REPORT

Energy efficiency improvements in the European Household and Service sector

- data inventory to the GAINS model

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The International Institute for Applied System Analysis has developed the GAINS model. The GAINS models most recent methodology updates allow for a detailed description of the residential and commercial sector with energy use, potential for energy demand reduction as well as energy demand reduction costs. To implement the new detailed methodology for the European version of the GAINS model, a data inventory is needed.

In this study, detailed data on energy use, building stocks and control technologies have been compiled and converted into the format suitable for the GAINS model. Bottom-up projections have been calibrated with the EU projection currently used as a European baseline in the GAINS model for the EU-27 countries as well as Norway, Switzerland and Turkey.

Keyword

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Foreword

The International Institute for Applied System Analysis (IIASA) has invited IVL Swedish Environmental Research Institute to participate in the process of producing detailed data sets for the residential and commercial sector for the EU-27 countries as well as Norway, Switzerland and Turkey. The data sets and projections produced in this project enables estimates on future patterns in energy use, technologies available to reduce energy demand as well as the investment costs associated with these technologies. These datasets are used by IIASA in the GAINS model.
This study has been financed by the Swedish Energy Agency, FORMAS and the Swedish Environmental Protection Agency. The study was performed from October 2008 until March 2009.

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Summary

Further improvements in the energy performance of buildings and equipment are important to Europe as means reducing energy demand as well as greenhouse gas emissions. For both the residential sector and the service sector, heating and ventilation as well as air conditioning constitutes a large proportion of the total energy use in these sectors, and there are large potentials for further improvements in the energy performance in the 'climate shell' of most European houses and buildings.

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Background

The emissions of greenhouse gases (GHG) and the growing concern for global warming and energy security are motivating increased European concern for energy demand reductions. The sectors usually linked to direct emissions of air pollutants are often also linked to energy conversion and emissions of carbon dioxide, a GHG. In these sectors, the research for cost effective solutions to curbed emissions of air pollutants have been ongoing since almost half a decade. As concerns for global warming and energy security increase the focus on emissions of GHG and energy demand, new sectors become more interesting as potential sources for cost effective solutions to further curbed emissions and decrease energy demand.

In the domestic sector, which includes households, commercial activities, agricultural activities, forestry etc, large potential for energy demand reduction has been identified in earlier reports. It has also been seen that energy use in this sector grow in many European countries, thanks to the increasing number of equipment in households and changing energy consumption patterns. Furthermore, the lifetime of buildings provides another dimension to the problem of energy demand management. The buildings constructed today is likely to stand for a hundred years, and the energy performance given to these buildings today will have a long impact on future energy demand as well as future energy bills.

In this study, efforts are made to perform numerical estimates on energy use and energy demand reduction possibilities. Focus lies on two subsectors to the domestic sector, the residential and the commercial sector.

Introduction

The residential and service sectors (from now on referred to the residential (RES) sector and commercial (COM) sector) in Europe account for roughly 40 percent (the COM sector accounted for 12 percentage, and RES for 26 percentage) of the EU-27 final energy consumption in 2005. Half of this share origin from fossil fuels and is thereby directly causing fossil CO_2 emissions. The major service derived from energy consumption in the RES and COM sector is to provide the service heat. For EU-27, the share of energy used for heat in the RES and COM sector is approximately 70 percent units out of the above mentioned 40 percent. It is generally considered that the RES and COM sector are subject to a wide variety of cost-effective options enabling a reduction of the fossil fuel use as well as reduction of energy used for heat purposes within the union.

The international research organization IIASA was established in 1972 and is located in Laxenburg, Austria. The institute conducts inter-disciplinary scientific studies on environmental, economic, technological and social issues related to the human dimensions of global change. IIASA deliver estimates on emissions of greenhouse gases and their abatement potential and costs to the UNFCCC. For this purpose, IIASA use the Integrated Assessment Model (IAM) GAINS. Emissions of GHG are caused by energy in all sectors of society. Two of these are the residential (RES) and commercial (COM) sectors.

IVL Swedish Environmental Research Institute is an independent research body that, since 1966, has been involved in the development of solutions to environmental problems on behalf of the business sector and the community and is today Sweden's leading organization for applied environmental research. IVL are currently developing a Swedish version of the GAINS model. IIASA invited IVL and Sweden to participate with collection, evaluation and delivery of data for the RES and COM sectors in the EU-27countries and Norway, Switzerland and Turkey (EU-27+3).

Purpose with the project

The purpose with this project is to gather national data for the EU-27+3 countries of relevance for the GAINS RES and COM sectors and deliver these data in the format suitable to IIASA. The data is then used in the European version of the GAINS model as a basis for estimates on future emission abatement possibilities.

By the delivery of data sets to the GAINS model, and by using the methodology developed, the future importance of abatement measures in the RES and COM sector can be further explored and comparisons can be made between countries. The compilation of the data set ensures that the methodology used in the different versions of the GAINS model to estimate emission reduction potentials are identical for all Annex 1-parties to the UNFCCC, which ensures harmonization of national estimates.

Disposition of the report

This report is disposed of as follows. The chapter on methods briefly explains data and sources for estimates as well as methods used to adapt data and estimates to suitable GAINS format. The chapter on methods also clarifies where assumption and simplifications are required. The chapter on results presents numerical results in varying the level of detail dependent on what is estimated as suitable. Following the numerical estimates is a more detailed description of how these estimates have been obtained and adapted for the GAINS format. The latest part of the main report is the discussion where data, project difficulties and future needs are discussed. This report serves only as a presentation of the data needed in the GAINS model, and no real conclusions can be drawn before the data are used in the GAINS model. Finally, detailed descriptions on the estimated nation-specific energy needs are given in the appendices.

Method

The method for calculating GHG and air pollution mitigation options in the GAINS model is described in Cofala et al. (2008). The data inventory work performed in this project follows the method described in Cofala et al. (2008) and is aimed at completing missing or incomplete data estimates in the GAINS model database. Data needed for implementation of the method on an EU-27+3 level are to a large extent collected from official statistical agencies such as Eurostat and UNECE, other international projects such as Odyssee, as well as national statistical offices and other official offices.

In this chapter we firsts present an aggregated description of the data needed to use the method described by Cofala et al. 2008. Following the overview, the method and data sources for 2005 are presented first, followed by the inventory of energy demand reducing mitigation technologies together with the method to estimate technology penetration in 2005. The method used to project the level of energy use for 2020 and 2030 is described in the next part. Finally, the method used to estimate the penetration of these technologies in 2020 and 2030 is presented.

Energy needs in the Residential and Commercial sector 2005 and 2020/2030

In international statistic sources a common level of data aggregation related to energy needs is to represent non-industrial, non-power plant energy needs in the domestic sector, which includes services, households, military, etc. In the GAINS model, the domestic sector is represented by the abbreviation DOM that then sub-split into the residential (RES), the commercial (COM), and the other (OTH) sectors. In this project, we focus on the data inventory for the RES and COM sectors. The energy needs to characterize the largest electricity and heat consuming energy uses parameters for the residential and commercial sector in the GAINS model following the following grouping.

Table 1: Specific energy needs in the residential and commercial sectors

Sector/Need	GAINS code	Activity variable	Intensity indicator
Residential sector	RES		
Heating, ventilation and air conditioning	HVAC	Living space	GJ/m2
- Space heating	SPACE_HEAT	Living space	GJ/M2
- Space cooling	SPACE_COOL	Living space	GJ/M2
Water heating	WATER_HEAT	Housing unit	GJ/h_unit
Cooking	COOKING	Housing unit	GJ/h_unit
Lighting	LIGHTING	Housing unit	GJ/h_unit
Large appliances (refrigerators, freezers, washing machine, dishwashers, dryers)	APPL_LARGE	Housing unit	GJ/h_unit
Small appliances (computers, TV sets, audio and other electronic equipment)	APPL_SMALL	Housing unit	GJ/h_unit
Commercial sector	COM		
Heating, ventilation and air conditioning (HVAC)	HVAC	Building space	GJ/m2
- Space heating	SPACE_HEAT	Building space	GJ/M2
- Space cooling	SPACE_COOL	Building space	GJ/M2
- Space ventilation	SPACE_VENT	Building space	GJ/M2
Water heating	WATER_HEAT	Building space	GJ/m2
Cooking	COOKING	Building space	GJ/m2
Lighting	LIGHTING	Building space	GJ/m2
Large appliances (refrigerators, freezers, washing machine, dishwashers, dryers)	APPL_LARGE	Building space	GJ/m2
Small appliances (computers, TV sets, audio and other electronic equipment)	APPL_SMALL	Building space	GJ/m2
Other needs (not included separately)	OTHER	Building space	GJ/m2

Source: Cofala et al. 2008

The 'Activity variable' for each specified energy need represents the data used for calculating the total energy used for each country and energy need. The 'Intensity indicator' represents the country's specific intensity of each energy need and the unit used in these calculations.

Since the energy performance of buildings to a large extent depends on the age of the building, the GAINS model use four dwelling categories in the residential sector and two building categories in the commercial sector.

Table 2: Building representation in the GAINS model

Residential sector:	Commercial sector:
- Existing houses	- Existing buildings
- Existing apartments	
- New houses	- New buildings
- New apartments	

Existing houses/apartments/buildings are built in or before 2005 while new dwellings and buildings are built after 2005. Each of the above mentioned dwelling and building types has different energy performance. Existing dwellings and buildings have poorer energy performance than new.

Furthermore, the dwellings and buildings are in the model constituted out of three different energy performance stages:

- No control (NOC)
- Stage 1
- Stage 2

These stages are further represented later in the chapter.

The specification of energy needs in Table 1 above shows what types of the activity parameter that is of relevance in the GAINS model when estimating energy use. HVAC energy needs are estimated for existing and new dwellings and building since HVAC energy use depends largely on building construction years and construction type. The other energy needs described in the table are determined per household for the RES sector and per m^2 for the COM sector.

The energy services of interest in the residential and commercial sectors are of two types:

- Thermal energy (TH): include all fuels (coal, oil, gas and biomass) as well as heat supplied through the district heating system). Thermal energy services can be used in four categories of energy needs: HVAC, water heating, cooking and other.
- Electricity (ELE). Electricity energy services can be used in all categories.

- 2005

- ***Energy statistics and estimates***

The data for the total energy use of TH and ELE for each country in EU-27+3 are obtained from Eurostat and the current baseline scenario delivery to the GAINS model. The share of energy needs data for average EU-27+3 is found mainly in the Odyssee database[1]. For most countries, the

(1) [1] www.odyssee-indicators.org

split of energy needs in the RES sector can be found in the Odyssee database or from National Statistical surveys. However, for the COM sector, information of the division into the relevant seven energy needs is limited. Therefore, division of average EU-27 energy needs is used for the majority of the countries in the COM sector. To compare a country to another similar country, the country-specific number of heating and cooling degree-days and GDP/capita is used as an indicator of which countries that are suitable for comparison. The penetration in 2005 of the technologies aimed at reducing energy use in the respective energy needs is presented in the technology chapter.

- ***Building stock statistics***

The building stock statistics needed for 2005 are constituted out of the following:

Housing units:
The total number of dwellings (*Housing units*) for each country is given from a variety of National statistic's sources and from Werner 2006. *The share of apartment (percentage)* was given from the Federcasa (2006) and is compared with data from National statistic's sources when that kind of data can be found from national sources.

Average floor space:
The average floor space housing units for each country is calculated with data from NBHBP (2005) and adjusts to 2005 level with the annual rate of the change multiplier, which is given by the GAINS database. *The average floor space apartment* is calculated by *average floor space housing units* divided with *share of apartments (percentage)* and *share of house (percentage)* multiplied with factor 2. *The average floor space housing units* is assumed to be twice as large as *Average floor space (apartment).*

Floor space housing units total:
Floor space housing units total is the sum of *floor space apartments total (existing)* and *floor space houses total (existing)*, which is the product of *average floor space apartments and houses* and *existing apartments and houses*.

Energy demand reducing technologies

The technologies available to reduce the energies used for the specified energy needs are aggregated into two groups, stage 1 and stage 2 for each energy need. These technologies (or control options, mitigation options), can substitute the low efficiency solution represented by the No Control solution (NOC). The technologies available for reduction of the energy used are presented for each energy need. Following the technology presentation is a presentation on the method used for estimating the penetration rates of the technologies in 2005.

In this section, the group of abatement technologies for energy efficiency is compiled. The groups are divided into the RES and COM sector technologies. For each technology the investment cost, life time and energy efficiency are presented given the data availability. It is uncommon to find all the sought parameters in the literature estimates, and usually only two out of three parameters are given. For the Non-HVAC stages, most useful information was found at the Energy Star homepage. Their energy efficiency calculator presents numbers for all the sought parameters and provides information with both for standard units well as Energy Star classified units. As for the data collection in general, more information is available for the RES sector than for the COM sector. Energy Star does however provide information for the residential and commercial sector.

The GAINS model calculates emission mitigation costs in the €2005 currency. When literature estimates are given for other currencies and years, these are adjusted for through correction for consumer price indices and exchange rates between the currency and € in 2005.
The mitigation cost of the technologies takes into account annualized investments, the lifetime of equipment, interest rates as well as relative energy prices (Cofala et al. 2008). In this report, the costs presented are investment costs. All cost estimates exclude taxes.

Some of the technology estimates in the literature, the energy savings and the investment costs are given per the installed unit or other metric. In these cases, the estimates are adjusted to fit the activity description in the GAINS model. As expressed earlier in this chapter, the HVAC technologies for new or existing buildings (the new construction of houses or refurbishing) differ concerning their efficiency and investment cost. The technology estimates the origin from literature as well as on-line calculators. The results are presented in the following chapter on results.

- ***Technology Penetration in 2005***

The penetrations of technologies are estimated from Klaassen et al. (2005) and estimates from Ecofys (2002). The penetration rate of HVAC measures is to a large extent a weighted estimate base on available construction standard information. For other energy needs, the penetration rates of mitigation technologies are estimated from European inventory surveys and projects such as the ODYSSEE database and MURE tool (Bosseboeuf 2007). Also, important guidance when estimating nation-specific penetration rates is the national policy summaries available.

- 2020 / 2030

- ***Energy use development***

The development of the energy used by the specific energy needs is dependent on the expected penetration rate of the technologies available for energy demand reduction as well as the underlying change in demand for the respective energy needs independent of the technologies introduced to check the emissions from the specific energy need. The latter is represented by the change in the Intensity indicator for each energy need. The national policy on energy efficiency available in autumn 2007 indicates the expected penetration of energy demand reducing technologies in each country. National policy summaries are mainly taken from the Odyssee database[1] as well as Sveriges Byggindustrier (2008a). Furthermore, energy/GDP intensities as well as Energy/"Economic Value Added" intensities are calculated as indicators of the aggregated penetration of efficiency improving technologies in the studied countries. This is a very crude indicator and is used only to give a general guideline. The intensity indicators are mainly derived from EU-studies (EC DG TREN 2007) and the Odyssee database. The energy use development is calibrated with the PRIMES C&E package 2007 scenario as delivered by the IIASA team.

- ***Building stock development***

Housing units:

The trends in number of housing units from 2005 to 2030 are calculated by *the total population* per year divided into *household size* (people per the household). The household size is given from the scenario studied. The numbers of *existing houses* and *existing apartments* are correlated to *existing housing unit's demolition rate* that is explained below.

Average floor space:

The trend from 2005 to 2030 for *the average floor space housing unit* is calculated with *floor space housing units total* divided with *housing units*. The trends from 2005 to 2030 for *the average floor space apartment and houses* are calculated with *the total average floor space for apartment and house* divided with *total apartments and houses*.

To calculate the number of existing dwellings and buildings in 2020 and 2030 the annual demolition rate is required. The number of new dwellings and buildings can then be calculated from the estimate on total dwellings minus the calculated number of existing dwellings.

Existing housing unit's demolition rate (built in or before 2005)
When calculating *existing housing unit's demolition rate*, value for the annual number of demolished houses is used. This is found for 18 countries in the UNECE database[2]. For each country value for the number of the demolished house is divided with the total number of dwellings that year to calculate the demolition rate. When estimates for 2005 are not found the closest available estimate is used. For the 8 countries where no data is found, demolition rate is estimated by calculating a mean value from the neighbouring countries. For the 18 countries where data is found, a mean demolition rate value of 0.113 %/year (median 0.077 %/year) is indicated. The demolition rate is assumed to be constant from 2005 to 2030.

The demolition rate for existing commercial floor space is assumed to be the same as the corresponding the housing unit's demolition rate for each country and year.

Construction rates of new houses 2005
From Visier et al., 2002, and NBHBP (2005), *the average floor space for existing houses* is given for the period 1991-2003. To calculate the construction rate, values for the annual number of completed dwellings NBHBP (2005), and the UNECE database[2] is divided with the average floor space for existing houses. When estimates for 2005 are not available, the closest available estimate is used. For the 6 countries where no data is available, construction rate is estimated by an average EU-27 construction rate.

Floor space multipliers
To calculate *floor space per the new housing unit multiplier*, which is needed to calculate the total dwelling and building area in 2020 and 2030, the average dwelling area of buildings constructed in 2005 is compared with the average dwelling area for the total dwelling stock in 2005 to derive a housing unit multiplier for 2005. The average EU-27 the annual rate of change for space per dwelling is given by EC DG TREN (2007), which together with the floor space multiplier for 2005 gives the floor space multiplier for 2010, 2015, 2020, 2025 and 2030.

- ***Technology Penetration in 2020 and 2030***
The nation-specific technology penetrations in 2020 and 2030 are based on the background information supporting the baseline to which the energy use is calibrated. Furthermore, other projection provides substantial information on expected penetration rates. In the projection of future technology penetration it is important to remember the conditions valid for the baseline scenario. One example is that the EU C&E package was not yet decided upon during the construction of the baseline scenario. Neither had the EU ban on ordinary light bulbs been implemented.

- Currency and currency year
In the GAINS model database, the investments and costs are presented in Euro with the currency exchange rate as it was in 2005. The currency exchange rate between US$ and Euro was in 2005

(2) [2] http://w3.unece.org/stat/HumanSettlements.asp

0.8045; between UK£ and Euro 1.4627; between Swedish Krona and Euro 0.1078. All cost estimates are adjusted to year 2005 values by adjusting for consumer price indices.

Results

This chapter presents the statistics, estimates and projections compiled in this study. The main energy need results are presented in an aggregated format first followed by the detailed data estimates and projection estimates. The detailed building related statistics, estimates and projections are then presented followed by the estimates on control technologies as well as their estimated penetration rates in 2005, 2020 and 2030. The nation-specific distribution of HT and ELE use within the RES and COM sector energy needs are presented in appendix A.

Results - Energy needs in the Residential and Commercial sector 2005 and 2020/2030

- Energy consumption allocated towards energy needs

- 2005

- ***Energy statistics and estimates***

The specification of HT and ELE energy used in the respective energy needs is to estimate the relative contribution of emissions as well as the impact from applying for control technologies. The EU-27+3 average energy use distribution for the specified energy needs is given in the table below.

Table 3: Average EU-27+3 energy needs in residential and commercial sector

EU-27 energy needs 2005 (The Odyssee database)	**Residential sector** Share of total energy need	**Commercial sector** Share of total energy need
Space heat (HVAC)	69%	40%
Water heat	14%	9%
Cooking	4%	4%
Lighting	2%	8%
Large appliances	6%	8%
Small appliances	5%	12%
Other	-	18%

For the residential sector, the largest energy use is to be found in the HVAC energy needs, which is also where you can see large improvement potentials. The situation is similar for the commercial sector. However, the relatively large contribution to the total energy use from lighting, small appliances and other uses change the relative importance of the energy needs compared to the residential sector. The Odyssee database[1] estimates are compared with the REMODECE database[3] for consistency check.

(3) [3] http://www.isr.uc.pt

For more information about each country in EU-27+3 total energy needs, total thermal energy needs and total electricity energy needs divided into seven energy need categories, see Appendix, A-C.

- ***Building stock statistics***

The statistical sources presented in the previous chapter gives the following average housing unit and floor space numbers for 2005.

Table 4: EU-27 residential and commercial statistics of housing units and average floor space

	Housing units Residential [million]	Average floor space Residential [m_2]	Floor space Residential [million m_2]	Floor space Commercial [million m_2]
Austria	3.48	94	327	119
Belgium	4.44	85	378	150
Bulgaria	3.72	64	236	31
Cyprus	0.33	114	37	8
Czech republic	4.19	76	320	108
Denmark	2.49	109	273	114
Estonia	0.63	60	38	14
Finland	2.67	77	206	101
France	30.59	90	2748	861
Germany	39.55	85	3367	1852
Greece	4.42	83	368	109
Hungary	4.17	75	314	101
Ireland	1.54	105	161	62
Italy	28.46	92	2627	534
Latvia	0.99	55	55	22
Lithuania	1.36	61	82	14
Luxembourg	0.19	126	24	7
Malta	0.19	107	21	4
Netherlands	6.86	99	679	183
Norway	2	107	214	95
Poland	12.78	68	871	396
Portugal	4.7	84	393	126
Romania	7.89	75	592	139
Slovakia	2.61	56	147	81
Slovenia	0.81	75	61	16
Spain	18.7	85	1599	341
Sweden	4.27	92	393	165
Switzerland	4.04	89	359	136
Turkey	25	89	2222	892
United Kingdom	17.61	95	1673	277

Technologies

Technologies available for reduction of the energy needed in the respective energy needs are grouped into a stage 1 and stage 2 group for each energy need. The following mitigation technologies are presented in this chapter:

- HVAC Stage 1, existing houses (infer changes in HVAC for new buildings as well as new and existing apartments)
- HVAC Stage 2, existing houses
- Large_App Stage 1, large appliances
- Large_App Stage 2, large appliances
- Water_heat Stage 1, water heating
- Water_heat Stage 2, water heating

The control stages not specified in the bullets above are not considered in this report.

HVAC Stage 1, existing houses

HVAC stage 1 and 2 consists of three parts in the GAINS model; improvements in the building envelope; improving the boiler/heater thermostat; and improving the air conditioner efficiency.

- ***Technology presentation, t***

Information from the *Energy savings trust*[4] is adapted and used to estimate energy efficiency measures in existing buildings. These estimates are compared with the existing GAINS database estimates and other sources.

The measures considered for improving the energy performance of related to the building envelope in stage 1 are specified as:

- Loft insulation 50-270 mm
- External wall insulation
- Double Glazing
- Draught proofing
- Filling gaps between floor and skirting board

The measures improving the performance of the boiler/heater/thermostat in Stage 1 are:

- Condensing boiler
- Heating controls upgrade

For Stage 1, no specific improvement in Air Conditioning is considered more than the Heating controls upgrade considered as a boiler/heater/thermostat measure.

- ***Energy demand reduction efficiency, x and Investment, I***

In order to calculate the energy demand reduction efficiency as percentage improvement for the above mentioned HVAC stage 1, a low-efficiency energy use reference case is needed. The energy used for heating and cooling in a poorly insulated semidetached house in the United Kingdom is estimated to ~30 MWh / household and year in 2005, which is used as a low-efficiency reference and is based on adaptation from Shorrock & Utley (2003).

(4) [4] www.energysavingtrust.org.uk

From the numbers in the table below (the *annual savings per the year* column and the *CO2 saving per the year column*) it is possible to calculate the saved amount of energy per year with the knowledge that the numbers are calculated for natural gas with a price of 0.16 €/kWh and a CO_2 emission of 201.5 gram/kWh. Some of the energy efficiency measures are overlapping and some do not affect the energy need for heating. To get a reasonable combination of energy efficiency measures that could be combined, five measures where selected for the building envelope parts of the HVAC Stage 1. All costs are given in the euro 2005 value and exclude taxes. Furthermore, the costs reflect the cost that can be considered as attributable for the efficiency improvement, the costs do not cover the entire cost of the installation.

Table 5: Information for different building envelope measures

Efficiency measures costs (€)	Annual savings per year (€)	Installed cost (€)	Installed payback (years)	CO2 saving per year (kg)
Loft insulation 50-270 mm	67	672	4	300
External wall insulation	557	2016	11	2 500
Double Glazing	140	403		720
Draught proofing	33	269	7	150
Filling gaps between floor and skirting board	28	n.a.		130
Total:		**3360 €**		

As a total, stage 1 efficiency improvements in the building envelope would imply an extra investment of € 3360.

The combined efficiency improvement of the boiler/heating measures presented by the energy saving trust would be 17 % compared to low efficiency equipment. However, the estimations in the GAINS-model database of 15 % are very similar to the estimates in this report and the 15 % is therefore used. For electricity heated houses the improvement of installing thermostats as a heating control upgrade is the only measure included in the boiler/heater part of HVAC stage 1. That partial efficiency improvement corresponds to 8 %.

Table 6: Energy efficiency of the measures calculated in percentage, based on the numbers described above and prices for natural gas in the example.

Heat efficiency improvements	Energy saved, kWh/a (NG-price)	Energy saved, kWh/a (NG-emissions)	Efficiency improvement
Loft insulation 50-270 mm	1 489	1 489	4%
External wall insulation	12 407	12 407	40%
Double glazing	3 474	3 573	11%
Draught proofing	744	744	2%
Filling gaps between floor and skirting board	620	645	1%
Building envelope Total:			**50%***
Heater/boiler/thermostat Total:			**15%**

* The total % is lower than the sum of the parts due to the relative decrease in individual performance when all measures are introduced

How the measures above affects the cooling demand is very difficult to estimate. The increased insulation will reduce the need for cooling as well. Less heat will be transported into the house when it is warmer outside than inside. Improved windows will also include technologies to reduce the solar radiation to enter the building (at least in warmer countries) which means that cooling demand will decrease. The affect has been estimated to around 20% decreased cooling demand due to improvements in the building envelope as described above.

The installation of the thermostat will also reduce cooling demand as well as installation of better air conditioner. Improved air conditioner is included in this category because it is assumed that either an installation in a new boiler or in a new air conditioner will be implemented. The improved energy efficiency is assumed to be 21% for introduction of thermostat and improved air conditioner in stage 1 (8% for thermostat and 14% of improved air condition efficiency[5]. The estimated investment for heater/boiler/thermostat combination is 940 € excl taxes[4].

The combined efficiency improvement of these measures for stage 1 (building envelope & heater/boiler) is calculated to give; a 58 % reduction in space heating demand when using district heating or other small scale heating systems; a 54 % reduction in space heating demand when using electricity; and a 37 % reduction in space cooling demand.
For HVAC Stage 1, the total investment is 4300 € excl taxes.

- ***Max penetration rate, xmax***

The HVAC stage 1 control option can be implemented during refurbishing of existing houses. In this report it is assumed that current estimates on annual refurbishment rates of ~1-2 % (Shüring & Lechtenböhmer 2008) can be more than doubled up to ~4,5 % per year so that the number of existing houses refurbished with a HVAC Stage 1 control option in 2030 is three times as big as the corresponding number in 2005. It must be stressed that current estimates on refurbishment rates are scarce.

Stage 2

- ***Technology presentation, t***

The efficiency measures below are developed for existing buildings in Sweden. The existing Swedish energy performance standard in houses and apartments in 2005 is similar as the HVAC stage 1 for houses and apartments. According to Ekström et al. (2006) the total number of detached and semi-detached houses where any of these measures could be implemented is 1.4 million. The corresponding number for apartment buildings is expressed as an area of 149 million m2. The estimated energy use per house (20 MWh) for detached and semi-detached houses and the energy use per m^2 (177 kWh) for apartment buildings is used to weight the calculated energy efficiencies for detached and semi-detached dwellings and apartment buildings. The total energy use estimated as suitable for efficiency improvements is for detached and semi-detached dwellings estimated to 27 TWh for Sweden in 2005. The total energy use estimated as suitable for efficiency improvements is for apartment buildings estimated to 26 TWh for Sweden in 2005.
From Ekström et al. (2006), the following measures are aggregated into the GAINS model HVAC stage 2 option.

- GAINS model HVAC stage 2 building envelope/insulation:
  Further insulation of roof and 3-pane windows
- GAINS model HVAC stage 2 boiler/heater/thermostat (electricity):
  Heat Pump, *FTX-unit*, *optimization of heating system* and *internal payment for heat*
- GAINS model HVAC stage 2 boiler/heater/thermostat (thermal):

(1) [5] www.energystar.gov

Boiler (thermal), *FTX-unit*, *optimization of heating system* and i*nternal payment for heat*

- ***Energy demand reduction efficiency, x and investment I***

In Table 7 and 8 the efficiency improvements of the HVAC stage 2 measures are presented in the categorization adapted to the GAINS model.

Table 7: Efficiency potential for different measures, compared to Swedish building stock in 2005

Source: Ekström et al. (2006)	Detached and semi-detached dwellings	Apartment buildings	Offices etc
Building envelope/insulation:			
Insulation of roof	10%	3%	
Better windows (3 glasses instead of 2)	14%	14%	18%
Boiler/heater/thermostat (electricity):			
Heat Pump	25%	11%	15%
FTX-unit	35%	30%	30%
Low energy lamps		6%	
Optimization of heating system	20%	6%	5%
Boiler/heater/thermostat (thermal):			
Boiler (thermal)	14%	6%	6%
FTX-unit	35%	30%	30%
Optimization of heating system	20%	6%	5%
Internal payment for heat		9%	

Table 8: Efficiency potential for HVAC Stage 2 options on top of HVAC Stage 1, existing buildings

Efficiency potential	Detached and semi-detached dwellings	Apartment buildings	Weighted efficiency, HVAC Stage 2	Investment: €/housing unit
HVAC Stage 2: Building envelope/insulation: *Insulation of roof and better windows*	23%	16%	**19%**	**4915**
HVAC Stage 2: Boiler/heater/thermostat (electricity): *Heat pumps, FTX-units, optimization of heating system, internal payment for heat*	61%	47%	**54%**	4485
HVAC Stage 2: Boiler/heater/thermostat (thermal): *Boiler (thermal), FTX-units, Optimization of Heating system, Internal payment for heat*	54%	41%	**48%**	2156
Average for the electricity and thermal boilers				**3440**

- ***Cumulative energy demand reduction, and investment***

Table 9: The result when these measures are added on top of the measures in stage 1

	Efficiency improvement	Investment in €
Building envelope / insulation	60 %	8 275
Boiler/heater/thermostat (electricity)	58 %	-
Boiler/heater/thermostat (thermal)	55 %	-
Average for the electricity and thermal boilers		4 380

As presented above for stage 1 it is very difficult to estimate how the above measure is affecting the cooling demand. The aggregated effect for stage 1 and 2 is estimated to 30% decreased cooling demand for improving the building envelope/insulation. The investment cost is assumed to be included in the above specified investment costs. The aggregated effect for stage 1 and 2 for heater/boiler/thermostat is estimated to 38% (12% for the thermostat and 29% for the air conditioner[5]. The installation of the thermostat will also reduce cooling demand as well as installation of better air conditioner. Improved air conditioner is included in this category because it is assumed that either an installation in a new boiler or in a new air conditioner will be implemented.

- ***Max penetration rate, xmax***

The increase in penetration rate between 2005 and 2020, 2030 is based on the same annual refurbishing rate estimates as for HVAC Stage 1.

- ***Cumulative max penetration rate, xmax***

The cumulative max penetration rate is assumed to be equal to the max penetration rate for HVAC Stage 1 measures.

- Final note on HVAC measures

The estimates on efficiency improvements used in this report are taken from two sources in order to keep consistency between estimated efficiencies. However, the authors have compared the estimates with Ecofys (2005) and the values presented here are in the same magnitude.

Large appliances (electricity)

Stage 1

- ***Technology presentation, t***

Data from Energy Star[5] about the situation in US has been used as stage 1 for large appliances. Their information is presented in table 10 (column 1 and 2).

- ***Energy demand reduction efficiency, x, and investment I***

By using the split of energy use for these different large appliances in Sweden (column 3) it is possible to calculate the overall efficiency improvement in stage 1 for large appliances to 18 % compared to low efficient appliances. The split of energy consumption for various large appliances is supplied by Griffin & Fawcett (2000), IVA (2002) and the Swedish Energy Agency (2009).

Table 10: The overall efficiency improvement for the large appliances, stage 1

Appliance	Efficiency improvement	Investment cost (€)	Split of energy consumption
Refrigerator	15%	19	64%
Freezer	10%	21	
Dishwasher	56%	0	16%
Clothes Washer	31%	129	19%
Dehumidifier	20%	0	
Sum		169	

- ***Max penetration rate, xmax***

The maximum penetration rate for the aggregated stage 1 control technology for large appliances is assumed to be 100 % by the year 2020 since it is assumed that the average equipment is being replaced at least once every 15 years.

Stage 2

- ***Technology presentation, t***

Data for stage 2 has been collected from Electrolux where information about best available appliance (new) and a new ordinary appliance has been obtained.

- ***Energy demand reduction efficiency, x and Investment I***

Table 11: Best available appliances (new)

Appliance Source: Electrolux 2008[6]*	Efficiency improvement	Investment cost (€)	Usage rate	Division of energy consumption
Refrigerator	23%	24	50%	64%
Freezer	7%	n.a.		
Combination refrigerator and freezer	37%	98	50%	
Dishwasher	17%	n.a.	-	16%
Clothes Washer*	25%	201	-	19%
Dehumidifier*	47%	503	-	
Sum		826		

*The efficiency improvements for dishwasher and clothes washer are compared to models used today, because of difficulties to get comparable data for ordinary new appliances.

To be able to calculate an overall efficiency improvement for the large appliances, an assumption that 50% of the houses have a refrigerator and a freezer, and 50% has a combination of a refrigerator and a freezer has to be done (usage rate). Information about usage of different appliances in homes are also needed and where collected from household surveys performed by Griffin & Fawcett (2000), IVA (2002) and the Swedish Energy Agency (2009). The split between the energy usages for the appliances included here is presented in column 4 in Table 11.

The overall efficiency calculated for stage 2 for large appliances is 25% compared to the stage 1-level calculated to 18%.

- ***Cumulative energy demand reduction,***

Combining the two levels an efficiency improvement of 38% is reached.

- ***Max penetration rate, xmax***

The max penetration rate for the stage 2 control technology for large appliances is assumed to be 100 % in 2020, since the average lifetime of appliances is assumed to be shorter than 15 years.

(2) [6] www.electrolux.se

- ***Cumulative max penetration rate, xmax***

Following that the max penetration rate is assumed to be 100 % for both stage 1 and stage 2 control technologies, the cumulative max penetration rate is also set to 100 % by the year 2020.

Water heating (thermal and electricity)

Options available to control energy use for water heating are estimated based on the Eurelectric project 'Role of electricity' from 2006 which studied the environmental impact of an electricity-intensive European energy system (Eurelectric 2006).

Stage 1

- ***Technology presentation, t***

For water heating (thermal) stage 1 the improvement from conventional gas storage to a high-efficient counterpart has been selected. For water heating (electricity) the improvement from conventional electric storage to high-efficient storage is selected.

- ***Energy demand reduction efficiency, x and Investment I***

For water heated by other means than electricity (thermal), the efficiency improvement is 12 % and the investment cost 131 €. For water heating by using electricity the efficiency improvement is 5 % and the investment cost is 82 €.
The following table shows the options available for reducing the energy demand for water heating, as presented by Eurelectric (2006).

Table 12: Collected data for water heating

Water heat type	Efficiency	Inv. Cost 1[7] (€)	Annual energy Cost 2[8] (€)	Life (year)	Cost (3) over 13 years (€)
Conventional gas storage	57	380	537	13	7361
High-eff gas storage	65	525	471	13	6648
Conventional oil storage	55	950	440	8	5420
High eff. oil storage	66	1400	360	8	5680
Conventional electric storage	90	350	820	13	11010
High eff. electric storage	95	440	760	13	10320
Demand gas	701	650	480	20	10250
High eff. pilotless demand gas	84	1200	270	20	6600
Electric heat pumps	300	2000	280	13	5640
Indirect water heater with efficiency gas or oil boiler	79	600	300	30	9600
Solar with electric back-up	-	2500	250	20	7500

Eurelectric 2006

- ***Max penetration rate, xmax***

The maximum penetration rate for water heating control options by 2020 is assumed to be 100 %.

[7] Cost 1: approximately cost incl. installation
[8] Cost 2: energy costs based on hot water needs for typical family of four person and energy cost of € 0,15/kWh for electricity, € 0,75/ m3 for gas and € 0,40/litre of fuel oil. Future operation cost are neither discounted nor adjusted for inflation.

Stage 2

- ***Technology presentation, t***

For stage 2 the improvement from conventional gas storage to a high-efficient pilotless demand gas water heater is selected as representing stage 2 control technologies for water heating using non-electric heating sources. For electric water heating, the shift from a conventional electric storage to electric heat pumps is selected to represent the stage 2.

- ***Energy demand reduction efficiency, x and Investment I***

For thermal water heating stage 2 control technology, the efficiency improvement is estimated to 32 % compared to the low-efficiency water heating and the investment cost is 738 €. For stage 2 control technology applied to electric water heating, the corresponding increase in energy efficiency is 70 % and the investment cost equal 1485 €.

- ***Max penetration rate, xmax***

The maximum penetration rate, as well as the maximum cumulative penetration rate is set to 100 % by 2020.

Mitigation Technology Penetration in 2005

A policy inventory as well as a technological specific inventory is used to estimate the penetration of the available mitigation technologies in the model. This inventory of technology penetration in 2005 serves the purpose of calibrating the European data and thereby supplying a base for the estimates on potentials for further energy efficiency improvements. The following table presents the estimated penetration of HVAC stage 1 control in European households in 2005. The conversion from Eurostat estimates (Klaassen et al. 2005) is calibrated towards a Swedish expert estimate on 70 % penetration of stage 1 control in Sweden 2005.

Table 13: Estimated penetration of HVAC stage 1, 2005

Technological Inventory: HVAC penetration in 2005	Insulation in Eurostat inventory [%]	Re-calibrated to GAINS stage 1	Comment:
Austria	32	22	Klaassen et al. (2005)
Belgium	40	28	Klaassen et al. (2005)
Bulgaria	30	21	Assumed to be same as Romania
Cyprus	30	21	Assumed to be same as Greece
the Czech Republic	36	25	Estimated from insulation thickness in walls, given by Ecofys (2002)
Denmark	73	51	Klaassen et al. (2005)
Estonia	54	38	Estimated to be about 20 % higher than Poland, based on insulation levels given by Ecofys (2005)
Finland	100	70	Klaassen et al. (2005)
France	54	38	Klaassen et al. (2005)
Germany	42	29	Klaassen et al. (2005)
Greece	30	21	Estimated from insulation thickness in walls, given by Ecofys (2002)
Hungary	36	25	Assumed to be same as Slovakia and Czech republic, according to Ecofys (2005)
Ireland	45	32	Estimated from insulation thickness in walls, given by Ecofys (2002)
Italy	30	21	Estimated from insulation thickness in walls, given by Ecofys (2002)
Latvia	54	38	Estimated to be about 20 % higher than Poland, based on insulation levels given by Ecofys (2005)
Lithuania	54	38	Estimated to be about 20 % higher than Poland, based on insulation levels given by Ecofys (2005)
Luxembourg	51	36	Assumed to be same as Austria
Malta	30	21	Assumed to be same as Italy
Norway		70	Assumed similar to Sweden
the Netherlands	51	36	Klaassen et al. (2005)
Poland	45	32	Estimated from insulation thickness in walls, given by Ecofys (2002)
Portugal	54	38	Estimated from insulation thickness in walls, given by Ecofys (2002)
Romania	30	21	Assumed to be somewhat smaller than Hungary
Slovakia	36	25	Estimated from insulation thickness in walls, given by Ecofys (2002)
Slovenia	36	25	Assumed to be same as Slovakia and Czech republic, according to Ecofys (2005)
Spain	54	38	Estimated from insulation thickness in walls, given by Ecofys (2002)
Sweden	100	70	Klaassen et al. (2005)
Switzerland		22	Assumed similar to Austria
Turkey		25	Assumed similar to Hungary
the United Kingdom	45	32	Klaassen et al. (2005)

Stage 2 control technologies are to a very limited extent assumed to be implemented in 2005.

For other energy needs, the penetration rate of stage 1 control options is assumed as ~15 % in 2005. The value varies between different countries with respect to economic wealth and national energy efficiency policies already in place.

Current state and projections regarding energy efficiency policies

The odyssee database and the MURE project[1] provide a thorough summary of energy efficiency policies in the European countries. Furthermore, the Swedish organisation Sveriges Byggindustrier (2008a, 2008b) has summarised European energy efficiency policies. These policy summaries are used as indicators on the existing and future penetration of energy efficiency measures in the EU-27 + Norway, Switzerland and Turkey.

- Odyssee building policy summary

Evolution and Monitoring of Energy Efficiency in the New EU Member Countries and the EU-25 (Bosseboeuf 2007)

Energy efficiency Policies in the Residential sector
Legislative-normative (building regulations implementing the European Directive for the Energy Performance of Buildings (EPBD) and the building certificates associated with this Directive) or legislative information measures in the residential sector are high impact measures to increase energy efficiency. There where six numbers of legislative-normative measures in 2005. Fewer countries in the New Member Countries (NMC: s) than in EU-15 consider building regulations as a high-impact measure. The reason for this can be that NMC: s has stronger barriers than EU-15 countries due to a lack of qualified staff in NMC: s.

Table 14: Examples of high impact measures for NMC: s in the residential sector

High impact measures for New Member Countries (NMC: s)		Measure types
Bulgaria	Individual billing (multi-family houses)	Legislative-normative
	Buildings-Minimum Thermal Insulation	Legislative-normative
	Residential Energy Efficiency Credit Facility (REECL)	Subsidies
Cyprus	Law for the energy performance of buildings	Legislative-normative
	Governmental financial support schemes for investments in RES/RUE/EE	Subsidies
	Scheme for subsidising CFL lamps	Subsidies
Hungary	Energy efficient renovation of residential buildings built with industrialised technology	Subsidies
Malta	Rebates on investments in energy efficient by domestic consumers	Subsidies
Poland	Technical Requirements for Buildings and their Location	Legislative-normative
Slovakia	Energy efficiency Certificates for Buildings	Legislative-information

Lithuania implemented a new regulation in August 2005, "Thermal Technique of Envelopes of the Buildings' (STR. 2.05.01:2005) and have improved the walls and roofs by a factor 4, and windows by a factor 2. Lithuania is now at the same level of performance as Finland that has a similar climate zone as Lithuania.

Examples of Innovative energy efficiency measures:
Bulgaria has provided a *building tax exemption* from 2005 for owners of buildings having obtained a certificate category A or B. Slovakia has implement 'On the Defined Time and Quality of the heat Delivered for the Final Consumer' 2004 that defines the time of heat delivery and sets the indoor temperature during the heat period September 1st to March 31st. The heat delivery starts when the average outdoor temperature is below 13℃ two preceding days. The State Energy Inspectorate control and monitor the measures. *Building certificates* are supposed to be implemented by all EU Member States, in the frame of the European Directive for the Energy Performance of Buildings. Nevertheless, problems with introduction of the certificates and qualification of auditors have delayed the implementation.

Energy efficiency Policies in the Commercial sector
Legislative-normative is also the dominance measure for the commercial sector, as for the residential sector. Subsidies and Information measure are also two important measures.

Table 15: Examples of high impact measures for NMC: s in the commercial sector

High impact measures for New Member Countries (NMC: s)		**Measure types**
Bulgaria	Individual billing (multi-family houses)	Legislative-normative
	Buildings-Minimum Thermal Insulation	Legislative-normative
	Residential Energy Efficiency Credit Facility (REECL)	Subsidies
Cyprus	Governmental financial support schemes for investments in RES/RUE/EE	Subsidies
	Energy performance buildings regulation	Legislative-normative
	Information, awareness, training campaigns for energy saving technologies, practices, ethos and policies/incentives of government	IET*
Poland	Technical Requirements for Buildings and their Location	Legislative-normative
Slovakia	Thermal Insulation Standards in Buildings	Legislative-normative
	Energy Audit Training Programme	IET*/Subsidies
Slovenia	Energy audits and feasibility studies subsidies	IET*/Subsidies

* IET (information, education and training)

Examples of innovative energy efficiency measures:
In Hungary has implemented a Programme for the energy efficient modernisation of public educational institutions. Bulgaria has provided a Regional council on Energy Efficiency (RCEE) and Mandatory energy Actions Plans for municipalities.
Mandatory elaboration of energy audits according to energy consumption is implemented in The Czech Republic.

- Sveriges Byggindustrier policy summary

Sveriges byggindustrier, *Rena vinster bakom en finansiell barriär* , 2008
A report by the Swedish Building Industry of Energy efficiency in existing buildings.

- The building construction industry sector accounts of 40% of society's use of energy in Europe.
- 90% of the new buildings today will remain 40 years from now, since the renovation cycle are 40-60 years of new buildings.
- Households account for 66% of the energy used in EU’s total buildings stock.

Sweden, Germany, France and England invest in energy efficient buildings in different ways:
The Swedish national ambition is to reduce the energy use with 20% by 2020, and with additional 50% until 2050 relative to 1995 level of energy use for the building stock in Sweden. However, the economical incentives for energy efficient buildings in Sweden have been low. The Swedish use of electricity on the other hand is very high in contrast to other European countries, since Sweden has less expensive electricity costs. Compared to Germany, Sweden has 50% lower electricity costs, but the price of electricity has increased the last ten years and is expected to increase more in Sweden.

‘The million buildings program’ of residential buildings in Sweden:
750 000 dwellings were built in the 1950-60 century and uses 60% more energy than buildings constructed after 1960. Residential buildings have an expected life time period of 40-60 years, so refurbishment is expected. It is less expensive to refurbish the dwellings than to build new dwellings since the investment costs are repaid in 2-4 years. With existing technologies, if there is an

increase of refurbishment of buildings from 25 000 to 65 000 dwellings per year, energy consumption can be spared by 50% and will save 40 billion annually in energy consumption in 50 years.

Table 16: The million buildings program, energy performance of buildings

The Program of Million buildings		Newly-produced buildings
Isolation:		
insulation outer walls	10cm	20cm
insulation in the roof	15cm	40cm
Window:	3 W/m2	1.2 W/m2
Other:	Climate shells are not airtight, poor efficiency and isolation of pipes.	

Germany has 17.3 million residential buildings today. 73% of the residential buildings were built before 1978 and have inadequate insulation. 2003 Germany introduced an energy efficiency strategy and plan to introduce subsidies and direct support for low-energy residential buildings. Only Germany, of these four countries, has an official definition of low energy buildings. Germany also wants to introduce an indirect support for the future where buildings not in used are excluded from the obligations, which will reduce the cost of renovations.

France has rules for building components and policy initiatives called 'Le Grenelle de l'Environment' that involves direct supports with green loans, loans without interest and tax exemptions. France has also an indirect support that is a financial support for the investment of energy efficient equipment.

The United Kingdom has programs for energy efficiency and investment in energy efficiency inventions.

Return on investment:
Energy efficient interventions at renovations can be done by for example: more energy efficient windows, insulations of front walls, electricity-efficient fans, heat-recycling and water-saving fixtures.

Energy efficient interventions at renovations of existing buildings can be achieved by for example: isolations of windows (that can make a 5% energy use savings and provide repayment in two years), change of windows to windows with U-value 1W/m² (that can save 5% energy use provide repayment in two years), and replacement of the ventilations system in multi-dwellings to el-efficient fans with air temperature-controlled-pressure regulation (that can make a 10% energy use saving and provide replacement in four years).

Table 17: A comparison of heating and electricity consumption in a typical house and in an energy efficient house for.

Comparison:	Typical house: 220 kWh/Atemp	Energy efficient house: 92 kWh/Atemp
Radiator-heat	125	27
Water heating	40	25
Housing unit Electricity	20	27
Household electricity	35	13

- 2020 / 2030

- energy use development

The development of national energy use for the residential and service sectors are given by the PRIMES model energy projections for 2007 as delivered to IIASA. These projections were not including the agreement of the EU Climate & Energy package and are projecting increasing energy uses in the residential and commercial sectors for most countries.

Other parameters of relevance for energy use in the residential and commercial sectors are summarized and presented below. These parameters are used for a detailed estimate for the countries. The following building stock parameters are presented in the text below:

- demolition rate of buildings,
- floor space multipliers (changes in household area)

- building stock development

Existing housing units' demolition rate (built in or before 2005)

Information on national demolition rates can only be derived for 18 countries. For these countries, the available data gives a mean demolition rate of 0.113 %/yr (median 0.077 %/yr). The demolition rate is assumed to be the same from 2005 to 2030.

The demolition rate for existing commercial floor space is assumed to be the same as the corresponding housing units' demolition rate for each country and year.

Table 18: demolition rate for all EU-27 countries, plus Norway, Switzerland and Turkey

Demolition rate	%/year
Austria (Data from Odyssee, calculated by IVL)	0.273
Belgium (Data from Odyssee, calculated by IVL)	0.076
Bulgaria (Data from Odyssee, calculated by IVL)	0.022
Cyprus (Data from Odyssee, calculated by IVL)	0.031
Czech Republic (Data from Odyssee, calculated by IVL)	0.032
Estonia (Data from Odyssee, calculated by IVL)	0.032
Finland (Data from Odyssee, calculated by IVL)	0.124
France (Data from Odyssee, calculated by IVL)	0.073
Germany (Data from Odyssee, calculated by IVL)	0.148
Hungary (Data from Odyssee, calculated by IVL)	0.107
Ireland (Data from Odyssee, calculated by IVL)	0.534
Latvia (Data from Odyssee, calculated by IVL)	0.104
Lithuania (Data from Odyssee, calculated by IVL)	0.077
Netherlands (Data from Odyssee, calculated by IVL)	0.201
Romania (Data from Odyssee, calculated by IVL)	0.055
Slovenia (Data from Odyssee, calculated by IVL)	0.025
Spain (Data from Odyssee, calculated by IVL)	0.091
Sweden (Data from Odyssee, calculated by IVL)	0.032
Mean value	**0.113**
Median	**0.077**
Denmark (Calculated as a mean value of Sweden, Finland and Germany)	0.101
Greece (Calculated as a mean value of Bulgaria, Romania and Hungary)	0.061
Italy (Calculated as a mean value of Austria, France and Slovenia)	0.124
Luxembourg (Calculated as a mean value of Belgium, Netherlands and Germany)	0.141
Malta (Assumed to be the same as for Italy)	0.124
Norway (Assumed to be the same as for Sweden)	0.03
Poland (Calculated as a mean value of Germany, Czech Republic and Lithuania)	0.086
Portugal (Calculated as a mean value of France and Spain)	0.082
Slovakia (Calculated as a mean value of Czech Republic and Hungary)	0.070
Switzerland (Mean value, average EU-27)	0.113
Turkey (Mean value, average EU-27)	0.113
United Kingdom (Calculated as a mean value of Ireland, Netherlands and France)	0.269

Floor space multipliers

The floor space multipliers given from the statistics on average building stock size, the average building size on new buildings in 2005, as well as the annual building area growth indicated by EC DG TREN (2007) are presented below.
The annual average EU-27 rate of change for space per dwelling 0.9% per year (EC DG TREN, 2007) are calculated with each countries floor space multiplier for 2005, to find the floor space multiplier for 2020 and 2030.

Example:
Sweden had floor space multiplier of 1.4 by 2005, with the average EU-27 annual increase rate 0.9% the unit multiplier 2020 and 2030 are estimated as predicted to be 1.6 and 1.75 respectively compared to the building stock constructed up until 2005.

Table 19: EU-27 countries average floor space, construction rate and unit multiplier

Average floor space , dwellings completed in 2005		Average floor space, total dwelling stock in 2005	Floor space multiplier (2005)	FS multiplier (2020)	FS multiplier (2030)
Austria	101***	93.6**	1.1	1.26	1.38
Belgium	119*	86.3[1]	1.4	1.60	1.75
Bulgaria	-	-	1.2[4]	1.37	1.50
Cyprus	197.6**	-	1.2[4]	1.37	1.50
Czech	104.9***	76.3*	1.4	1.60	1.75
Denmark	112.4*	109.1**	1.0	1.14	1.25
Estonia	89.1***	60.2***	1.5	1.72	1.88
Finland	90.2***	77**	1.2	1.37	1.50
France	112.6**	89.6**	1.3	1.49	1.63
Germany	113.9***	89.7**	1.3	1.49	1.63
Greece	124.6*	82.7[2]	1.5	1.72	1.88
Hungary	94.1**	75*	1.3	1.49	1.63
Ireland	105***	104***	1.0	1.14	1.25
Italy	81.5[3]	90.3[1]	0.9	1.03	1.13
Latvia	-	55.4***	3.5	4.00	4.38
Lithuania	106.2***	60.6***	1.8	2.06	2.25
Luxemburg	120.2**	125*	1.0	1.14	1.25
Malta	-	106.4**	1.2[4]	1.37	1.50
Netherlands	115.5[3]	98[3]	1.2	1.37	1.50
Norway			1.4[5]	1.60	1.75
Poland	99.3**	68.2**	1.5	1.72	1.88
Portugal	88.9***	83*	1.1	1.26	1.38
Romania	-	-	1.2[4]	1.37	1.50
Slovakia	117.8**	56.1*	2.1	2.40	2.63
Slovenia	113.5**	75**	1.5	1.72	1.88
Spain	96.1**	90*	1.1	1.26	1.38
Sweden	128***	91.6***	1.4	1.60	1.75
Switzerland			1.2[4]	1.37	1.50
Turkey			1.2[4]	1.37	1.50
United Kingdom	-	86.9*	1.2[4]	1.2	1.2
Source:	NBHBP 2005.		Calculated by IVL	Annual increase: 0.9%, EC DG TREN (2007)	
*2001, **2002, *** 2003 [1] 1991, [2] 1994, [3] 2000, [4] Average EU-27, [5] compared to Sweden					

- Technology Penetration in the baseline 2020 and 2030

The projections for the European countries are calibrated with the EC-DGTREN (2007) projection for Europe. This projection was developed before the signing of the EU Climate & Energy package. The future penetration of control stages is therefore not considered as very ambitious in the calibration. Information from the projections delivered by the PRIMES modelling

group, supporting the EC-DGTREN (2007) is used to estimate projections on energy intensity in households and the service sector. The energy intensities are used as indicators on energy use development for the different energy uses.
The calibrated estimates on stage 1 and stage 2 technology penetration in 2020 and 2030 consider the existing national policies presented above as well as the calculated energy intensity indicators.

- Intensity indicator multipliers in 2020 and 2030

Intensity indicators are used to represent changes over time concerning the use of appliances as well as the energy used for heating, ventilation and cooling. The indicators are needed to illustrate changes in consumer behaviour, such as the increase in use of small appliances such as TV-sets and personal computers. The estimations on intensity indicators for the years 2020 and 2030 are based on EC-DG TREN (2007), the energy intensity calculations from the PRIMES model projections (which supported the EC-DG TREN (2007) projection, Eurelectric (2006), as well as the Odyssee project and database[1].

European Energy and Transport – trends to 2030, updated 2007 - Summary

Residential sector:
As household seek the maximize utility, they are the main driver of energy consumption. Change in lifestyles and investment behaviour influence the energy consumption, for example the quite new trend implying a large increase in cell phone and computer ownership. The energy price also influences household's energy consumption. Higher price for energy may influence people's behaviour by for example turning off the lights in empty rooms. However, energy savings leads to lower energy bills that can influence people to consume more energy given the additional income and are the so called 'rebound effect'.

The increase in income motivates construction and use of larger dwellings and with greater heating comfort. However, space per dwelling and number of households are increasing at a rate below the rate of the disposable income. Average floor space is increasing because of improving living standards and the increasing income. Population growth is low and the number of persons per households is decreasing.

Table 20: Average annual rate of change (%) 2005-2030

Parameter	Annual change
Income	2.03 % per year
Space per dwelling	0.90% per year
Number of households	0.53% per year
Population	0.05% per year
Persons per households	-0.48% per year

2005, the residential sector consume 26% of the total energy consumption in EU, and is projected to be almost the same by 2030, 24%. The baseline scenario in the report projected an annual increase by 0.4% from 2005 to 2030.

Electric consumption per dwelling increased with in average 1.1% per year during the period 1990-2005 because the growth in appliances in households. Almost every household owns a TV, refrigerator, and circa 80% of all households in EU own a washing machine. New appliances are increasing the energy consumption, however new appliances have high energy efficiency standards.

Useful energy from the increasing use of appliances has increased twice as much as electric consumption for appliances. As a result of this, energy intensity decrease between 1990-2005 with 1.1% per year.

The Baseline scenario project a slow increase of energy for space heating, while cooling are projected to grow fast, from 1% 2005 to 2% 2030 with faster growing of energy demand from cooling than electric demand from cooling. This is because of technological improvements in heat pumps that are projected to be more than 75% more efficient in 2030 than today. Water heating and cooking are projected in the baseline scenario to increase at an average annual rate of 0.2% between 2005 to 2030. Energy demand for lighting is projected to increase slowly until 2020 and than decline, since the overall energy efficiency 2030 is projected to be 25%. Electricity consumption is projected to grow almost as fast as disposable income, from 6.5% 2005 to 11% 2030.

Table 21: Energy consumed by energy need in the EU residential sector, 2005

Energy need	Share
Space heating and cooling	66%
Cooling	< 1%
Water heating, Cooking	22%
Lighting	5%
Electricity appliances	6.5%

Commercial sector:
The Commercial sector is accountable for 12% of total final energy demand, with an increasing rate of 2.6-2.8 % per year from 1990-2005. The last fifteen years, the commercial sector have been growing at a rate above the GDP growth rate and is the fastest growing sector in the EU economy that have contributed to an increase in employment. Over the fifteen years there have been improvements in office space per employment (which has increased with 0.5% per year), heating and cooling system and access to office equipment. New commercial buildings have high quality, and have affect energy consumption per employee. The baseline scenario predicts that the trends towards more energy needs and higher comfort in the commercial sector will continue to increase since useful energy needs had an annual growth with 1.7% the previous period. Useful energy demands are therefore projected to be increasing at a yearly rate of 1.8% over the period 2005-2030. The energy demand is expected to grow with a rate by 0.9% per year.

As shown in the table, electricity demand is predicted to grow with 3.1% per year from 2005 to 2030, where just cooling energy needs are predicted to grow with 3.9% per year. Heat uses tends to be growing with 0.7% per year. For commercial buildings this will depend on the characteristics of the buildings and the potential active or the passive system.

Table 22: Baseline scenario estimations for final energy consumption split into four uses.

Energy use	Growth rate: 2005-2030
Heat uses	0.7% per year
Value added	2.2% per year
Electric uses	3.1% per year
Cooling	3.9% per year

The baseline scenario based on the PRIMES-model project the ratio of final energy per unit of useful energy (indicator of energy conversion efficiency) to decrease with 0.88% yearly between

2005 to 2030. In the period 1990 to 2005 modern structures and energy efficiency decreased the ratio with 15% (1% per year).
Space heating and other heat uses dominate the commercial sector's final energy demand. 2005, space heating and other heat uses accounted for 73% and are projected to account for 62% by 2030. Energy efficient improvements of space heating and other heat uses are projected to follow the baseline scenario 2005-2030, which show a little lower rate than for the previous period 1990-2005. Cooling and lighting on the other hand is projected to be subject to technological improvement in the baseline scenario because of the energy efficient heat pumps and efficient lighting with good profitable pay-back time. Use of electric appliances is projected to increase, and are therefore having a more conservative trend in energy efficiency improvement in the baseline scenario.

Table 23: Energy efficiency improvements in the baseline scenario

Energy use	**Annual rate from 2005-2030**
Space heating	0.5%
Other heat uses	0.6%
Cooling	1.5%
Lighting	5.5%
Electric appliances	0.1%

Cooling and lighting have a small share of final energy consumption in the commercial sector. The share of lighting in final energy consumption is projected to decrease from 2000 until 2030. Appliances are supposed to represent the fastest growing share of energy consumption in commercial sector.

Table 24: Final energy consumption by type of use

	Final energy consumption 2000, by type of use:	Final energy consumption projected to 2030, by type of use:
Cooling	6%	9.3%
Appliances	15.5%	27%

Electricity enables a substitute for fossil fuels in the heat use and is projected to stand for nearly 50% of total energy consumption 2030, compared to 42% 2005. Growth in electricity demand is projected to remain at an average growth rate of 1.9% per year during the period 2005-2020, and 0.8% per year between 2020 and 2030.

- Other prognoses

The following text presents the information of relevance for the estimates on energy need intensity indicators from Eurelectric (2006) and the Odyssee project[1].

- Eurelectric project 'the role of electricity' summary

Union of the Electricity Industry, *The role of electricity,* 2006

Table 25: Overview of energy demand and electricity demand in EU-27

	Energy use 2005, Mtoe	Energy use 2030, Mtoe	Electricity use 2005, TWh	Electricity use 2030, TWh
Residential sector	295	352	784	1281

Service sector	174	227	748	1163

Under the baseline condition in Eurelectric (2006) and the PRIMES economic model, tertiary sector (including the commercial sector) between 2005 and 2030 will have an annual increase of energy consumption by 1%. The growth of electricity demand in both residential and tertiary sector will increase with 1.9% per year.

Lighting:
In a domestic dwelling a lamp (incandescent lamps, GL: s) have in average a life of 1 000 hours. 85% sold to residential households are still GL: s lamps that consume 60W. The fluorescent lamps (FL: s) are much more efficient and emitts up to 80 lumen/W with an average life of 12 000 hours. Compact fluorescent lamps (CFL: s) are a higher efficient lamp and their use is growing fast at the market. Therefore it is likely that efficient lamps will cover about 50% of all lighting needs by 2030 and are projected to reach 30% KWh savings in the average households. Next revolution in lighting technology are the light-emitting diodes (LED: s), which today use 1.2 W per light source and are expected to give higher outputs during the following years.

Public lighting consumes ca 1% of electricity use in some of the EU countries. Here, only 25% of office lighting is efficient today.

Heating and cooling:
A heat pump can produce 2-6 times more heat per kWh than an electric radiator, and have zero CO_2 emissions. The expected annual growth of the heat pumps market between 2000 and 2010 is in the 15-40% range, in the most active countries.

Households and office appliances:
Consumption of standby power is projected to be the fastest-growing area in residential electric end-use. The present total EU power consumption by household consumer electronics on stand-by is estimated at about 36 TWh and is forecast to rise to 62TWh by the year 2010. Electric devices consume 2-4W of stand-by power, and can be reduced to less than 1 W by using electric circuit.

Residential and Tertiary Sector Technologies
Union of the electricity industry, *Role of Electricity – demand*
The International Energy Agency estimated that even with a continuation of all existing appliance policy measures the appliances electricity consumption will grow by 13% from 2000 to 2010, and by 25% to 2020. Stand-by power is the fastest growing electricity demand. 15 % of total appliance electricity consumption is standby functionality, by 2030.

Space heating can be a great potential for electricity saving with installation of central system and technological improvement. Implementation of energy labels, with EU directive can reduce the energy use.

Space heating is projected to continue to grow by 2.5 % per year until 2030 in EU-25 countries and are projected to account of more than 71% of the EU-25 economy.
Total energy demand is expected to grow at the rate: 1.3% per year until 2030 in EU-27.

Table 26: the appliances electricity consumption

<u>Residential cool appliances, refrigeration:</u> 'Ambitious scenario' of the CECED: average energy efficiency index:	
Average new 2005 refrigerator (EEI=60):	energy use 289 kWh/year (counting for 2/3)
Average freezer (EEI=70)	consumes 308kWh/year (counting for 1/3)
Average annual consumption: Product life: 12 years	295 kWh/year
<u>Dishwasher machine:</u> 65 million units is assumed to be the sales, in EU-25 (2004)	
Average stock Product life: 12 years	1.45kWh/cycle
<u>Washer machines:</u> Energy saving of washing machines in EU, from 1994 to 2002: 30%, around 5% from 2000 to 2002.	
<u>Cooking:</u> Energy factor (EF) = Annual useful cooking energy output / annual energy use	
Electric cook tops:	Total losses 56% Achieved efficiency: 80-90%
Gas cook tops:	Total losses 50% Achieved efficiency: 40-60%
<u>Water heating:</u> Energy consumption per year taken to heat 0.5 l of water, regarding the latest technologies and favours electricity give the 35% savings. Domestic water heating accounts for between 15% and 25% of a home's energy use.	

Table 27: Electric consumption in the tertiary sector.

Tertiary sector:	**Electricity consumption by the main end-uses**	**Evolution of electricity consumption by end use (GWh)**	
		2005	**2020**
Space and water heating:	20%	75 000	90 000
Pumps	6%	20 000	30 000
Cooling and ventilation	15%	50 000	75 000
Cooking:	6%	15 000	20 000
Lighting: Commercial and street lighting	32%	200 000	250 000
Large appliances: Commercial refrigeration	7%	20 000	50 000
Small appliances: Office equipment	8%	50 000	100 000
Other:			
Conveyors	4%	10 000	10 000
Miscellaneous	2%	5 000	5 000

The present total EU consumption for homes consumer of electronics in stand-by functionality is estimated to 36TWh, and is forecast to increase to 62 TWh by 2010, and is estimated to be 15% of total electric consumption by 2030. All domestic equipment is likely to be controlled by electronic equipment in the future, and will lead to an increase in the stand-by electronic consumption. This is because more than 75% households in EU own more than one TV (around 25% of all families have 3 TVs in the there homes) and that DVD players are expected to increase tenfold in the next 10 years. A 40% increase is expected up to 2015 with the strongest growth in the number of laptops. 50% of households had a personal or laptop computer in the home in the year 2005, and more than 50% of the EU households had internet connection in 2005.

Space heating and cooling in the residential and tertiary sectors:
10% to 20% of space heating energy balance is used as electricity to run the electrical components of the central heating system. 5 millions new boilers are sold in the EU per year.

Central air condition systems are defined as air conditioning systems with more than 12kW of cooling capacity, in the EU. The most efficient air condition products use only 35% of the electricity of the least-efficient products when providing the same cooling service. The evolution of electricity consumption for cooling and ventilation in the tertiary sector has increased with 80 000 GWh between 2005 to 2020.

- Odyssee energy demand summary

Evolution and Monitoring of Energy Efficiency in the New EU Member Countries and the EU-25 (Bosseboeuf 2007)

The conclusion of the Evolution and Monitoring of Energy Efficiency in the New EU Member Countries and (NMC: s) the EU-25 (2007) is that energy efficiency of final energy consumption improved with 14% during the period 1990-2004, on average in the EU-25.

Residential sector:
Energy efficiency in the residential sector increased with 3.4% between 1996 to 2004 in EU-25, and is partly a result of EU directives and national measures such as financial incentives and building standards. There is still a different between NMC: s and EU-25 in electricity consumption. NMC: s has in average 40% lower electricity consumption than in average EU-25 countries. However, Baltic countries are catching up in equipment ownership and Mediterranean countries have a rapid distribution of air conditioning.

2004 did the residential sector consume 26% of the final energy use in EU-25. Electricity has increase from 19% to 22% from 1990 to 2004 in EU-25. In EU-10 the electricity is less developed with only 14% of the market 2004.

The energy consumption growth is driven by the number of dwellings in the residential sector that has increase more than the population, 1% per year versus 0.3% per year (1990-2004). This is because of persons per dwellings has decreased from 2.8 to 2.5 during this period. The dwelling size has also increase from an average of 85m^2 to 88m^2 during the same period. For the most of the new EU members there are a decrease in energy consumption, except for Cyprus, Estonia, Hungary and Slovakia. In the EU-15 countries there are a small increase in unit consumption per dwelling with 0.3% per year.

Table 28: Average consumption per dwelling per year (%) 1990-2004:

Average energy consumption per dwelling	1.5% per year
Income per households	0.8% per year

Concerning energy consumption for thermal uses, Bulgaria and Lithuania have much lower energy consumption per m^2 compared to other EU-25 countries which not symbolize energy efficiency but can be a result of high price and limit comfort. Slovenia, Latvia and Hungary have the highest thermal energy consumption and may be a result of poor energy efficiency.

Commercial sector (service sector that include energy use in buildings of the public and private service sector):
The data for the commercial sector is poor, especially for floor area and sub sectors and have to be improved in view of the fact that energy demand will grow in the commercial sector. Between 1996-2000 have energy consumption increased from 12% to 13%; the electricity intensity has in average decreased with 0.7% per year. In EU-10 and NMC: s there is a slow growth of electricity consumption.
The commercial sector has been growing fast with an average annual growth at 3.2% from 1990 to 2004, which is faster than the GDP-growth with an average annual growth rate of 2%. The commercial sector has as a result of the fast annual increase growth also increased its contribution to the GDP. Cyprus and Estonia have the highest share of service in the GDP while Hungary, Lithuania, Czech Republic and Slovenia have the lowest.

Energy demand per employee decreased with 0.5% per year from 1996 to 2001, but increased by 1.1% per year between 2001 and 2004, and where at the same level 2004 as 1996. Electricity consumption increased with 0.8% per year between 2001 to 2004, with average annual electricity consumption per employee by 2% per year. Electricity demand has increased from 31% to 41% because of the growing use of electricity appliances, for information and communication matter and for an increasing use of air condition.

Discussion

This report presents the data compiled and the documents supporting the estimates on existing and potential future use of energy efficiency measures in the EU-27+Norway, Switzerland and Turkey. The European-scale current knowledge on energy use and energy efficiency is scarce and the project participants are therefore forced to make assumptions on many occasions. It has been the intention of the authors to clearly point out when such assumptions are made. However, as a first step towards a better representation of the built society as an important source for energy efficiency and thereby reduced emissions of greenhouse gases, this report compiles much of the information available on a European scale. The GAINS model requirements and the time availability limits the level of detail provided, which makes the estimates on energy efficiency rather course. But it must be kept in mind that the background information is for many countries not available, and one can therefore argue that a very detailed methodology with respect to control options and description of current and projected energy use is not of urgent need.

The process of calibrating projections towards an already existing scenario is difficult given that the databases on control options and projected energy-related behaviour might be different. But given that the major importance lies in the estimates on abatement potentials, this effort must be done. One must keep in mind the underlying assumptions on policy developments made in the scenario to which one calibrates.

Furthermore, the authors expect IIASA to further review and compare the estimates on the investment costs and efficiencies of control options since there are many estimates available with different assumptions. Further adaptation of the delivered numbers is to be expected and have already taken place.

It was the ambition of the authors to help highlight the importance of further improvements in the energy performance of the residential and service sectors, since much improvement can be done in these sectors, and it is our understanding that the work performed in this project has helped in the GAINS model development.

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Appendix A: Total energy consumption 2005:

Residential sector **Total energy consumption (%)** Source: Odyssee (Average EU-27)* National statistics	**Space heating**	**Water heating**	**Cooking**	**Lighting**	**Large appliances**	**Small appliances**	**Total**
Austria Odyssee Austria, *	78%	11%	2%	2%	4%*	3%*	100%
Belgium *	70%*	12%*	6%*	3%*	5%*	4%*	100%
Bulgaria Odyssee (Average EU-27) *	73%*	5%*	6%*	2%*	8%*	6%*	100%
Cyprus *compared to Greece	70%*	6%*	6%*	9%*	6%*	3%*	100%
Czech Republic Odyssee Czech Republic * compared to Austria	75%	11%	7%	2%*	3%*	2%*	100%
Denmark *	72%*	14%	4%*	2%*	5%*	3%*	100%
Estonia * compared to Sweden	65%*	17%*	4%*	4%*	7%*	3%*	100%
Finland Griffin & Fawcett 2000, *	68%	14%	2%	3%*	7%*	6%*	100%
France Odyssee France * compared to UK	74%	8%	6%	2%*	5%*	5%*	100%
Germany Destatis, The use of environmental resources by the consumption activities of private households, *	71%*	12%	4%	5%	5%	3%	100%
Greece Odyssee Greece	72%	5%	6%	9%	6%	2%	100%
Hungary * compared to Austria and Germany	72%*	12%*	4%*	4%*	5%*	3%*	100%
Ireland * compared to France	57%*	23%*	12%*	1%*	4%*	3%*	100%
Italy Odyssee Italy	70%	10%	5%	3%	6%	6%	100%
Latvia * compared to Sweden	73%*	5%*	14%*	2%*	4%*	2%*	100%
Lithuania * compared to Sweden	69%*	15%*	4%*	2%*	6%*	4%*	100%
Luxemburg * compared to Austria and Germany	77%*	11%*	3%*	2%*	4%*	3%*	100%
Malta * compared to Greece	70%*	6%*	6%*	9%*	6%*	3%*	100%
Netherlands Odyssee Netherlands	63%	19%	5%	2%	6%	5%	100%
Norway * compared to Sweden	61%*	22%*	2%*	4%*	7%*	4%*	100%

Poland Odyssee Poland	71%	16%	7%	2%	2%	2%	100%
Residential sector **Total energy consumption (%)** Source: Odyssee (Average EU-27)* National statistics	**Space heating**	**Water heating**	**Cooking**	**Lighting**	**Large appliances**	**Small appliances**	**Total**
Portugal Griffin & Fawcett 2000, * compared to Spain	18%	42%	25%	3%*	6%*	6%*	100%
Romania * compared to Germany	72%*	14%*	5%*	3%*	4%*	2%*	100%
Slovakia * compared to Austria and Germany	74%*	12%*	6%*	2%*	4%*	2%*	100%
Slovenia Statistic office of the Republic of Slovenia, * compared to Germany	53%	13%	25%	2%	4%	3%	100%
Spain Ministerio de Industri, turismo y comercio, *	42%	26%	11%	9%	7%*	5%*	100%
Sweden Swedish Energy Agency (2002), *	61%	22%*	2%*	4%	7%	4%	100%
Switzerland * compared to Austria	78%*	11%*	2%*	2%*	4%*	3%	100%
United Kingdom Griffin & Fawcett 2000	57%	25%	5%	2%	6%	5%	100%
Turkey * compared to Bulgaria and Greece	73%*	7%*	9%*	3%*	6%*	2%*	100%

Appendix A: Total energy consumption 2005:

Commercial sector Total energy consumption (%) Source: Odyssee (Average EU-27)* National statistics	**Space heating**	**Water heating**	**Cooking**	**Lighting**	**Large appliances**	**Small appliances**	**Other**	**Total**
Austria *	39%*	9%*	5%*	8%*	8%*	12%*	19%*	100%
Belgium *	46%*	11%*	6%*	5%*	5%*	8%*	19%*	100%
Bulgaria *	48%*	10%*	4%*	8%*	6%*	9%*	15%*	100%
Cyprus *	42%*	8%*	7%*	10%*	8%*	8%*	17%*	100%
Czech Republic *	40%*	9%*	5%*	8%*	8%*	12%*	18%*	100%
Denmark EL-Tertiary (2008), *	37%*	9%*	4%*	12%	9%*	12%*	17%*	100%
Estonia *	41%*	9%*	4%*	8%*	8%*	12%*	18%*	100%
Finland *	41%*	9%*	4%*	8%*	8%*	12%*	18%*	100%
France *	45%*	10%*	7%*	2%*	2%*	14%*	20%*	100%
Germany EL-Tertiary (2008), *	45%*	10%*	6%*	2%	8%*	9%	20%*	100%
Greece *	41%*	9%*	4%*	8%*	8%*	12%*	18%*	100%
Hungary * Compared with Germany	45%*	9%*	6%*	6%*	6%*	8%*	20%*	100%
Ireland Codema - Sustainable Dublin, * Compared with France	42%*	10%*	6%	5%	8%	16%	13%	100%
Italy *	45%*	9%*	4%*	8%*	8%*	12%*	14%*	100%
Latvia *	41%*	9%*	4%*	8%*	8%*	12%*	18%*	100%
Lithuania * Compared with Sweden	41%*	9%*	4%*	8%*	8%*	12%*	18%*	100%
Luxemburg *	41%*	9%*	4%*	8%*	8%*	12%*	18%*	100%
Malta *	41%*	9%*	4%*	8%*	8%*	12%*	18%*	100%
Netherlands *	41%*	9%*	4%*	8%*	8%*	12%*	18%*	100%
Norway * Compared to Sweden	41%*	9%*	4%*	8%*	8%*	12%*	18%*	100%
Poland *	41%*	9%*	4%*	8%*	8%*	12%*	18%*	100%
Portugal *	41%*	9%*	4%*	8%*	8%*	12%*	18%*	100%
Romania *	50%*	10%*	6%*	4%*	4%*	6%*	20%*	100%
Slovakia *	45%*	9%*	9%*	6%*	6%*	7%*	18%*	100%
Slovenia *	41%*	9%*	6%*	8%*	6%*	12%*	18%*	100%
Spain *	41%*	9%*	4%*	8%*	8%*	12%*	18%*	100%
Sweden *	41%*	9%*	4%*	8%*	8%*	12%*	18%*	100%
Switzerland *	39%*	9%*	5%*	8%*	8%*	12%*	19%*	100%
United Kingdom *	41%*	9%*	4%*	8%*	8%*	12%*	18%*	100%
Turkey *	41%*	9%*	4%*	8%*	8%*	12%*	18%*	100%

Appendix B: Total Thermal (TH) energy consumption 2005

Residential sector Total Thermal (TH) energy consumption (%) Source: Odyssee (Average EU-27)* National statistics	**Space heating, TH**	**Water heating, TH**	**Cooking, TH**	**Total**
Austria EVA, 1998a, updated with *	89%	11%	1%	100%
Belgium *	83%*	12%*	5%*	100%
Bulgaria *	85%*	10%*	5%*	100%
Cyprus * compared to Greece	90%*	8%*	2%*	100%
Czech Republic * compared to Austria	85%*	11%*	4%*	100%
Denmark *	85%*	13%*	2%*	100%
Estonia * compared to Sweden	79%*	17%*	4%*	100%
Finland *	84%*	14%*	2%*	100%
France * compared to United Kingdom	86%*	8%*	6%*	100%
Germany Destatis, The use of environmental resources by the consumption activities of private households, *	84%*	12%	4%*	100%
Greece Odyssee Greece, *	90%	5%*	5%*	100%
Hungary * compared to Austria and Germany	84%*	12%*	4%*	100%
Ireland Codema - Sustainable Dublin - Action Plan on Energy for Dublin (2005), *	69%*	28%	3%*	100%
Italy ENEA, 1999	85%	10%	6%	100%
Latvia * compared to Sweden	80%*	5.5%*	14.5%*	100%
Lithuania * compared to Sweden	80%*	16%*	4%*	100%
Luxemburg * compared to Austria and Germany	86%*	11%*	3%*	100%
Malta * compared to Greece	87%*	7%*	6%*	100%
Netherlands (Netherlands): BEK, 1996; BAK, 1997	75%	20%	6%	100%
Norway * compared to Sweden	90%*	10%*	0%*	100%
Poland * compared to Sweden	77%*	17%*	6%*	100%

Portugal (Portugal) ISR, 1998; CCE, 1997, * compared to Spain	16%	50%*	34%	100%
Residential sector **Total Thermal (TH) energy consumption (%)** Source: Odyssee (Average EU-27)* National statistics	**Space heating, TH**	**Water heating, TH**	**Cooking, TH**	**Total**
Romania * compared to Germany	80%*	15%*	5%*	100%
Slovakia * compared to Austria and Germany	83%*	11%*	6%*	100%
Slovenia Statistic office of the Republic of Slovenia, *	62%	10%*	28%	100%
Spain Ministerio de Industri, turismo y comercio, *	60%*	30%*	10%	100%
Sweden Energimyndigheten (2002), *	84%*	16%*	0%	100%
Switzerland * compared to Austria	89%*	10%*	1%*	100%
United Kingdom *	69.5%*	25%*	5.5%*	100%
Turkey * Compared to Bulgaria and Greece	83%*	7%*	10%*	100%

Appendix B: Total Thermal (TH) energy consumption 2005

Commercial sector Total thermal energy (TH) consumption (%) Source: Odyssee (Average EU-27)*	**Space heating, TH**	**Water heating, TH**	**Cooking, TH**	**Other, TH**	**Total**
Austria *	49%*	14%*	7%*	30%*	100%
Belgium *	55%*	14%*	7%*	24%*	100%
Bulgaria *	73%*	13%*	4%*	10%*	100%
Cyprus *	46%*	14%*	19%*	21%*	100%
Czech Republic *	51%*	14%*	8%*	27%*	100%
Denmark *	52%*	15%*	5%*	28%*	100%
Estonia *	48%*	14%*	7%*	28%*	100%
Finland *	53%*	15%*	7%*	25%*	100%
France *	40%*	18%*	7%*	35%*	100%
Germany *	55%*	10%*	8%*	27%*	100%
Greece *	47%*	17%*	10%*	26%*	100%
Hungary * Compared with Germany	58%*	11%*	6%*	25%*	100%
Ireland * Compared with Germany	56%*	15%*	7%*	22%*	100%
Italy *	54%*	15.5%*	7%*	24%*	100%
Latvia *	56%*	13%*	5.5%*	26%*	100%
Lithuania * Compared with Sweden	50%*	14%*	6%*	30%*	100%
Luxemburg *	45%*	23%*	22%*	10%*	100%
Malta *	45%*	20%*	14%*	21%*	100%
Netherlands *	54%*	14%*	5.5%*	27%*	100%
Norway * Compared to Sweden	60%*	15%*	1%*	24%*	100%
Poland *	51%*	14%*	6%*	29%*	100%
Portugal *	50%*	15%*	8%*	27%*	100%
Romania *	57%*	11%*	7%*	25%*	100%
Slovakia *	52%*	12%*	12%*	24%*	100%
Slovenia *	53%*	14%*	8.5%*	25%*	100%
Spain *	50%*	17%*	8%*	25%*	100%
Sweden *	60%*	16%*	1%*	23%*	100%
Switzerland *	51%*	13%*	7%*	29%*	100%
United Kingdom *	50.5%*	14%*	7%*	29%*	100%
Turkey *	50%*	16%*	7%*	27%*	100%

Appendix C: Total electric (ELE) energy consumption 2005

Residential sector Total Electric (ELE) energy consumption (%) Source: Odyssee (Average EU-27)* National statistics	**Space heating, ELE**	**Space cooling (air condition) ELE**	**Water heat, ELE**	**Cooking, ELE**	**Lighting, ELE**	**Large appliances, ELE**	**Small appliances, ELE**	**Total, ELE**
Austria EVA (1998a)	27%	0%	14%	9%	11%	22%	17%	100%
Belgium IEA/OECD (1998b), *	23%	1%*	12%	10%	13.5%*	22.5%*	18%*	100%
Bulgaria	35%*	4%*	12%*	9%*	5%*	20%*	15%*	100%
Cyprus * Compared to Greece	49%*	3%*	4%*	10%*	17%*	11%*	6%*	100%
Czech Republic * Compared to Austria	36%*	2%*	12%*	18%*	6%*	14%*	12%*	100%
Denmark Prognoserapport (2006), *	21%	0%*	18%*	12%*	10%	24%*	15%*	100%
Estonia * Compared to Sweden	5%*	0%*	17%*	4%*	21%*	37%*	16%*	100%
Finland *	39%*	1%*	14%*	2%*	8%*	19%*	17%*	100%
France * Compared to United Kingdom	42%*	2%*	8%*	6%*	7%*	17%*	18%*	100%
Germany Destatis, The use of environmental resources by the consumption activities of private households, *	16%	0%*	13%	5%*	25%	26%	15%	100%
Greece Odyssee Greece, *	20%*	1%*	5%*	9%*	34%	23%	8%	100%
Hungary * Compared to Austria and Germany	6%*	0%*	13%*	4%*	26%*	32%*	19%*	100%
Ireland Codema - Sustainable Dublin - Action Plan on Energy for Dublin (2005), * compared to France	19%*	0%*	10%	39%*	4%*	16%*	12%*	100%
Italy ENEA (1999), *	2%*	2%*	10%*	3%	17%	33%	34%	100%
Latvia * compared to Sweden	15%*	0%*	4%*	11%*	17.5%*	35%*	17.5% *	100%
Lithuania * compared to Sweden	11%*	0%*	10%*	5%*	12%*	38%*	24%*	100%
Luxemburg	3%*	0%*	10%*	3%*	19%*	37%*	28%*	100%

* compared to Austria and Germany								
Malta * compared to Greece	57%*	1%*	6%*	6.5%*	14.5%*	10%*	5%*	100%
Residential sector Total Electric (ELE) energy consumption (%) Source: Odyssee (Average EU-27)* National statistics	**Space heating, ELE**	**Space cooling (air condition) ELE**	**Water heat, ELE**	**Cooking, ELE**	**Lighting, ELE**	**Large appliances, ELE**	**Small appliances, ELE**	**Total, ELE**
Netherlands BEK (1996), BAK (1997), *	15%*	1%*	16%	4%	10%	30%	25%	100%
Norway * compared to Sweden	51%*	1%*	26%*	3%*	6%*	9%*	6%*	100%
Poland Odyssee Poland, * compared to Sweden	25%*	1%*	9%*	14%*	17%	17%	17%	100%
Portugal (Portugal) ISR, 1998; CCE, 1997, * compared to Spain	21%*	1%*	27%*	9%	9%*	17%*	17%*	100%
Romania * compared to Germany	5%*	1%*	6%*	5%*	28%*	37%*	18%*	100%
Slovakia * compared to Austria and Germany	26%*	1%*	15%*	7%*	13%*	25%*	13%*	100%
Slovenia Statistical Office of the Republic of Slovenia (2004)	20%	0%	25%	14%	9%	18%	14%	100%
Spain Ministerio de Industri, turismo y comercio, *	9%*	1%*	19%*	13%	25%	19.5%*	13.5% *	100%
Sweden Energimyndigheten, *	35%*	0%*	28%*	5%	8%	15%	9%	100%
Switzerland * compared to Austria	43%*	1%*	14%*	5%*	8%*	16%*	13%*	100%
United Kingdom DTI, 1997, *	16%	0%	25%*	3%*	9%	26%	22%	100%
Turkey * compared to Bulgaria and Greece	5%	1%	7%*	3%*	23%	46%	15%	100%

Appendix C: Total electric (ELE) energy consumption 2005

Commercial sector Total Electric energy (ELE) consumption (%) Source: Odyssee (Average EU-27)* National statistics	**Space heating, ELE**	**Space cooling (air condition) ELE**	**Space cooling (ventilation)**	**Water heat, ELE**	**Cooking, ELE**	**Lighting, ELE**	**Large appliances, ELE**	**Small appliances, ELE**	**Other**	**Total, ELE**
Austria *	6%*	9%*	8%*	3%*	2%*	21%*	18%*	27%*	5%*	100%
Belgium *	5%*	6%*	5%*	1%*	1%*	22%*	22%*	36%*	2%*	100%
Bulgaria *	11%*	12%*	10%*	7%*	9%*	12%*	9%*	13%*	16%*	100%
Cyprus*	11%*	12%*	11%*	3%*	5%*	17%*	14%*	13%*	14%*	100%
Czech Republic *	6%*	7%*	7%*	1%*	1%*	21%*	22%*	33%*	2%*	100%
Denmark EL-Tertiary (2008)[9], *	1%*	10%*	9%	3%*	3%*	26%	19%*	25%*	4%*	100%
Estonia *	11%*	12%*	10%*	3%*	1%*	17%*	17%*	25%*	4%*	100%
Finland *	10%*	10%*	9%*	3%*	1%*	16%*	16%*	24%*	11%*	100%
France EL-Tertiary (2008), *	32%	5%	13%	1%*	6%*	5%	4%	30%	4%	100%
Germany EL-Tertiary (2008), *	6%	12%*	11%*	10%	2%*	6%*	24%*	27%	6%*	100%
Greece *	13%*	14%*	12%*	6%*	2%*	11%*	11%*	16%*	15%*	100%
Hungary * compared with Germany	1%*	3%*	2%*	3%*	6%*	24%*	25%*	32%*	4%*	100%
Ireland Codema - Sustainable Dublin, * compared with France	1%*	11%	10%	3%	5%	12%	19%	38%	1%*	100%
Italy *	11%*	12%*	10%*	1%*	1%*	18%*	18.5%*	27.5%*	1%*	100%
Latvia *	2%*	3%*	2%*	1%*	1%*	26%*	26%*	38%*	1%*	100%
Lithuania * compared with Sweden	10%*	10%*	9%*	2%*	1%*	18.5%*	18.5%*	28%*	3%*	100%
Luxemburg*	15%*	14%*	12%*	8%*	3%*	8%*	8%*	13%*	19%*	100%
Malta *	14%*	14%*	12%*	7%*	2%*	9.5%*	9.5%*	14%*	18%*	100%

(1) [9] http://www.eu.fhg.de/el-tertiary/

Netherlands*	4%*	8%*	7%*	1%*	1%*	22%*	22.5%*	33.5%*	1%*	100%
Commercial sector Total Electric energy (ELE) consumption (%) Source: Odyssee (Average EU-27)* National statistics	**Space heating, ELE**	**Space cooling (air condition) ELE**	**Space cooling (ventilation)**	**Water heat, ELE**	**Cooking, ELE**	**Lighting, ELE**	**Large appliances, ELE**	**Small appliances, ELE**	**Other**	**Total, ELE**
Norway * compared to Sweden	13%*	5%*	17%*	7%*	5%*	11%*	11%*	16%*	16%*	100%
Poland *	6%*	10%*	9%*	1%*	1%*	20%*	20%*	30%*	3%*	100%
Portugal *	11%*	12%*	11%*	4%*	1%*	14%*	14.5%*	21.5%*	11%*	100%
Romania *	6%*	7%*	5%*	1%*	1%*	22%*	22%*	35%*	1%*	100%
Slovakia *	11%*	9%*	9%*	3%*	2%*	19%*	19%*	22%*	6%*	100%
Slovenia *	7%*	7%*	6%*	1%*	1%*	22%*	17%*	33.5%*	5%*	100%
Spain *	13%*	13%*	10%*	4%*	2%*	12.5%*	12.5%*	19%*	14%*	100%
Sweden SCB (Sweden) *	11%	2%	16%*	5%	6%	13%*	13%*	19.5%*	15%*	100%
Switzerland *	6%*	6%*	11%*	2%*	2%*	21%*	22%*	33%*	2%*	100%
United Kingdom *	10%*	11%*	9%*	3%*	1%*	18%*	17%*	26%*	5%*	100%
Turkey *	10%*	6%*	11%*	2%*	2%*	15.5%*	15.5%*	23%*	10%*	100%