different types of electronic equipment in the households. These are values for the typical household.
Table 1: Standby energy consumption – results from the measurement campaign.

<table>
<thead>
<tr>
<th>Appliance</th>
<th>Spot Measurements</th>
<th>Average Standby Power Considering Ownership</th>
<th>Considering Ownership At EU-12</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>W</td>
<td>W</td>
<td>kWh/year/household</td>
</tr>
<tr>
<td>Microwave oven</td>
<td>2,2</td>
<td>1,5</td>
<td>11,2</td>
</tr>
<tr>
<td>Desktop PC including monitor</td>
<td>6,4</td>
<td>5,0</td>
<td>38,7</td>
</tr>
<tr>
<td>Laptop PC</td>
<td>2,1</td>
<td>0,9</td>
<td>6,7</td>
</tr>
<tr>
<td>Router for internet, Modem, Wireless access point</td>
<td>8,0</td>
<td>3,8</td>
<td>29,4</td>
</tr>
<tr>
<td>Scanner</td>
<td>6,3</td>
<td>2,3</td>
<td>17,8</td>
</tr>
<tr>
<td>All in one printer</td>
<td>4,4</td>
<td>1,9</td>
<td>14,9</td>
</tr>
<tr>
<td>Printer</td>
<td>4,8</td>
<td>3,2</td>
<td>24,6</td>
</tr>
<tr>
<td>Fax machine</td>
<td>4,0</td>
<td>0,7</td>
<td>5,3</td>
</tr>
<tr>
<td>Phone</td>
<td>2,8</td>
<td>2,5</td>
<td>19,4</td>
</tr>
<tr>
<td>TV CRT</td>
<td>3,1</td>
<td>2,9</td>
<td>22,0</td>
</tr>
<tr>
<td>TV LCD</td>
<td>1,8</td>
<td>0,4</td>
<td>3,2</td>
</tr>
<tr>
<td>TV Plasma</td>
<td>1,6</td>
<td>0,1</td>
<td>1,1</td>
</tr>
<tr>
<td>TV Projector</td>
<td>37,5</td>
<td>0,4</td>
<td>3,2</td>
</tr>
<tr>
<td>Home cinema</td>
<td>2,7</td>
<td>0,5</td>
<td>3,7</td>
</tr>
<tr>
<td>VHS recorder/player</td>
<td>4,9</td>
<td>3,2</td>
<td>24,3</td>
</tr>
<tr>
<td>DVD recorder/player</td>
<td>3,8</td>
<td>2,5</td>
<td>19,4</td>
</tr>
<tr>
<td>Hi-Fi</td>
<td>4,7</td>
<td>3,4</td>
<td>25,8</td>
</tr>
<tr>
<td>Satellite/cable/air set top box</td>
<td>6,4</td>
<td>2,6</td>
<td>20,2</td>
</tr>
<tr>
<td>Hard disk (TV recorder)</td>
<td>2,1</td>
<td>0,5</td>
<td>3,5</td>
</tr>
<tr>
<td>Video game</td>
<td>1,5</td>
<td>0,4</td>
<td>2,9</td>
</tr>
<tr>
<td>Compact Hi-Fi</td>
<td>2,8</td>
<td>1,0</td>
<td>7,7</td>
</tr>
<tr>
<td>Total</td>
<td>113,9</td>
<td>39,8</td>
<td>305 kWh/Year</td>
</tr>
</tbody>
</table>
Figure 7: Electricity savings potential per household and appliance, by switching to the BAT.

Many appliances with standby energy demand were not part of the metering campaign of REMODECE. These appliances are for example:

- Electrical toothbrush, shavers and other toilet requisites.
- Electrical tools with chargers: Drill, saw, screwdrivers and other tools.
- Electronics as DAB radios, Amplifiers, Pc-games hardware, Musical instruments, Video games, Home cinema etc.
- Some kitchen equipment.
- Garden equipment with chargers.
- Home security systems.
- Garage door openers.

Some of the new electronic appliances have a relatively high share of standby consumption. In such appliances standby may be the electricity required to keep information (such as storing TV stations in set top boxes, etc.) in the appliance memory. On average the standby electricity consumption per household and per year is about 305 kWh, which is about 11% of the total annual electricity consumption per household. Standby power is roughly estimated to be about 40 W per household. Assuming that electronic appliances are in the standby mode during 7,665 hours per year (corresponding to 3 hours of active use per day), the standby power consumption of these appliances represents about half of the electronic loads consumption, which is 585kWh per year per household.

In terms of behaviour, households seem to behave pretty well concerning turning off the computers and monitors. On opposite they let fax machines, modems and routers/hubs, on stand by mode because they fear to lose the pre-definements and have to reprogramed them if they turn them off. Roughly 40% of the households do not turn off the television with the on-off button, keeping it on standby mode.

**Potential Electricity Savings**

As it was already mentioned, the technical potential electricity savings was estimated based on the replacement of the existing installed inefficient technologies with the Best Available Technology (BAT). Hence, the BAT is a combination of Best Available Technology and Best Practice or most economical use of the appliances. This combination is referred as BAT only, even if in some cases most of the savings are allocated to Best Practice. 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. The total savings (technical potential) by replacing installed inefficient technologies by BAT/BP in the market are therefore estimated. Structural effects are not integrated in the calculations. The lifetime of the equipment or penetration time of BAT was not taken into account. Equipment with short lifetimes, e.g. desktops and laptops, will be replaced soon but other appliances like electric cooker/oven may

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4. Can be avoided by using "non-volatile" electronic components storing information even if the power supply is disconnected.
have a long lifetime and it may take several decades to replace today’s equipment with the Best Available Technology.

The annual electricity savings in a typical European household, by switching to the BAT per type of appliance is presented in Figure 7.

The savings from switching from present state to best available technology were estimated to be about 1300 kWh/year/household. The aggregated annual electricity savings by using best available technology in European households for the EU-12 countries of the study were found to be 165 TWh per year, representing about 48% savings potential. These electricity potential savings will translate in 727 million ton CO2 emission savings per year by switching from present technology (PV) to best available technology (BAT). At European level (EU-27), the electricity savings would translate into 268 TWh that is 116 million ton CO2 emission savings.

For assessing the quality of the estimated values for the different appliances, the number of measurements per appliance and confidence intervals was calculated with standard statistical methods. Generally a high number of measurements give a more significant and accurate estimate than just a few measurements. A small confidence interval indicates a significant estimate, which is due to a low standard deviation in the energy consumption. In general, within each appliance, there are a lot of models with different yearly consumption (e.g. energy efficiency classes). Also, the use of some appliances is varying a lot among different consumers. A high confidence interval indicates a large uncertainty, probably associated with the fact that there are too few measurements for this appliance type. The result of this analysis is that the estimates of refrigeration and washing appliances, PCs, CRT and LCD TVs are trustworthy, while they are uncertain for PC peripherals and plasma TVs.

5. For calculation of the saved 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 CO2 emissions of electricity production under average generator efficiency using the average mix of fuel.

**Figure 8: Average efficiency class of white appliances in EU-12.**

**Potential Strategies for market transformation**

**PROBLEMS IDENTIFIED**

Although there are some supportive instruments available in most countries, they seem not to be adequate and satisfactory. The energy labelling alone proved to be inadequate to promote energy efficient appliances. The need for accompanying measures such as raising awareness and information campaigns in what concerns the benefits of efficiency as well as incentives to the end users, are considered to be necessary, in order to achieve market penetration of efficient appliances. This need is even more important in countries where the electricity price is low (BG, NO) and the economic gain of using energy efficient appliances is not so obvious to consumers. In these countries the savings from the purchase of high-energy efficient appliances are not comparable with the price difference, as the pay back time is relatively long for the households criteria.

In Denmark the taxes on electricity consumption for domestic customers are very high (all taxes plus VAT together constitute around 2/3 of the domestic electricity price). Only a small part of the taxes imposed are used to promote and support electricity savings but the high price gives anyhow a strong incentive for energy saving. In Belgium the electricity prices are high and there is no political will to impose higher taxes. In Czech Republic there are some problems identified in the existing tariff structure where the tariffs for residential customers basically differentiate between use of electric energy “only” for standard purposes (lighting, domestic appliances) and also for meeting heat energy needs (hot water preparation, heating). As a result, those who use electricity just for basic purposes may have as much as two times higher unit price of energy supplied/consumed than those who use it also for production of heat for the same amount of electricity consumed. Such a practice does not motivate household consumers to use electricity in a rational way. A problem identified in Bulgaria, is that there is no effective procedure for verification of the compliance with the ordinance of labelling. Moreover it is assumed that there is a practice of false labels. This includes misrepresentation of information, false and misleading information, etc.
In some countries such as Portugal and Greece there is a lack of high efficiency appliances in the market such as A++ refrigerators, washing machines and dishwashers which are not easily available in the market. As it can be seen in the Figure 8, the project concluded that most countries have a big percentage of unknown labelled equipment. This lack of knowledge is generally associated with the age of the equipment people own - people tend to forget about the specifications of their older appliances - or with the lack of interest with energy efficiency issues leading to bad choices when buying new appliances. The share of A++ and A+ appliances is still very low, representing around 10% of cooling appliances in EU-12, and less than 1% of the washing machine and dishwasher, and being insignificant for tumble dryers, see Figure 8.

RECOMMENDATIONS

[Boardman B. 2007] mention that the most effective way for market transformation is the combination of policies such as: tough minimum energy standards for homes, lighting and appliances, regulation of utilities, generous financial support through grants, funding and the reform of energy tariffs, and much greater information for the consumers. To take advantage of REMODECE identified energy-saving opportunities new minimum efficiency standards need to be introduced for some appliances (e.g. air conditioners) and others have to be tightened for other appliances (e.g. cold appliances), coupled with suitable policy incentives, as it is the situation in Denmark, with the most recent stock of appliances within the households due to the intensive Danish energy saving policies available. Several energy efficiency incentive programmes are available in Denmark that helps households to change their old inefficient appliances by new ones. Labelling of electricity consumption, including low power modes, appears to be essential to raise consumer awareness. Current regulations and fuel subsidies, for example, often favour consumption over efficiency. But many possible actions are not taken, because energy users lack information nor do not value energy efficiency enough to change their buying habits. Regulation changes, information campaigns, with clear and simple messages targeting households, together with suitable financial incentives, revision, enforcement and expansion of the energy label ratings, and behavioural changes in the equipment selection and operation, are among the most effective strategies to stimulate energy efficiency in the residential sector. Based on the findings of the project, the policy recommendations below to promote energy efficiency are identified.

Revision of the energy label ratings A–G and its enforcement

The existing A–G ratings have become obsolete, as the improvement in energy performance that many products have undergone in the last years, is significant. The best examples of this are in the refrigeration and washing machines labels: for refrigeration new labels were uniquely introduced at A+ and A++ and in the European washing machine market, virtually all of the products are now A-rated [ceee, 2008]. Therefore, there is a need to adapt the existing labelling scheme in order to update it in a flexible and more dynamic way, but always bear in mind that the changes made should not confuse the consumers, because this scheme during the years has achieved a high recognition due to its simplicity, transparency and comprehensibility and it is considered to be a valuable instrument that can promote energy efficiency and deliver significant energy and carbon dioxide savings.

In order to reinforcing the energy labelling scheme, there is a need of carrying out inspections of the selling points to assure that energy labels are correctly exhibited and to assure that the retail staff is informed adequately about energy labels so as to be able to provide right information to the consumer.

Expansion of the energy label in order to include more products and setting more ambitious Minimum Energy Performance Standards

Up until now, the energy labelling scheme referred to white appliances, light bulbs and air-conditioners. Recent market surveys [Schlomann, 05], have shown that the household electronics market has increased significantly in the EU countries in the last years. The ownership levels of different appliance types are shown in Figure 1. Most of the electronic appliances have high ownership rates. Therefore, an expansion of the energy labelling scheme should be considered in order to include other goods such as TVs and other entertainment equipment in general. Moreover the survey carried out showed that the knowledge on the Energy Star Label is poor and therefore an extension of the scope of the label should be considered.

Another aspect of the electronic equipments is the standby consumption which was estimated to represent about half of the electronic loads consumption. The potential of energy savings that lies in these standby consumptions can be achieved with setting strict requirements for standby power besides consumer behavioural changes that can also lead to significant energy savings. Labelling of electricity consumption, including low power modes, appears to be essential to raise consumer awareness. On 8th July 2008, the European Union (EU) member states have endorsed the European Commission’s proposal for a regulation reducing standby energy consumption by household and office products. This proposal includes a very positive step and there should also be an attempt to upgrade existing Minimum Energy Performance Standards (MEPs) based on the EuP studies as well as to develop new MEPs based on lifecycle cost considerations.

MEPs are urgently needed for air conditioning equipments being sold in Europe: residential air conditioning loads are increasing fast in Southern Europe and are already a major contributor to summer peak demand in Mediterranean countries. The European air conditioning market is flooded with very low cost and very inefficient units, therefore action is needed urgently banning low efficient units as low efficient air conditioning units that are even not allowed in China and Japan are invading the European market.

Raising awareness about labelling schemes

Even though energy labelling is a well known and accepted scheme that is active for quite some years now, work still needs to be done in the area of consumer’s awareness and enforcement. Two trends at EU level are established: there is lack of awareness first in what concerns energy labelling and second in

6. In Europe mandatory MEPs are available for refrigerators and freezers since 1999 and for magnetic ballasts since 2004. Other MEPs are under consideration, for a variety of appliances.
what concerns Energy Star products [REMODECE, 2008]. It is important to inform consumers with awareness campaigns in any form (TV spots, brochures, etc.) about the importance and the benefits of buying energy efficient appliances and about the importance of choosing Energy Star products, when it comes to office equipment. Another strategy is to organize training programs for retailers giving them also sales arguments but this is very difficult because the front desk staff in shops is shifting very frequently.

Promotion of behavioural changes
One of the most effective ways to save energy and achieve the reduction potential in the residential sector is probably through behavioural changes. From the analysis of the data collected in the REMODECE surveying campaigns, consumers’ behavioural trends were established through a series of questions that were included in the questionnaires. The identified “false” behaviours (pretending rational behaviour) were related with most of the domestic appliances and many of these behaviours could change through awareness raising campaigns which will focus on behavioural matters. Change of washing temperature and less use of tumble dryer are examples of campaigns concerning change of behaviour.

Combination of technological advancement (introduction of new products) with financial incentives
The [REMODECE, 2008] identified the biggest potential savings in cooling appliances (for refrigerators with freezer compartment the savings are estimated to be 182 kWh/year/household and for freezers 162 kWh/year/household), in desktop PCs including monitors (the savings are 139 kWh/year/household), in oven/cookers (with 60 kWh/year/household) and in lighting (303 kWh/year/household). For these categories of appliances incentives for switching to best available technology should be given, as they will deliver important reduction to electricity consumption. An additional solution is to forbid the sales of electrical appliances in classes below ‘A’, as well to ban the sales of incandescent light bulbs and appliances without on/off power switch. Based on the EuP lot 19 works, EU decided in December 2008 to phase the use of GLS lamps (frosted GLS by October 2009 and clear GLS and the worst halogen lamps by 2016). Another technology that could be banned is e.g. inefficient plasma TV where the electricity consumption is around the double compared to LCD TV.

For lighting, one other possible solution in order to speed up market transformation could be the establishment of taxes related to inefficiency into the price of the lamp. According to that solution an incandescent light bulb will have the higher price, due to tax impose while efficient CFL or LEDs lamps will be tax free, leading to a low price. Taxation might also be imposed for TV screens over a certain size (e.g. 45 inches) in order to stop the actually trend of buying larger and larger screens resulting in a much higher electricity consumption than necessary.

Financial incentives for the replacement of old appliances
[REMODECE, 2008] found that in most of the countries, white appliances such as fridge, freezers, washing machines, tumble dryers etc. are older than ten years, in percentages that in some cases reached 50%. The only country that has very low percentages (1-3%) of appliances older than ten years is Denmark. So, in the rest of the countries the issue of giving incentives to consumers to replace their old appliances deserves to be carefully addressed to promote the scrapping of old inefficient appliances. Possible incentives are:

- Reducing VAT on highly energy efficient products may not be the best solutions, as this measure lowers the price of the product to the eyes of the consumer and creates a false perception that energy efficient products don’t have an extra cost (people usually retain the gross price of a product and don’t look whether the reduced price is the result of a reduced VAT or not). The signal that should be sent out is exactly the opposite, meaning that energy efficiency has a value. So, it is better if the financial incentive is given in an indirect way in the form of personal tax credits or rebates.

- If the incentives given to consumers are in the form of rebates and subsidies, then it must be assured that they will be given only for appliances with small market penetration and only for best available technologies. It is also important when giving a subsidy to have a fixed amount of money (xxx euro/appliance) in order to avoid over sizing, as people tend to buy larger appliances if the amount of the subsidy depends on the size.

- Demand side management programs from utility companies, also considered in the ESD directive, can lead to giving incentives to consumers. These incentives could be rebates and subsidies for replacement of old appliances or for buying state of the art energy efficient appliances and lighting, aimed at lowering the cost of more efficient energy-using equipment at the point of purchase [P. Waide & B. Buchner, 2008]. Another possible solution for utility companies could be to amend electricity prices with a view to reward energy savings, for example in open markets if the revenue of the utility is decoupled from the sales, introduction of the proper taxation can lead to escalated electricity prices that reward energy savings (change in behavior and efficiency).

- Tax credits given to manufacturers as suggested by CECED [CECED, 2008], could be an effective incentive for market transformation that would also benefit the consumer. The tax credits philosophy is to grant to the manufacturer a fiscal benefit for each new eco-efficient product, for example Class A+ or A++ refrigerators, manufactured and sold that is above what was manufactured and sold in a reference year. The consumer would benefit from buying a technologically advanced product in a highly competitive market. By reducing the amount of taxes paid, producers of household appliances will have the resources to offer new products at competitive prices, which, combined with appropriate marketing and information campaigns, will lead to consumers replacing their appliances at a quicker rate.

- White certificates scheme can be a powerful mechanism which can create dynamic energy services in the residential sector. There is increasing political interest in market-oriented schemes to promote energy savings in the sectors not covered by the EU Emissions Trading Scheme and one suggested route is a tradable white certificate (TWC) scheme. Each certificate represents a certain amount of energy savings achieved through, for example, better insulation of a
building [Energy Efficiency, 2008]. A (tradable) white certificate scheme does not replace but complements existing policies and measures, and aims to contribute to achieving current or newly formulated Energy Efficiency targets in a cost-effective way [EuroWhiteCert]. With respect to energy efficiency in the household sector White Certificates scheme can be implemented in projects promoting the use of energy efficient lighting and energy efficient household appliances, including air conditioning. An example of such a scheme is the promotion of the use of CFLs in the household sector that has been applied in France by ADEME, EDF and others relevant parties.

Conclusions
The REMODECE project increased the level of knowledge about electricity use in the European Union. 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 (e.g. air conditioners). It is also necessary to perform new measurements to observe changes over time and to include new energy efficient appliances and lamps (e.g. LEDs). It is also important to keep track on the influence of new trends like shift to larger sized appliances or to many more lighting points than before (rebound effect). Such measurements will permit to obtain better estimates of the potential savings by replacing old inefficient equipment as well as to design suitable strategies to tap those savings.

Regulation changes, information campaigns, with clear and simple messages targeting households, combined with suitable incentives seem the best effective way to stimulate market transformation towards more energy efficient appliances, in the residential sector. Tough European Minimum Energy Standards on lighting and appliances, and its rapid implementation are needed.

The most important steps and tips to save electricity identified, through the proper selection and operation of equipment are the following:

- Phasing out indoor and outdoor incandescent lamps with CFLs and LEDs. Initial cost of the bulbs is higher but investments will be recovered from the electricity that they will pay for themselves several times over, as CFLs and LEDs last much longer. Actually it is very important to promote use of new LEDs lamps displacing the growing share of inefficient halogen spot lamps. In the near future. LED can be used instead of the high amount of small reflector halogen lamps which are very rapidly penetrating into the kitchen, bathroom, stairway etc. (often a low quality of lighting with glare problems. At a later stage during the next decade, LEDs have the potential to become the dominant lighting technology, because of the superior overall performance (efficiency, lifetime, environmental impact).

- Selection of the most efficient appliances namely the change to A+ and A++ appliances.

- Behaviour changes also play a key role in decrease electricity use. For example in the case of washing machine possible improvements can be achieved namely through the use of washing cycles at full load, washing with the coldest water as possible, as well as drying clothes by natural means whenever possible.

- Selection of efficient entertainment equipment (e.g. LCD TVs instead of plasma or CRT TVs) as well as energy-star labelled office equipment with reduced standby power requirements. Because standby represents about half of the consumption of electronic appliances, behaviour changes like switching-off electronic appliances (TV, DVD, Hi-Fi, Computer, monitor, printer, etc.) when not in use are critical to cut wasteful consumption.

- Since air conditioning is growing fast in Southern Europe, the selection of the most efficient equipment (COP>4) needs to be ensured through minimum efficiency standards. Again behaviour changes can strongly mitigate not only the consumption, but in some conditions even the need of air conditioning. A good example is the use of night ventilation for free-cooling in the summer.

- Promotion of the use of renewable energies (e.g. sun and wind for drying clothes, solar water heating, biomass for fireplaces).

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