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 Integrated Assessment Model GAINS. 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 energy projections 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 measures to reduce energy demand as well as greenhouse gas emissions. For both the residential sector and the service sector, energy needed for heating and ventilation, as well as air conditioning represents the largest share of all energy needs in these sectors, and there are large potentials for further improvements in the energy performance in the climate envelope of most European houses and buildings.

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Table of contents

Summary 2
Ordlista / Abbreviations 4
1 Background 5
2 Introduction 6
2.1 Purpose of the project 6
2.2 Disposition of the report 6
3 Method 7
3.1 Energy needs in the Residential and Commercial sectors 2005 and 2020/2030 8
3.1.1 Overview of data requirements 8
3.2 Activity data 9
3.2.1 Activity Data for the year 2005 11
3.2.2 Activity data for the year 2020 and 2030 11
3.3 Energy efficient technologies (*t*) 14
3.3.1 Technology Implementation rate in 2005 ($X_{DOM,RES,n,t,2005}$ and $X_{DOM,COM,n,t,2005}$) 15
3.3.2 Technology Implementation rate in 2020 and 2030 ($X_{DOM,k,n,t,2020}$ and $X_{DOM,k,n,t,2030}$) 15
3.4 Energy demand in the domestic sector 15
3.4.1 Energy statistics and estimates for 2005 15
3.4.2 Energy use development until 2020 and 2030 16
4 Results 17
4.1 Activity data and Multipliers in the Residential and Commercial sectors 17
4.1.1 Energy statistics and Activity data for 2005 17
4.1.2 Activity projections for 2020 and 2030 18
4.1.3 Intensity indicator multipliers in 2020 and 2030 21
4.2 Energy efficient technologies (*t*) 23
4.2.1 Heating, Ventilation and Air Conditioning 24
4.2.2 Stage 1 24
4.2.3 Stage 2 26
4.2.4 Large appliances (electricity) 29
4.2.5 Stage 1 29
4.2.6 Stage 2 29
4.2.7 Water heating (thermal and electricity) 30
4.2.8 Stage 1 31
4.2.9 Stage 2 31
4.3 Mitigation Technology Implementation in 2005 32
4.4 Mitigation Technology Implementation in the baseline 2020 and 2030 33
4.4.1 Current state and projections regarding energy efficiency policies 33
4.4.2 Calibration of Mitigation Technology Implementation in the baseline 2020 and 2030 33
5 Discussion 35
6 References 36
Appendix A: Total energy consumption 2005: 38
Appendix B: Total Thermal (TH) energy consumption 2005 41
Appendix C: Total electric (ELE) energy consumption 2005 44
Appendix D: Literature review, support for estimation of Energy intensity indicators and Implementation rates of control stages 48
References in the Appendices 56

Ordlista / Abbreviations

CFL	Compact Fluorescent Lamps
COM	Commercial sector
ELE	Final energy delivered as electricity
Final energy	the converted and functional form of energy carriers (heat or electricity)
FL	Fluorescent Lamps
GAINS	The Greenhouse gas - Air pollution INteractions and Synergies model (http://gains.iiasa.ac.at/index.php/home-page)
GHG	Greenhouse Gases
GL	Gas Lamps
GWh	Gigawatt hour (1000 000 kWh)
HVAC	Heating, Ventilation and Air Conditioning
kWh	Kilowatt hour
MWh	Megawatt hour (1000 kWh)
m^2	Square meter
NMC	New Member Countries to the European Union
Primary energy	The energy carrier needed to deliver energy services (coal, oil etc.)
PRIMES	A detailed partial equilibrium energy model detailed at EU Member States level. It is used to assess changes in the energy system in detail (e.g. investment costs, changes in fuel mix and consumption).
RES	Residential sector (households)
Thermal Energy (TH)	Final energy delivered as heat via combustion of fuels
TWh	Terawatt hour (1000 000 000 kWh)
UNFCCC	United Nations Framework Convention on Climate Change
Useful Energy	The final utility derived from use of final energy (indoor temperature etc.)

1 Background

The emissions of greenhouse gases (GHG) and the growing concern for global warming and energy security are motivating increased European concern for reduction in energy demand. 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 reduce emissions of air pollutants have been on-going for almost half a century. As concerns for global warming and energy security increase the focus on emissions of GHG and energy demand, new sectors become more interesting when identifying cost effective solutions to further reduce emissions and decrease energy demand.

In the domestic sector, which in the terminology used in this report includes households, commercial activities, agricultural activities; forestry etc., large potential for reduced energy demand has been identified in earlier reports (Petersdorff et al. 2005, EC 2005, 2006). It has also been seen that energy use in this sector increases in many European countries, partly due 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 are likely to have a lifetime of a hundred years, and the energy performance given to these buildings today can have a long impact on future energy demand as well as on future energy bills.

The International Institute for Applied System Analysis (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 delivers estimates on emissions of greenhouse gases and their abatement potential and costs as support to the United Nations Framework Convention on Climate Change (UNFCCC). IIASA has developed the Integrated Assessment Model (IAM) Greenhouse gas - Air pollution INteractions and Synergies (GAINS), which is used to deliver these estimates. The GAINS model is currently developed for several geographical regions with, examples are GAINS-Europe, GAINS-China, and GAINS-Annex1. The GAINS Annex 1 version of the model includes all the countries grouped into the 'Annex1' group in the UNFCCC. Annex 1 countries are currently the countries with emission reduction obligations under the UNFCCC Kyoto Protocol. Emissions of GHG: s is mostly caused by energy use in all sectors of the society. Two of these are the residential (RES) and commercial (COM) sectors, and energy efficiency improvements in these sectors are in focus in this report.

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 is currently developing a Swedish version of the GAINS model. IIASA has invited IVL and Sweden to participate with collection, evaluation and delivery of data for the RES and COM sectors in the EU-27 countries and Norway, Switzerland and Turkey (EU-27+3).

2 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 per cent of the EU-27 final energy consumption in 2005 (the COM sector accounted for 12%, and RES for 26%). Half of this share origin from fossil fuels and is thereby causing fossil CO_2 emissions. The major service derived from energy use in the RES and COM sectors is the energy service *heat*. For EU-27, the share of energy used for heating in the RES and COM sectors is approximately 70% of the above-mentioned 40% (Eurostat 2008, EEA 2001). It is generally considered that the RES and COM sectors 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 heating purposes within the union (Petersdorff et al. 2005, EC 2005, 2006).

2.1 Purpose of the project

The purpose of this project is to gather national data and projections for the EU-27+3 countries of relevance for the GAINS RES and COM sectors and deliver these data and projections in the format suitable to GAINS model methodology. The data and projections will then be used in the Annex1 and European version of the GAINS model as a basis for estimates on future energy use and potential for reductions in energy demand and associated abatement costs and emissions.

By the delivery of data and projections to the GAINS model, and by using the methodology developed, the future importance of abatement measures in the RES and COM sectors can be further explored, and comparisons can be made between sectors and countries. The compilation of the data and projections ensures that the methodology used in the different versions of the GAINS model to estimate emission reduction potentials and abatement costs is identical for all the Kyoto protocols' Annex 1-parties to the UNFCCC, which ensures harmonization of the results.

2.2 Disposition of the report

This report is disposed 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 results presents numerical results and a more detailed description of how these estimates have been obtained and adapted for the GAINS format. The last part of the main report is the discussion where data, project difficulties and future needs are discussed. Finally, detailed descriptions on the estimated nation-specific energy needs are given in the appendices.

3 Method

This report presents a data and estimate inventory performed to suit the method used to calculate energy efficiency improvements in the GAINS model. The term 'implementation of mitigation technologies / efficiency options' refers to the usage of a certain technology in a specific energy need.

The method for calculating GHG and air pollution mitigation options in the GAINS model is described in Cofala et al. (2008). More specifically, for the Residential (RES) and Commercial (COM) sectors, calculation of energy consumption, which is a driver of emissions of GHG and air pollutants, is in Cofala et al (2008) described as follows:

The energy consumption by need *n* after implementation of efficiency options can be calculated from the following formula:

$$EC_{j,k,n,c,r} = A_{j,k,n,r} * M_{j,k,n,r} * enin_{j,k,n,c} * \sum_t (1-\eta_{j,k,n,c,t}) * X_{j,k,n,t,r}$$

where:
n – energy need type (e.g., space heating)
t – energy efficiency technology/option
$A_{j,k,n,r}$ – value of activity variable used to assess energy consumption for need *n* in sub-sector *k* of sector *j* in time period *r*
$M_{j,k,n,r}$ – intensity multiplier for need *n* in sub-sector *k* of sector *j* in time period *r*
$enin_{j,k,n,c}$ – consumption of energy type *c* by need *n* in sub-sector *k* of sector *j* in time period *r* without energy efficiency measures
$X_{j,k,n,t,r}$ - implementation rate of technology *t* for need *n* in sub-sector *k* in time period *r*
$\eta_{j,k,n,c,t}$ – reduction in consumption of energy type *c* used to satisfy need *n* in sub-sector *k* caused by application of technology *t*.

Source: (Cofala et al 2008)

The total energy use in the RES and COM sectors is dependent on two variables. The first variable is the total demand for a specific energy 'service'. Examples of services are an indoor climate of certain temperature and air flow, or a certain lumens in the lighting, or number of cooking hours per day, or number of hours of television watched per day. In the GAINS model, these energy services are parameterised in energy units (MJ) and grouped into different energy 'needs'. The second variable is the energy intensity required to deliver the service in question. The first variable is mainly a product of social preferences, while the second variable is a product of how energy efficient the technologies delivering the services are.

In the GAINS model, there are two categories of 'final energy' which supply functional energy for the energy service / need required:

- Thermal energy (TH): includes heat delivered from combustion of fuels (coal, oil, gas and biomass) as well as heat supplied through the district heating system). Thermal energy can be used in four categories of energy needs: Heating & Ventilation & Air Conditioning (HVAC), water heating, cooking and other.
- Electricity (ELE). Electricity can be used for all energy needs.

The data inventory work performed in this project follows the method described in Cofala et al. (2008) and is aimed at adapting the data estimates in the GAINS model database to EU27+3 conditions. The data inventory is needed for the parameters described in the above mentioned equation. Data needed for the EU-27+3 countries are to a large extent collected from official statistical agencies such as Eurostat and UNECE, other international projects such as the ODYSSEE/MURE databases, as well as national statistical offices and other official offices.

The GAINS-Annex1 model requires RES and COM sectors' data for the following countries:

Table 1: Countries of consideration for data compilation.

Country	Comment	Country	Comment
Austria	EU	Lithuania	EU
Belgium	EU	Luxemburg	EU
Bulgaria	EU	Malta	EU
Cyprus	EU	The Netherlands	EU
Czech Republic	EU	Norway	Non-EU
Denmark	EU	Poland	EU
Estonia	EU	Portugal	EU
Finland	EU	Romania	EU
France	EU	Slovak Republic	EU
Germany	EU	Slovenia	EU
Greece	EU	Spain	EU
Hungary	EU	Sweden	EU
Ireland	EU	Switzerland	Non-EU
Italy	EU	Turkey	Non-EU
Latvia	EU	United Kingdom	EU

These countries are in the report presented as EU27+3.

3.1 Energy needs in the Residential and Commercial sectors 2005 and 2020/2030

3.1.1 Overview of data requirements

The GAINS model approach to data aggregation related to energy needs is to classify stationary non-industrial, non-power plant energy needs into the domestic sector, which includes services, households, military, etc. In the GAINS model, the domestic sector is represented by the abbreviation DOM (sector *j*), with the sub-sectors residential (RES, sub-sector *k*), commercial (COM, sub-sector *k*), other (OTH, sub-sector *k*). In this project, the focus has been on data inventory for the RES and COM sectors.

In the GAINS models RES and COM sectors, the energy used is categorised in 7-8 energy needs, with specified activity variables and energy intensity indicators for which EU27+3 data are needed. Some of the energy needs can use heat or electricity (cooking for example), while other can use only electricity (example small appliances). The table below presents the energy needs with associated activity variables and intensity indicators as specified in the GAINS model.

Table 2: Specific energy needs in the residential and commercial sectors.

Energy needs (*n*)	**GAINS model abbreviation**	**Activity variable**	**Intensity indicator**
Residential sector (subsector *k*)	RES		
Heating, ventilation and air conditioning (HVAC)	HVAC	Living space	GJ/m^2
- Space heating	SPACE_HEAT	Living space	GJ/m^2
- Space cooling	SPACE_COOL	Living space	GJ/m^2
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 (subsector *k*)	COM		
HVAC	HVAC	Building space	GJ/m^2
- Space heating	SPACE_HEAT	Building space	GJ/m^2
- Space cooling	SPACE_COOL	Building space	GJ/m^2
- Space ventilation	SPACE_VENT	Building space	GJ/m^2
Water heating	WATER_HEAT	Building space	GJ/m^2
Cooking	COOKING	Building space	GJ/m^2
Lighting	LIGHTING	Building space	GJ/m^2
Large appliances (refrigerators, freezers, washing machine, dishwashers, dryers)	APPL_LARGE	Building space	GJ/m^2
Small appliances (computers, TV sets, audio and other electronic equipment)	APPL_SMALL	Building space	GJ/m^2
Other needs (not included separately)	OTHER	Building space	GJ/m^2

Source: Cofala et al. 2008

The specification of energy needs in the table above presents what type of activity parameters that are of relevance in the GAINS model when estimating energy use in the DOM sector. In this report, energy needs related to HVAC are estimated for existing and new houses and apartments (RES) and existing and new buildings (COM), 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.

3.2 Activity data

The 'Activity variable' for each specified energy need represents the specific activity that in the model is the main driver for the use of energy for the specific energy need. The 'Intensity indicator' represents the country's specific use of energy for each energy need.

The GAINS models' four dwelling categories in the residential sector and two building categories in the commercial sector and their associated energy needs are presented in the table below.

Table 3: Building representation in the GAINS model ($A_{DOM,k,n,r}$).

Activity	Unit	Abbreviation	Related energy need
Subsector COM			
Commercial floor space existing	10^6 m^2	*fs_com_ex*	HVAC
Commercial floor space new	10^6 m^2	*fs_com_new*	HVAC
Commercial floor space total	10^6 m^2	*fs_com_tot*	Other needs
Subsector RES			
Existing houses	10^6	*nr_hous_ex*	Other needs
New houses	10^6	*nr_hous_new*	Other needs
Houses – Total	10^6	*nr_hous_tot*	Other needs
Floor space existing houses	10^6 m^2	*fs_hous_ex*	HVAC
Floor space new houses	10^6 m^2	*fs_hous_new*	HVAC
Floor space houses total	10^6 m^2	*fs_hous_tot*	HVAC
Existing apartments	10^6	*nr_apar_ex*	Other needs
New apartments	10^6	*nr_apar_new*	Other needs
Apartments – Total	10^6	*nr_apar_tot*	Other needs
Floor space existing apartments	10^6 m^2	*fs_apar_ex*	HVAC
Floor space new apartments	10^6 m^2	*fs_app_new*	HVAC
Floor space apartments total	10^6 m^2	*fs_apar_tot*	HVAC
Floor space housing units total	10^6 m^2	*fs_hutot*	HVAC
Housing units total	10^6	*nr_hutot*	Other needs

In the GAINS model, 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 have different energy intensities. Existing dwellings and buildings have poorer energy performance (higher energy intensity) than new ones.

Not all of these data on dwellings and buildings can be collected directly from data or projection sources. But most of them can be indirectly derived by collecting data or estimates for the parameters described in the table below. The data availability varies between countries, as does the need for supporting calculations by using the parameters described below.

Table 4: Parameters used for supporting calculations on building representations.

Description	Unit	Abbreviation
Population - total	10^6 people	*Pop*
Existing commercial floor space demolition rate	%/year	*dem_rate*
Commercial floor space per capita	m^2/cap	*fs_com_pcap*
Average floor space per commercial building	m^2/building	*av_comsqm*
Household size	pers/H_unit	*househ_size*
Share apartments of total housing units	%	*sh_app*
Average floor space house	m^2	*av_hosqm*
Average floor space apartment	m^2	*av_apsqm*
Average floor space housing unit	m^2	*av_husqm*
Floor space per new housing unit multiplier	-	*act_mult*
Existing housing units demolition rate	%/year	*dem_rate*

For some countries, data was not available for certain parameters. When this was the case, the data used in the PRIMES model calculations were used.

The PRIMES model is a 'Partial Equilibrium Energy System Model', detailed at EU Member States level that describes country-specific energy demand and supply scenarios while keeping European supply and demand in balance (NTUA, 2008). Several scenario results from the PRIMES model are used as input in many scenarios developed with the GAINS model. One of these scenarios is the scenario used for the supporting calculations to the baseline in EC DG TREN (2007), which is also the scenario towards which we calculate in this report.

3.2.1 Activity Data for the year 2005

Building stock statistics ($A_{DOM,k,n,2005}$)

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

RESIDENTIAL SECTOR

Housing units:

The total number of dwellings (*nr_hutot*) for each country is given from a variety of National statistic's sources and from Werner et al. (2006). The share of apartments *(sh_app)* was given from Federcasa (2006) and is controlled against 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 (*av_husqm*) for each country is calculated with data from NBHBP (2005) and adjusts to 2005 level with the floor space per new housing multiplier (*act_mult*), which is given by the NBHBP (2005) and EC DG TREN (2007). The average floor space apartment (*av_apsqm*) is calculated as:

$$av\_apsqm = \frac{av\_husqm}{sh\_app + (1 - sh\_app) * 2}$$

The average floor space housing house (*av_husqm*) is assumed to be twice as large as the average floor space apartment (*av_apsqm*).

Floor space housing units total:

Floor space housing units total *fs_hutot* is for the year 2005 the sum of floor space apartments existing (*fs_apar_ex*) and floor space houses existing (*fs_hous_ex*), which is the product of average floor space apartments and houses (*av_ap_sqm* and *av_hou_sqm*) and the number of existing apartments and houses (*nr_apar_ex* and *nr_hous_ex*).

COMMERCIAL SECTOR

The floor space for existing commercial buildings (*fs_com_ex*) is for the year 2005 collected from Werner et al. (2006). The floor space for existing commercial buildings is in 2005 equal to the total floor space in the commercial sector.

3.2.2 Activity data for the year 2020 and 2030

When estimating the corresponding activity data for the years 2020 and 2030, more calculations are needed. For the residential sector, the demand for new dwellings correlates with projected population size and household size as well as projected demolition rates of existing buildings. For the commercial sector, demand for commercial floor space correlates with the projected population size and projected demolition rate.

Building stock development ($A_{DOM,k,n,r}$)

The activity variable A is for the HVAC energy needs calculated by adjusting the existing building stock with respect to population growth, changes in household sizes, household areas, and demolition rates. The activity variable A is calculated for both existing and new dwellings as well as for commercial buildings.

THE RESIDENTIAL SUBSECTOR

Calculating floor space

For HVAC energy needs, ***A*** is given in the unit 10^6 m² floor space. For existing houses in 2020, ***A*** (*fs_hous_ex*) is calculated as follows:

$$A_{DOM,RES,HVAC,2020} = \left(\frac{nr\_hous\_ex_{2015} * (1 - dem\_rate_{2020})^5}{nr\_hous\_ex_{2005}}\right) * fs\_hous\_ex_{2005}$$

Where:

$A_{DOM,RES,HVAC,2020}$ = *fs_hous_ex* = Remaining floor space of pre-2005 houses in 2020 [10^6 m²]
$nr\_house\_ex_{2005}$ = Number of existing houses in 2005 [million]
$nr\_hous\_ex_{2015}$ = Number of existing houses in 2015 [million]
dem_rate_{2020} = Existing housing units demolition rate in 2020 [% / year]
$fs\_hous\_ex_{2005}$ = Floor space in existing houses in 2005 [10^6 m²]

For new houses in 2020, ***A*** is calculated as follows:

$$A_{DOM,RES,HVAC,2020} = av\_hosqm_{2005} * act\_mult_{2020} * (nr\_hutot_{2020} * (1 - sh\_app_{2020}) - nr\_hous\_ex_{2020})$$

Where:

$A_{DOM,RES,HVAC,2020}$ = *fs_hous_new* = Floor space of houses constructed after 2005 in 2020 [10^6 m²]
av_hosqm_{2005} = Average floor space per house in 2005 [m²]
act_mult_{2020} = Floor space multiplier for new houses in 2020 [-]
nr_hutot_{2020} = Total amount of dwellings (Housing Units) in 2020 [10^6]
sh_app_{2020} = Share apartments of all dwellings in 2020 [%]
$nr\_hous\_ex_{2020}$ = Number of existing houses in 2020 [10^6]

The aggregated floor space for all housing units is then equal to the sum of the floor spaces for the buildings represented in the model (existing/new houses/apartments).

Calculating the number of dwellings

The number of housing units (*nr_hutot*) in the RES sub-sector is calculated by dividing the projected population with the projected household size (persons / housing unit), with some exceptions (see below). Projections are given in the given PRIMES model scenario.

The number of houses and apartments are calculated according to the following equation (exemplified with number of existing houses in 2020)

$$nr\_house\_ex_r = nr\_hous\_ex_{r-5} * (1 - dem\_rate_r)^5$$

The number of new houses and apartments are calculated by the following equation:

$$nr\_apar\_new_r = nr\_hutot_r * sh\_app_r - nr\_apar\_ex_r$$

For other energy needs, the activity variable ***A*** equals the number of dwellings in the two categories houses and apartments (*nr_hous_tot* and *nr_apar_tot*).

Parameters used when calculating Activity data

Housing Units

For countries where statistical estimates on number of housing units (nr_hutot) were found for the year 2005, the number of housing units for the following years was calculated with the following equation:

$$nr\_hutot_r = nr\_hutot_{2005} * \frac{pop_r / househ\_size_r}{pop_{2005} / househ\_size_{2005}}$$

Floor space multipliers

In order to calculate the dwelling and building floor space area in 2020 and 2030, a floor space per new housing unit multiplier (*act_mult*) is needed. This multiplier is calculated by dividing the average dwelling area of buildings constructed in 2005 with the average dwelling area for the total dwelling stock in 2005. This gives the floor space multiplier for 2005. Data are collected from Visier et al., 2002, and NBHBP (2005), and the UNECE human settlements database (http://w3.unece.org/stat/HumanSettlements.asp, 2008).

In order to derive floor space multipliers for the years after 2005, an annual rate of change is needed. The average EU-27 annual rate of change for space per dwelling is given by EC DG TREN (2007) and NBHBP (2005), which together with the floor space multiplier for 2005 gives the floor space multiplier for 2010, 2015, 2020, 2025 and 2030. The annual rate of change is constant over the years, which implies the assumption that the trend in dwelling sizes will remain stable over the years (see table 8).

Average floor space:

The trend from 2005 to 2030 for the average floor space housing unit (*av_husqm*) is calculated by dividing the total floor space for housing units (*fs_hutot*) with the number of housing units (*nr_hutot*). The same calculation is performed for houses and apartments.

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

When calculating the demolition rate (*dem_rate*), statistical estimates for the annual numbers of demolished houses are used. This is found for 18 countries in the UNECE human settlements database. For each country the value for the number of the demolished dwellings 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 12 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, while the country-specific values were used in the data sets (see table 7). The demolition rate is assumed to be constant from 2005 to 2030.

THE COMMERCIAL SUBSECTOR

The m^2 commercial floor space is given by the PRIMES model projections or Werner et al. (2006) dependent on country.

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

3.3 Energy efficient technologies (*t*)

In the GAINS model, dwellings, other buildings, appliances and other equipment are in the model represented in three different energy performance categories. These categories are grouped into three stages: No control (NOC); Stage 1; and Stage 2. These stages represent different construction/technology types with different energy intensities. The NOC stage represent the least energy efficient construction type (high energy intensity), while Stage 2 represent the most energy efficient construction type (low energy intensity). The stages 1 and 2 can substitute the low efficiency solution represented by the No Control stage (NOC). In this study, specification of technologies with low energy intensity was done for the energy needs: HVAC; Water heating and Large Appliances. For the other energy needs, data on technologies with low energy intensity as presented in Cofala et al (2008) was used. These stages are further presented later in this chapter.

The technologies with low energy intensity are divided into the RES and COM sector technologies. For each technology the investment cost, life time and energy efficiency improvement are presented given the data availability. It is uncommon to find all the needed parameters in the literature estimates, and usually only two out of three parameters are given. For energy needs other than HVAC, most of the useful information was found from the Energy Star energy efficiency standards (www.energystar.gov, 2008). Their energy efficiency calculator presents numerical estimates for all the needed parameters and provides information 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 sectors separately.

The GAINS model calculates emission mitigation costs in $€_{2005}$. 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 the year 2005.

In the GAINS model, 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, a part of the total mitigation cost calculations in the GAINS model. All cost estimates exclude taxes.

For 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 parameters 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. In this inventory, the estimates on technology efficiency and investment costs origin from literature as well as on-line calculators. The results from the inventory on technologies with low energy intensity are presented in the following chapter on results.

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

3.3.1 Technology Implementation rate in 2005 ($X_{DOM,RES,n,t,2005}$ and $X_{DOM,COM,n,t,2005}$)

The implementation rate of technologies is estimated from Klaassen et al. (2005), Petersdorff et al. (2002) and expert estimates. The implementation rate of HVAC measures is to a large extent a weighted estimate based on available construction standard information. For other energy needs, the implementation rates of technologies are estimated from European inventory surveys and projects such as the ODYSSEE database and MURE tool (Bosseboeuf 2007).

3.3.2 Technology Implementation rate in 2020 and 2030 ($X_{DOM,k,n,t,2020}$ and $X_{DOM,k,n,t,2030}$)

The nation-specific technology implementations in 2020 and 2030 are based on the background information supporting the baseline to which the energy use is calibrated (EC DG TREN 2007). Furthermore, other projections provide substantial information on expected implementation rates. In the projection of future technology implementation it is important to remember the conditions valid for the baseline scenario. One example is that the EU Climate & Energy package was not yet decided upon during the construction of the baseline scenario. Neither had the EU ban on ordinary light bulbs been implemented (Directive 2005/32/EC, adopted 18th of March 2009).

The EU Climate & Energy (CE) Package includes: the EC regulation No 443/2009; Directive 2009/29/EC amending Directive 2003/87/EC; Directive 2009/30/EC amending Directive 98/70/EC and Council Directive 1999/32/EC; Directive 2009/31/EC amending Council Directive 85/337/EEC, European Parliament and Council Directives 2000/60/EC, 2001/80/EC, 2004/35/EC, 2006/12/EC, 2008/1/EC and Regulation (EC) No 1013/2006, and Decision No 406/2009/EC). The CE Package was adopted on the 23rd of April 2009.

3.4 Energy demand in the domestic sector

3.4.1 Energy statistics and estimates for 2005

The data for the total energy use of Thermal energy (TH) and Electricity energy (ELE) for each country in EU-27+3 are obtained from Eurostat (2008) and the PRIMES model baseline scenario delivery to the GAINS model. This scenario described the projected energy use in the RES and COM sectors in accordance with the projections from the European Union Directorate General for Energy and Transport (EC DG TREN 2007). This energy projection was in the EU used as support for the negotiations of the EU Climate and Energy Package.

The use of energy in the energy need categories specified above for average EU-27+3 is found mainly in the Odyssee database (www.odyssee-indicators.org, 2008). The average distribution of energy use between different energy needs for EU27+3 was used as proposed distribution for the countries where no data was available. For most countries, the energy use split between different 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, the average EU-27 split between energy needs is used for the majority of the countries in the COM sector. To compare the distribution of energy needs in a country to another similar country, the country-specific number of heating and cooling degree-days and

GDP/capita are used as indicators of which countries that can be assumed to have similar characteristics regarding distribution of energy use between the energy needs. The estimated implementation of energy efficient technologies, which correspond to the total energy use for the respective energy needs in 2005, is presented later in the report.

3.4.2 Energy use development until 2020 and 2030

The development of the energy use in 2020 and 2030 is dependent on the expected implementation rate of the energy efficient technologies as well as the underlying change in demand for the respective energy needs. The latter is represented by the 'Intensity Multiplier' for each year and energy need. The national policies on energy efficiency available in autumn 2007 indicate the expected implementation of energy efficient technologies for each country. National policy summaries are mainly taken from the Odyssee database as well as Sveriges Byggindustrier (2008a). Furthermore, energy/GDP intensities as well as Energy/"Economic Value Added" intensities are calculated as indicators on the aggregated implementation of energy efficient technologies in the studied countries. This use of 'energy/GDP' and 'energy/Economic Value Added' intensities gives a very crude indication and is used only to give a general guideline and separation between countries. The intensity multipliers are mainly derived from EU-studies (EC DG TREN 2007) and the Odyssee database. The energy use development is calibrated with the PRIMES models C&E package 2007 scenario as delivered to the project group by IIASA. An overview of the Odyssee database, Sveriges Byggindustrier (2008a) is found in the Appendix D to this report.

4 Results

This chapter presents the statistics, estimates and projections compiled in this study. The aggregated energy need results are presented in a EU27 level of aggregation, while it is the country-specific share of energy needs that are used in the data sets compiled in this study. The country-specific distribution of thermal energy and electricity use for each energy need within the RES and COM sub-sectors are presented in appendix A, B, and C. The country-specific building related statistics, estimates and projections are then presented, followed by the definition of control technologies as well as their estimated implementation rates in 2005, 2020 and 2030.

4.1 Activity data and Multipliers in the Residential and Commercial sectors

4.1.1 Energy statistics and Activity data for 2005

The specification of thermal energy and electricity used for the respective energy needs provides information on the relative contribution of emissions as well as the impact from applying for control technologies. For the EU-27, the country average energy use distribution for the specified energy needs is given in the table below. The sums do not equal 100% due to rounding errors.

Table 5: Energy needs in residential and commercial sectors, country-based average for EU-27.

EU-27 energy needs 2005 (The Odyssee database and national statistics)	**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%

Source: Odyssee database & National statistics

The table above presents the average value for the EU-27 countries percentage distribution of energy needs, and serves as an overview of the country-specific results presented in the Appendices A, B, and C. The table does not give an average energy use distribution for the EU-27, but average % for the EU27 countries.

In general, 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 energy needs in the commercial sector change the relative importance of the energy needs compared to the residential sector. During the compilation of data the Odyssee database estimates have been compared with the REMODECE database to ensure consistency (www.isr.uc.pt, December 2008).

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

Building stock statistics ($A_{DOM,k,n,2005}$)

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

Table 6: 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

4.1.2 Activity projections for 2020 and 2030

Total energy needs in 2020 and 2030

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 did not include the agreement of the EU Climate & Energy package and project 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%/year (median 0.077%/year). 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 7: 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), is used together with the floor space multiplier for 2005 to calculate each country's 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 8: 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

4.1.3 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 scenario that supported the EC-DG TREN (2007) scenario, Eurelectric (2006), as well as the Odyssee database. The text gives a short description of the information used.

European Energy and Transport – trends to 2030, updated 2007 (EC-DG TREN 2007) – Summary

Residential sector:
Households are main drivers of energy consumption. Changes 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 lead to lower energy bills that can influence people to consume more energy given the additional disposable income. This effect is usually referred to as the 'rebound effect', but is not considered in this project.

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 increase of the disposable income. Population growth is low and the number of persons per household is decreasing.

Table 9: 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

In 2005, the entire residential sector consumed 26% of the total energy consumption in EU, and this is projected to be almost the same by 2030, 24%. The baseline scenario in EC DG TREN (2007) 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 ~ 80% of all households in EU own a washing machine. New types of appliances are increasing the energy consumption, however new appliances have high energy efficiency standards. Overall, the energy intensity with respect to income (final energy consumption over household income) has increased with 1.1% per year between the years 1990-2005.

The baseline scenario projects a slow increase of energy demand for space heating, while cooling demand is projected to grow fast, from 1% per year in 2005 to 2% per year in 2030 with faster growth of thermal energy demand for cooling than electric demand for 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 and 2030. Energy demand for lighting is projected to increase slowly until 2020 and then decline, since the overall energy efficiency improvement by 2030 is projected to imply 25% higher efficiency. Electricity consumption for appliances is projected to grow almost as fast as the growth in disposable income, from 6.5% of energy consumption in 2005 to 11% 2030.

Table 10: Energy consumed by energy need in the EU residential sector in the year 2005.

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

Commercial sector:

The entire commercial sector is accountable for 12% of total final energy demand in the EU in 2005. Between the years 1990 to 2005, the final energy demand in the commercial sector increased by a rate of 2.6-2.8% per year. The last fifteen years, the economic value added in the commercial sector has been growing at a rate above the GDP growth rate in the EU. Over the fifteen years, the office space per employee has increased with 0.5% per year, and heating and cooling systems as well as access to office equipment have become more common. New commercial buildings have a better energy performance than older buildings, which have affected the 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. Useful energy demand had an annual growth with 1.7% the previous period. Useful energy demands are projected to be increasing at a yearly rate of 1.8% over the period 2005-2030, a bit higher than the previous 1.7% per year. The final energy demand is expected to grow with a rate by 0.9% per year.

As shown in the table below, 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 for active (heat pumps etc.) or passive (self-ventilation) ventilation system.

Table 11: EU commercial sector baseline scenario estimations for final energy consumption split into four uses.

Energy use	Growth rate: 2005-2030
Heat uses	0.7% per year
Economic 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 and 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 demand and lighting demand on the other hand are projected to be subject to technological improvement in the baseline scenario due to the increasing use of energy efficient heat pumps and efficient lighting with good profitable pay-back time. Use of electric appliances is projected to increase, and is therefore having a more conservative trend in energy efficiency improvement in the baseline scenario.

Table 12: EU commercial sector 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 the final energy consumption is projected to decrease from 2000 until 2030. Appliances are supposed to represent the fastest growing share of energy consumption in the commercial sector.

Table 13: EU commercial sector cooling and appliances share of final energy consumption.

	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 the 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.

4.2 Energy efficient technologies (*t*)

Technologies available for reduction of the energy needed for the respective energy needs are grouped into a stage 1 and stage 2 group for each energy need. The following energy efficiency 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 but are covered in Cofala et al. (2008).

4.2.1 Heating, Ventilation and Air Conditioning

Measures to increase the energy performance of the building envelope are in the GAINS model grouped into one common group of measures, HVAC, with two stages defined in this report. There are several ways to combine measures into HVAC stages. The combinations chosen in this report represent the stages 1 and 2 and are combinations as recommended by expert estimates. HVAC stages 1 and 2 consist of three parts in the GAINS model; improvements in the building envelope; improving the boiler/heater thermostat; and improving the air conditioner efficiency.

4.2.2 Stage 1

- ***Technology presentation***

Information from the *Energy savings trust* is adapted and used to estimate energy efficiency measures in existing buildings (www.energysavingstrust.org.uk, December 2008). These estimates are compared with the existing GAINS database estimates and other sources.

The measures considered for improving the energy performance 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, η 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 (Stage 0) and is based on adaptation from Shorrock & Utley (2003).

From the numbers in the table below (columns 'Annual savings per year', 'CO_2 emission saving per year') 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 building envelope measures have been selected for HVAC Stage 1. All costs are given in the euro 2005 currency year and exclude taxes. Furthermore, the investment costs reflect the cost that can be considered as attributable for the efficiency improvement, the costs do not cover the entire cost of an installation.

Table 14: Investment, savings and emission reduction from different efficiency improvements.

Efficiency measures costs (€)	Annual savings per year (€)	Investment cost (€)	Investment payback (years)	CO_2 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 €**		

Source: adaptation from energysavingstrust.co.uk, December 2008

In total, stage 1 efficiency improvements in the building envelope would imply an extra investment of € 3360 compared to the low efficiency option (Stage 0).

The combined efficiency improvements of the boiler/heating measures presented by *the Energy saving trust* would be 17% compared to low efficiency equipment (www.energysavingtrust.org.uk, December 2008). However, the already existing estimations in the GAINS-model database of 15% are similar to the estimates in this report and are therefore used in this report. For houses heated with electricity, 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%.

When adapting the table above to the price of natural gas and emissions from natural gas in the example, the following results can be calculated.

Table 15: 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/year (NG*-price)	Energy saved, kWh/year (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%
Combined efficiency Building envelope Total:			**50%****
TH Heater/boiler/thermostat Total:			**15%** (*17%*)
ELE Heater/boiler/thermostat Total:			**8%**

* Natural Gas
** 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 as for heating. Less heat will be transported into the house when it is warmer outside than inside. Energy efficient windows will also include technologies to reduce the solar radiation entering the building (at least in warmer countries) which means that cooling demand will decrease. The effect has in this study been estimated to around 20% decreased cooling demand due to improvements in the building envelope as described above.

The installation of a thermostat will also reduce cooling demand as well as installation of more energy efficient air conditioners. Improved air conditioner is included in the Stage 1 category because it is assumed that either an installation of a new boiler or a new air conditioner will be implemented. The combined 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 when introduced separately). The estimated investment for the heater/boiler/thermostat combination is 940 € excl. taxes.

Based on the numbers presented above, the combined efficiency improvement of HVAC and Boiler/heater/thermostat measures joined in stage 1 is calculated to give a:

- 58% reduction in space heating demand when using district heating or other small scale heating systems
- 54% reduction in space heating demand when using electricity, and
- 37% reduction in space cooling demand.

The cumulative effect of a group of energy efficiency measures is smaller than the sum of the individual measures since the marginal improvement in energy efficiency is diminishing. The cumulative effect will not be equal to the sum of the two stages (58% = 1-(50%)*(1-15%)).

The total investment for HVAC Stage 1 is calculated to € 4300 excl. taxes for existing houses.

- ***Max implementation 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 higher than the corresponding number in 2005. The term refurbishment rate refers to the % of the building stock that is subject to renovation/refurbishment at any given year. It must be stressed that current estimates on refurbishment rates are scarce.

4.2.3 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 the Stage 2 options could be implemented was 1.4 million in Sweden 2005. The corresponding number for apartment buildings is expressed as an area of 149 million m^2. 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 (Ekström et al 2006) are in this study 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):
  Boiler (thermal), *FTX-unit*, *optimization of heating system* and i*nternal payment for heat*

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

In the tables below the efficiency improvements (on top of Stage 1) of the HVAC stage 2 options are presented in the categorization adapted to the GAINS model.

Table 16: Efficiency potential for different measures, compared to Swedish building stock in 2005.

	Efficiency improvement Detached and semi-detached dwellings	Efficiency improvement Apartment buildings	Efficiency improvement 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%	

Source: Ekström et al. (2006)

Table 17: 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 costs (Stage 1 + 2)***

As explained earlier, the cumulative effect of a group of energy efficiency measures is smaller than the sum of the individual measures since the marginal improvement in energy efficiency is diminishing. The cumulative effect will not be equal to the sum of the two stages.

Table 18: Efficiency improvement and investment costs for Stage 2 measures.

	Efficiency improvement	Investment in € (Stage 1+2)
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

The investments costs in the table above are calculated as the sum of the costs for Stage 1 measures + additional investment cost for Stage 2 measures.

As presented above for Stage 1 it is very difficult to estimate how the presented Stage 2 measures are affecting the cooling demand. In this study the aggregated effect for stages 1 and 2 is estimated to 30% decreased cooling demand when improving the building envelope/insulation according to the Stage 1 +2 specification. The investment cost is assumed to be included in the above specified investment costs. The combined efficiency improvement on space cooling demand for stage 1 and 2 heater/boiler/thermostat measures is estimated to 38% (12% for the thermostat and 29% for the air conditioner separately).

When comparing with the low-efficiency option (stage 0), the combined efficiency improvement of Stage 2 HVAC and Boiler/heater/thermostat measures implies a:

- 82% reduction in space heating demand when using district heating or other small scale heating systems;
- 83% reduction in space heating demand when using electricity; and
- 37% reduction in space cooling demand.

The combined efficiency is lower than the sum of separate efficiency measures since the cumulative effect is diminishing when more measures are introduced (82% = 1-(60%)*(1-55%)).

The total investment for HVAC Stage 2 is calculated to € 12 655 excl. taxes for existing houses.

- ***Max implementation rate, xmax***

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

- ***Cumulative max implementation rate, Xmax***

The cumulative max implementation rate is assumed to be equal to the max implementation 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 of this report have compared the estimates with Petersdorff et al. (2005) and the values presented here are in the same order of magnitude.

4.2.4 Large appliances (electricity)

4.2.5 Stage 1

- ***Technology presentation, t***

Stage 1 for large appliances is defined in accordance with the requirements set by the Energy Star criteria (www.energystar.gov, December 2008). The efficiency improvement compared to inefficient appliances and associated investments are presented in the table below (column 2 and 3).

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

By using the split of energy use for these different large appliances in Sweden (column 4 in the table below) it is possible to calculate the overall efficiency improvement in Stage 1 for large appliances to 18% compared to inefficient appliances. The split of energy consumption for various large appliances is supplied by Griffin & Fawcett (2000), IVA (2002) and the Swedish Energy Agency (2009). The investments costs are taken from the Energy Star estimates.

Table 19: The overall efficiency improvement for the large appliances, Stage 1.

Appliance type	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	18%

- ***Max implementation rate, xmax***

The maximum implementation 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.

4.2.6 Stage 2

- ***Technology presentation, t***

Data for Stage 2 has been collected from Electrolux (www.electrolux.se, December 2008) where information about best available appliance (new) and a new ordinary appliance has been obtained.

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

Table 20: Best available appliances (new).

Appliance Source: Electrolux 2008*	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% have a combination of a refrigerator and a freezer has to be made (usage rate). Information about usage of different appliances in homes are also needed and were 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 5 in the table above.

The overall efficiency improvement calculated for Stage 2 for large appliances is 38% energy saved compared to Stage 0, while the Stage 1 level is calculated to 18%.

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

When combining the two stages, an efficiency improvement of 38% compared to the low efficient stage (Stage 0) is reached.

- ***Max implementation rate, xmax***

The max implementation 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.

- ***Cumulative max implementation rate, Xmax***

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

4.2.7 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).

4.2.8 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, η 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). These options are used for the definition of both Stage 1 and 2 control options.

Table 21: Collected data for water heating, used for Stage 1 and 2.

Water heat type	Efficiency	Investment (€)	Annual energy Cost (€)	Life time (year)	Cost over 13 years (€)
Conventional gas storage	57	380	537	13	7361
High-efficiency 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

Source: Eurelectric 2006 – The role of electricity

The investments in the table above include cost for installation as well as equipment. The annual energy costs expressed by Eurelectric (2006) are based on hot water needs for a four person household and energy costs of € 0.15 / kWh for electricity, € 0.75 / kWh for gas and € 0.40 / litre of fuel oil. Future operation costs are neither discounted nor adjusted for inflation.

- ***Max implementation rate, xmax***

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

4.2.9 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, η 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 (Stage 0) 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 implementation rate, xmax***

The maximum implementation rate, as well as the maximum cumulative implementation rate, is assumed to be 100% by 2020.

4.3 Mitigation Technology Implementation in 2005

A policy inventory as well as a technological specific inventory is used to estimate the implementation of the available mitigation technologies in the model. This inventory of technology implementation in 2005 serves the purpose of calibrating the country-specific European data and thereby supplying a base for the estimates on potentials for further energy efficiency improvements. The following table presents the estimated implementation 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% implementation of Stage 1 control in Sweden 2005.

Table 22: Estimated implementation of HVAC Stage 1, 2005.

Technological Inventory: HVAC implementation 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 Petersdorff et al. (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 Petersdorff et al. (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 Petersdorff et al. (2002)
Hungary	36	25	Assumed to be same as Slovakia and Czech republic, according to Petersdorff et al. (2005)
Ireland	45	32	Estimated from insulation thickness in walls, given by Petersdorff et al. (2002)
Italy	30	21	Estimated from insulation thickness in walls, given by Petersdorff et al. (2002)
Latvia	54	38	Estimated to be about 20% higher than Poland, based on insulation levels given by Petersdorff et al. (2005)
Lithuania	54	38	Estimated to be about 20% higher than Poland, based on insulation levels given by Petersdorff et al. (2005)
Luxembourg	51	36	Assumed to be same as Austria
Malta	30	21	Assumed to be same as Italy

Technological Inventory: HVAC implementation in 2005	Insulation in Eurostat inventory [%]	Re-calibrated to GAINS stage 1	Comment:
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 Petersdorff et al. (2002)
Portugal	54	38	Estimated from insulation thickness in walls, given by Petersdorff et al. (2002)
Romania	30	21	Assumed to be somewhat smaller than Hungary
Slovakia	36	25	Estimated from insulation thickness in walls, given by Petersdorff et al. (2002)
Slovenia	36	25	Assumed to be same as Slovakia and Czech republic, according to Petersdorff et al. (2005)
Spain	54	38	Estimated from insulation thickness in walls, given by Petersdorff et al. (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 assumed to be implemented to a very limited extent in 2005.

For other energy needs, the implementation 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.

4.4 Mitigation Technology Implementation in the baseline 2020 and 2030

4.4.1 Current state and projections regarding energy efficiency policies

The Odyssee database and the MURE project 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 implementation of energy efficiency measures in the EU-27 + Norway, Switzerland and Turkey. In Appendix D to this report we present short summaries of the results from these sources.

4.4.2 Calibration of Mitigation Technology Implementation in the baseline 2020 and 2030

The projections for the European countries from Odyssee, MURE and Sveriges Byggindustrier are calibrated with the EC-DG TREN (2007) projection for the European countries. This projection was developed before the signing of the EU Climate & Energy package. The future implementation of control stages is therefore not considered as very ambitious in the calibration. Information from the scenario delivered to the GAINS model by the PRIMES modelling group, supporting the EC-

DG TREN (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 implementation in 2020 and 2030 take into account the existing national policies presented above as well as the calculated energy intensity indicators.

5 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 improvements, 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 in this project limit the level of details provided, which makes the estimates on energy efficiency rather coarse. 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 and the international work on improving energy efficiency in the residential and commercial sector.

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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)[1], *	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) [1] 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%

Appendix D: Literature review, support for estimation of Energy intensity indicators and Implementation rates of control stages

The following text presents the information of relevance for the estimates on energy need intensity indicators as well as implementation rates of control stages in 2020. The review includes Eurelectric (2006), the Odyssee project, and Sveriges Byggindustrier (2008a).

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

Table D 1: 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

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

Public lighting consumes ~ 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. 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 in Eurelectric (2006) projected to be the fastest-growing area in residential electric end-use. The year 2000 total EU power consumption by household consumer electronics on stand-by was estimated to ~36 TWh and forecasted to rise to 62 TWh by the year 2010. Electric devices consume 2-4W of stand-by power, which 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 reports states that the International Energy Agency (2003) estimates that even with a continuation of all existing appliance-related policy measures the appliances electricity consumption will grow by 13% to 2010, and by 25% to 2020 compared to 2000. Stand-by power is the fastest growing electricity demand. 15% of the total appliance electricity consumption is expected to be used for standby functionality by 2030.

Space heating can provide a great potential for electricity saving with installation of central systems and technological improvements. Implementation of energy labels, via EU directives 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 D 2: Electricity consumption of appliances.

Residential cool appliances, refrigeration: '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
Dishwasher machine: 65 million units is assumed to be the sales, in EU-25 (2004)	
Average stock Product life: 12 years	1.45kWh/cycle
Washer machines: Energy saving of washing machines in EU, from 1994 to 2002: 30%, around 5% from 2000 to 2002.	
Cooking: 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%
Water heating: 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 D 3: 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

In the report it is estimated that all household equipment is likely to be controlled via electronic display devices in the future which will lead to an increase in the electricity consumption for stand-by functionality. This is because more than 75% households in EU own more than one TV (around 25% of all families have 3 TVs in their homes) and that DVD players are expected to increase tenfold in the next 10 years. A 40% increase in appliance ownership is expected to 2015 with the strongest growth in the number of laptops. 50% of the EU households had a personal or laptop computer in the home in the year 2005, and more than 50% of the households had internet connection.

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 million new boilers are sold in the EU per year.

Central air condition systems are in the EU defined as air conditioning systems with more than 12 kW of cooling capacity. The most efficient air condition equipment use only 35% of the electricity needed in the least efficient equipment 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 and 2020.

Odyssee - 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 (NMC: s) and 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:
Overall energy efficiency in the residential sector increased with 3.4% between 1996 and 2004 in EU-25, which is partly a result of EU directives and national measures such as financial incentives and building standards. There is still a difference between NMC: s and EU-25 in electricity consumption. NMC:s have on average a 40% lower electricity consumption than the average EU-25 countries. However, Baltic countries are catching up in equipment ownership and Mediterranean countries experience a rapid increase in the distribution of air conditioning.

In 2004, the residential sector consumed 26% of the final energy use in EU-25. Electricity consumption has increased from 19% to 22% between 1990 and 2004 in EU-25. In NMC:s, the electricity demand is lower with only 14% of the market in 2004.

The energy demand growth in the residential sector is mainly driven by the number of dwellings, which has increased more than the population, 1% per year versus 0.3% per year (1990-2004). This is because of average number of persons per dwelling has decreased from 2.8 to 2.5 during this period. The dwelling size has also increased from an average of 85 m^2 to 88 m^2 during the same period. Most of the new EU members experienced a decrease in energy consumption during the period, except for Cyprus, Estonia, Hungary and Slovakia. In the EU-15 countries there has been a small increase in energy consumption per dwelling with 0.3% per year. The table below presents relevant energy use parameters for the EU-25.

Table D 4: Trends in energy consumption & income 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. This is not because of energy efficient buildings, but is rather a result of high energy prices and limited comfort. Slovenia, Latvia and Hungary have the highest heat consumption which 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 the share of energy consumption in the commercial sector compared to EU total has 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 in electricity consumption.

The economic value added in 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 sector contribution to 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. The net result was that the energy demand per employee was at the same level in 2004 as in 1996. Electricity consumption increased with 0.8% per year during the period 2001 to 2004, with an average annual increase in electricity consumption per employee of 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.

Odyssee - 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. In the EU, there were six legislative-normative measures in 2005 related to energy efficiency in the residential sector. 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 have stronger barriers than EU-15 countries due to a lack of qualified staff in NMC:s.

Table D 5: 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	Subsidies

	consumers	
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 energy performance of most 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°C during two conceding 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 most common policy measure for the commercial sector, as for the residential sector. Subsidies and information measures are also important.

Table D 6: 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:
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, *Rena vinster bakom en finansiell barriär* , 2008a
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 economic 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 1960'ies and use 60% more energy than buildings constructed after the 1960'ies. 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 reduced by 50% and energy consumption costs of 40 billion SEK per year can avoided.

Table A 7: The million buildings program, energy performance of buildings

The Program of Million buildings		**Newly-produced buildings**
Isolation:		
insulation outer walls	10 cm	20 cm
insulation in the roof	15 cm	40 cm
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. In 2003 Germany introduced an energy efficiency strategy and planned 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 use 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.
As examples: isolations of windows (that can make a 5% energy use savings and provide repayment in two years), change of windows to windows with an U-value of 1W/m² (that can save 5% energy use provide repayment in two years), and replacement of the ventilation systems in multi-dwellings to electricity-efficient fans with air temperature-controlled-pressure regulation (that can make a 10% energy use saving and provide replacement in four years).

Table D 8: A comparison of heating and electricity consumption in a typical house and in an energy efficient house

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

References in the Appendices

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