Accounting for electricity consumption in buildings and evaluating the saving potential: what have we achieved and how much more can we save

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Abstract

Electricity consumption in the EU-25 Member States, Candidate and Accession countries has continued to grow in the last years despite numerous energy efficiency polices and programmes at EU and national level. Total electricity consumption in the residential sector in the EU-25 has grown by 10.8 % in the period 1999-2004, at almost the same rate as the economy (GDP). Similar trends are also observed in the tertiary sector and to a lesser extend in industry. The electricity consumption in the tertiary sector has grown by 15.6 % in the period 1999-2004 and by 2.0 % in the period 2003-2004. For the tertiary sector there is even much less data available for individual electricity end-uses than for the residential sector, and only a few sources or countries attempted to split the total electricity consumption among the different end-uses. Despite this increase and the consequent impact on CO_2 emissions, there is little knowledge at European level, where the electricity is uses, what is the status of efficiency of the installed and sold equipment and what is the likely impact of the planned policies. This paper summarises the result of a 2006 in-depth survey on the electricity consumption in buildings in the enlarged EU and Candidate Countries, together with the present market share of efficient appliances and equipment. The survey is based on interviews with experts, market research, and evaluation of end-use monitoring campaigns, including the REMODECE and EL-TERTIARY Projects. The aim of the paper is to show the present status of electricity consumption for the main appliances and equipment, and on the base of the best available data estimate the saving potential for electricity in buildings in New Member States and Candidate Countries.

Introduction

Gas and electricity consumption in the EU-25 Member States, Candidate and Accession countries has continued to grow in the last years despite the numerous energy efficiency polices and programmes at EU and national level. The gas consumption of the residential sector has continued to grow in the period 1999 to 2004 in the EU-25 from 4 721 PJ to 5 399 PJ with an increase of 14 %, while the yearly growth rate in the period 2003-2004 has been 2,2 %. Total electricity consumption for the residential sector for the EU-25. has grown by 10,8 % in the period 1999-2004, from 690 TWh in year 1999 to 765 TWh in year 2004 and by 1,8 % in the period 2003-2004. Electricity use grows at almost the same rate as the economy (GDP). Increasing electricity demand is due to many different factors, including:

- More penetration of "traditional" appliances (e.g. dishwashers, tumble driers, air-conditioners, personal computers, which are all still far away from saturation levels); introduction of new appliances and devices, mainly consumer electronics and information and communication technology (ICT) equipment (Set Top boxes, DVD players, broadband equipment, cordless telephones, etc.) many with standby losses.
- Increased use of "traditional" equipment: more hours of TV watching, more hours of use of personal computer (driven by some tele-working, and increased used of internet), more washing and use of hot water.

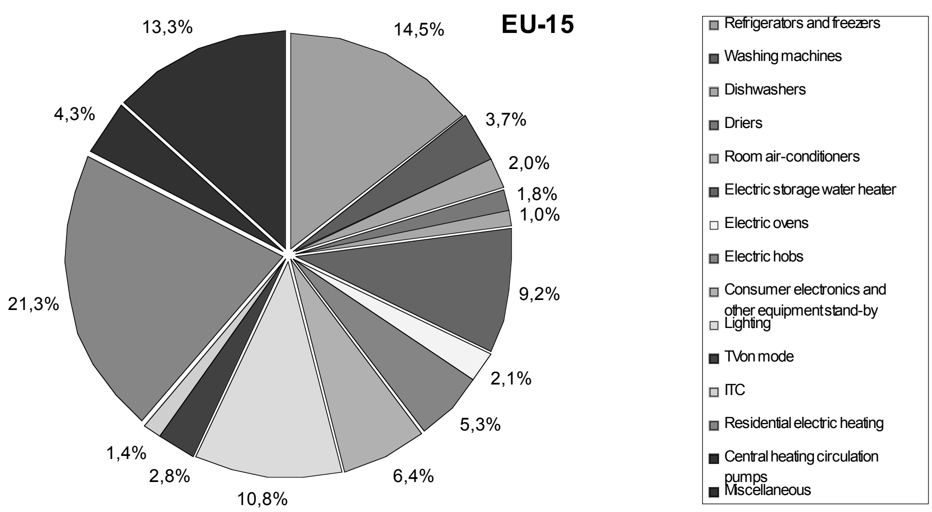

Fig 1: Split of electricity consumption among residential end-use equipment in EU-15, yr. 2004, (Atanasiu, Bertoldi, 2007), (International Energy Agency, 2003),(Waide, Lebot, Harrington, 2004),(Waide, 2004)

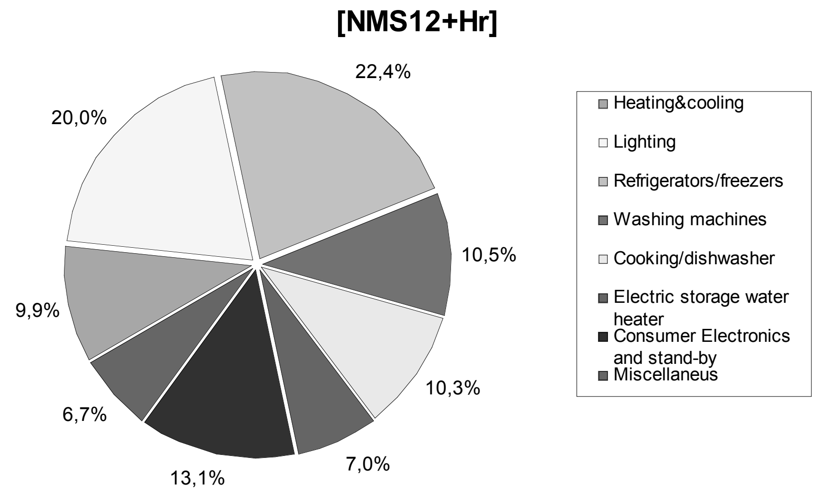

Fig 2: Split of electricity consumption among residential end-use equipment in NMS12+Hr, yr. 2004, (Atanasiu, Bertoldi, 2007)

- Increased number of double or triple appliances, mainly TVs and refrigerators-freezers.
- More single family houses, each with some basic appliances, and larger houses and apartments. This results in more lighting, more heating and cooling, and last but not least, older population demanding higher indoor temperatures and all-day heating in winter and cooling in summer, and spending more time at home.

Electricity end-use in the residential sector

On the basis of recent surveys, the total residential electricity consumption is apportioned to the different end-uses devices. There is still a substantial difference between the former EU-15, where the largest electricity use is still heating, followed by refrigerators and freezer and lighting, and the new Member States where refrigerators and freezer and lighting are more or less on the same level and are the largest electricity end-use, and where very little electricity is used for space heating and cooling. Some equipment, e.g. electric storage water heater, room air-conditioners, electric direct resistance heating, electric hobs, are present only in a limited number of dwellings, and concentrated in some specific countries. Space heating, although present only in a limited number of households in particular in some countries (mainly present in Sweden and France, and to a lesser extend in Germany and UK), still represents the largest single electricity end-use equipment in the residential sector (about 20 % of the total electricity consumption in the residential sector) followed by refrigerators and freezers, lighting and water heating. Direct resistance heating, electric and storage water heating are decreasing their market share due to strong competition from natural gas. Only in a few Member States heat pumps are replacing fossil fuel boilers for heating purposes (figures 1 and 2). (Atanasiu, Bertoldi, 2006)

Electricity consumption per appliance in households in "real" situation (through monitoring) has not yet been very well documented. Some monitoring campaign has collected data (France, Italy, Denmark and Portugal). On average measurements of some households' electricity consumption in Italy and Denmark - without the space and water heating uses are 3 358 kWh/year for Denmark and 3 157 kWh/year for Italy (Pagliano, Pindar, Ruggieri, Di Andrea,2003). In France, an average electricity consumption excluding water and space heating is about 2 500 kWh/year. Moreover the observed mean electricity consumption of electric water heaters amounts to 2 364 kWh/year (Sidler, 2006). The average consumption in he EU-15 (total electricity consumption of the residential sector divided the number of households) is 4 343 kWh/year. More recent monitoring campaigns in Sweden, based on a statistical sample, monitored 400 households covering both single family houses, and apartments, excluding electric heating and water heating. The preliminary results of the survey are 5 034 kWh/year on average for the single families' households, and 2 954 kWh/year for the apartments (Bennich, Persson, 2006). Recently a new SAVE project, REMODECE, has been started to carry out additional monitoring survey in several EU Member States, the results will be available in 2007.

AIR-CONDITIONING APPLIANCES

In the 'southern' countries (IT, ES, PT, EL and Southern FR) one of the main drivers in electricity consumption and more important to electricity peak demand is a fast penetration of small residential air-conditioners (less then 12 kW output cooling power) and their extensive use during the summer months. Due to the heat wave in the summer of 2003 in Italy during that year all small air-conditioners available on the market were sold and installed. Total residential air-conditioners' electricity consumption in EU-25 in year 2005 was estimated to be between 7-10 TWh/yr. For room air-conditioners (up to 12 kW output power), the Labelling Directive (2002/31/EC) has been adopted by the European Commission and was published in March 2002. (Directive 2002/31/EC, 2002) Although the full mandatory application of this Directive was fixed for 30 June 2003. The relevant test standard needed to serve as the reference document was missing; the new revised standard EN 14511 covering all products in the scope of the Directive was not been finalised before May 2004. The European Commission in agreement with the Labelling Committee decided to postpone the application till just before the summer 2004. The A class limit for the split, non ducted, air-cooled air conditioners up to 12 kW is set at EER of 3,2; some new models have been introduced on the market with EER above 4, the best models on the market having an EER of 5,51. This indicates that the A class level is not very ambitious. In addition, there are still several E and D class models on the European market, with EER at around 2,5. For room air-conditioners (up to 12 kW) the improvement of the EER can be attributed to the technological development and transfer (mainly from Japan, where there are very ambitious energy efficiency targets) and to the publication of the EER (and last year also of the energy label) in the Eurovent Certification Scheme. Eurovent-Cecomaf has also committed to withdraw from the market the models in G class. Implementation of this proposal started in January 2004 with the elimination of Class G products.

MAJOR HOUSEHOLD APPLIANCES

Sales of major domestic appliances (MDAs) in 2005 (refrigerators, freezers, washing machines, dishwashers, tumble driers, ovens, cookers and hobs) were about stable compared to 2004 in the EU-15. For 10 EU countries (SE, UK, BE, NL, IT, DE, AT, FR, ES, PT) a total of about 52,7 million MDAs were sold in year 2005: about 12 million refrigerators, 12 million washing machines, 5 million dishwasher, 3 million driers, 3 million freezers, 12 million cooking appliances (Soregaroli, 2006). European Committee of Domestic Equipment Manufacturers (CECED) reported a production for the EU market including import for the companies who have signed the unilateral commitment of about 20,2 millions cold appliances, and 15,4 millions washing machines for the EU-15.

Refrigerators and freezers

The efficiency improvement trend continued for refrigerators and freezers. For domestic refrigerators, the energy efficiency index (EEI)[1] is defined in the "Cold Appliances" labelling Directive (Directive 2003/66/EC amending Directive 94/2/EC); the EEI was set at 102 for the average model on the market in year 1992, as reported by the GEA study. Among the combined refrigerator-freezer, the best models on the market in the year 2005 were models rated A++ with an EEI below 30; as example a model with 215 fresh food volume and 60 l of freezer (4*) volume has an annual consumption of 137,0 kWh/year for. For the same size a C class model just meeting the efficiency requirements would use 522 kWh/year (a factor four energy reduction!). There are still a limited number of models in A++ class (EEI below 30), and still difficult to find them in shops, while there is already several models in A+ class. It is interesting to notice that in 2005 new cold appliances sales in NMS and CC are almost identical to the EU-15 in term of efficiency index. The sale data for 2005 for cold appliances show that in some markets (and in particular in the Netherlands and Germany) the A+ appliances are starting to have an important market share (14,8 % market share of A+ class in Germany), while at European level the share of A class has reached 60 % of the sales, with 9 % in A+ class. In all countries the share of A and A+ appliances has strongly increased in 2005 compared with previous years. Large differences still exist between countries due to different national and regional policies and programmes with the lowest share of sales of A class appliances in the west European countries covered by the GfK panel 2004 in Spain (36,1 %), and the highest share in the Netherlands (71,1 % in A class plus 19,2 % in A+ class), this remarkable high share is due in particular to incentives for very high efficient appliances. Also worth noticing is that the share of A class appliances in new refrigerators sales is higher in the New Member States (again comparing only among the countries covered by the GfK panel). The strongest progress in the period 2002 to 2005 happened in the UK mainly due to the Energy Efficiency Commitment[2] under which about 1 million efficient cold appliances have been sold per year. The major European policy measures already in place are the mandatory energy labelling (Directive 94/2/EC), including the Amended Directive of 2003 (Directive

1. The EEI is defined as the ratio between the energy consumption of the sold appliance compared to the one of reference appliance as defined in Directive 94/2/EC.

2. Energy Energy Efficiency Commitment (EEC) runs in 3-year cycles from 2002 to 2011. EEC-1 program required that all gas and electricity suppliers with 15 000 or more domestic customers deliver a certain quantity of 'fuel standardised energy benefits' by encouraging or assisting customers to take energy-efficiency measures in their homes.

2003/66/EC) to introduce the A+ and A++ classes, and the CECED unilateral agreement (CECED, 2005) (Arnold, 2006)

Washing machines

As far as the sales of washing machines are concerned, the share of A class appliances was already above 50 % in 2002, in 2005 in some Member States (Germany, the Netherlands, and Belgium) there is a large penetration of A+ appliances (not defined in the labelling Directive but agreed among CECED manufacturers), and the combination of A and A+ in these markets is approaching the 100% market. The most remarkable market change from 2002 for washing machines has happened in the UK due to the Energy Efficiency Commitment (about 800 000 washing machines have been subsidised each year under EEC). It is also interesting noting that the class B has almost disappeared from the market, but there is an increased share of not labelled appliances. Class A appliances are seen by consumers as a high quality product (most of A class appliances are AAA, associating to the low energy consumption, high spin speed and good washing performances). In 2005 there was not any improvement in the share of sales of A and A+ washing machines in the EU-15 (only in the countries covered by GfK), while in the New Member Sates the combined share of a and A+ models continued to grow reaching around 75 % of the market share (Soregaroli, 2005). The production weighted average consumption of washing machines was 0,95 kWh in the year 2004 per wash for a 5 kg cotton load at 60ºC cycle. The best model on the market (already for several years) has an EEI[3] of 0,85 kWh. This indicates that even with the present technology there is a large energy saving potential of about 12%, between the average model on the market and the best model. The major European policy measures already in place are the mandatory energy labelling (Directive 96/89/EC amending Directive 95/12/EC) and the CECED Unilateral commitment (CECED, 2004). The CECED notary report of 2004 shows an average mean value of 0,195 kWh/kg. The value 0,195 kWh/kg of the notary report corresponds very well with the value of the CECED technical database, which in 2004 was 0,192 kWh/kg for the old Member States (EU15) and as well 0,192 kWh/kg for the new Member States. A+ models have started to be significantly placed on Community market. There are already 1 042 A+ models in a total of 4 097 models in the CECED EU-15 database, and already 290 A+ models in new Member States, for a total by 1 066 models put on EU-10 markets. The relative proportion of A+ is thus quite similar between 'old' and 'new' member States. In the period 1996 to 2004 there has been an efficiency improvement of about 20 %.

Dishwashers

For dishwashers there was only a relatively small efficiency progress between year 2001 and 2005. In the year 2003 the average consumption per test cycle wash of a 12 place setting dishwasher was 1,197 kWh down 10 % from the average consumption in 2001. The best model on the market (already for some years) has an EEI of 1,05 kWh per wash cycle. This indicates that even with the present technology there is not any-more large energy saving potential (this also means that there is no possibility to introduce a A+ class). The sales of dishwashers by energy class follow a similar patter to the one of the washing machines, with the class A already above the 50 % threshold. The lowest share of sales of A class appliances in 2005 was in Spain 69 % (up from 31 % in 2002), with the highest share 94 % in Belgium. Remarkable progress in energy efficiency of new models took between 2002 and 2005 in all EU-15 countries, especially in the UK and Italy. Very impressive also is the high A class market share in some of the New Member States. The major European policy measures already in place are the mandatory energy labelling (Directive 97/17/EC amended by Directive 1999/9/EC) as well was the CECED agreement till December 2004 when expired (CECED, 2004).

Cooking Appliances

Electric ovens represent 97 % of the ovens sales in the EU-15 in 2005, with similar trends in the 10 New Member States. For free standing cookers the share of electric one is 34,5 % and for gas ones is about 44 %; interesting to notice also that for hobs the share in sales among electric and gas is 58,4 % electric and 37,4 % gas models, with almost 100 % electric hobs in Germany and Sweden, and almost 100 % gas hobs in Italy. Hobs represent 43 % of total sales in the EU-15 and about 20 % in the New Member States, followed by ovens with 26 % and 13 % respectively, and with 26 % and 66 % for free standing cookers. This does not include microwave ovens which have an increasing penetration, but are not yet used to cook major meals. Total electricity consumption for electric cooking is estimated to be 52 TWh (around 37 TWh electric hobs and 15 TWh electric ovens). There is a mandatory energy label (Directive 2002/40/EC) only for electric ovens, which covers also the electric ovens in free standing cookers. The impact of the energy labelling is starting to be visible on the market. The best electric oven models on the market just meet the A class level (0,8 kWh for the test cycle), while a typical model has an energy consumption in the test cycle of 1,2 kWh. Even in 2005 was registered an increase of the A class ovens share on the market comparing with the previous year[4] there is still a long way before the class A appliances will dominate the market as for dishwashers. (Soregaroli, 2006)

Dryers

Dryers are the appliance where little progresses in energy efficiency have been achieved with the mandatory energy label (Directive 95/13/EC, 1995). In theory, gas heated (which are not labelled) and heat pump dryers (most of them are in A class and tend to be much more expensive than conventional models), which use much less primary energy[5], are already on the market, but have almost no market share (with the exception of gas dryers in the UK). Transforming the dryer market to A-label machines will save a lot of energy: for the Netherlands

3. For washing machines the EEI is expressed as the energy used per kg of soiled cloths in a 60ºC cotton cycle (kWh/kg)

4. The A class ovens share was 48 % in 2005 (from 33,8 % in 2004) as average of 10 Western European countries and 79,8 % in 2005 from 76,5 % in 2004 in Germany where was registered the largest penetration of A classes from all the countries under the GfK survey. On 6 Central and Eastern European countries market considered by GfK survey was registered also an increase of A class ovens penetration, from 23 % in 2004 to 38 % in 2005.

5. For gas driers, this statement is based on the average European fuel mix and efficiency for power generation

alone calculated savings would be in the magnitude of 0,8 PJ per year. (Hans Paul Siderius, 2004)

Electric Water Heaters

Electric water heaters are responsible for a considerable share of the total residential electricity consumption (9 % in EU-15 and about 7 % in EU-10+2). Electric storage water heaters with a capacity over 30 litres represent about 28,8 % of the installed park for primary water heaters ("Eco-design of Water Heaters"2006), with an additional share of 7 % for instantaneous electric water heater. In term of sales about 6 million of storage model where sold (or about 34,3 % of total water heaters sales), with 2,4 millions instantaneous models. Until year 2006 there has been little EU level policy to improve efficiency of electric water heaters, due to the lack of suitable measurement standards, the many different types of water heaters (gas, district heating, solar, electric). Past activities for electric water heaters have concentrated on storage (tank) models and in particular on the reduction of the standing losses, through increased insulation. The only real policy action was a unilateral agreement by the main European manufacturers through their trade association, CECED. The agreement was concluded by the manufacturers at the end of 1999, and lasted till the end of 2003. (CECED 1999)

CONSUMER ELECTRONICS, INFORMATION AND COMMUNICATION EQUIPMENT

Televisions

This is the fastest growing electricity end-use in the residential sector. It includes more "traditional" equipment such as TVs and Hi-Fi, and "new" devices such as MP3 players, PVRs etc. CRT TVs and VCRs are also sharply reducing their sales in favour of flat TVs and DVDs. In this sector there is a fast turnover and technological development which could change the energy consumption in a rather fast way. TVs are the largest electricity consuming appliance in this sector. According to GfK total sales of TV continues to grow, and reached 30 million in 2005. In addition in 2005 non CRT models gained a considerable market share. GfK presented at the EEDAL'06 conference (Boyny, 2006) data for a selected number of EU-15 Member States that confirmed the increased penetration of TV in households (more TVs per household, often old TVs moved to a different room), and the increased number of viewing hours. The study in the frame of the Eco-design Directive (ecotelevision 2006) calculated for the EU-25 an average penetration rate for TV set of 1,48, which is expected to grow to 2,08 by 2010. European policies to improve TV efficiency were introduced staring from 1996 and initially covered standby losses. The first measure was the TVs and VCRs standby losses unilateral agreement which was signed in 1997 by 16 companies and notified to the competition authorities by the consumer electronic trade association (at the time EACEM, now EICTA). Manufacturers agreed that the company sales-weighted average would be progressively reduced towards 3 W by 2009. The target refers to the company *sales-weighted* TVs and VCRs standby consumption. Models with standby consumption over 10 W were to be phased out. In 2003 already sale-weighted average power consumption of 2,21 W and 3,53 W was achieved for TVs and VCRs respectively. More recently EICTA (the European Industry Association for Information Systems, Communication Technologies and Consumer Electronics) submitted in 2003 to the European Commission a new Self Commitment (unilateral commitment), signed by the a large number of the their member companies, to reduce the energy consumption of consumer electronics by continuously seeking to improve the energy performance per appliance. Although in 2005 the sales weighted average stand-by consumption was higher (2,2 W) compared to the equivalent 2003 figure (1,75 W, which was the lowest achieved), it is well below the target set for 2005 of a sales weighted average of 3,0 W standby passive (EICTA, 2005). Many new TV models have now standby consumption well below 1 W, some companies have introduced a company policy to have all their models below 1 W. For VCRs the best appliances have a standby consumption around 1 W (eco-mode), many have standby consumption around 2 W. However, it must be noted that VCRs sale are decreasing very rapidly. For DVD-players (which take the place of VCRs on the market and are experiencing a boom in sales) standby passive of best appliances is below 0,5 W. The data on TVs' EEI is still very limited because most manufacturers do neither indicate the energy efficiency index nor the power consumption in the on-mode. New trend on the market having an important impact on energy consumption are larger screen sizes and plasma TVs, which use considerable more energy (350-400 W, but new developments can decrease this to less than 300). Smaller LCD TVs typically have an EEI of 0,4, larger LCD TVs tend to have the same consumption as CRT TVs. The best CRTs on the market have an EEI of 0,995. Finally, prospects for improving efficiency in LCD TVs are better than for improving efficiency in CRT TVs, in particular by introducing solid state lighting in the backlighting systems. (Siderius, 2004).

Digital TV services

Another major driver for the increase in electricity consumption is the move to digital TV and broadband communication. The European Union is rapidly moving toward the switch to digital TV and the phase-out of analogue broadcasting. This means that the current stock of analogue TVs will need converter boxes in order to function. In 2004 and 2005 millions of these boxes were be sold in Italy, the UK and other European countries. At the same time, pay-TV is competing on the market with more sophisticated services and offers, resulting in even more complex set-top boxes, which show a worrying trend in rising energy consumption levels. In addition to the digital TV services supplied through satellite, terrestrial and cable (fibre or coax), there are new service providers starting to offer digital TV and video-on-demand through the telephone lines with DSL modems or using power line technology. These trends will accelerate the convergence between Information Communication Technology equipment and consumer electronics and have a big impact on energy consumption (more than one system always on in each dwelling, and increasing electricity demand for each device as it gets more powerful). According to the Canalys research company the number of households with digital TV in Western European countries was already over the 50 million during the first half of 2005. This high number has been reached through the switch from analogue to digital by pay-TV providers and the set up of free-to-air services in many Member States. The European Commission has indicated a switchover target of 2010, and the stronger than anticipated success of digital TV in several countries - including France, Germany and Sweden - means that many European countries would be meeting the target. (Tilak, 2005) Canalys estimates that 50 % of digital TV households in Western Europe today receive service by satellite, with 24% using terrestrial broadcast, followed by 22 % on cable and 4 % via IPTV. Although the majority of European digital TV viewers are still paying for the service, free services are growing quickly and already account for more than one-fifth of the market. Canalys expects over 40 % of European digital TV households to be using only the free services by 2008 (Tilak, 2005). Subscription digital satellite TV at the end of 2005 reached about 15 % of Western Europe household (Lamp MediaPedia, 2006). There are different digital technologies in the national markets. Cable is dominating the market in Belgium and Switzerland while satellite is predominated in Austria and Spain. Among the broadcasters, Sky leads due to its large installed base in the UK, and is followed by Canal+, Premiere, Digital Plus and Mediaset. Across Europe, however, the various free-to-air providers as a group already have more customers than Sky (Lamp MediaPedia, 2006). According to 'European Switchover Strategies', a report from market research firm Informa Telecoms & Media, 44,9 million European households will have access to DTT signals on their main TV set by 2011 (Tilak, 2006). From the New Member States, the Czech Republic launched its DTT services in October 2005 and 150 000 DTT set-top boxes have been sold. DTT launches have been announced in Estonia, Slovakia and Lithuania. Ongoing DTT trials are in place in Croatia, Romania, Estonia, Hungary, Lithuania, Macedonia, Poland, Serbia-Montenegro, Slovakia and Slovenia. With potentially over 200 million of these boxes across the EU - equivalent to one per household – the annual electricity requirement for digital service systems with full functionality and poor power management could be around 60 TWh. To limit the potential growth in energy consumption a voluntary programme was introduced, the European Code of Conduct for Digital TV Services[6], developed by a working group which includes all relevant stakeholders. The Code of Conduct sets out the basic principles to be followed by all parties involved in digital TV services, operating in the European Community in respect of energy efficient equipment. STBs not designed to be efficient may always be on with a power consumption of 20 W or more. It is also important to notice that both the standby and on-mode power have decreased in the period 2001 to 2005 despite a strong improvement in performance and features.

Broadband Equipment and office equipment

Another driver in the increase of consumption in households (and also in the service sector in the network infrastructure and data centres) has been broadband communication and office equipment (PCs, printers, scanners, monitors, etc.). According to the Eco-design study on Personal Computers and Monitors (ecocomputer 2006) in 2005 there were about 105 millions desktop, 24 millions laptops and 104 million monitors (of which 47 where flat panel) installed in household in the EU-25. The only policy measure in place for office equipment is the voluntary quality labelling Energy Star[7]. Broadband is one of the fastest among new communication technologies in Europe. The total number of broadband lines in the EU has quadrupled in just three years. Detailed data on DSL usage in Europe is still in compilation. In October 2005, 80 % of broadband subscribers in the EU-25 used DSL to connect to broadband Internet. Cable modems currently account for about 16 % of all broadband connections in the EU-25 (European Commission, 2006). In January 2006, broadband reached almost 60 million subscriber lines in the EU-25 and had a penetration rate of about 25 % of households. Growth in broadband is mainly market-driven. Broadband growth is uneven across Member States. The best performers on broadband penetration have been and are the Netherlands, Denmark and Finland, with a penetration rate above 20 %. Belgium and Sweden follow closely, and the U.K. and France have achieved 15 %. Most new Member States, plus Ireland and Greece, lag behind, with Greece, Poland, Slovakia, Cyprus, Latvia, Hungary and Ireland at penetration rates below 5 % in October 2005 (European Commission, 2006). Current projections show that the predicted uptake of the two key broadband WANs (wide area communication networks), DSL (digital subscriber line) and digital cable, will have a large potential impact on European household energy consumption. Even with the unlikely application of best practice in energy efficiency for all the network and end-user hardware, a simple broadband terminal for, say, 200 million EU households by 2010 would increase annual domestic electricity demand by an estimated 6,6 TWh. This could effectively be doubled by associated LAN equipment. The EU added in 2005 more than 17 million new DSL subscribers in the period to reach 52,8 million – at a growth of 48 % – extending its global share of the DSL subscriber market to almost 35 %. To address the issue of energy efficiency whilst avoiding competitive pressures to raise energy consumption of equipment all service providers, network operators, equipment and component manufacturers helped the European Commission to develop the Code of Conduct for Broadband equipment[8]. The Code of Conduct sets out the basic principles to be followed by all parties involved in broadband equipment, operating in the European Community, in respect of energy efficient equipment. The Code of Conduct covers, both on the consumer side (end-use equipment) and the network side (network equipment), for services providing a two way data rate of 144 kb/s or above. With the general principles and actions resulting from the implementation of the new Code of Conduct on energy consumption of broadband equipment the (maximum) electricity consumption in this sector could be limited to 25 TWh per year.

External Power Supplies

Another component that is contributing to the increase of the electricity consumption are the external power supplies. These external power supplies are used for many different types of electric and electronic devices, such as mobile telephones, digital cameras, cordless phones, notebook PCs, modems,

6. All the information can be found at http://energyefficiency.jrc.cec.eu.int/html/standby_initiative_digital%20tv%20services.htm

7. For more information http://www.eu-energystar.org

8. all the information can be found at http://energyefficiency.jrc.cec.eu.int/html/standby_initiative_broadband%20communication.htm

kitchen tools, power tools, etc. The study on External Power supplies in the frame of the EcoDesign Directive (ecocharger 2006) assumed sales in the EU for external power supplies and battery chargers of about 500 millions, with mobile telephone representing about 50 % of these sales. The study estimated the current stock of external power supplies to be in the order of 2 billions, which correspond to an average of about 12 external power supplies per household, however the stock includes the external power supplies in the non residential sector. A better estimate will be to have 5 to 8 external power supplies per household. For external power supplies, the only energy efficiency policy in place at the moment is the European Code of Conduct[9], which was introduced in year 2000 to reduce the no-load losses, and recently also to improve the on-mode efficiency. Before the introduction of the Code of Conducts many external power supplies had no-load power consumption above 1 W, and low efficiency in operational modes. By 2005 many of the external power supplies in the European market have no-load losses below 1 W.

RESIDENTIAL LIGHTING

Lighting in the residential sector has been reported to consume 86 TWh per year in the EU-15 in year 1995 in the DELight Study (Environmental Change Unit, 1998). The DELight study predicted an increase of residential lighting consumption to 97 TWh by 2010[10]. More recently the European Climate Change Programme (EECP, 2001) and the 2004 JRC Status Report (JRC, 2004) calculated the following lighting consumption in the EU-15: 85 TWh growing to 94 TWh by 2010, without additional and new policies and programme introduced. Other experts calculated 79 TWh in 2005 for the OECD Europe (Waide, 2006). Compact Fluorescent Lamps (CFLs)[11] represent one of the most efficient solutions available today for improving energy efficiency in residential lighting. The recent drop in price together with several information and promotion campaigns had a positive impact on sales. In particular, two different types of CFLs are marketed: the short life (average life around 6 000 hours) and the professional models (average life around 12 000 hours). The first type is mainly marketed for the residential sector. Direct sales comparison between incandescent lamps and CFLs is not meaningful as CFLs have a longer life time (6 to 12 times or more). Moreover it is difficult to gain access to sales data, and sales data available includes lamps not destined to the residential sector. The European Commission investigated energy consumption and energy savings in lighting since the beginning of the nineties, when a number of studies and pilot projects on lighting in the residential and tertiary sector were launched under the SAVE programme. These studies have resulted in a number of polices and programmes adopted to reduce lighting consumption. At the same time a number of successful governmental and utility driven programmes took place in most Member States to promote efficient lighting. These activities have resulted in a substantial market transformation in some Member States. However, there is still a large cost-effective saving potential of at least 11,7 TWh per year in the enlarged EU (or 12,8 TWh, including Romania and Bulgaria). With more aggressive policies the saving potential could reach 21,9 TWh and 24,1 TWh respectively. This savings can be achieved in a rather short time (e.g. by 2010), due to the fast turnover of lamps. The estimated savings do not include the additional savings that will be introduced by new promising technologies such as LEDs. (Bertoldi, Atanasiu, 2006)

Tertiary Sector Building Electricity Consumption

The gas consumption of the tertiary sector has continued to grow in the period 1999 to 2004 in the EU-25 from 2 070 PJ to 2 362 PJ with an increase of 14 %, while the yearly growth rate in the period 2003-2004 has been 1,9 %. Total electricity consumption for the tertiary sector for the EU-25 was 628 TWh in year 1999 and 726 TWh in year 2004. The electricity in the tertiary sector has grown by 15,6 % in the period 1999-2004 and by 2,0 % in the period 2003-2004. For the tertiary sector (in this paper it is defined as the public sector, education, healthcare, services and commerce) there is much less data available for individual electricity end-uses than for the residential sector, and only a few sources attempted to divide the total electricity consumption among the different end-uses. The European Climate Change Programme (ECCP) in year 2000 agree on a breakdown that was endorsed by the all the ECCP experts (ECCP 2001) The difficulty to arrive to the individual end-use consumption is due to the fact that both sales and stock data for the different end-use equipment are difficult to find, that the type of buildings and the associated energy consumption are much different (ranging from data centres to primary schools), and for many type of equipment there is not yet an energy efficiency indexes or label to track the penetration of efficient equipment and the market share among new sales.

Lighting is by far the major end-use category in tertiary sector consumption, responsible for about 175 TWh or 26 % of total electricity consumption in the tertiary sector. As far as non-residential buildings lighting is concerned, this is dominated in lumen and energy terms by linear fluorescent lamps. T12 fluorescent lamps are the oldest technology of fluorescent lamps. These lamps have an efficiency of less than 75 lumens per Watt (lm/W). In the majority of cases there exists a T8 lamp that can be retrofitted into the same lighting point. Depending on whether this T8 lamp is a halo phosphor or a tri-phosphor the lamp efficiency can be improved to between 80 lm/W (halo phosphate) and 90 lm/W (tri phosphor). The T8 lamp now dominates the linear fluorescent market. The existing mix of lamps is still two-thirds halo phosphate lamps with the remaining third being three-band rare earth phosphor lamps which are currently increasing their market share year by year. Barrier coat technology has allowed the mercury content in

9. all the information can be found at http://energyefficiency.jrc.cec.eu.int/html/standby_initiative_External%20Power%20Supplies.htm

10. The lighting consumption increased due to the increase of population (and also more old people), the increase of households no., changes in the life style (more lighting points etc.)

11. CFLs are of two types, with an integral ballast (ballast inside the package) or pin-based. The first type dominates the market for the residential sector. Recently some pin-based CFL luminaires have appeared on the EU market for residential lighting, however, no sales figures are available. Of particular interest are the CFL based "torchieres", which could replace halogen based upright floor lamps, the latter using light sources up to 500 W. For the residential sector any linear fluorescent lamps even with a magnetic ballast could be considered an efficient solution if it replaces an incandescent lamp.

current tri-phosphor lamps to be reduced to below 5mg[12]. The average lamp wattage for T12 lamps is 65 W (1 500 mm long). The average energy saving per lamp when switching from T12 (65 W) to T8 (58 W) is 12 %. The total annual sales figure for T12 lamps in the European Union is 16 million lamps. This is more or less a stable replacement market. The total sale of linear fluorescents is estimated to be 350 million lamps per year (Strickland, 2004). There is a relatively new technology, T5 which has a higher efficiency (in addition these lamps run only with an electronic ballasts, and perform best at a temperature of about 35°C, which is often the case in luminaries, while T8 perform best at 25°C) and is designed to be fed only by electronic ballasts. However, the market penetration of T5 lamps is still limited, though slightly increasing overtime. About 207 millions are new installed lamps in 2004 (CELMA, 2005), which tends to be of higher efficiency compared to already installed lamps. There are two very different technologies for ballasts: the magnetic type and the electronic type. The latter lower power losses and also allow operating the lamp at lower wattage for the same light output. There is a voluntary classification scheme for the combination of lamp ballasts introduced in the year 1998 by the lighting equipment manufacturers' trade association, CELMA (CELMA, 2005). The classifications scheme[13] together with the minimum efficiency requirements for ballasts (Directive 2000/55/EC), which came into effect in 2002, have resulted in a gradual market transformation. The Directive phases out low efficiency magnetic ballasts (class D) and class C ballast representing the largest shared of the market. The EU Directive 2000/55EC aims to reach a market transformation by 31.12.2005 with the following values: **class A** ballast 55 %, and **class B** ballasts 45 %. At the moment there are, however, no sale data available for 2005 to evaluate the impact of the second phase. In year 2004, the electronic ballast sales reached a market share of 31 %. Lighting equipment energy consumption is not only determined by the lamp, ballast and luminaries efficiency, but also by the running hours and the output light provided. In order to save energy of particular interest is the introduction of technologies to reduce the light quantity (dimming) as function of day lighting, and the operating hours in functions of the occupancy. There are no data on the present penetration of occupancy sensors, and day-light sensors, and other control systems associated with dimmable ballasts. A recent survey by the IEA has identified the following parameters for the OECD Europe (International Energy Agency, 2006): average lighting power density 15,6 W/m², average energy consumption 27,5 kWh/m² per year, average operating hours 1 781. Some examples of advanced lighting for office buildings from the GreenLight[14] programmes have reported for office buildings lighting power densities in the range of 7 to 10 W/m², and annual power consumption density of 19 kWh m².

For ***other tertiary sector end-use equipment*** (e.g. central air conditioners, chillers, commercial refrigeration, pumps, etc.) there is even less information on market penetration of efficient equipment. ***Air-conditioners*** in non residential buildings are estimated to consume about 70 to 80 TWh of electricity (Adnot, 2003). In the UK the MTP has calculated approximately 14,4 TWh for non-domestic and domestic air conditioning (the residential share being almost negligible) (Market Transformation Programme, 2006).Eurovent established classification for full load Energy Efficiency Ratio of each type of chillers. The classification follows the A to G approach used in the European Energy Label for household appliances but the limits between classes have been defined for the existing chillers listed in Eurovent directory. (Saheb, Becirspahic, Simon, 2006). The classification has been implemented in February 2005. It is too early to see the influence of this classification on energy efficiency. However, the distribution shows that 7 % of certified chillers are in Eurovent Class A and in total only 5 % of the certified chillers are in Eurovent Class G.

Another important share of electricity is consumed by ***fans for ventilation systems***, which result in about 114 TWh in the tertiary sector (Fraunhofer ISI 2001). For the time being there are no European polices to improve efficiency of ventilation systems.

A similarly important sector in terms of consumption is ***commercial refrigeration***. Estimate for the total European consumption range from 70 to 100 TWh per year. Only scarce national data is available, in Germany consumption of 13 TWh has been estimated for commercial refrigeration in the service sector, while another estimate shows around 8 TWh in the wholesale, retail trade, hotels and restaurants (Therburg, 2004). In the UK, the MTP estimates that the consumption of commercial refrigeration equipment represent 8,5 % of the total non domestic energy consumption. The specific refrigeration products covered by commercial refrigeration equipment, are: process chillers, Refrigerated display and service cabinets, Cellar cooling, Ice making machines (non domestic), Walk-in Cold Stores, Refrigerated vending machines, Refrigeration compressors, Air-cooled condensing units, Heat exchangers (process/industrial applications). (Market Transformation Programme 2006a).

For ***office equipment*** there is not much data on the total energy consumption. According to the Ecodesign study (ecocomputer 2006) in year 2005 there where 44 Million desktop computers installed in non residential applications, and another 36,5 million laptops, and about 44 million monitors, of which 45 % were flat panel. In the year 2003 a rapid penetration of LCD screens occurred, ad was sustained in year 2004 and 2005, which should have led to a decrease of the total monitor consumption. A German Survey has identified the ICT electricity consumption in the tertiary sector buildings to be 11 % of total electricity consumption in this sector (Schlomann, 2006) (Grueber, 2006). This is in good accordance with the ECCP finding. The ICT sector is predicted to increase its share in total electricity consumption (more equipment and more use of the equipment, in particular data centres are large electricity using buildings). The UK Market Transformation Programme in its Policy Brief dedicated to Information and Communication

12. According to the RoHS directive (2002/95/EC), which entered into force 1 July 2006, tri phosphor lamps may contain 5 mg of mercury per lamp and halo phosphate lamps may contain 10 mg mercury per lamp. The tri phosphor lamps on the European market contain 3 mg of mercury per lamp. These lamps are more expensive, but they have significantly longer life-time than the halo phosphate which gives a total price per hour approximately the same. Thus, there is a great potential of lowering the consumption of mercury in florescent tubs in EU if the tri phosphor lamps containing less than half the amount of mercury as the halo phosphate was used instead. It is also possible to lower the content of mercury in the tri phosphor lamps even further (below 3 mg) and to increase the life-time, but that needs some time for technical development.

13. The classification scheme is available at http://www.celma.org/pdf_files/BallastGuideEN200212.pdf

14. All the information are available at www.eu-greenlight.org

Technology (ICT) Equipment (Market Transformation Programme, 2006) indicates that "Non domestic ICT equipment was responsible for over 7 % (16,5 TWh) of non domestic energy consumption in 2004 (excluding servers and data centres). Non-domestic electricity use by ICT equipment has increased by over 70 % between 2000 and 2006. Non-domestic ICT consumption is expected to continue to increase by almost 40 % between 2006 and 2020. Risks include expected increases in ICT equipment functionality and networking capabilities and barriers to the ability of the PC to enter low power consumption modes such as sleep." (Market Transformation Programme 2006b). However it is important to notice that the UK figure includes also the ICT consumption of the industrial sector. It also important to notice that in the UK the residential energy consumption of office equipment is estimated to be 7 TWh (or 6 % of total residential consumption). It is assumed that office equipment (ICT equipment) is responsible for about 60 to 80 TWh per year in the tertiary sector, but more research is needed to arrive at a more precise evaluation. In the residential sector ICT is responsible for about 10 to 20 TWh. (Market Transformation Programme 2006b) Other experts calculated that office consumption in France was only around 4 TWh. The only policy in place at European level to reduce energy consumption of office equipment is the Energy Star label; however there is no data on the market share of the equipment meeting the Energy Star levels or on the rate of equipment with the power management enabled.

For commercial buildings another interesting *energy efficiency indicator* is the **total primary energy consumption** (or the specific electricity consumption) per square meter. From a monitoring exercise carried out in Germany the following data has been compiled (Therburg, 2004) (Herkel, Pfafferott, Löhnert et alea, 2006). A number of office and educational buildings have total primary energy below 100 kWh/m^2 per year, with lighting at about 10 kWh/m^2 and ventilation at 10 kWh/m^2. To reach such a low energy consumption values such buildings use natural or passive cooling technologies (including ground loop heat pumps).

Recently has been started a new IEE' SAVE project, EL-TERTIARY, with the aim to carry out additional monitoring survey in several EU Member States (monitoring electricity consumption in 100 tertiary buildings). It will provide additional important data for the non-residential buildings.

Conclusions

The energy efficiency policies and programmes (regulatory measures, unilateral agreement by trade associations, utility DSM programmes, incentives, white certificates, etc.) implemented at EU level and national level have resulted in the market transformation described in the previous sections These actions are evaluated on the basis of the annual electricity savings they have delivered and will continue to deliver in the coming years. While the various energy efficiency indicators for end-use equipment described in the previous sections are somehow 'relatively' easy to evaluate, it is necessary to build a detailed and dynamic stock model in order to evaluate the annual energy savings. Important information needed to create the stock model is the present stock of installed appliances and equipment, and their energy consumption (in real life conditions not in the energy consumption test mode), the average life of a appliances and equipment, annual replacement rate and any change in ownership penetration, patterns of use, size, together with the key demographic indicators (e.g. number of households, people per household).

Since only a percentage of the installed equipment is replaced each year, the impact of energy efficiency polices tends to be relatively slow and modest at the beginning, though continually increasing over time. However, in a time span of 10 to 15 years, when almost the whole stock has been replaced and the full effect of the policy measure has taken place, annual electricity savings in the order of tens of TWh will be achieved for several types of appliances and equipment described in the previous sections. The annual savings resulting from each individual policy are calculated against the Business as Usual (BaU) scenario, which correspond to the most likely trend in consumption, if the policy was not introduced. The BaU scenario includes the natural efficiency improvements (due to the autonomous market and technology developments), and the autonomous trends in sales.

One of the possible policy actions is to accelerate the *replacement rate* of "old" installed equipment, thus reducing the time for the complete turn over of the installed stock. CECED in a recent report (CECED, 2005), (Rüdenauer, 2006) presented at the EEDAL'06 conference claims that by replacing the 188 Million appliances older than 10 years with the best on the market 44 TWh could be saved. Of course attention must be paid that old appliances are withdrawn from household and "scrapped", as well as appliances are replaced with models of the same size.

For some appliances although there is a positive impact due to the policy action resulting in energy savings compared to the BaU scenario, there could still be a net increase in the electricity consumption, due to a larger penetration rate (this is the case for example for residential room air-conditioners, dishwashers, dryers). Another element to evaluate the result from a given policy is the possible competition between gas and electricity, and possible energy savings in terms of primary energy or CO_2 emission reduction. For examples electric storage water heaters are decreasing their total electricity consumption, due to the fact that are being replaced by instantaneous gas, thus resulting in CO_2 emission savings. Similar benefits could be achieved by replacing electric hobs (resistive type) with efficiency gas hobs, and replacing conventional driers with gas models.

As already indicated in previous reports standby energy consumption in entertainment electronic and ICT equipment is growing at a worrying rate. This because a lot of new equipment is added to the present stock (STBs, DVD players new TVs and surround sound systems, mobile telephones, broadband communication including home network). In addition some old replaced equipment may still stay in use in different locations in houses (e.g. older TVs moving to children's bedrooms together with old VCRs). Some equipment which did not "traditionally" have any standby consumption such as traditional white goods, start to have AC/DC converters, displays, modems, microprocessors, all devices that are likely to be always on and to add a few watts of standby consumption. While these additional features may be desirable and even useful to save energy in the operation modes, every step during the design phase has to be taken by designers and manufacturers to make sure that while in standby the added electronic devices draw as little power as possible and power management is always implemented to use as little electricity as possible and to switch off all the devices not needed. Moreover, although new TVs use significantly less standby power than older models as results of the EICTA unilateral voluntary agreement introduced first in 1997, and new TVs models are beginning to lower in-home standby power use, the simple number of appliances with standby power mode continues to increase. The net effect of these trends is likely to be a continuing increase in standby power use.

TV reception platforms are rapidly moving toward digital broadcasting technology. As a result, set-top boxes (STBs) will be the source of significant new standby and on-mode power demand in the near future. Some STBs introduced on the market stay in on-mode all the time, consuming up to 20–30 W of power (this consumption tends to increase as more functionality is added to STBs). With the assumption of about 50 millions advanced STB (accessing pay per view services with recording and time shift capabilities) in household by 2010, this is an additional electricity consumption of **10 TWh** per year in the EU-25. In addition, with the phase out of the analogue TV signal, simple converter boxes will be required by the legacy of the old analogue TVs. Converter boxes now on the market tend to consume about 10 W all the time. With the assumption of one converter boxes per household this will result in an additional **16 TWh** per year. The EU Code of Conduct for Digital TV Systems, if successfully implemented halves this predicted consumption and thus will deliver about **13 TWh** of annual electricity savings by 2010 compared to the business as usual.

A similar trend is also observed for broadband communication (mainly through DSL, but could also be implemented through cable and satellite STB, G3 mobile phones, and PLC) a number of new devices such as modems, routers, switches are introduced and are often always on. Depending on the penetration level, the specifications of the equipment and the requirements of the service provider, a total European Union consumption of up to 50 TWh per year can be estimated for the year 2015. With the general principles and actions resulting from the implementation of new Code of Conduct the electricity consumption could be limited to 25 TWh per year, i.e. a savings of **25 TWh** against the BaU scenario.

As far as the traditional white goods and other residential sector appliances and equipment are concerned electricity savings per year in the order of **24 TWh** to **30 TWh** have been achieved in the last decade (CECED in the same period estimate an energy savings of 34 TWh). In particular it is worth to notice that **65 TWh** to **75 TWh** will be saved per year by **2010 compared to 1995** in total by the current polices already in place (appliances labelling, efficiency requirements, unilateral voluntary agreements, Code of Conducts, etc.). It is important to highlight that there is still a huge saving potential available if further cost-effective[15] measure are implemented. In particular larger saving potentials exist for reducing **stand-by losses** (20 TWh), which is also the sector with the highest consumption growth with the current polices (+50 %). Large saving potential is also available in residential **refrigeration appliances** (16 TWh), and **residential lighting** (10 to 20 TWh, in lighting with the current policies there will be a consumption increase of about 10 %, the cost-effective technology CFLs is already in the market, bout not yet used in all the cost-effective lighting points in households).

Equally important to mention is the fact that with a prompt introduction of additional polices based on least life cycle cost and accelerated replacement of additional appliances and lighting the electricity of the residential sector could be reduced by an additional **60 TWh** to **90 TWh** per year by year 2015 compared to the current policies scenario.

The "Ballast" Directive will deliver electricity savings of about **5 TWh** by year 2010, while the economic potential for **non-residential lighting** will be at least **20 TWh** if the whole lighting system is considered. The European GreenLight programme (www.eu-greenlight.org) is promoting this concept and has already achieved remarkable savings (in the order of 100 – 200 GWh) (European GreenLight Programme, 2004). Other important electricity savings in the non-residential building sector are in office equipment (hence the need of a more effective implementation of the Energy Star programme), and in the cooling and ventilation systems (through the use of natural ventilation, and free cooling, as well the introduction of energy efficient compressor based cooling and tri-generation).

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15. Most of the energy efficiency measures are cost-effective. This means that they will results in net money savings for the users, as the reduced electricity cost over the life time of the appliances will be bigger than any additional purchasing cost for the more efficient model. Over the last ten years the EU white goods manufacturers have become more profitable, appliances cost less, and the efficiency has improved, this despite fears by manufacturers that the policy action introduced in the 90ies could have had a negative impact. Therefore it can be concluded that energy efficiency measures and in particular standards and labels are cost effective for society and reduce CO2 emissions at a negative cost.

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