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Heat and cooling demand and market perspective

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1. Introduction

In order to fully understand the national potentials for cogeneration, it is essential to identify the existing and prospective demand of heat and cooling by sector. A study will be performed on a MS level to describe the demand of heat and cooling by different sectors (i.e. industrial, residential), demand types (different temperatures) and supply technologies.

Task 4.1 aims to analyze the current situation and future trends of heat and cooling demand in the EU, as well as, the use and availability of industrial. Within each sector the demand will be presented for different segments. The focus is to map the demand of heat and cooling on temperature intervals possible to be supplied by district heating, district cooling or CHP. In order to capture the characteristics of heat, heat is split into different types; space heating, warm water, cooking, and industrial heat. For cooling, space cooling is the main type applicable to district cooling.

2. Methodology and objectives

The objective is to map the heat demand in temperature intervals possible to be supplied by district heating or conventional CHP. In order to capture the characteristics of heat, heat is split into the following types; space heating, warm water, cooking, and industrial heat. Industrial heat is divided into three intervals: heat with temperatures lower than 100°C (Low temperature heat), heat with temperatures from 100°C to 400°C (Medium temperature heat) and heat with temperatures higher than 400°C (High temperature heat). The intervals are in line with the ranges in the Ecoheatcool study. Space cooling is the main temperature level applicable to be supplied by district cooling, and therefore, the cooling temperature will be focus on it. This study is divided into three sectors; Industry, Residential and Service.

The delicate matter concerning heat and cooling is that they in general are not measured. What is measured is what is purchased at the customer's door; electricity, oil, natural gas, district heating, etc. The used heat will depend on the efficiency of the technology. Even within one kind of technology the efficiency will differ substantial depending on age and maintenances. In addition, some energy carriers are used for many different energy services where the most complex is electricity that in households can be used for space heating, warm water, space cooling, lighting, appliances, etc. This is the reason why there is extremely limited access to heat and cooling statistics.

2.1. Definitions

Useful energy is the energy available to the consumers after the last conversion made in the consumer energy conversion equipment, hence final energy consumption minus conversion losses (Häfele, 1977).

Final energy consumption is defined by Eurostat as the energy supplied to the final consumer's door (Eurostat statistics, 2010).

Heating Degree-Days are the number of degrees per day that the daily average temperature is below a given temperature (18°C or 65°F). The given temperature is the point below which the consumer is assumed to use fuels for space heating and varies from country to country (IEA definitions, 2010).

Cooling Degree-Days are the number of degrees per day that the daily average temperature is above a given temperature (18°C or 65°F). This temperature is the point above which the consumer is assumed to use energy for space cooling. During the cooling season, warmer-than-normal temperatures tend to lead to increased electricity use, with increased demand for electricity often met by incremental use of oil products and natural gas (IEA definitions, 2010).

Drivers are explanatory factors that have a direct physical relationship with energy use. In the residential sector it is population, number of households, number and size of dwellings, central/local heating and ownership of appliances (Ademe, 2009).

Explaining variables are the factors that influence energy consumption indirectly, e.g. by changing energy using behavior. Examples are income, energy prices and savings policy, but also saturation could play a role in explaining energy trends (Ademe, 2009).

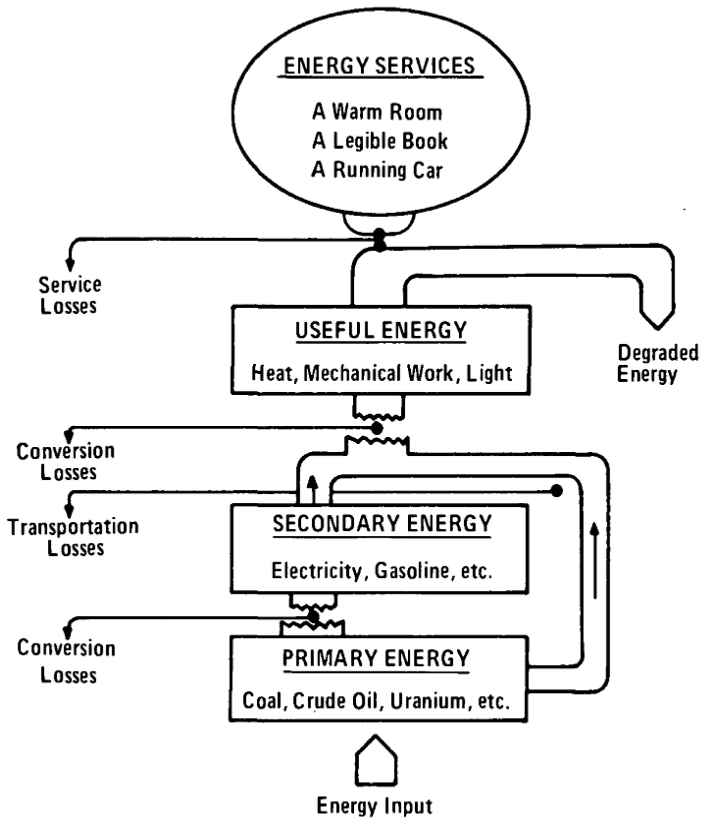

Fig. 2.1. Simplified schematic of energy flow and energy services from Häfele (1977)

2.2. Defining what we are mapping – Useful Energy

The aim of the present report is to map the demand of heat and cooling in Europe, by country and sector. The aim is to identify the useful energy or energy service needed by consumers for a different kind of heating and cooling purposes, for example, warm water, space heating and cooling. "Useful energy differs from final energy, purchased by the consumer, by the efficiency of the end use appliances". (Lapillonne, 1978). Useful energy meaning the energy available to the consumers after the last conversion made in the consumers equipment, hence final energy consumption for heat minus conversion losses. Final energy consumption, using Eurostats definition, "covers Energy supplied to the final consumer's door". Figure 2.1 shows the flux of the energy from the origin until the end service.

Most of the annual final energy consumption can easily be traced from the consumers' energy bills, with exceptions for solar energy, and wood from private properties or purchased from smaller retailers. Useful energy, on the other hand, depends on many different parameters that are both linked to technology (i.e., the efficiency of the energy conversion equipment) and to the behaviour of the user (i.e., shower in 5 or 20 minutes per day). Parameters that are impossible to measure by source on a national level, hence a generic approach is needed. When the final energy consumption is used for one kind of useful energy, for example oil for space heating, a generic approach is feasible. However for energy carriers, like electricity, with a diversity of possible application another approach is needed. One approach is to use standard figures of activity level (i.e., building standards of average consumed warm water per households) and energy intensity (heat demand per litre of warm water). Energy intensity is commonly used as a measurement of the energy intensity of a country's economy, for example by EIA (2010) when presenting the "total primary consumption per dollar of GDP" for each of the countries. However, the concept of energy intensity is wider and in the present study will be defined as "the energy use per unit of end-use-activity".

From above, we derive that useful energy for heat versus cooling can be estimated either from the final energy consumption (equation 1.1) or from the energy insensitivity of the segment (equation 1.2), depending on which parameters are known (or most certain). A segment is a part of a sector. Given the challenge to find accurate data, a mixed approach is needed. Each segment is unique and so is each of the energy carriers. In order to know which approach to use, we will first map the available data within each sector and segment per member state level. Thereafter an approach is chosen for each of the segment.

Estimating Useful Energy from Final Energy Consumption (Equation 1.1).

(Useful Energy)E,S,C,Y = ∑ f = 1 to F ((Final energy consumption)S,C,Y * (Share) E, S,C,Y * (Equipment Efficiency)E,S,C,Y

- (Useful Energy)E,S,C,Y: The annual Useful Energy for Energy-Service E in Segment S in Country C, Year Y.
- (Final energy consumption)S,C,Y : The energy for heat delivered to the final consumers door in Segment S in Country C, Year Y.
- (Share) E,S,C,Y: The share of total Useful Energy for Energy-Service E in Segment S in Country C, Year Y.
- (Equipment Efficiency)E,S,C,Y: The efficiency of the Equipment for transforming final energy into useful energy for Energy-Service E in Segment S in Country C, Year Y.
- f : Fuel or Energy Carrier

Estimate Useful Energy from standard figures of activity level and energy intensity (Equation 1.2)

(Useful Energy)E,S,C,Y = (Activity Level)E,S,C,Y * (Energy Intensity) E,S,C,Y

- (Useful Energy)E,S,C,Y: The annual Useful Energy for Energy-Service E in Segment S in Country C, Year Y.
- (Activity Level) E,S,C,Y : The average annual activity level for Energy-Service E in Segment S in Country C, Year Y.
- (Energy Intensity) E,S,C,Y: The average Energy Intensity level for Energy-Service E in Segment S in Country C, Year Y.

The applicability of these equations have two challenges:

- To discern the share of final energy consumption used for different Energy-Services (hence for different kind of heat or cooling needs).
- To distinguish between different technologies used to convert to useful energy.

The most difficult energy carrier to deal with is high-quality electricity, when electricity has so many possible applications. Apart from heating and cooling, electricity can be used for transportation, lighting, mechanical drive, etc.

2.3. Treatment of demand variation

Load duration curve

A load curve describes the load variations over a certain period while the load duration curve describes its cumulative duration for each capacity. The load curve start at the first day/hour, while the load duration curve starts with the day/hour with the highest energy demand and ends with the day/hour with the lowest energy demand. Day or hour depends on the needed level of detail. In addition, the annual heating or cooling energy use of a system is obtained by multiplying the area under the load curve and the annual peak load. The load duration curve is obtained from the load curve, as the load curve represents the demand of electricity, heat or cooling variation over time and made up on daily averages. The load curve contains more information than the duration curve, as it contains information regarding the moment during the year that a specific load level occurs. This information is lost when it is transformed into a duration curve. The load curve is specially used to calculate which production plants should be operated to cover the heating load day by day, while the duration load is more suitable to consider the base load and peak load plants as well as to calculate the total yearly energy production from each type of plant given their capacities (NRCAN 2011), (Tosato, 2008).

Heating Degree day data (can be used to create load curve)

As the heating load duration curve usually requires hourly loads, and this information is not always available in the design or feasibility stage for a system, the Retscreen CHP (cogeneration) model developed a method to derive the duration curve from the monthly degree days. The data used to develop the method is taken from very detailed studies of a relatively large district heating system in Uppsala, Sweden. It includes empirical monthly factors that represent the influence of solar gains, wind, and occupants' habits on the energy requirements of the building (NRCAN, 2011).

The characteristics of the demand decide the resolution needed to analyze the demand. For example; an industry with 24 hours shift and a close to constant demand could be enough to be defined with an average yearly demand. Whereas, a cooling demand needs both, seasonal and day/night division in order to fully capture the need for energy supply.

3. Mapping – Industrial Sector

3.1. Industry - General description of the sector

The most usual division of the sector is among energy-intensive industries and non energy-intensive industries. The industries included in the first group are i) Iron and Steel industry, ii) non-ferrous metal industry, iii) chemical industry, iv) non-metallic mineral products industry and v) pulp and paper industry. The rest of industries (food, drink and tobacco, textile, leather and clothing, ore extraction, engineering and other metal industry) are included in the group of the non-energy-intensive industries. This is the common approach followed by the European Commission in its trends up to 2030 (European Commission, 2007a) and by the International Energy Agency (IEA, 2007; IEA, 2009a, IEA, 2009b, IEA 2010). For the IEA, the treatment of the non-ferrous metal industry and the non-metallic mineral products boils down to explore the aluminum and cement, respectively, treating the rest of the energy-intensive industries aggregating all their products. The approach followed in (Ecofys and JRC-IPTS, 2009) provides limited information about non-energy-intensive industries giving more information about the subsectors contained in each one of the energy-intensive industries. The breakdown of the industry sector included in Eurostat is in Table 3.1:

Table 3.1. Classification of the industry used by Eurostat

101800 - Final energy consumption – Industry
101805 - Final energy consumption - Iron and steel industry
101810 - Final energy consumption - Non-ferrous metal industry
101815 - Final energy consumption - Chemical industry
101820 - Final energy consumption - Non-metallic mineral products industry
101825 - Final energy consumption - Ore extraction (except fuels) industry
101830 - Final energy consumption - Food, drink and tobacco industry
101835 - Final energy consumption - Textile, leather and clothing industry
101840 - Final energy consumption - Paper and printing industry
101845 - Final energy consumption - Engineering and other metal industry
101850 - Final energy consumption - Other non-classified industries
101899 - Final energy consumption – Adjustment

It is also noteworthy that when using the statistical information about final energy consumption, care should be taken since these figures should exclude quantities used to generate electricity and the part of heat that is for sale.

Giving the impossibility to analyze in detail the energy consumption of each one of the subsectors under the heading of non-energy-intensive industries due to its complexity, this chapter will only include the information gathered from Eurostat and the rest of bibliography whereas that for the energy insensitive industries it will provide information about the main products associated. This approach is similar to the one followed in (European Commission, 2007, IEA, 2007, IEA, 2009a, IEA, 2009b, IEA, 2010). However, the food, drink and tobacco industry has the higher energy consumption within the non-energy-intensive industries and it will be treated devoting a specific point to it. In fact, its consumption is slightly lower that the one of the pulp and paper industry. This approach is also justified by the fact that this industry stands out in the opportunities that it offers to co-generation plants and it has the highest electrical energy consumption for refrigeration.

In order to describe the quality of the heat demanded by the industry, it is followed the approach defined in (Ecoheat & Power, 2006) considering three temperature intervals in the industrial sector. The lower range, temperatures lower than 100°C, corresponds to processes as washing, rinsing, food preparation and it also may correspond to the energy needed for space heating of the industrial facilities and hot water preparation. The medium range, temperatures from 100°C to 400°C, corresponds to processes of drying or evaporation. This energy is normally produced by steam. The higher range, temperatures over 400°C, the energy is used for the transformation processes that take place in the industry; reduction of the ore, calcination, electric induction, etc.

The estimated useful energy demand for the industrial sector in EU-27 Members States is presented in Table 3.2 and Figure 3.1 presents the employed methodology. This table was constructed using the 2009 final energy data published by Eurostat, together with the breakdown by temperatures, the breakdown of the energy that is going to process for heating in each sector and the energy efficiency of each equipment based on the type of fuel (Ecoheatcool WP1, 2005; Eurostat, 2011; DOE, 2011, ETSAP, 2011).

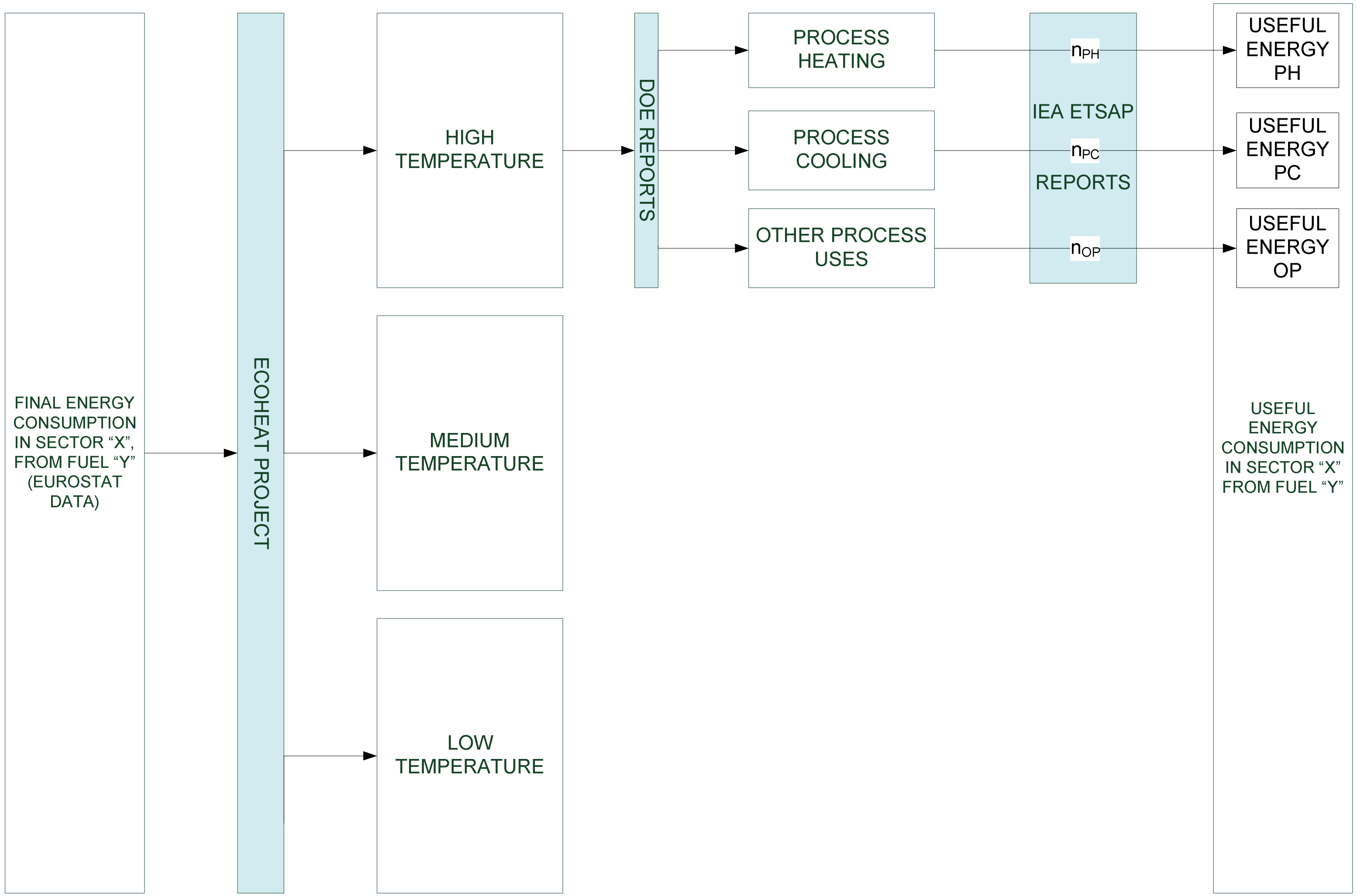

Figure 3.1. Methodology for the calculation of the estimated useful energy demand in the industrial sector of EU-27

Table 3.2.a. Breakdown of useful heat demand for the industry in EU-27 in PJ for 2009

PJ	Iron & Steel			Non-ferrous metal			Chemical			Non-metallic mineral products			Ore extraction (except fuels)		Food, drink & tobacco	
	High Temp.	Medium Temp.	Low Temp.	High Temp.	Medium Temp.	Low Temp.	High Temp.	Medium Temp.	Low Temp.	High Temp.	Medium Temp.	Low Temp.	Medium Temp.	Low Temp.	Medium Temp.	Low Temp.
Austria	49,7	2,5	1,6	3,2	0,2	0,2	3,8	1,9	3,0	18,2	1,2	1,1	0,1	0,2	3,3	5,4
Belgium	38,4	1,9	1,0	3,4	0,2	0,1	25,3	12,5	21,0	22,5	1,5	1,3	0,1	0,1	6,3	9,7
Bulgaria	4,1	0,2	0,1	2,1	0,1	0,6	2,4	1,3	10,4	12,9	0,8	0,8	0,0	0,0	1,4	2,4
Cyprus	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	4,9	0,3	0,3	0,0	0,0	0,0	0,0
Czech republic	58,0	3,1	3,5	0,6	0,0	0,1	12,7	7,3	11,1	19,2	1,2	1,6	0,1	0,1	3,2	6,3
Denmark	1,2	0,1	0,2	0,1	0,0	0,0	0,8	0,4	0,8	11,3	0,8	1,3	0,2	0,2	3,6	5,9
Estonia	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,1	0,4	3,2	0,2	0,3	0,0	0,0	0,4	0,6
Finland	26,2	1,3	2,3	0,8	0,0	1,1	5,1	2,8	11,1	5,6	0,4	0,8	0,0	0,1	0,9	6,0
France	111,1	5,8	3,2	8,9	0,4	0,2	43,2	23,6	17,0	72,2	4,7	4,4	0,4	0,4	26,7	37,7
Germany	269,6	13,8	9,0	19,3	0,9	1,2	58,2	29,1	86,9	122,9	8,0	8,1	1,5	1,7	26,9	42,5
Greece	2,7	0,1	0,1	7,5	0,4	0,2	2,0	1,1	0,8	20,4	1,4	1,3	0,2	0,2	3,8	5,9
Hungary	12,3	0,6	1,1	1,8	0,1	1,6	1,6	0,8	6,1	10,0	0,6	0,8	0,0	0,1	2,5	4,2
Ireland	0,0	0,0	0,0	7,5	0,4	0,2	2,2	1,2	0,9	8,9	0,6	0,6	0,2	0,2	2,9	4,2
Italy	92,2	4,5	12,7	12,0	0,6	0,4	22,6	11,3	41,8	148,6	9,5	11,9	0,2	0,2	16,4	28,0
Latvia	3,0	0,1	0,1	0,1	0,0	0,0	0,2	0,1	0,2	1,8	0,1	0,1	0,0	0,0	0,6	1,0
Lithuania	0,0	0,0	0,0	0,0	0,0	0,0	1,1	0,5	4,9	3,2	0,2	0,2	0,0	0,0	1,0	1,7
Luxembourg	6,1	0,2	0,1	0,0	0,0	0,0	0,1	0,1	0,0	3,0	0,2	0,2	0,0	0,0	0,0	0,1
Malta	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Netherlands	51,0	2,7	1,5	2,5	0,1	1,1	47,4	25,0	38,8	15,9	1,0	1,0	0,2	0,9	11,3	18,6
Poland	48,9	2,4	5,4	8,5	0,4	2,4	24,4	13,9	34,7	58,6	3,9	4,8	0,3	0,7	13,2	18,2
Portugal	2,1	0,1	0,0	0,6	0,0	0,0	3,0	1,5	4,9	37,2	2,3	2,5	0,2	0,4	3,1	5,5
Romania	38,9	1,9	1,1	0,0	0,0	0,0	19,8	10,1	12,1	11,1	0,7	0,8	0,1	0,1	3,5	5,4
Slovakia	47,9	2,5	1,4	1,0	0,0	0,0	2,0	1,0	2,2	8,9	0,6	0,8	0,0	0,0	0,9	1,3
Slovenia	2,1	0,1	0,2	1,3	0,1	0,1	1,0	0,5	1,1	4,1	0,3	0,3	0,0	0,0	0,4	1,0
Spain	60,2	2,7	1,5	7,7	0,4	0,2	35,2	17,9	13,7	135,1	8,6	8,1	0,5	0,6	10,9	16,3
Sweden	26,2	1,3	0,7	2,1	0,1	0,1	3,3	1,7	1,3	8,6	0,6	0,5	0,4	0,4	1,9	2,7
United Kingdom	92,8	5,0	2,7	7,4	0,3	0,2	28,8	14,4	25,8	58,2	3,8	3,6	0,0	0,0	17,2	24,9
EU-27	1044	53	50	98	5	10	346	180	351	826	53	57	5	7	162	256

Table 3.2.b. Breakdown of useful heat demand for the industry in EU-27 in PJ for 2009

PJ	Textile, leather & clothing			Paper & printing			Transport Equipment			Machinery			Other industries			Total		
	High Temp	Med. Temp	Low Temp	High Temp	Med. Temp	Low Temp	High Temp	Med. Temp	Low Temp	High Temp	Med. Temp	Low Temp	High Temp	Med. Temp	Low Temp	High Temp	Med. Temp	Low Temp
Austria	0,2	0,6	0,4	5,0	13,3	6,9	0,0	0,1	0,8	0,3	0,6	2,0	0,2	0,4	0,8	80,7	24,3	22,3
Belgium	0,5	1,2	0,7	2,3	6,1	4,4	0,1	0,3	0,6	0,1	0,2	0,6	0,6	1,2	1,9	93,2	31,3	41,4
Bulgaria	0,2	0,4	0,4	0,2	0,5	0,3	0,0	0,0	0,0	0,0	0,1	0,2	0,0	0,1	2,2	21,9	5,0	17,6
Cyprus	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,2	0,2	5,0	0,5	0,5
Czech republic	0,2	0,6	0,9	1,9	5,2	3,1	0,2	0,5	1,5	0,4	0,8	3,7	0,8	1,6	2,2	93,9	23,6	34,1
Denmark	0,0	0,1	0,1	0,2	0,6	0,7	0,0	0,1	0,2	0,2	0,3	1,3	0,3	0,5	1,0	14,1	6,6	11,8
Estonia	0,0	0,0	0,3	0,1	0,3	0,2	0,0	0,0	0,0	0,0	0,0	0,1	0,1	0,1	0,3	3,6	1,2	2,2
Finland	0,1	0,3	0,5	15,5	42,0	35,6	0,0	0,1	0,4	0,0	0,1	1,8	0,4	0,8	2,1	53,7	48,8	61,8
France	0,8	2,2	1,1	5,7	15,2	7,3	0,5	1,3	2,7	0,9	1,9	5,1	2,1	4,3	5,8	245,3	86,4	85,1
Germany	1,2	3,2	2,0	12,9	34,9	28,8	0,9	2,4	10,2	2,4	5,1	15,6	3,5	6,9	15,8	490,8	132,7	221,9
Greece	0,2	0,5	0,3	0,3	0,9	0,5	0,0	0,1	0,1	0,0	0,0	0,1	0,7	1,4	1,9	33,8	9,9	11,2
Hungary	0,0	0,1	0,1	0,2	0,6	1,4	0,1	0,1	0,4	0,1	0,3	0,9	0,2	0,3	0,6	26,4	6,1	17,4
Ireland	0,0	0,1	0,1	0,0	0,1	0,1	0,0	0,0	0,1	0,2	0,4	1,1	0,1	0,2	0,3	19,0	6,2	7,6
Italy	3,7	9,9	5,9	4,9	13,0	23,2	0,0	0,0	1,4	2,6	5,5	15,1	0,4	0,8	13,3	286,8	71,5	153,9
Latvia	0,0	0,1	0,1	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,0	0,0	0,0	5,2	1,2	1,5
Lithuania	0,1	0,2	0,2	0,1	0,3	0,2	0,0	0,0	0,0	0,0	0,0	0,1	0,0	0,1	0,1	4,5	2,3	7,3
Luxembourg	0,1	0,2	0,1	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	9,3	0,8	0,6
Malta	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,2	0,2	0,1	0,2	0,2
Netherlands	0,3	0,9	0,5	1,6	4,1	6,4	0,1	0,2	0,5	0,4	0,9	2,6	0,4	0,8	1,3	119,7	47,1	73,2
Poland	0,3	0,9	0,8	3,7	10,3	7,4	0,2	0,4	1,9	0,3	0,6	2,8	0,5	1,1	2,1	145,3	47,4	81,2
Portugal	1,0	2,8	2,7	3,9	10,2	6,4	0,0	0,1	0,1	0,1	0,2	0,4	0,1	0,2	0,2	47,9	20,7	23,2
Romania	0,5	1,4	1,0	0,2	0,7	0,5	0,1	0,2	0,6	0,2	0,4	1,5	0,3	0,6	1,0	71,1	19,5	24,1
Slovakia	0,1	0,2	0,2	2,3	6,2	3,5	0,1	0,2	0,4	0,1	0,2	0,4	0,1	0,3	0,4	62,5	12,2	10,6
Slovenia	0,1	0,2	0,1	0,6	1,6	0,8	0,0	0,1	0,1	0,1	0,1	0,5	0,1	0,2	0,4	9,3	3,6	4,7
Spain	1,1	3,0	1,5	6,5	17,5	8,4	0,4	1,2	2,4	0,7	1,5	4,0	3,8	7,1	10,3	250,7	71,3	67,0
Sweden	0,1	0,2	0,1	17,9	47,7	21,3	0,0	0,1	0,3	0,1	0,2	0,5	0,3	0,5	8,3	58,6	54,6	36,2
United Kingdom	2,3	6,4	3,2	5,4	14,5	7,4	0,8	2,1	4,4	1,0	2,2	6,0	13,4	28,0	45,8	210,2	94,0	124,1
EU-27	**13**	**36**	**23**	**92**	**246**	**175**	**4**	**10**	**29**	**10**	**22**	**67**	**29**	**58**	**119**	**2462**	**829**	**1142**

3.2. Industry - Characteristics

This point will introduce the key subsectors one by one. In each one of the sub-sectors will answer the following questions:

- Which are the most important industries within each sub-sector? In what respect are they important?
- What are the proportion between the different kinds of heat and cooling?
- Does the sub-sector mainly use high temperature heat or does it use half medium and half low temperature heat?
- How is the variation of heat/cooling over the year and over day/night?

There is a large difference among how the power sector and the industry sector meet their demand. Whereas in the power sector energy production has to meet the demand, (a small portion of the electricity can be stored and returned to the system to flatten the load profile), the production processes of energy-intensive industries do not follow cyclical short term behaviour of the demand. Therefore, in general terms, the industry tends to operate at full capacity to ensure maximum returns for their intensive capital investments (i.e. normal ranges of utilisation are between 80% and 90% for the chlor-alkali process, 80% for mechanical wood pulp production, around 95-98% for the aluminium electrolysis, 75% for the electric arc furnaces and around 80 % for the cement mills (Moritz and Borggret, 2011). In some cases, it can be feasible certain shifting or rescheduling of the load aiming at relieving the peak of the demand of electricity, but always without affecting the production. This shifting of the load aims at obtaining some discount in the electricity bill (Bassols et al, 2002). Therefore, it can be said that, in general, all energy intensive industries operate at the same rate (with the same load factor) without any seasonality, whereas in non energy-intensive industries their heat demand is more dependent on production and working hours of employees, i.e on social components.

3.2.1. Chemical and petrochemical industry

The chemical and petrochemical sector has a share of more that 30% of the total energy use worldwide (including feedstock). In the EU, in 2005, according to IEA, Eurostat and Primes statistics the sector used some 2300PJ of final energy (14% of total industrial consumption). Additionally, the sector incorporated 3400 PJ of energy carriers into products. This means that feedstock accounts for 60% of total energy products and fuel and power for almost 40%, taking all sources of energy into account (Ecofys and JRC-IPTS, 2009). However, the energy incorporated as feedstock in the products is not included when reporting about progress achieving energy efficiency targets.

There are 16 million organic compounds known, 1-2 million inorganic compounds, and the number of chemical compounds produced is about 70000-80000. Despise the large variability of products use in the European chemical industry, about 72 % of the fuel consumed for energy is used in only three processes; 12.9 % for the ammonia production by steam reforming of natural gas, 50.2 % for steam cracking of naphtha and 9.1 % for steam cracking of gas oil. In addition, chlor-alkali production accounts for 16.7 % of the electricity consumed. In EU chemical industry, 8 chemicals are able to account for 80% of the NO2 and CO2 emissions (nitric acid, cracker products, ammonia, adipic acid, hydrogen/synthesis gas, soda ash, aromatics and carbon black) (Ecofys, 2009a). The number of products/processes used to describe the GHG emissions for the benchmarking exercise amounted to nine (nitric acid, steam cracking, ammonia, adipic acid, hydrogen and synthesis gas, soda and sodium bicarbonate, aromatics, carbon black, Glyoxal and glyoxylix acid), whereas the number of products consider in Ecofys and JRC-IPTS (2009) to analyze the potential GHG emissions and associated costs amounted to 19 chemicals/processes.

According to Euroheat and Power industrial heat demand survey in 2006, the European Chemical industry's low and medium temperature heat demand (100-400°C) is at least half of the total heat demand (IEA, 2009a). These values are in line with the percentage of industrial heat demand 49%, 28% and 23% for the high, medium and low range of temperature of the heat demand estimated in Ecoheat & Power (2006).

The electricity consumption in refrigeration processes (including air conditioning) in the chemical industry is considered around 103 PJ which is 32.3% of the total electricity consumption in the European Industry (Ademe, 2006; Almeida et al., 2000).

3.2.2. Pulp and paper industry

The pulp and paper industry produces different types of pulp, from virgin (wood) or from recycled material that are afterwards processed into a variety of paper products. The two main processes for (virgin) pulp making are the chemical route and the mechanical route. In Europe, there are 203 pulp mills, and about 18% are integrated mills producing both virgin pulp and paper (Ecofys, 2009) .

Pulp production from recycled fibres is almost always integrated with paper production. Integrated plants are more energy efficient because they can save in transport, in the drying of the pulp between mills and can manage more efficiently surpluses of heat in pulp manufacturing. In 2007, the current total number of pulp and paper mills (all grades) in Europe was 203 and 944, respectively (European Commission JRC-IPTS IPPC, 2009a). Sweden is the country with higher number of pulp mills (44 pulp mills), followed by Germany (24 pulp mills). The two countries with higher number of paper mills are Italy and Germany with around 180 paper mills each, follow by France, with around 105 paper mills (European Commission JRC-IPTS IPPC, 2009a).

Europe has one of the highest recovery and utilization rates of fibres in the world (72% in 2009) (CEPI, 2009). Except for a small number of deinked market pulp mills, pulp production from recycled fibres is always integrated alongside paper production. The main grades of wood pulp for papermaking in 2007 across Europe were sulphate pulp - Kraft process - (60% of total pulp production) followed by mechanical and semi-chemical pulp (33% of pulp production) and sulphite pulp (5% of total pulp production (European Commission JRC-IPTS IPPC, 2009a)).

The pulp and paper industry is one of the energy-intensive sectors of the EU and global industry (about 1400PJ of final Energy in 2005 – 9% of industrial consumption – (Ecofys and JRC-IPTS, 2009)). The percentage of industrial heat demand is 18%, 55% and 27% for the high, medium and low range of temperature of the heat demand (Ecoheat & Power, 2006). However, there are large variations on the energy profiles for different technologies. The electricity/steam consumption ratio at paper mills enables an efficient use of co-generation of heat and power (CHP). Most modern paper mills have their own CHP unit. On the overall European balance, the industry in 2008 bought 72 TWh of electricity, sold 9 TWh of electricity, and produced 53 TWh of electricity (CEPI, 2009). Despite the high penetration of the cogeneration only around 40% of CHP potential capacity has been installed in this industry (Rodriguez Morales, 2011).

Taking into account the different energy intensities of the various product types, the average specific heat consumption for the sector is between 4-7 GJ/t to create an end product (European Commission JRC-IE, 2010a). The lowest values are for recycled newsprint, and the highest for specialty papers and packaging. Specific primary energy consumption in 2008 was 13.41 GJ/t, based on the overall totals of energy and production data (CEPI, 2009). Half of the energy used by the industry (53.9% in 2009) comes from biomass and 38% from natural (CEPI, 2009).

3.2.3. Iron and Steel industry

The energy consumption of the Iron and steel sector represented 16% of total energy consumption (around 2500 PJ of final energy) (Ecofys and JRC-IPTS, 2009). There are the two main routes to produce steel: the integrated steel route and the recycling route. The integrated steel route is based on the reduction of iron ore and relies on the use of coke, sinter, blast furnaces and Basic Oxygen Furnace (BOF) converters. The current energy consumption for this process route is estimated to lie between 17 and 23 GJ per ton of hot rolled product within the EU (European Commission JRC-IE, 2010b). The value of 17 GJ is considered by the sector as a good benchmarking value of an integrated plant and can be considered as a good benchmarking value even at a world level (European Commission JRC-IE, 2010b). A consumption of 21 GJ per ton of hot rolled product is considered as an average value throughout the EU27 (European Commission JRC-IE, 2010b). It is noted that part of the total energy consumption may be committed to processes downstream of the reduction of the iron ore (the gaseous fuels produced in coke ovens, blast furnace and BOF converters are used in other processes or to produce electricity through captive power plants). The main difficulty for assessing the specific energy consumption is the lack of a clear definition of the plant boundaries. Part of the excess energy consumption of some installations may be allocated to supply external consumers (i.e. central heating). However, there is no data available yet to quantify these amounts (Ecofys, 2009b).

The recycling route is based on the use of scrap as raw material. The main energy requirement is linked to the electricity consumption for smelting the scrap. A good reference value of energy consumption for this route is assumed to be 3.5 GJ/t hot rolled product. The average value within EU27 is around 4.5GJ/t (European Commission JRC-IE, 2010b). Prospective reductions by shifting from BOF to Electric Arc Furnace (EAF) is confined by the scrap availability and its quality.

Around 95%, 4% and 1% of the energy used is in the high, medium and low range of temperature (Ecoheat & Power, 2006). This reflects the relative low use of the steam in this industry.

The situation for radical CO_2 emission reduction differs significantly. Following a thorough assessment performed in the context of the EU FP funded project ULCOS, 3 main family of technologies have been identified that can provide significant reduction gains: Carbon Capture and Storage (CCS), decarbonization of steel production (electricity and hydrogen) and use of biomass. The CCS based route is considered to be the closest to commercialization. Within the CCS family, three main processes have been earmarked for further development: i) Top Gas Recycling Blast Furnace (TGR BF) (blast furnace with CCS), ii) ULCORED (advanced Direct Reduction with CCS), iii) HIsarna. More radical breakthroughs based on another reduction carrier such as electricity or hydrogen are considered still to be needed more up-stream research activities.

3.2.4. Non-metallic mineral products industry

The energy consumption of the non- metallic mineral products in the EU was around 1750 PJ of final energy (Ecofys and JRC-IPTS, 2009). This amount represents around 11% of total industrial energy consumption.

Within this industry, only the cement sector represented 1 150 PJ. In this industry most of the heat demand is over 400°C, in fact, this supposes around 88% of the heat demand, whereas the 12% remaining is distributed equally in the medium and low range of temperatures (Ecoheat & Poweer, 2006). The cement European production, with 254 Mt cement in 2008, represented a 9% of the world cement production (2820 Mt cement). Clinker, the main component of cement, is obtained through the calcination of limestone. The energy requirement is split between process heat and electrical energy, the latter accounts for around 20% of the cement energy needs. The best available value for the production of clinker ranges between 2.9 - 3.3 GJ/t (under optimal conditions (European Commission JRC-IPTS IPPC, 2010a). The average heat consumption of the EU industry was 3.6 GJ/t clinker in 2006. In European Commission JRC-IE (2010c), it was expressed by the sector that 3.2 GJ/t on a annual basis is an engineering limit.

Carbon Capture and Storage (CCS) technology has been earmarked as an important technology for the sector to reduce its CO_2 emissions. The potential for the use of CCS in the cement industry comes from the fact that this industry has its CO_2 emissions concentrated in few locations and at the same time the concentration of CO_2 in their flue gas is twice the concentration found in coal-fired plants (about 14-33% compared to 12-14%) (IPCC, 2005). It is noteworthy to mention that cement emission are 5% of anthropogenic worldwide emissions.

In 2005, the total production of the glass industry within the EU25 was approximately 37.7 millions tonnes, including all the products, represented about 30% of the total world production (European Commission JRC-IPTS IPPC, 2009c)]. Also in 2005, the number of furnaces, 628, showed a wide range of melting techniques that range from small electrical heated furnaces to large cross-fired regenerative furnace (European Commission JRC-IPTS IPPC, 2009c). However, the dominating subsectors are container glass and flat glass, which account for 83% of European production. For the container glass, the average energy consumption was 7.7 GJ/t glass in 2005, whereas for the flat glass this figure amounts to 10.1 GJ/t glass (Ecofys and JRC-IPTS, 2009).

Regarding the ceramics materials, there are a large range of products; however the most representative ones, by the amounts produced, are bricks and roof tiles, wall and floor tiles and refractory products. Their productions are 55 Mt, 25 Mt and 4.5 Mt, respectively, with a specific energy consumption of 2.31 GJ/t for the first one and around 5.6 GJ/t for the other two (Ecofys, 2009e; European Commission JRC-IPTS IPPC, 2009d; Ecofys and JRC-IPTS, 2009). The production processes involved are based on thermal processing in furnaces and the use of electricity on specific electricity uses.

3.2.5. Non-ferrous metal industry

Under the heading of the sector Non-Ferrous Metal Industry there are at least 42 non ferrous metals plus ferro-alloys and carbon and graphite produced in the EU. The sector consumes in Europe around 500 PJ of final energy. Only the aluminum industry accounts for almost 55% of this energy consumption. The structure of the industry varies metal by metal. No company produces all non ferrous metals although there are a few companies producing several metals (European Commission JRC-IPTS IPPC, 2009a).

The manufacture of many metals (copper, aluminum, lead, zinc and others) shares common characteristics: i) recycling constitutes an important route for their production, ii) electricity, that accounts for 7.6% of total electricity consumption in the industry, is used almost entirely in specific electrical processes and represents more that 50% of total energy needs of the sector (European Commission, 2007a), iii) 95 % of the industrial heat demand is of the higher range of temperatures, the remaining 4% and 1% belongs to the medium and lower ranges.

Total EU production of refined aluminum in 2005 was about 8 million tonnes. The integrated route and the recycling route are the main process for the production of aluminium. In 2005, their production was 3.4 and 4.6 millions of tonnes of aluminium respectively (European Commission, 2007b). The primary route first uses the mineral ore (bauxite) to produce alumina (aluminum oxide) and later aluminum by means of a melting-electrolysis process (Hall-Heroult process). The energy consumption of these processes is around 21 and 55 GJ/t aluminum, respectively (European Commission JRC-IPTS IPPC, 2009a). The second route is based of remelting the aluminum scrap. The energy required for refining aluminum scrap is only 5% of the primary production process (European Commission JRC-IPTS IPPC, 2009a). In 2007, for the primary route, there were a total of 25 primary aluminum smelters operating in the EU27. For the secondary route, the number of companies is much bigger; over 130 companies produce more that 1000 tonnes per year of secondary aluminum each (European Commission JRC-IPTS IPPC, 2009a).

In a similar way to the production of the aluminum, around 60% of the raw material used in copper production comes from mineral ore, the rest comes from scrap or secondary materials (European Commission JRC-IPTS IPPC, 2009a). In 2005, EU27 production amounted to about 4.8 Mt of copper equivalent (more than one quarter of world production). The energy consumption required is in the range of 14-20 GJ/t of cooper (European Commission JRC-IPTS IPPC, 2009a). The number used in PRIMES assumes a total consumption of 17GJ/t, (10.2 GJ/t in from fuels consumption and 6.8 GJ/t in the form of electricity) (Ecofys and JRC-IPTS, 2009).

The zinc has the third highest usage of non-ferrous metal, behind aluminium and cooper. There is only one facility in Europe using blast furnaces (Imperial smelting furnace process – IFS -), the rest of facilities using primary production route use the electrolytic process, with a total production capacity of 2.5 Mt per year in 2007 (European Commission JRC-IPTS IPPC, 2009a). The average consumption is around 14 GJ/t of zinc (Ecofys and JRC-IPTS, 2009). Around 30% of the yearly zinc consumption in Europe is recycled zinc.

3.2.6. Food, drink and tobacco industry

In 2005, the global food, drink and tobacco industry reach a value of € 3 312 Billion[1], and Europe accounted for 39% of the global industry group value (Datamonitor, 2006). Within the industry, the sale of food, drinks and tobacco products represented 63.5%, 25% and 11% of the industry value respectively.

According to Ecoheat & Power (2006), 45% of the heat demand is consumed in the medium range of temperatures (100 to 400°C) and 55% in the low range (below 100°C). The broad range of products of this industry, each one with their own manufacturing process renders complicated to describe specific energy consumptions and potential improvements of processes and products (The BREF (European Commission JRC-IPTS

[1] Rate exchanges 1 € equal to 1.25 $

IPPC, 2006) describes 56 different processes and 12 subsectors in the food industry). However, it is noteworthy to observe that the food manufacturing industry utilises chilling and freezing processes as a means of preserving food. In fact, around 40% of all food requires refrigeration and 15% of the electricity consumed worldwide is used for refrigeration (James and James, 2006; Coulomb, 2008). For EU27, the electricity consumption is estimated to lay between 6 % and 9.6% of the total electricity consumption in industry (Ademe, 2006; Almeida et al. 2000). Almost 34% of this energy is consumed in the refrigeration (and air cooling) that take place in the Food, drink and tobacco industry which supposed around 109 PJ in 2005 (Ademe, 2006).

It can be expected that the heat demand of this industry will no vary during the year since, in general, it is not related to outdoor temperature. In this case, the heat demand is basically dependent on production and working hours of employees, i.e on social components. The electricity consumption of the processes related to the refrigeration is also independent of the time.

3.2.7. Rest of industries

Under this heading, the ore extraction (except fuels), the textile, leather and clothing industry, the engineering and other metal industry and other non classified industries are grouped together. According to Ecoheat & Power (2006), in the engineering and other metal industries, around 65% of the heat demand is consumed in the low range of temperatures (below 100°C), 35% in the medium range (100 to 400°C) and 10% in the high range (over 400°C), whereas the heat demand of ore extraction industry is equally spitted between the low and medium range of temperatures. In the rest of the industries, this division is about 16%, 35% and 49% in the high, medium and low range of temperatures, respectively.

In these industries, the electricity consumption in refrigeration processes (including air conditioning) is estimated to be 28.9% (92.5 PJ) (Ademe, 2006) of the total electricity bound to these refrigeration in the European Industry (around 320 PJ (Ademe, 2006; Almeida et al. 2000)).

3.3. Industry – Evolution

3.3.1. Chemical and petrochemical industry

In 2008 energy intensity was 41% lower than in 1995, this means an average annual decline of the energy intensity of 4%. During this period, EU chemical production increased annually 3.1%, whereas the total energy consumption decreased annually at a rate of -1.1% [CEFIC, 2010].

The theoretical potential for improvement for ammonia, methanol and ethylene production using (steam cracking) ranges between 10% and 50% of the current final energy use (Neelis, et al., 2007). These values are in line with the assumptions adopted in Ecofys and JRC-IPTS (2009), which suppose that new production capacity could generate a generic energy efficiency improvement of 30%, with an implemented rate of this new capacity of 2% per year.

On global terms, the improvement margin of energy consumption identified by the IEA (IEA, 2009c) is also of 30%. This improvement is split in a 15% which come from the full implementation of best practice technologies and the additional 15% could be achieved with measures such as i) process intensification, ii) process integration, iii) greater use of combined heat and power (CHP) and iv) life time optimization by recycling and energy recovery from post-consumer plastic waste. In the same line, the deployment of the best available technologies in refrigeration systems could mean savings of around 20-30% of the electricity consumed in these systems (Swain, 2007).

3.3.2. Pulp and paper industry

From 1997 to 2007, the pulp production increased at an average of 1.6% annually, and the number of pulp mills decreased from 241 to 203. At the same time, the average size of pulp mills in Europe increased from 0,176 Mt/y to 0,232 Mt/y (CEPI, 2009).

From 1990 to 2006 the improvement in specific primary energy and electricity consumption has been 16.5% and 16.1%, respectively. It is also noteworthy that total direct CO_2 emissions have kept almost constant despite the 62% increase of the pulp and paper production (CEPI, 2009). The main drivers of this efficiency gains have been i) the fuel prices, ii) the continuous renewal in the industry through replacing old machinery with new generations of larger, faster, and more efficient machines, iii) and the pressure of customer and regulatory demand for more environmentally friendly technologies (European Commission JRC-IE, 2010a). The increase over the years of the share of recycled paper has played against the trend to reduce CO_2 emissions as the processing of recycled paper usually leads to less bio-energy usage.

If breakthrough technologies are not deployed in the sector, the expected improvement in energy consumption and emissions is roughly estimated at about 25% by 2050, achievable through the deployment of BATs from now to 2050 (European Commission JRC-IE, 2010a). This value agrees with the generic 20% of energy efficiency improvement assigned to new production capacity in Ecofys and JRC-IPTS (2009) (implemented at a rate of 2% per year). The prime processes candidates for improvements are the boilers followed by the most energy-intensive part of the paper production (the drying of the paper) (European Commission JRC-IE, 2010a).

3.3.3. Iron and steel industry

In the last 40 years, the industry has decreased its energy consumption by about 50%. One of the main drivers of this steep decrease has been the growth of the “recycling route” at the expense of the integrated route (the percentage has increased from 20% in the 70’s to around 40% nowadays) (European Commission JRC-IE, 2010b). The other source of this steep decrease of energy consumption has been the improvement of the “integrate route” to reduce specific consumption near to thermodynamic limits. This has been achieved thanks to a better understanding and mastering of the blast furnace, preparation of the iron coke and mastering of the gas flow. It is noted that the main driver for these results has been the overriding share of energy costs in the final product economics.

Marginal improvement in terms of energy efficiency is expected in the short and medium term. The technologies used have already undergone significant improvements and developments. The best technologies are already operated close to their thermodynamic limits. The main driver in the short term for energy efficiency improvement will continue to remain the increase of the use of scrap material. Another significant driver is the diffusion of best available technologies. The full alignment of all plants to the best performers could result in an increase of about 10 to 15% of the global efficiency (in next 15 years) (European Commission JRC-IE, 2010b). Additional incremental improvements are also expected due to learning effect and R&D that can result in a 2 to 5% efficiency gains with respect to the current best available plant (European Commission JRC-IE, 2010b). All these progresses will be driven by energy integration and optimization, and by the recovery of waste heat, including low temperature. The demand for new products have or will have little impact on the energy consumption in spite of the fact that their improved characteristics contribute to lower consumptions in users of these new steels.

The growth of the EU27 iron and steel production can be estimated to be 1.18% per year up to 2030 (European Commission, 2007). This would imply a production of around 260Mt of crude steel in 2030. The increase in the production is estimated to be covered mainly by an increase in the recycling route. The production from the integrate route will stay around their current values.

3.3.4. Non-metallic mineral products industry

As a mature industry, no breakthrough technologies in the cement manufacturing are foreseen that can reduce significantly thermal energy consumption. Currently, the main evolution of the sector to improve its energy and environmental performance is towards higher uses of clinker substitutes in the cement, higher use of alternative fuels such as waste and biomass and still the deployment of more energy efficiency measures such as best available technologies.

The market penetration of cements with a decreasing clinker to cement ratio will depend on i) availability of raw materials, ii) properties of those cements, ii) price of clinker substitutes, iii) intended application, iv) national standards and vi) market acceptance (WBCSI, 2009). Whereas higher use of alternative fuels will depend on i) waste legislation, ii) cost of alternative fuels, iii) social acceptance and iv) waste collection.

According to CEMBUREAU figures (Cembureau, 2009), the use of alternative fuels represents, today, 18% of the fuels consumption of the sector in Europe, with large differences between countries (in Netherlands is 100% and Germany, France, Belgium, Austria is above 50%). There is no technical barrier to higher use of alternative fuels. However, their availability can be an issue in the future. Whereas no shortage of wastes is foreseen, biomass resources are expected to be less and less accessible for the sector due to competition with other sectors.

Alternative technologies such as fluidized bed are not considered as an important short term technology. There are some other measures such as the waste heat recovery that are not being implanted in the EU but are implemented in all new plants by law in other countries like China. In 2009 in China there were 120 cement plants equipped with waste heat recovery systems with a total capacity of 730 MW (Rainer, 2009), whereas the number of EU27 plants recovering waste heat are is very limited. In spite of the fact that the thermal energy consumption has decreased by only 8% from 1990 to 2007 this percentage increases up to a 60% if 1960 is taken as the reference year.

With respect to electricity consumption, it is not expected a significant decrease over the years, reaching a plateau at 105 kWh/t by 2030, and 90 kWh/t by 2050. This number depends, of course, on the evolution of the substitute used, for instance, using ore slag will require more power. It is noted that an electricity consumption of 90 kWh/t is already reached by a few plants.

Thanks to the important restructuring carried out by the glass industry in last fifteen years, specific energy consumption of glass melting has dropped by 60% (European Commission, 2007). However, the energy consumption when using best available technologies in the container glass and in the flat gas is 6.0GJ/t glass and 7.4GJ/t glass, respectively. When weighting these values relative to the market share of these products, and compared to current consumption, this could mean 21% of energy savings (Ecofys and JRC-IPTS, 2009). Regarding the ceramics materials, the alignment of the kilns with best practices could decrease the energy consumption in bricks and roof titles from 2.3 GJ/t to 1.7 GJ/t (Ecofys and JRC-IPTS, 2009). Again, the specific energy consumption within reach using latest kilns in the wall and floor tiles and in refractory products are 4 GJ/t and 4.7 GJ/t (Ecofys and JRC-IPTS, 2009).

3.3.5. Non-ferrous metal industry

The main driver for the decrease of the energy consumption of the sector is the increased use of the recycling route. It can be expected that by 2030, the overall production from the recycling route will be around 60%, up from 40% in 2000 (European Commission, 2007).

The most efficient technology for the manufacture of aluminium (Point Fed Prebake – PFPB) is present in 80% of the existing plants. The improvement compared to previous technologies ranges between 1% and 5% of the electricity consumption. Other technologies (Prebake reduce Temperature Electrode - PBRTE - and Prebake Anode – PBANOD) could be ready for a market roll out in 2015 and 2020 or 2025 respectively, and could offer a reduction of energy consumption of 20% and 30% respectively.

The effect that retrofitting of old plants in the cooper industry combined with the improvement of the processes in copper manufacturing could be translated in some savings of 49% and 47% in the electricity and fuels consumption (Ecofys and JRC-IPTS, 2009).

In the manufacture of zinc, in the roasting process, about 2.5 to 3.6 GJ of steam per tonne of zinc are already recovered, offering an addition recovery of 1.4 GJ/t of zinc feasible (Ecofys and JRC-IPTS, 2009).

3.3.6. Food, drink and tobacco industry

The expected overall evolution of the industry has more to do with the evolution of the market than with the development of manufacturing processes. The main drivers of the industry are i) globalization, ii) increased international competition as a result of trade policy changes, iii) economic growth iv) demographic changes v) increased global competition as a result of changes in relative competitiveness of EU agricultures vis a vis other countries, vi) further structural changes in the food retail industry vii) market developments for non-food agricultural products (using agricultural feedstock as biofuels) viii) agricultural and local development and ix) climate change. Also, a continuous reduction of consumption of tobacco can be expected as heath risks become more widely understood.

The full deployment of the best available technologies in the food refrigeration sector could mean an energy saving of about 20-30% (Swain, 2007). This would mean around 22-33 PJ. It is relatively easy to find good examples of poly-generation in this industry (Bassols et al. 2002). However, in 2004, the technical potential of cogeneration and tri-generation is estimated in EU15 around 263 PJ (this potential is around 75% of the electricity consumption in the food, drink and tobacco industry in EU15).

3.3.7. Rest of industries

When dealing with energy consumption in these groups of industries, a common approach is to deal with the horizontal aspects that in some extend affect to all industries.

The potential primary energy savings using best practice commercial technologies estimated by the IEA (IEA, 2007) for Europe are around 1-1.4 EJ/y for motor systems, 0.25 – 0.43 EJ/y for steam systems, a similar amount for process integration 0.27-0.43 EJ/y and 0.3-0.5 EJ/y for CHP. The last figure about the savings offered by CHP can be contrasted with the estimation of the primary energy savings calculated by the European Commission (European Commission, 2010). The economical potential identified amounts to an increment of the total electricity production from CHP of 1.2 EJ. This electricity production from CHP entails 2.8 EJ of primary energy savings. Half of these primary energy savings could take place in the industry. Therefore, the economical potential for CHP identified in European Commission (2010) is at least three times the value estimated by the IEA.

The deployment of the best available technologies described (Swain, 2009), could mean savings around 18 - 28 PJ for these industries.

3.3.8. Summary of the estimated evolution of useful energy

The table 3.3 summarizes the breakdown of energy consumption in EU27 in 2005 and 2009. Data of the first four columns comes from EURSTAT, whereas the useful heat demand has been estimated in this report.

Table 3.3 Break down of energy consumption in European Industry

PJ	Total final energy	Total final energy	Electrical Energy	Electrical Energy	Useful heat demand	Useful Heat demand
	2005	2009	2005	2009	2005	2009
Iron and steel	2 622	1 853	488	393	1 695	1 147
Non ferrous metals	486	373	291	223	149	113
Chemicals	2 480	2 109	736	629	955	877
Non metallic minerals	1 820	1 529	298	267	1 209	937
Paper and pulp	1 476	1 383	510	443	549	512
Food, drink and tobacco	1 261	1 149	401	393	481	418
Textiles	331	216	119	85	120	72
Other industries	3 163	2 669	1 228	1 099	191	358
Total	13 640	11 282	4 072	3 532	5 349	4 434

The estimated useful heat consumption of the industry for 2005 and 2009 is 5 349 and 4 434 PJ, respectively. The figure 3.2 collects the estimated prospective useful heat demand in the industrial sector. This estimation uses the three temperature intervals defined in (Ecoheat & Power, 2006).

Based on PRIMES scenarios projections, the estimated useful heat demand in 2020 and 2030 is 5 045 PJ and 5 020 PJ (European Commission DG-ENER, 2010). These estimations are based on the trends foreseen by PRIMES in the Reference scenario. This scenario includes all the assumptions of the 2009 Baseline plus the policies adopted between April 2009 and December 2009. This includes the ETS and assumes that national targets under the Renewables directive 2009/28/EC and the GHG Effort sharing decision 2009/406/EC are achieved in 2020. The figure 3.2 shows that the higher changes in the useful heat demand will take place in the high range of temperatures for the iron and steel industry and for the non-metallic mineral industry. However, there is a meaningful increase and decrease of the low and medium range of temperatures of the heat demand for the food drink and tobacco industry and the pulp and paper industry, respectively. In addition, the foreseen evolution of the estimated total useful heat demand in each EU27 country is presented in figure 3.3.

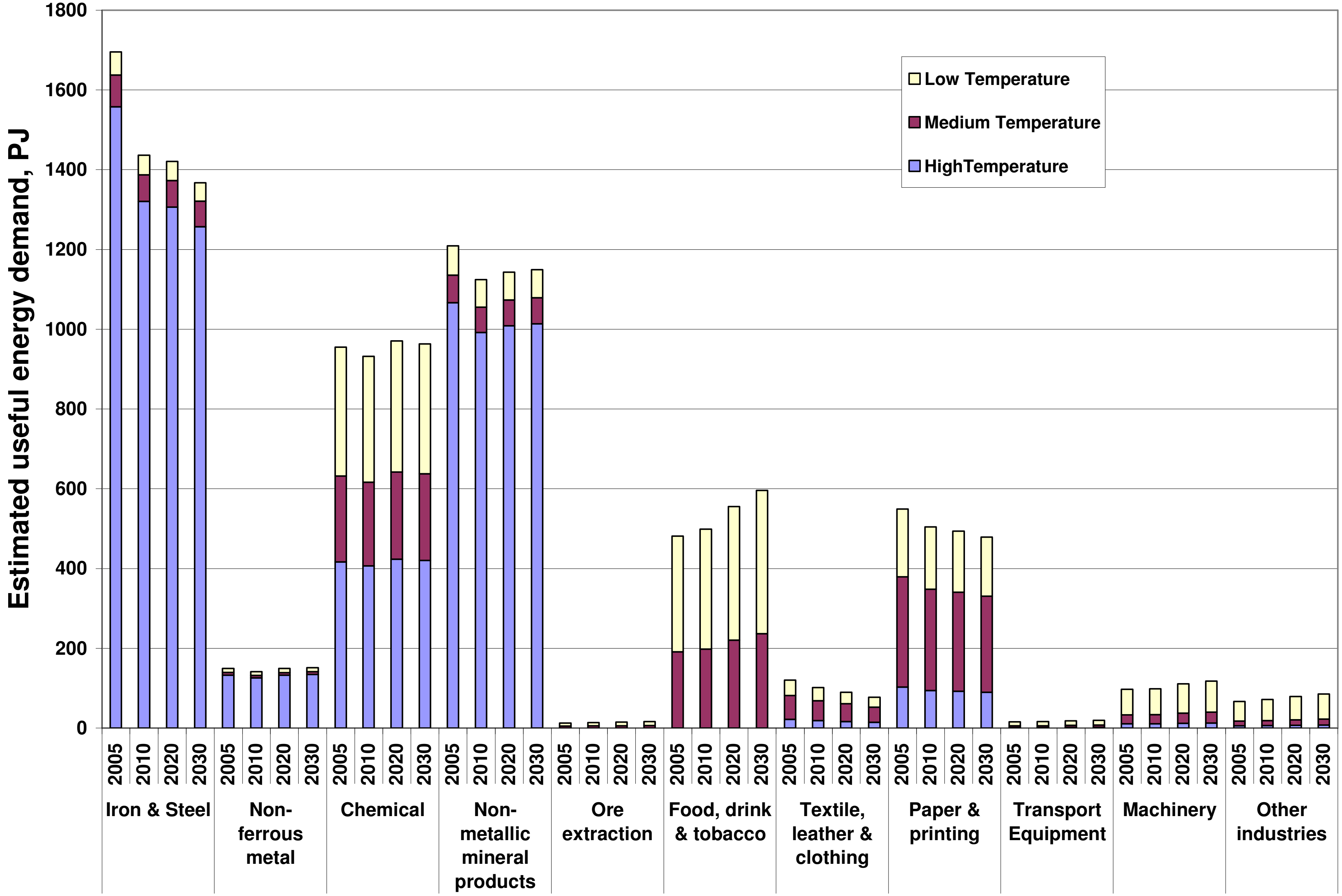

Figure 3.2 Estimated useful heat demand in the European Industry

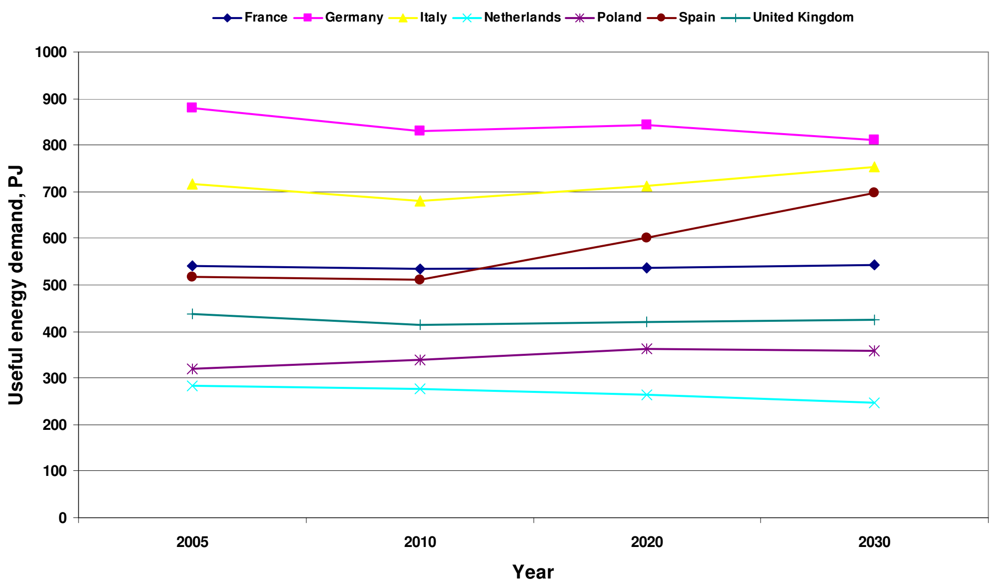

Figure 3.3.a. Estimated useful heat demand in the European Industry. Large-size industrial sector

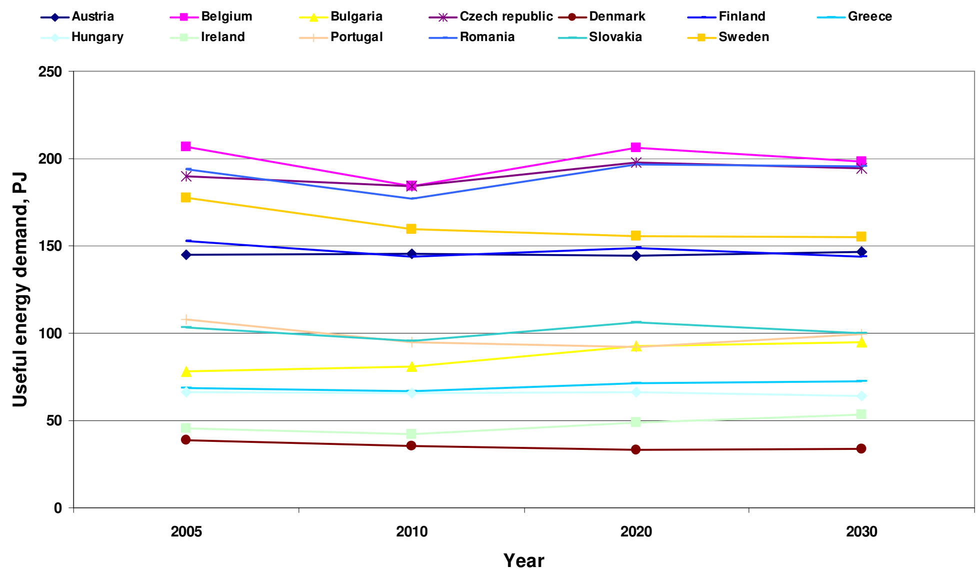

Figure 3.3.b. Estimated useful heat demand in the European Industry. Medium-size industrial sector

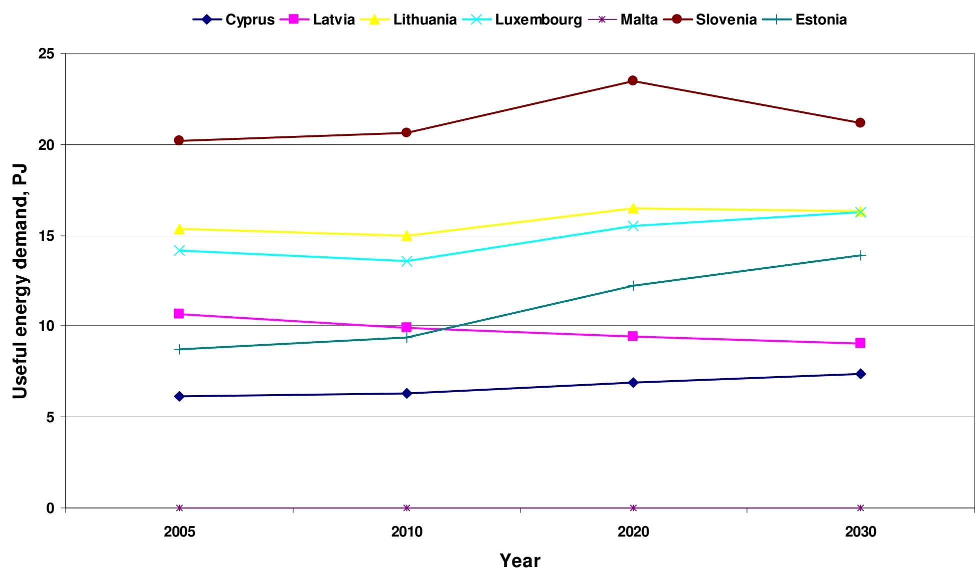

Figure 3.3.c. Estimated useful heat demand in the European Industry. Small-size industrial sector

4. Mapping – Residential Sector

4.1. Residential - General description of the sector

The residential sector is an energy-consuming sector that consists of living quarters for private households and excludes institutional living quarters. The residential sector can be split by subsector and end use.

Breakdown of the residential sector into subsectors

There are different subsector breakdowns in the residential sector depending on the source but the most common split is into single-family house, multi-family houses and high-rise buildings, for example Boverket (2005) and Nemry (2008). International energy statistics mainly contain information on final energy consumption in the residential sector at an aggregated level and do not split into the different subsectors, which is the case for both IEA and Eurostat.

The *Ecoheatcool project* (Ecoheatcool WP1, 2005) uses the residential building information from the annual publications of “Bulletin of Housing Statistics for Europe and North America” (UNECE, 2005) and “Housing Statistics in the European Union” (Boverket, 2005) and it does not include the energy consumption per subsector.

For non-energy purposes households are divided according to the inhabitants. This information can be used to estimate the evolution of the demand. Eurostat give statistics according to the number of people per household: single person, single parent with dependent children, two adults, two adults with dependent children, three or more adults, three or more adults with dependent children and unknown; the data is available for 1999, 1994, 1999 and 2005 for all the EU countries, but it contents energy consumption in the residential sector only at an aggregated level (Eurostat, 2011).

Age and geography of the building are example of other parameters that can affect the evolution of the demand. In Nemry (2008) 72 selected building models (53 existing buildings and 19 new building types) represent about 80% of the residential building stock in the EU-25. They are described in terms of their building stock representativity, geographical distribution, size, age, design, residual lifespan, and thermal insulation as well as material composition of the different building elements (roofs, external and interior walls, basement/foundation, floors, windows/doors). In Nemry (2008) the building are divided into three building types: single-family houses, multi-family houses, and high-rise buildings as these three building types represent 53%, 37% and 10% respectively of the existing EU-25 building stock. Single-family houses include individual houses that are inhabited by one or two families and terraced houses, Multi-family houses contain more than two dwellings in the house and less than 9 storeys and High-rise buildings are defined as buildings that are higher than 8 storeys (Nemry et al, 2008. page 18, 32, 33)

Breakdown of the residential sector by end use

Very few sources contain statistics split into end use. The main reason is that easily measured purchased energy commodities are used for more than one end use type (ie. space heating and warm water). In spite of this, some attempt to estimate the split into end use has been performed. (Morna and Van Vuren, 2008) estimates that energy in average EU-27 households are mainly used for space heating (70%); other important uses are appliances/lighting (13%) and hot water (14%), while cooking is relatively insignificant (4%). In the period 1997-2006 the fraction for appliances/lighting (including air-conditioning) increases with 1-2%-points at EU-27 level, the fraction for space heating is decreasing and the fractions for hot water and cooking are stable. However, for new member states and Spain fractions sometimes change substantially (Ademe, 2009. page 23). Therefore trends in energy demand for heating and cooling could be very important for the development of the energy system (Morna and Van Vuren, 2008).

Heating, cooling and appliances/lighting energy demand

Space heating

The energy use for heating ranges around 60-80% of the total. In Mediterranean countries the fractions are lower as they have mild winters. Between 1997 and 2006 the fraction for space heating energy demand decreases partly due to a strong growth of the electric for non-heating purposes (computers etc). The highest share for space heating is found in countries with moderate winters such as Ireland, Belgium, Denmark and Germany rather than in countries with colder winters like Finland and Sweden due to the use of less efficient technologies for insulation and heating systems (Ademe, 2009, page28).

The size, building shell and outdoor temperature determines the average energy demand for space heating (Ademe, 2009; Morna and Van Vuren, 2008).

Space cooling

The residential energy demand is related directly to the temperature increase. For cooling it is higher in warm regions with relatively high income. The highest demand on space cooling is found in countries with warm summers (Ademe, 2009; Morna and Van Vuren, 2008).

Warm water energy

Warm water for domestic purposes (for shower or cooking) is the second largest heat demand in the residential sector after space heating, and it is higher in the residential sector than in services sector. Warm water includes both water used in bathrooms and kitchen.

There is shortage of information about warm water consumption, but the project (Ecoheatcool WP1, 2005) estimates an average hot water consumption of 50 liters/day per capita assuming a temperature difference of 50 ºC between the hot and cold water side.

Cooking energy demand

The cooking energy consumption has a 4% share in the total residential energy demand and it has a constant evolution. Cooking energy demand is usually supplied by electricity or gas. In winter it contributes positively to the heat supply while in summer it has a negative effect on the cooling supply (Morna and Van Vuren, 2008).

Appliances/lightning energy demand

The level of household appliances ownership reflects modern lifestyles. Appliances and lighting are the largest electricity consumers per household for most EU countries; big and small appliances and lightning run on electricity so an increase in the ownership of refrigerators, washing machines, dish washers, television and lightning equipment increase the electricity consumption (Ademe, 2009).

During the period 1997-2006 electricity consumption for appliances & lighting increased in almost all countries. Countries with high electricity use like Sweden, Germany, UK and Denmark, increased in a moderate rate, Ireland increased its electricity consumption due to the high economic growth and southern countries due to the implementation of air conditioning, but some countries still had a relative low consumption like Bulgaria and Slovakia (Ademe, 2009).

The small appliances like light bulbs record a bigger breakdown in electric consumption in Europe than the large appliances like fridges, washing machines or dryers. From 1990 to 2007 the market share of small appliances increased from 23% to 36% while the big appliances market share declined from 48% to 46%. Lightning market share remains quite stable during these years with a 20% (Ademe, 2009).

The introduction of Directive on mandatory labels for appliances has stimulated the market for more efficient appliances and thus decreased electricity use for refrigerators, washing machines, cloth dryers, etc. Minimum efficiency standards for lighting of the EU force manufacturers to only offer compact fluorescent lamps (CFLs) instead of incandescent bulbs (Ademe, 2009).

Due to the relevance of the energy demand for space heating and hot water, Figure 4.1 compares the 'Final energy consumption', 'Final energy consumption for heating and warm water' and 'Useful energy for space heating and warm water' for the residential sector for each Member State. The estimated useful energy demand for the residential sector in EU-27 Members States is presented in Table 4.1 and Figure 4.2 presents the employed methodology. This table was constructed using the 2009 final energy data published by Eurostat, together with the breakdown for the residential sector according to three categories: single-family house, multi-family house and high rise, the breakdown of the end use of the energy: space heating, hot water, space cooling and the energy efficiency of each equipment based on the type of fuel (Ecoheatcool WP1, 2005; Nemry et al., 2008; Eurostat, 2010; Astrom et al. 2010).

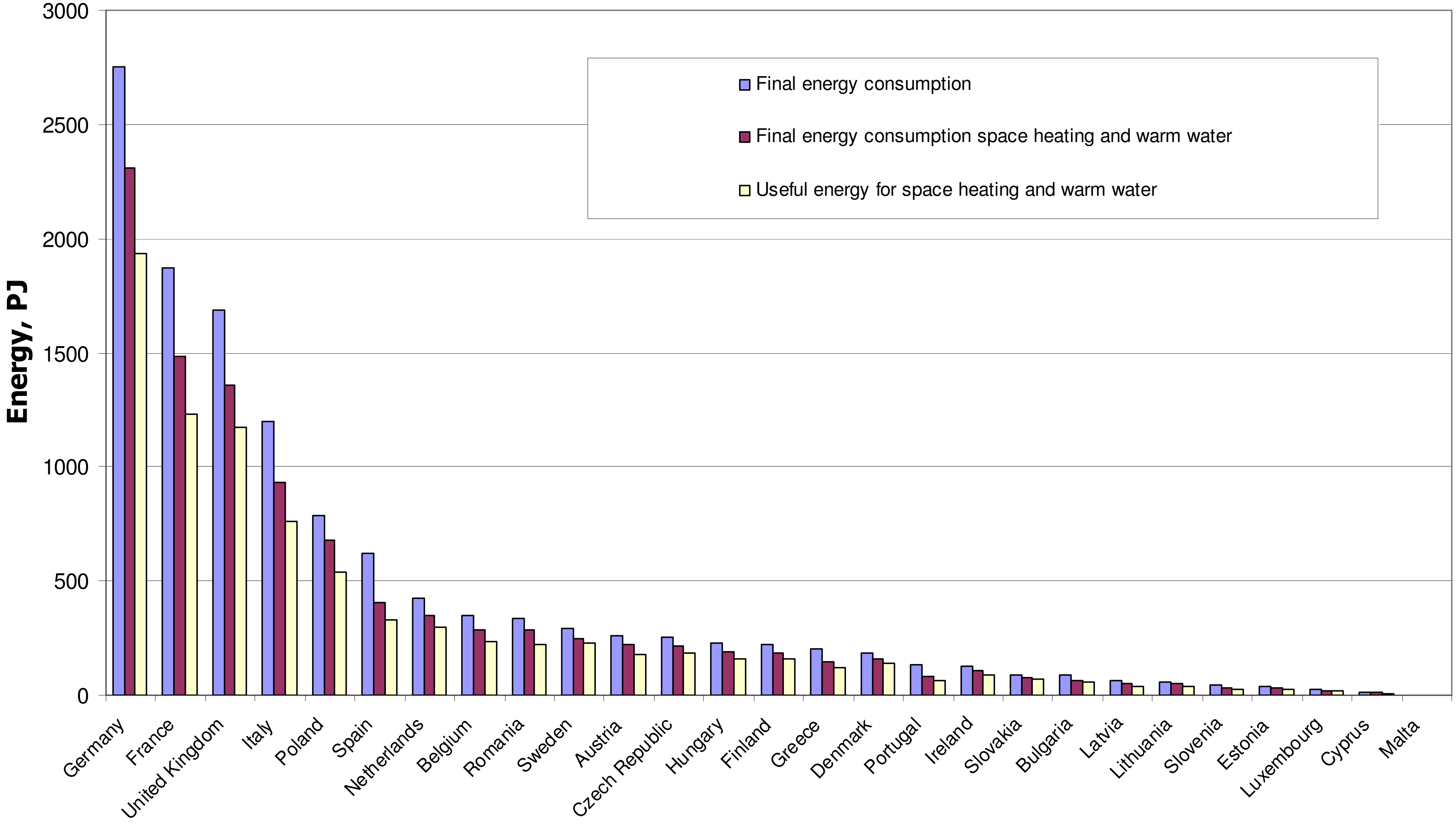

Figure 4.1. Estimations of the 'Final energy consumption', 'Final energy consumption for heating and warm water' and 'Useful energy for space heating and warm water' for the residential sector for each Member State

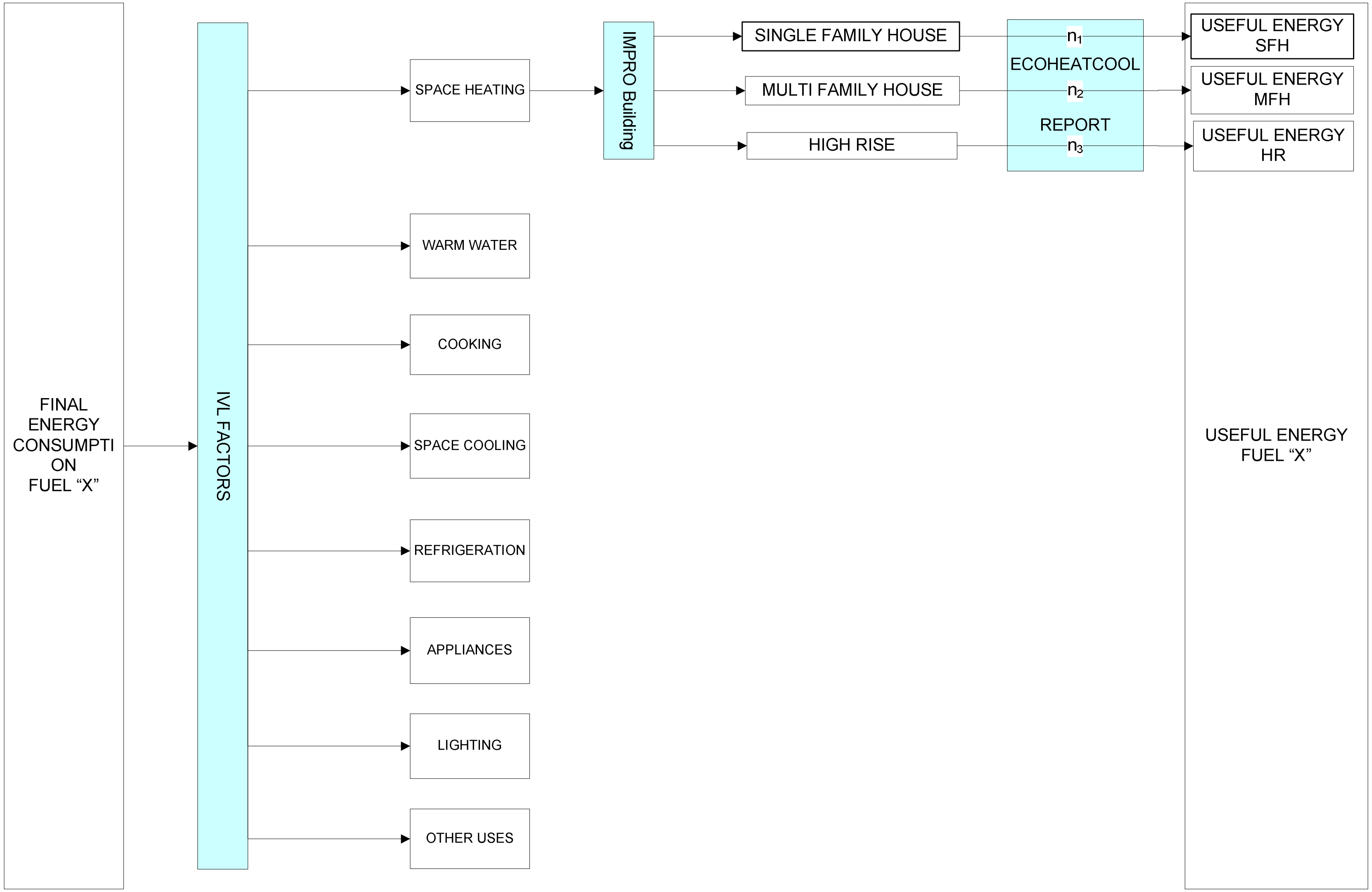

Figure 4.2. Methodology for the calculation of the estimated useful energy demand in the residential sector of EU-27

Table 4.1. Breakdown of estimated useful energy demand for the residential sector in EU-27 in PJ for 2009

PJ	Single-family houses			Multi-family houses			High-rise			Total		
	Space Heating	Water Heating	Space Cooling	Space Heating	Water Heating	Space Cooling	Space Heating	Water Heating	Space Cooling	Space Heating	Water Heating	Space Cooling
Austria	87.1	14.3	0.0	64.4	10.6	0.0	1.3	0.2	0.0	152.8	25.1	0.1
Belgium	159.0	28.0	1.7	40.4	7.1	0.4	1.8	0.3	0.0	201.2	35.4	2.2
Bulgaria	35.9	6.5	3.4	8.6	1.6	0.8	1.9	0.3	0.2	46.5	8.4	4.5
Cyprus	5.6	0.5	0.4	2.6	0.2	0.2	0.0	0.0	0.0	8.1	0.7	0.6
Czech Republic	90.3	13.9	1.8	51.8	7.9	1.0	15.0	2.3	0.3	157.1	24.1	3.2
Denmark	72.8	14.6	0.0	39.6	7.9	0.0	4.3	0.9	0.0	116.6	23.4	0.0
Estonian	10.0	2.6	0.0	8.0	2.1	0.0	3.9	1.0	0.0	21.9	5.7	0.0
Finland	75.7	15.9	1.5	57.8	12.2	1.1	0.0	0.0	0.0	133.5	28.1	2.7
France	758.0	87.8	25.6	282.1	32.7	9.5	62.3	7.2	2.1	1102.5	127.8	37.2
Germany	949.6	166.4	0.4	655.8	114.9	0.3	38.3	6.7	0.0	1643.7	288.1	0.7
Greece	83.1	6.5	1.5	25.8	2.0	0.5	0.0	0.0	0.0	108.9	8.6	2.0
Hungary	105.4	18.8	0.0	25.3	4.5	0.0	5.6	1.0	0.0	136.2	24.3	0.0
Ireland	59.3	24.6	0.0	2.1	0.9	0.0	0.5	0.2	0.0	61.8	25.7	0.0
Italy	385.8	59.3	8.8	229.8	35.4	5.3	45.9	7.1	1.0	661.5	101.8	15.1
Latvia	13.2	1.0	0.0	22.6	1.7	0.0	0.0	0.0	0.0	35.8	2.7	0.0
Lithuania	15.4	3.4	0.0	18.0	4.0	0.0	0.0	0.0	0.0	33.4	7.4	0.0
Luxemburg	10.1	1.5	0.0	3.8	0.6	0.0	0.8	0.1	0.0	14.6	2.2	0.0
Malta	1.0	0.1	0.0	0.7	0.1	0.0	0.0	0.0	0.0	1.7	0.2	0.1
Netherlands	150.2	46.9	1.8	69.4	21.6	0.8	7.0	2.2	0.1	226.6	70.7	2.7
Poland	225.9	51.4	1.5	176.8	40.2	1.2	37.8	8.6	0.3	440.5	100.3	3.0
Portugal	15.6	33.5	1.2	3.0	6.5	0.2	1.5	3.3	0.1	20.1	43.3	1.5
Romania	143.6	28.3	0.9	34.5	6.8	0.2	7.6	1.5	0.0	185.7	36.6	1.2
Slovakia	38.9	6.4	0.3	11.0	1.8	0.1	8.4	1.4	0.1	58.2	9.5	0.5
Slovenia	12.5	3.7	0.0	3.2	0.9	0.0	2.9	0.9	0.0	18.6	5.4	0.0
Spain	107.3	73.4	4.1	62.7	42.9	2.4	26.2	17.9	1.0	196.3	134.2	7.5
Sweden	97.1	37.0	1.7	66.6	25.4	1.2	0.0	0.0	0.0	163.6	62.4	3.0
United Kingdom	678.5	293.0	0.0	127.2	54.9	0.0	12.7	5.5	0.0	818.4	353.4	0.0
EU-27	**4386.8**	**1039.4**	**56.7**	**2093.5**	**447.5**	**25.5**	**285.6**	**68.5**	**5.2**	**6765.9**	**1555.4**	**87.4**

Table 4.2: Estimated useful Energy provided by District Heating and District Cooling in the European Residential Sector in TJ for 2009.

TJ	Single-family houses			Multi-family houses			High-rise			Total		
	DH - Space Heating	DH - Water Heating	DC - Space Cooling	DH - Space Heating	DH - Water Heating	DC - Space Cooling	DH - Space Heating	DH - Water Heating	DC - Space Cooling	DH - Space Heating	DH - Water Heating	DC - Space Cooling
Austria	10864	1329	50	8039	984	37	162	20	1	19065	2333	87
Belgium	347	50	0	88	13	0	4	1	0	439	63	0
Bulgaria	10036	1169	0	2408	280	0	532	62	0	12976	1512	0
Cyprus	0	0	0	0	0	0	0	0	0	0	0	0
Czech Republic	23030	2951	0	13198	1691	0	3826	490	0	40055	5132	0
Denmark	34927	5289	10	18982	2874	7	2060	312	0	55970	8475	17
Estonian	5041	1074	0	4050	863	0	1954	416	0	11045	2353	0
Finland	31160	5142	161	23788	3925	119	0	0	2	54948	9067	282
France	0	0	6	0	0	2	0	0	0	0	0	8
Germany	86486	12233	381	59721	8447	282	3485	493	6	149693	21173	669
Greece	1422	78	0	442	24	0	0	0	0	1863	103	0
Hungary	14817	2096	16	3555	503	12	786	111	0	19158	2710	28
Ireland	0	0	0	0	0	0	0	0	0	0	0	0
Italy	1073	125	208	639	74	154	128	15	3	1839	214	365
Latvia	4832	329	0	8291	564	0	0	0	0	13124	893	0
Lithuania	8051	1594	0	9447	1871	0	0	0	0	17498	3465	0
Luxemburg	552	70	0	208	26	0	41	5	0	802	102	0
Malta	0	0	0	0	0	0	0	0	0	0	0	0
Netherlands	5533	1461	40	2554	674	29	256	68	1	8344	2203	70
Poland	70794	15475	0	55393	12109	0	11855	2591	0	138042	30175	0
Portugal	26	81	10	5	16	7	3	8	0	34	105	17
Romania	30932	5742	0	7420	1378	0	1641	305	0	39993	7424	0
Slovakia	10747	1410	0	3032	398	0	2309	303	0	16089	2111	0
Slovenia	1688	270	0	436	70	0	395	63	0	2519	402	0
Spain	0	0	2	0	0	1	0	0	0	0	0	3
Sweden	54437	10266	1684	37336	7041	1246	0	0	25	91773	17308	2956
United Kingdom	1621	451	0	304	84	0	30	8	0	1955	544	0
EU-27	**408418**	**68685**	**2567**	**259336**	**43910**	**1897**	**29467**	**5271**	**39**	**697222**	**117866**	**4504**

District heating is more suitable to provide energy for specific low temperature uses such as space heating and water heating. By comparing the findings presented in Tables 4.1 and 4.2, district heating covers around 9% of the useful energy demand for space heating and hot water in the EU in the residential sector. The differences among countries are very wide. It is possible to find cases where the contributions of the district heating to the demand does not take place as in Spain or cases where the weight of the district heating is relatively high as Denmark with a around 46%. The contribution of the district cooling is around the 4% all the total cooling demand in the EU27. For Spain, Italy and France, which cooling demand suppose around the 68% of the total, the contribution of the district cooling only suppose the 0.03%, 2.4% and 0.02% respectively.

4.2. Residential - Characteristics

Heating

Heating load duration curve

The heating load duration curve shows three main contributions for a district heating system, namely: distribution losses, domestic hot water and building heating load as it is shown in Figure 4.3 (NRCAN, 2011). Distribution losses correspond to loss of heat from the buried pipes to their environment and stay fairly constant over the year, the domestic hot water load is also fairly constant over the year, with a reduction during the night and during summer months, the building heating load is the dominating load for most of the year and follows the seasonal variations of the climate (NRCAN, 2011).

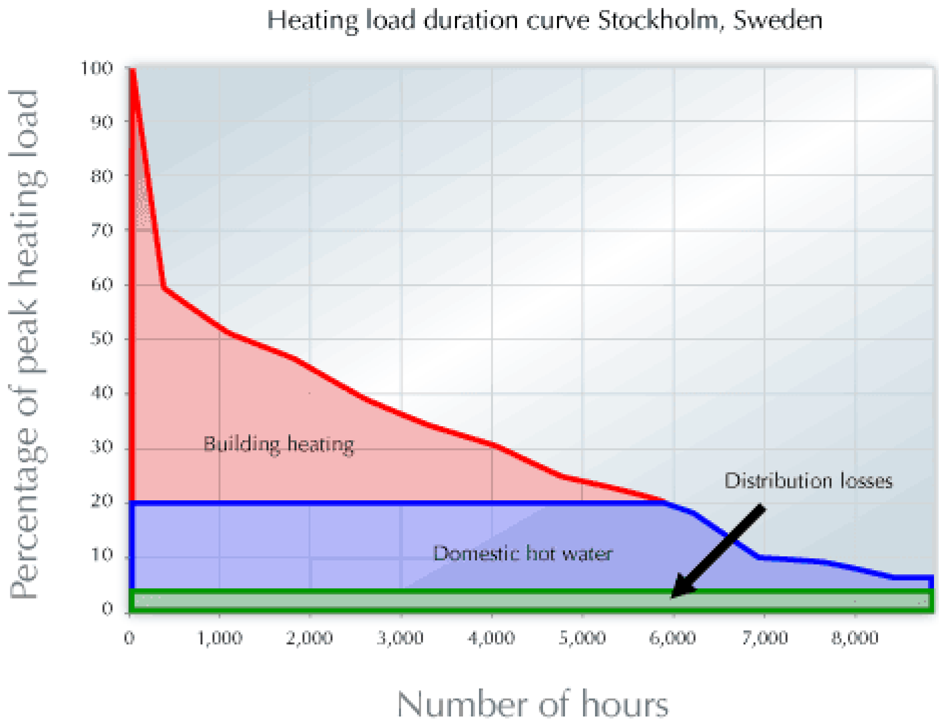

Fig. 4.3 Heating load duration curve Stockholm, Sweden (NRCAN, 2011).

The heating needs of a building can be assumed to be proportional to the number of heating degree-days in a first approximation but this relation is roughly proportional. The hot water load varies over the course of the year, both because input water is colder during the winter months and because hot water consumption may be reduced during the summer months. The Domestic Heat Water (DHW) load can be as much as 30 to 50% more in the winter compared to the summer and varies a lot during days and nights, weekends and holidays. Equivalent number of heating degree-days corresponding to the domestic hot water demand can be used to establish a heating load duration curve where hot water demand is considered in a coarse way (NRCAN, 2011).

Peak heat load

The peak load for space heating usually occurs under very cold conditions, although it depends not only on outside weather conditions (temperature, wind, etc) but also on other parameters such as the thermal mass of the building and the infiltration rate as can be shown in Figure 4.4. The peak heating load occurs during a short and very cold period, but for the rest of the year the heating load is only a fraction of the peak heating load depending upon climatic conditions. The heating design temperature is used to determine the *peak heating load* and to size the heating system (NRCAN, 2011).

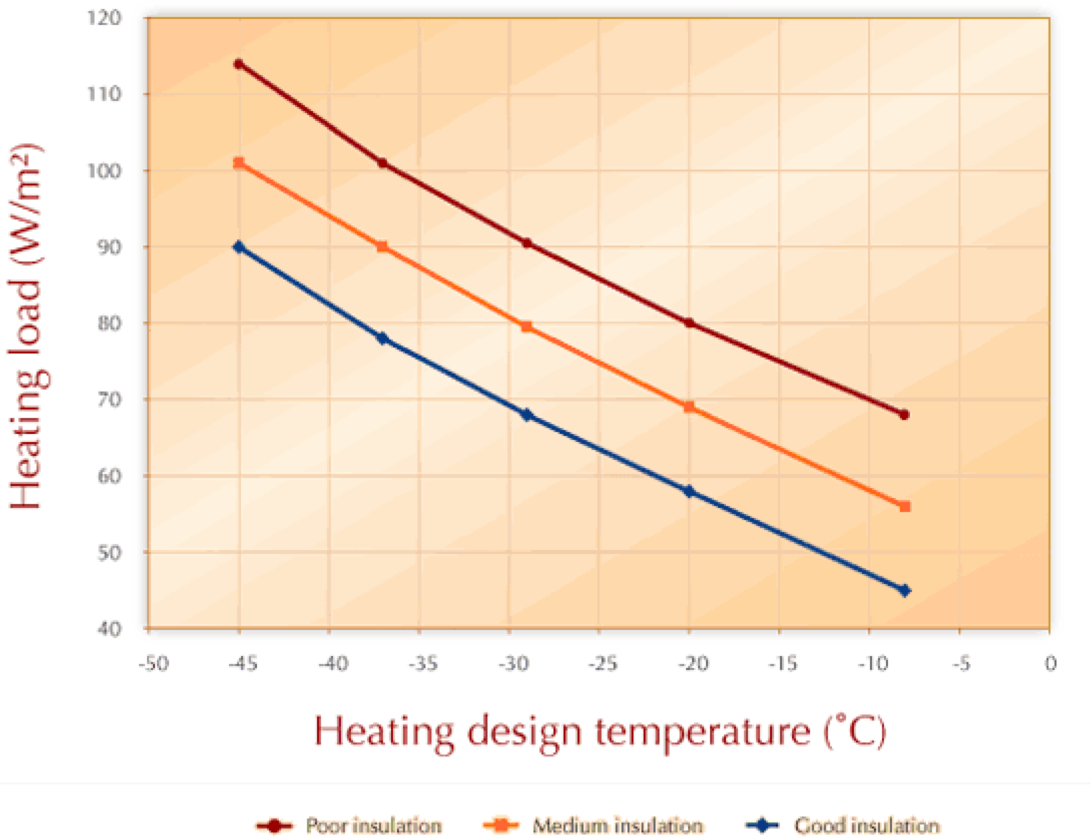

Fig. 4.4. Variation of the heating load for the different heating design temperatures and insulations (NRCAN, 2011).

Cooling

Space cooling load and energy calculation can be treated as heating load and energy use with a few variations. As in the heating case, it is very influenced by the climatic conditions and uses the concepts of *design cooling temperature* and *cooling degree-days* (NRCAN, 2011).

Load duration curve OR Monthly/Seasonal data

Cooling load duration curve can be calculated by the same procedure as the heating load duration curve. The peak cooling load occurs during a short and very hot period, but for the rest of the year the cooling load is only a fraction of the peak cooling load depending upon climatic conditions. Base load cooling represents non-weather dependent process cooling needs such as internal heating loads or constant cooling loads and is defined by the equivalent cooling degree-days. To build up the load duration curve the base cooling use replaces the domestic hot water demand and cooling degree-days replace the heating degree-days (NRCAN, 2011).

Peak cooling load

As for heating, the peak cooling load per unit area depends on the design cooling temperature for the specific location and on the building insulation efficiency. The Figure 4.5 below can be used as a guide to estimate peak cooling load as a function of location and building insulation (NRCAN, 2011).

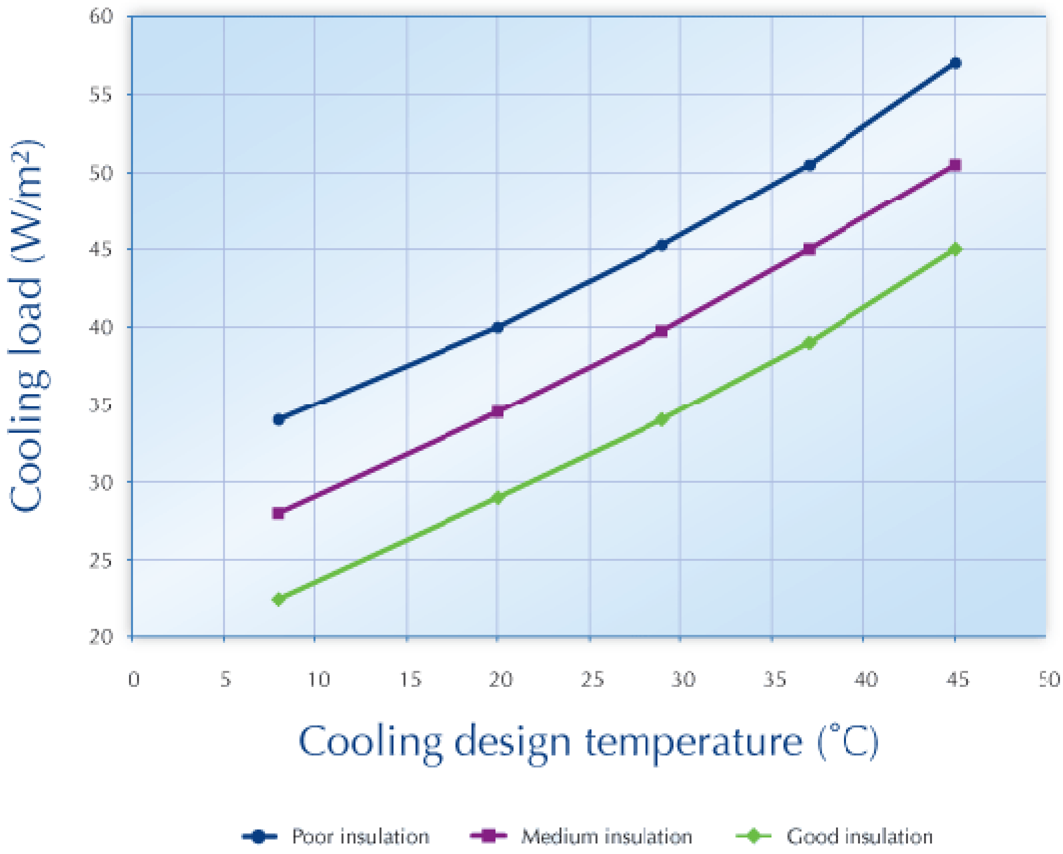

Fig. 4.5. Variation of the cooling load for the different cooling design temperatures and insulations (NRCAN, 2011).

A peak load period is added to represent the time of year where the cooling system works at full capacity. All the calculations follow the same procedure as the heating load but replacing cooling loads by heating loads (NRCAN, 2011).

4.3. Residential - Evolution

4.3.1. Space heating

High indoor temperatures and cold local climates increase the heat demand for space heating. Heat demand compensates heat transmission losses through walls and roofs, so the outdoor temperature is the most important variable that explains daily and annual heat demand variations. Solar gains through windows and wind chill influence in the heat balance of a building. Solar gain reduces the heat demand while wind chill increases it, but its magnitude is quite small when considering large aggregated volumes of buildings (Ecoheatcool WP1, 2005).

Useful energy drivers: The European Union (EU) building sector is a heterogenic sector where the characteristics of each building depend on the Climatic conditions size, age, design, thermal insulation and installed equipments (Nemry et al., 2008. page. 18).

Base on a study "Climate Change and the Long Term Evolution of the US Building Sector", prepared for the U.S. Department for Energy, the formulation for heating and cooling trends is complex because it must consider the implications of internal gains, building shells, and climate (Rong et al., 2007).

Temperature zone

Average Outdoor temperatures in Europe vary from –2 to 19ºC, giving very different conditions for space heating. Therefore Europe is divided into three temperature zones in this report. (Ecoheatcool, 2005, WP1). A good approach for the residential heat demand can be distributed according to the Heating Degree Days (HDD) into three main zones in Europe that roughly represent three climate zones according to Heating Degree Days (HDD). This indicator is the best way to represent similar zones for heating in the EU-25. The long term average of the heating degree days (HDD), based on the period 1980-2004, is used.

- Zone 1: South Europe 564 to 2500 HDD
- Zone 2: Middle Europe 2501 to 4000 HDD
- Zone 3: North Europe 4000 to 5823 HDD

The highest improvement potentials from the European perspective are for zone 2 partly due to the larger building stock in use and colder climate conditions. The major improvement potentials lie with single-, two-family and terraced houses, followed by multi-family buildings. Weather conditions influence space heating and cooling demands, which results in higher energy demand for buildings in northern European regions. However, buildings in these zones tend to have the best energy performances (Nemry et al., page. 22)

Heating intensity

The heating intensity includes aspects such as improved building isolation and increased internal gains from appliances. In the household sector, significant improvements in space heating intensity resulted in strong energy savings in the early 1990s. Energy demands are a function of the building shell thermal characteristics. This means that technological improvements might take place not only in the technologies that provide the services, but also in the building shells, reducing the demand for heating and cooling (IEA b, 2008).

The implementation of insulation material on the roof and/or on the external wall, or the reduction of ventilation losses on the existing building today reduces its energy demand for space heating. The reduction of the ventilation losses and new windows can increase insulation against noise. Roof insulation, façade insulation and reduced ventilation yield a significant environmental improvement potential, which, for a majority of buildings represent at least a 20% improvement (Nemry et al., 2008, page.109).

Insulation improves the thermal comfort. As the human body senses temperature by around two thirds through radiation exchange between the surrounding radiating surfaces, warmer surfaces (in winter time) caused by insulation of the wall and the roof create greater thermal comfort. Additional roof insulation and new ceilings to reduce ventilation represent the biggest potentials in CO2 emission reduction. The economical profitability is not systematic as the fuel costs savings not always compensate the high initial investments. Zone 2 shows higher improvement potentials due to the cold weather and larger building stock (Nemry et al., 2008. page.92, 22).

Heat losses from ventilation and infiltration are more significantly due to external walls for high rise buildings and roofs for single-family and multi-family houses, so isolation measures should be improved in these places. Windows are of lower importance (Nemry et al., 2008. page.20).

Size

According to the study “Climate Change and the Long Term Evolution of the US Building Sector”, the floor space per capita has been increasing (Rong et al., 2007)

Households have different sizes in each country therefore it is more useful to compare the energy use per m2 instead of use per dwelling (Ademe, 2009). Multi-family dwellings use less energy than single family homes, due primarily to the smaller wall and roof space, which means less volume to heat and cool. Based on US data, an average apartment uses about half the energy of a single family home although the smaller size means higher energy per square meter. All the main energy uses are significantly higher in single family homes.

The number of single and multifamily houses in Europe is roughly equal. Population increase encourages more multi-family buildings because of its more efficient use of land, urbanization growth and land shortages, but the ageing of population results into lower occupation densities and more single person households. On the other hand the economic development may have the opposite effect as people tend to move into single –family homes when they become wealthier (WBCSD, 2009. page 24).

Age

The aggregate household energy demand for heating is mainly determined by the existing stock of buildings. In Austria especially buildings from the period 1945 to 1980 that represent a large share of the total stock are characterized by a high specific energy demand. Thus, the construction year is also of importance for energy demand for housing. Due to the increasing diffusion of energy efficient housing technologies (e.g. passive houses) the influence of space in energy demand related difference plays a lesser role in new construction buildings. (Kletzan-Slamanig et al., 2009). New buildings show better environmental performance than existing ones due to better energy performances, especially building insulation (Nemry et al., 2008. page.20).

Demography

The *size of the population* plays an important role in consumption: population age groups, the location, number of people per household and living space available per person are determined by the size of population. The total population growth in Europe is very slow.

In January 2010 the population in the EU-27 reached 501 million (Eurostat, 2010). Immigration can drive the population growth to a faster rate and influence the consumption patterns (EEA, 2010).

The *ageing* of the European population can influence the consumption. Their reduced incomes result in a slower economic growth if the share of the EU-27 population aged 65 years and over is likely to rises significantly. In 2008 the share of population over 65 is 17.1 % (Eurostat, 2010).

The trend towards *smaller and more households* is expected to increase the household energy consumption per person. The people of the Baltic States, Bulgaria, Hungary, Poland, and Turkey are the least satisfied with the size of their living space and thus, depending on socioeconomic conditions, increases over the next years can be expected (EEA, 2010).

Infrastructures

Urban, suburban, semi-rural and rural areas have different conditions for space heating for the residential and service sectors. Energy supply as natural gas and district heating requires a certain heat demand density in order to justify investment in distribution pipes, so it is only possible in urban areas. This heat demand density is lower for natural gas than for district heating but the competences of each demand depend on national and local conditions. In rural areas, only individual heating solutions are possible (Ecoheatcool WP1, 2005).

Most part of the population (74%) lives in urban areas but ranges between 50 % and 97 % in the 32 European countries. The definition of an "urban" area is different among countries and is higher in the EU15 and EFTA3 countries compared to the NMS10 and ACC4 countries. As a clear majority of the heat demands for space heating and hot water supply are concentrated to urban areas common heat supply solutions can be considered (Ecoheatcool WP1, 2005,)

Low density areas can only be supplied with district heating when local competitiveness for district heating is high, as in Iceland (85 % of all single-family houses are connected to district heating), Denmark (47 %), Finland (12%), and Sweden (11 %).

The 73% of EU citizens live in urban areas and is expected to grow. Therefore most European consumption takes place in cities and towns. Rural residents in Europe often adopt urban lifestyles but urban living is more efficient energy consumption in urban areas accounts for 69 % of Europe's energy use (IEA, 2008a). The Finnish and the Swiss studies show that households that consume less energy tend to live in urban areas, have smaller living space per person and live in apartments rather than single family houses (EEA, 2010, page.17).

Consumption behavior.

User behavior concerns for example the desired room temperature in day and night time, the use of energy efficient light bulbs, etc (Kletzan-Slamanig et al., 2009). Changing behavior has increased the energy use, especially for space heating which is the main use in colder climates. In the past ten years indoor temperatures increased 3ºC in the UK, requiring a 20% increase in heating energy consumption (WBCSD, 2009).

Different types of consumers respond to different policy instruments. Values, attitudes, cultural backgrounds, different incomes, ages, genders, education and access to infrastructures make it possible to create consumers segmentation. Positive greens are willing and able to do more, concerned consumers and sideline supporters can be engaged through communications, community actions and opinion leaders, cautious participants and waste watchers are concerned about other people actions and can be influenced by sustainable lifestyle norms and finally stalled starters and honestly disengaged can be influenced through pricing policies and regulations (EEA, 2010, page.22).

Useful energy explaining factors

Economic

The *income* at the individual household level is the most influencing factor in consumption patterns. Baseline projections assume that GDP will grow between 2010 and 2020 but recent developments show that steady growth cannot be taken for granted. Before the financial crisis started in 2008 the price of oil, steel and other non renewable resources increased due to the increase of the demand. The price decreased during the economic downtown, but could reappear when a stable economic growth returns (EEA, 2010. pages 18-22).

The *consumption* patterns are drivers of the potential for growth; therefore the economy is now bounded by the ecological system and dependent on the services that the ecosystem delivers to the economy. As income is directly influenced by material consumption, the household consumption plays an important role. In the longer term, the ageing population could lead to a fall in the household savings rate, as older people tend to save less than people of working age. The degree of change in the consumers demand is influenced by the price elasticity, the consumers demand more of any product if the price goes down and less if the price increases (EEA, 2010. pages 18-22).

The *costs of the environmental degradation* are attributed to the society as these prices are not included in the prices of goods and services. Economic instruments, such as taxes, can be applied to overcome such market failures to ensure that prices include economic, social and environmental costs. Environmental and social standards could also internalize these costs by increasing the product prices and services with higher environmental impacts and lead to a reduction of its consumption (EEA, 2010. pages 18-22).

Policies

Subsidies have a big influence in consumption and environmental impact; they can be implemented for economic, environmental and/or social policy reasons. Economical reasons can encourage higher levels of consumption causing negative environmental consequences. But subsidies for environmental reasons like energy efficiency measures or renewable energy installations promote the implementation of eco-innovative technologies. Policies have the potential to promote competitiveness, attractiveness and availability to the market and are driving economic development towards a green economy: Taxes and charges, removal of environmentally- harmful subsidies and economic incentive at the sales point for environmentally friendly appliances (EEA, 2010. pages 18-22).

Evolution of the useful energy demand

New buildings, as currently erected, generally show better environmental performance than existing ones. This is due to the better energy performances achieved as long as the best available practices are applied, especially in terms of building insulation (Nemry et al., 2008. page.20)

The past trend in the EU was the reduction of number of people per household and is likely to continue until 2020. The demographic trend is towards smaller and therefore more households, these trends are expected to result in higher demand for space and increase the consumption of household goods. This phenomenon is observed in almost all industrialized and European countries. (EEA, 2010, p.19). A slight growth of population would increase the total area of dwelling space and therefore heating and cooling demand would increase unless isolation measures improve. The housing market has been very affected by the economic downturn and if incomes grow more slowly or even decline, the ability to buy houses and apartments will be affected. (EEA, 2010. pages 18-22).

Consumption in Europe is shaped by the size of its population, the share of the population in various age groups, location, the number of people per household and living space available per person (EEA, 2010, pages 18-22).

Table 4.3 Influence of different drivers on future trends and heat and cooling (H&C) demand.

Drivers	Temperature zone		Dwelling size	Insulation	New dwellings
	HDD	CDD			
Future trend	↓	↑	↑	↑	↑
Effect on H&C demand	↓	↑	↑	↓	↓

Final energy drivers

The final energy consumption is mostly driven by the efficiency of the equipment or the heating system

Technological development

The development of new technologies is nowadays related to eco-efficiency. Improvement of the efficiency might reduce the electricity consumption, but the rebound effect explains that technology and efficiency gains often lead to the increased consumption. This behavioural change occurs when the consumer replace the older equipment by a more efficient one. A direct rebound effect is that the reduced cost of consumption due to the lower demand of the higher efficient equipment leads to a rise of the consumption of the product. An indirect rebound effect explains that the reduction of a household consumption cost can raise the consumption of other goods and services. Other economic effects of the efficiency improvement are the change of the relative prices of the consumed product. Taxes and policies are able to mitigate the rebound effects (EEA, 2010, pages 18-22).

Efficiency gains

Space heating energy use is growing slowly and remains the most important energy use. According to IEA, two main parameters play an important role in the demand of space heating, the efficiency gains and the reduction in the energy intensity for space heating.

Higher efficiency heating technologies mean lower conversion losses. This has led to a reduction of 0.2 % per year. Additionally, a reduction of 1.2 % is defined by the energy intensity. On the other hand, larger dwellings sizes and occupancy rates push for higher energy demand. Nevertheless, the overall trend is described by an average annual reduction of energy demand between 1990 and 2005 of -0.2 % due to the efficiency gains and energy intensity.

Figure 4.6 shows the average annual percent change due to different causes (IEA, 2008b).

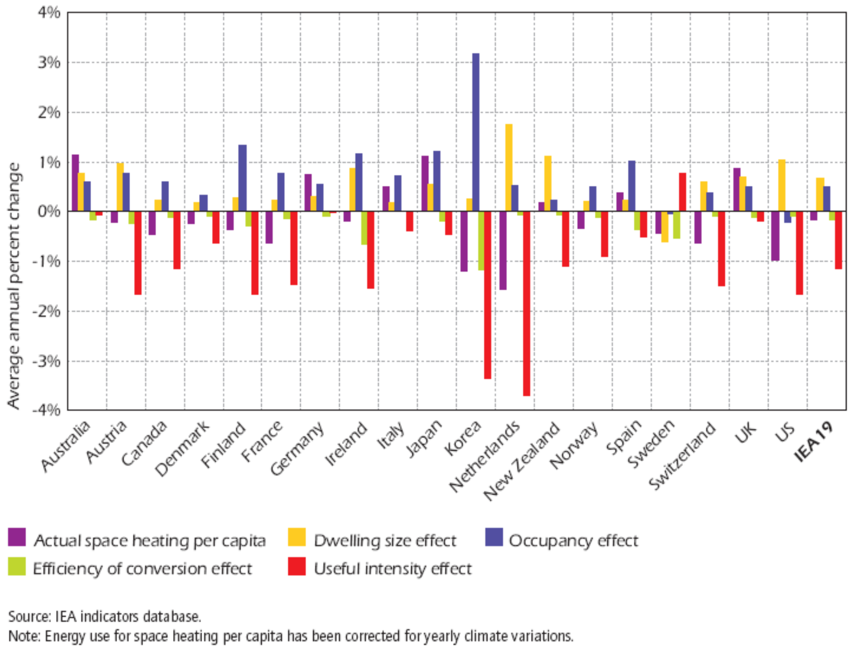

Fig.4.6. Decomposition of changes in space heating per capita, 1990 -2005 (IEA, 2008b)

Fuel substitution

In countries with high income growth the lack of effort for fuel savings keeps increasing. The largest consumer of *Solid fuels* is Poland, islands consume a big amount of liquid *fuel* probably due to the lack of gas grid (Cyprus, Greece and Ireland) possibly due to lack of gas grid and the high liquid fuel consumption for Luxemburg and Belgium has no obvious reason. The consumption of *Natural gas* increased in the new Member States but the highest consumption is in countries with own reserves of gas (Netherlands and UK). Baltic countries consume a big amount of *Heat from DH*, while in Romania it is decreasing due to the high prices. Countries with lower GDP (Portugal or Latvia) and/or much wood resources (Austria and Finland) consume big amounts of *Wood/biomass*: but in the rest of Europe it is decreasing. Small islands like Cyprus and Malta and countries with nuclear electricity production but limited gas grids like Sweden and Finland have high *electricity consumption*. Northern countries like Norway, Sweden and Finland consume high electricity for space heating and southern countries probably for air conditioning (Ademe, 2009).

Figure 4.7 shows the household energy use by end use, according to this figure the electricity consumption in households is increasing due to the penetration of larger and new appliances, computers, air conditioning (IEA b, 2008). Figure 4.8 shows the share of space heating by fuel, the employment of electricity and natural for heating is substantial due to these fuel have replaced to large degree oil in heating.

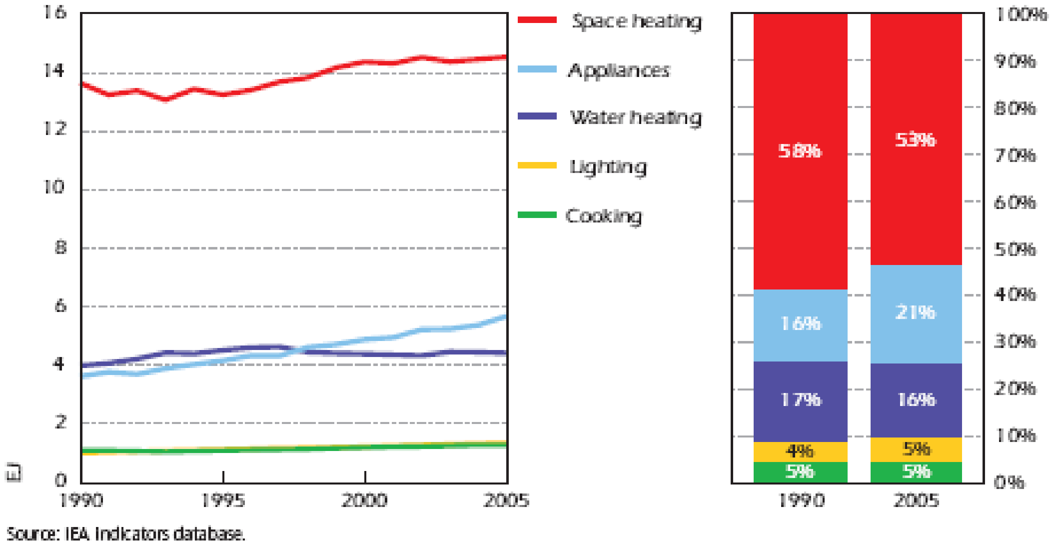

Fig. 4.7. Household energy use by end use. (IEA b, 2008)

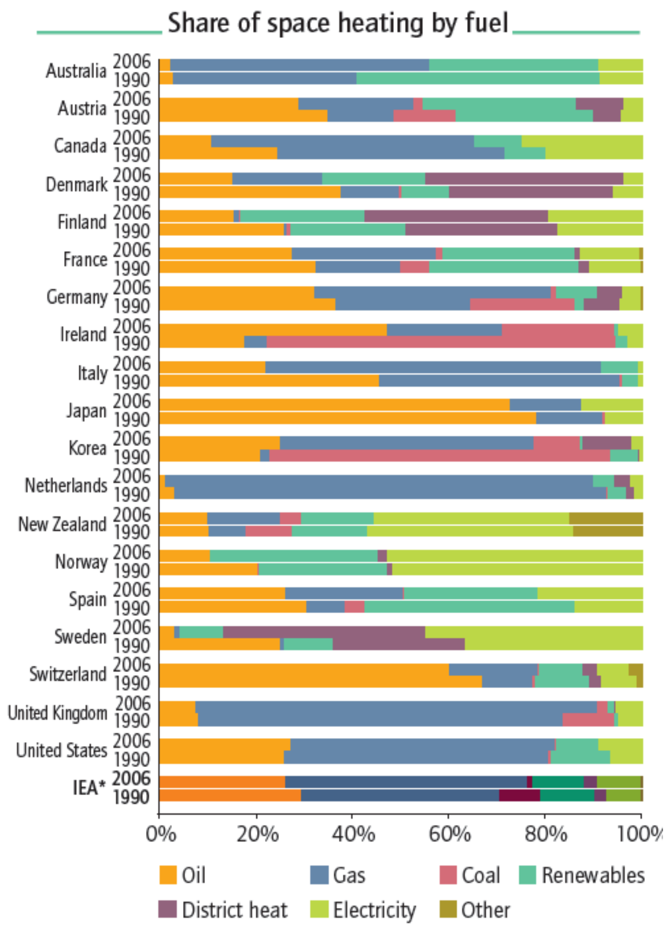

Figure. 4.8. Share of space heating by fuel. (IEA, 2009)

Final energy explaining factors

Policies

The main EU strategy to reduce household and services sector energy consumption for heating has been oriented towards promoting more energy-efficient building designs. Improvements to new building standards have helped to reduce energy requirements for heating in newly built properties. In fact, since 1990, new properties require 60% on average less energy for heating than those properties that were built before (Odyssee-Mure project, 2009).

In order to improve on energy efficiency, the most important EU policies for the households sector are the European Parliament Building Directive (EPBD), The Energy Services Directive (ESD) and The Eco-design Directive (European Parliament, 2006b; European Parliament, 2009; European Parliament, 2010).

EPBD 2010 stipulates measures to increase the number of buildings which not only fulfill current minimum energy performance requirements, but are also more energy efficient, thereby reducing both energy consumption and carbon dioxide emissions. For this purpose MSs should draw up national plans for increasing the number of nearly zero-energy buildings and regularly report such plans to the Commission (European Parliament, 2010). Also, prospective buyers and tenants of a building should, in the energy performance certificate, be given correct information about the energy performance of the building and practical advice on improving such performance. Information campaigns may serve to further encourage owners and tenants to improve the energy performance of their building. Comparison between buildings is possible by means of an energy performance index (EPI) in terms of energy consumption, carbon dioxide emissions or energy cost per unit of conditioned area. Labels for residential buildings with improved energy performance have emerged throughout Europe to promote energy efficiency and market demands, control grants and ensure the quality of high energy efficient projects. Additionally, the ESD expects that countries will achieve a 9% energy saving in the period 2008–2016. Although the ESD does not introduce specific policy measures, it will probably have significant influence in the implementation of new policy measures by MSs. Finally, the Eco-design Directive takes a step further by introducing minimum efficiency standards for the optimal use of energy. This Directive does not introduce directly binding requirements for specific products, but establishes a framework of conditions and criteria that need to be respected when introducing implementation measures.

These Directives have been implemented into the national legislation of each country. Nevertheless, the EPBD only asks MSs to set requirement levels, without specifying what the minimum requirement levels are. As such, each country has set its own national levels which, according to Panek(2010), have led to significant disparity in the implementation of EPBD standards. From 2012, MSs are required to transpose EPBD 2010 into their national law.

Besides policy measures aimed at improving the energy efficiency of buildings, EU authorities have also promoted the use of Renewable Energy Sources for heating and cooling uses (RES H&C) in order to reduce primary energy dependency and the stress of demand on primary energy resources. From an energy policy perspective, the substitution of natural gas by RES for these uses would contribute to a reduction in primary energy dependency and reduce stress on natural gas energy resources, thereby leading to a higher level of GHG abatement as required by EU energy strategy. However, although there is a wide range of technologies based on RES H&C, they cover only 2–3% of global energy demand for H&C (excluding traditional biomass; Seyboth et al., 2008). In fact, if biomass is included and we refer only to EU-27 MSs, the RES H&C consumption represented 11.9% of final heat use in 2008 (Eurostat, 2010).

As IEA (2009b) recently pointed out, part of the renewable energies growth is due to strong policy support. Over the last few years, several EU-27 MSs have developed a range of incentives to promote the use of RES H&C to increase national targets for renewable heat generation as a percentage of total heating and cooling energy demand. On February 14, 2006, the European Parliament adopted a report suggesting that the RES H&C share of total energy consumption should be increased up to 20% by 2020 (European Parliament, 2006)

Heating system solutions

Individual heating systems are used mostly in rural areas and in some cases in urban areas. Boilers that run on fuel oil, LPG, coal and firewood (usually only in rural areas where the source in closer) and in some cases electric appliances such as boilers, panel radiators, hot water storage tanks or heat pumps. Various individual heating solutions compete with each other in rural areas. Firewood is a common rural primary energy supply in all countries.

Central heating is usually a water based system, but in Norway and Sweden some central heating buildings use electricity. In some New Member States NMS10 and Accession 4 countries: Bulgaria, Romania, Croatia and Turkey (ACC4) , the fraction of central heating is equal to the fraction of dwellings connected to district heating systems. District heating systems require buildings with central heating systems to be applied.

District heating networks are more common in high density urban areas with multi-family, public, and commercial buildings. In suburban areas it is competitive only if the heat source is cheap and the alternative heat supply expensive. It competes with natural gas and other fossil-based energy supply in high heat density urban areas. For some countries like Austria and Belgium the energy demand due to space heating is even higher although the annual average temperature in Sweden is about 4ºC lower. This happens due to the existence of district heating in countries like Sweden or Denmark. The high efficiency of district heating makes it possible for countries with lower temperatures to consume less energy than countries with milder winters.

Central heating and district heating are more efficient solutions to supply the heat demand than the individual equipments. Central heating has more penetration in Northern Europe in opposition to the Mediterranean area where it is common not to have any heating system in some areas. The ACC4 countries have a very low fraction of central heating (Ecoheatcool, 2005, WP1).

The energy efficiency of heating systems and the energy performance building standards posed by several energy efficiency policies, can play an important role in improving the overall efficiency of meeting space heating needs (IEA b, 2008).

4.3.2. Space cooling

Heating and cooling markets can be analyzed simultaneously as heating and cooling demand have some common energy demand influencing factors. Climatic conditions, technical specifications, building standards, demography and the social behavior are common energy drivers, but the cooling market requires more complex estimations and predictions (Ecoheatcool WP2, 2005).

During the last decade the cooling market grew rapidly and it is predicted to continue growing at a fast rate around 3.14% p.a. (European Commission DG-ENER, 2010). This growth can be explained by different *explanation factors: S*tandards of living make this equipment more affordable while the comfort standard requirements increase and the residential floor area increase.

Useful cooling demand drivers are common to the ones of the useful heating demand: temperature, humidity, solar radiation and wind speed of the geographical positions and rural-urban areas, human thermal comfort and structural design as layout, insulation, window orientation, shading and ventilation, seasonal and day/night cooling supply, heat generation by latent and sensitive thermal loads like people , lightning, computers and other machines increase the cooling demand while decreases the heating demand, social behavior as working hours, vacations and required indoor temperature for the residential use. Ecoheatcool project creates a new European Cooling Index (ECI) and European Heating Index (EHI) in order to explain the geographical distribution of the average specific space cooling and heating demands in Europe by considering the cooling and heating degree days and the thermal insulation (Ecoheatcool WP2, 2005).

Specific cooling load demand in the residential sector is lower than in the service sector due to less internal heat generation and lower duration time. Tenants are not at home during the period in which the cooling demand is higher, so dimensioning load is about 20 to 30% lower and duration time up to 50% lower than for the service sector (Ecoheatcool WP2, 2005).

The *size* of the household is also an influencing driver on the cooling demand, as explained in the heating demand. The use of residential floor space increases with the national GDP, it is not directly proportional but it is proportional to the square root of the GDP (Ecoheatcool WP2, 2005).

The *electric power demand* is a key indicator of the increasing cooling demand due to that most of the air-conditioning and chillers are driven by electricity. Although there are other options, as the absorption machines, their use of in the residential sector is negligible. In the analysis of the historical trend of the electrical power demand in the EU-15 it has been found that there is an overall increase of the electrical power demand over time. During the years 1985-2003 it is found a 50% increase in the electric demand that might be caused by the increasing cooling demand and the ownership of cooling appliances (Ecoheatcool WP2, 2005). Currently around 1% of the total electricity consumed by the residential sector of the EU27 is consumed for cooling space (Astrom, 2010).

In Eurostat the final electric consumption in the residential sector includes electricity consumption due to cooling in the total electricity consumption, but the Odyssee database contains the electricity consumption per dwelling by thermal uses and electrical appliances for each country in year 2008 divided by the following end uses: Electrical appliances and lightning, water heating, air conditioning, space heating and cooking. The specific heating and cooling demand per square meter can be found in the Ecoheatcool study for 2005, but the estimation of the saturation rate is considered the same for all the European countries.

The *saturation rate* of the cooling market varies a lot within countries. Different assumptions have been considered but there is not a reliable value.

The *final cooling demand* is mostly driven by the efficiency of the equipment that can run on electricity or renewable sources. Conventional and low efficient cooling equipment have a negative impact on the electric consumption by creating peak demands and its consequent electricity price increase and pressing power production and transmission capacity. This high electric consumption will hinder the European commitments regarding CO2 savings and drive the need for capacity investments. As cooling needs is mostly met by electricity usage, the new directives on energy efficiency buildings should offer different cooling efficiency solutions; District Cooling has a major role to play in order to meet the challenges for Europe and provide a robust and environmentally sound framework for future energy solutions. Bench mark information for heating is more documented but for cooling it is aggregated in the total electricity consumption of a building. Sources for cooling electricity use vary from chillers, auxiliary equipment and ventilation systems which makes it more difficult to allocate the right amount to the right source (Ecoheatcool WP2, 2005).

4.3.3. Domestic Hot water.

Demand of hot water is the second largest heat demand in the residential sector after space heating. It is not available the magnitude of average hot water consumption in European countries and most hot water information is related to the design conditions for instantaneous and storage water heaters. (Ecoheatcool WP1, 2005). According to the study of the Agricultural University of Cracow (Trojanowska and Szul, 2006) the daily demand for preparing hot water is dependant on the number of residents, the average daily consumption of hot water per one resident, the water specific heat, the calculated temperature of hot water and the cold water mean temperature.

Domestic hot water heating often requires higher temperature water than space heating does. This is due to the fact that heat is being transferred to a 50°C or greater sink rather than the 21°C air in a space heat application. There are several ways to configure a domestic water heating system. The two most common are storage recharge and instantaneous (Rafferty, 2001). The total EU electricity consumption by Domestic Electric Storage Water Heaters in 1997 was 87 TWh and accounted the 15% of household electricity consumption. It is the second most important group of domestic appliances. About 30% of the EU's 142 million households used electric water heating systems and the percentage of households in each country using electricity to heat water is more than 40% in Luxemburg, Austria, France and Germany, between 30% and 40% in Italy, Belgium and Finland, just over 20% in the UK, between 10 and 20% in Portugal, Sweden, the Netherlands, Ireland, Denmark and Spain, and less than 10% in Greece (Ecoheatcool WP1, 2005).

The total hot water consumption per household is driven by the size of the household, number of inhabitants and standard of living, type and number of end use appliances and climatic conditions. The needs of the user can be expressed by certain quantities, MWI, of warm water at temperature TWI appropriate to use (e.g. 35-40°C for showering or bathing; up to 60°C for cleaning). The energy requirements for the hot water depend on the cold water temperature and in the case of mixing, the cold water temperature determines the amount of warm water that can be gained from a given amount of hot water (Ecoheatcool WP1, 2005).

The consumption of hot water can increase or decrease due to the different standards of living and the number of people per household. According to Energie Verwertungs Agentur (EVA, (1998) the average European consumes 36 litres of hot water each day (standardised to a temperature of 60°C, starting from cold water at 10°C) in 1998 but the latest available survey information to be used about the energy consumption in households in the EU15 and some CEE countries is Eurostat, (1999) and estimates an average hot water consumption of 50 liter/day for the 24 participating countries, but this value varies among the different countries (Ecoheatcool WP1, 2005).

The final energy demand depends on the efficiency and may vary depending on the efficiency of the equipment, fuel use and pipe insulation. Domestic electric water heating systems include *pure electric systems* like storage heaters, instantaneous heaters and heat pumps, *mixed energy systems* using electricity or parallel or alternating other energy sources like combination boilers ('combis') also supplying the space-heating system and solar collectors and *'multi point' versus 'single-point'*, that means hot water production for the household from one central heating source or point of use water heating with several independent systems (EVA, 2008. page.7).

4.4. Different technologies to supply useful demand of energy

Heating and cooling technology options include potential for energy savings and CO2 emission reductions:

To assess the best heating and cooling technology, it has to be consider different criteria: The annual thermal load profile for water and/or space heating, the annual cooling profile, The relative timing of thermal and electric loads, Space constraints, Emission regulations, Fuel availability, Utility prices for electricity and other fuel prices, First cost and the cost of financing, Efficiency of the equipment, Complexity of installation and operation, Reputation of the manufacturer, Architect/engineer/builder/installers knowledge of available technologies and models, etc (IEA 2011).

Active solar thermal (AST) can provide space and water heating, as well as cooling needs and can be used integrated in buildings or in district systems. Solar thermal cooling and air conditioning is an emerging application based on the sorption technology and is potentially attractive due to the usual simultaneity of solar radiation and cooling load. The two main technologies for solar thermal air conditioning in buildings are Thermally driven chillers, used to produce chilled water in closed cycles and provide space cooling and/or heating, and the Open cycles that are used for direct treatment of air in a ventilation system can be named as Desiccant Evaporative Cooling systems (DEC). However, costs of AST will have to come down and more variety of technologies has to be developed (IEA, 2011, page 12).

Combined heat and power (CHP) is a traditional and mature technology for space heating and cooling, air conditioning and water heating. A wide range of technologies is available depending on their performance and cost. *Reciprocating engines* is the most common technology and uses compression-ignited internal combustion engines (ICE) with efficiencies around 75-85% a more efficient technology is the *Stirling engines* it is a developing technology that uses external combustion engines with efficiencies higher than ICE (up to 95%) and can use a wide range of energy sources. *Gas turbines* use high-temperature and high-pressure hot gases to produce electricity and heat. They can produce heat and/or steam as well as electricity, and come in the megawatt size-range. Typical electrical efficiency is 20% to 45%, while overall efficiencies are 75% to 85%. *Microturbines* are smaller versions (typically 25 kWe to 250 kWe) of gas turbines and use recuperators to preheat combustion air, but are not very deployed. *Fuel cells* create electricity by means of a electrochemical process. It releases energy stored in hydrogen and is found in four different types of fuel cells: molten carbonate fuel cells (MCFC), solid oxide fuel cells (SOFC), phosphoric acid fuel cells (PAFC) and polymer electrolyte fuel cells (PEMFC). Fuel cells offer the advantage of nearly 1-to-1 electricity to heat ratios, making them well suited for modern low-energy buildings (IEA, 2011, page 14).

Heat pumps can be used for cooling and space and water heating and are highly efficient technologies. They use renewable energy from their surroundings (ambient air, water or ground) and by means of electricity or gas it increases or lowers the temperature. There are hybrid and reversible systems able to provide heat and cool alternatively or simultaneously. It is the most used technology for space cooling but the share of the heating market is not large. The most common heat pumps used in the residential sector are: *Air-to-air* "room" and "split" air conditioners is the most common technology for room air conditioning, *Air-source* heat pumps (ASHPs) provide sanitary hot water and space heating and avoid the need for expensive ground or water loops. *Water-to-water and water-to-air* heat pumps have higher efficiencies than air-air but need a close water source. *Ground-source* heat pumps (GSHPs) use a buried in the ground heat exchanger and have higher efficiencies in cold weather than ASHPs. The heat pump system consists of a heat source, the heat pump unit; and a distribution system to heat/cool the building. Its performance has been improved by implementing new technologies and components (compressor, pumps, fans, heat exchangers, expansion valves and with the use of inverters). The efficiency of a heat pump depends on the difference between indoor and outdoor temperature, technical specifications, partial or full load operation, increase or decrease temperature, indoor and distribution system temperature (IEA 2011, page.17).

Thermal storage can maximize energy savings potentials of all the described technologies. Applied to renewable energies thermal storage improves the efficiency and reduces the CO2 emissions and can have daily or seasonal applications depending on the size. This technology is also used for load shifting providing a larger share of electricity production from renewable energy sources. The store period ranges from hours to days by means of chilled water or ice storage and is used for large buildings with a high cooling demand and its priority is to reduce the electricity peak demand due to air conditioning in summer. The most common use of this technology is the insulated tank for working fluid or hot water. It is cheap and can storage the heat for days or a week, but it is not a long term solution due to the big space it occupies. Thermal energy can be stored by sensible storage, underground thermal energy storage, latent thermal storages (provide higher capacities for the same volume at a constant discharging temperature like ice storage for cooling) and as reversible chemical reactions (it achieves higher per unit capacities and different discharging temperatures depending on the properties of the reaction). Applications: residential heating, cooling and dehumidification, district heating and cooling, temperature comfort of electronic equipment, conservation of temperature of sensitive goods, cold bags, warm keeping or medical wraps. At a larger scale Underground Thermal Energy Storage (UTES) large scale water tanks use the land as insulation and Aquifer Thermal Energy Storage (ATES) use natural water saturated and permeable underground layer as a storage medium (IEA 2011, page.20).

Heating and cooling systems should be identified by mandatory efficiency labeling by 2020. To standardize this information and compare the different options there are two types of labels: *Comparison labels* provide the efficiency of the product using an index system and/or energy cost/consumption information and *Endorsement labels* to identify the appliance class according to their performance. This information will help decision makers to identify the most efficient and lowest carbon emission technology before the purchase (IEA, 2011, page.39).

4.5. Barriers for improvements

Potential of energy reduction exist due to the barriers that impede energy efficiency measure implementation: *Structural barriers* appear when the market or the environment make less possible to achieve energy efficiency. *Behavioral barriers* explain why an end user who is structurally able to capture a financial benefit still decides not to do it; It usually occurs due to the uncertainty over the durability of the measures and their savings, the lack of awareness, old habits or hurdle rates. *Non-availability* barriers prevent end user who would choose energy efficiency technologies due to non availability of the product or improper use of the technology. The mix of these barriers complicates the energy efficiency growth.

Energy efficiency potential of different houses can be assessed; *for existing non-low-income homes*, the low consumer awareness and demand can be solved by home energy assessments, financing solutions and mandatory upgrades; *for the existing low income homes* the same solutions as for non-low-income homes can be applied; *for new homes* the lack of incentive of builders to construct high efficiency homes can be solved by incentives, building codes and a greater penetration of building labeling; *Electrical devices and small appliances* consumption voluntary labeling and mandatory standards can increase the efficiency or consumption patterns; *Lighting and major appliances* is an important share of the electricity consumption, the efficiency of the technology and consumption behavior play an important role and can be achieved through labeling, economic incentives and mandatory standards.

There are some solutions that can help to overcome these barriers: *Information and education* by increasing the awareness of energy use and energy savings would enable the end users to perform in their own financial interest by including more information on utility bills or implementation of awareness campaigns. *Incentives and financing* by means of subsidies, grants and tax reduction may increase the efficiency potential. *Codes and standards* can be used when end user or manufacturer awareness is low, audits, assessments, building codes or equipment standard may increase the efficiency potential. *Third party involvement* occurs when a private company, utility, government agency or non governmental organization purchases and installs energy efficiency improvements for the end user, therefore it addressees all the barriers except from the economical. A combination of solutions could unlock the barriers of energy efficiency potential (Granade, et al., 2009, page.24-27).

4.6. Results – Evolution of the demand

Figure 4.9 presents the evolution of the energy demand for space heating, hot water and space cooling in terms of end use, for the EU27 residential sector for the according to the PRIMES scenario (European Commission DG-ENER, 2010). The decrease in the demand for heating and cooling is mainly achieved by the construction of more energy efficient buildings and by the modification of the existing structures with energy saving measures (wall insulation, double glaze windows, window shades, etc.). This figure shows that, in spite of the growth of the cooling demand is estimated in 3.14% p.a. (European Commission DG-ENER, 2010) its relative weight respect the space heating and hot water is relatively low in the context of the residential sector of the EU27 up to 2030.

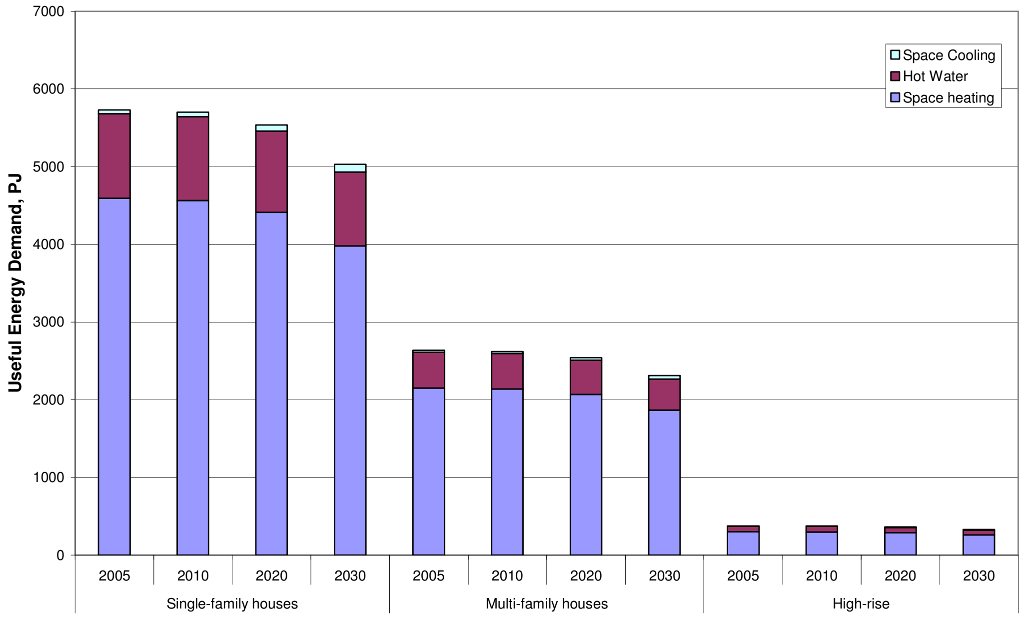

Figure 4.9: Evolution of the Energy consumption in the residential sector by end use in the EU27.

The evolution of the demand in the residential sector is mainly affected by the sector growth in the specific country, which is translated to new buildings with better energy performances, and the refurbishment of old building with better insulated envelop and better technologies. In addition, changes in the building policy of the MS are a key point to promote of the measures to improve the energy efficiency of this sector.

Figure 4.10 shows the projection up to 2030 of the energy consumption for the residential sector of each MS. The EU27 countries are cluster in three categories according to the size of it residential sector: Large-size, Medium-size and Small-size. In general term a reduction of the energy consumption takes place in all MS although there some countries with a rapid growth as Ireland and Cyprus where construction sector suppose a high weight in their economies.

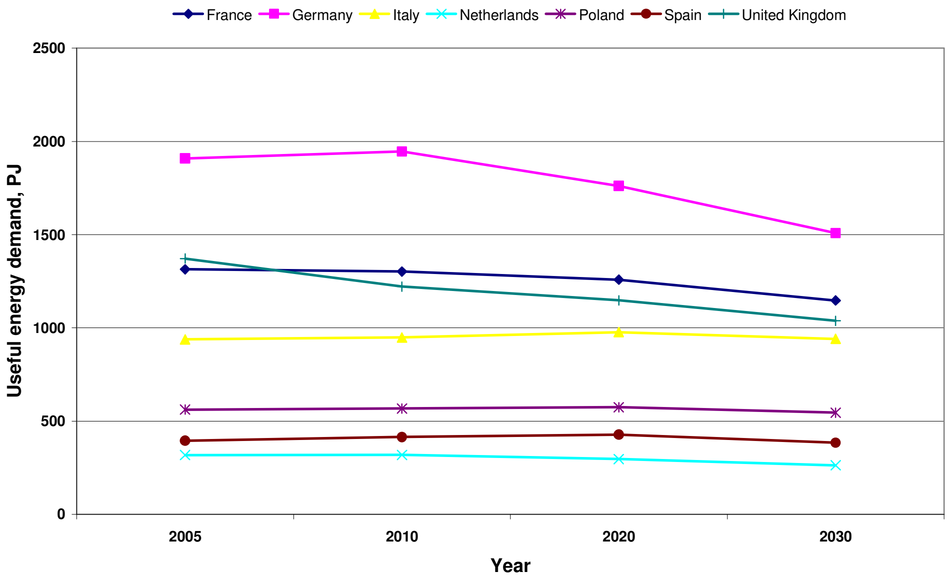

Figure 4.10a: Estimated useful heat demand in the residential sector. Large-size residential sector

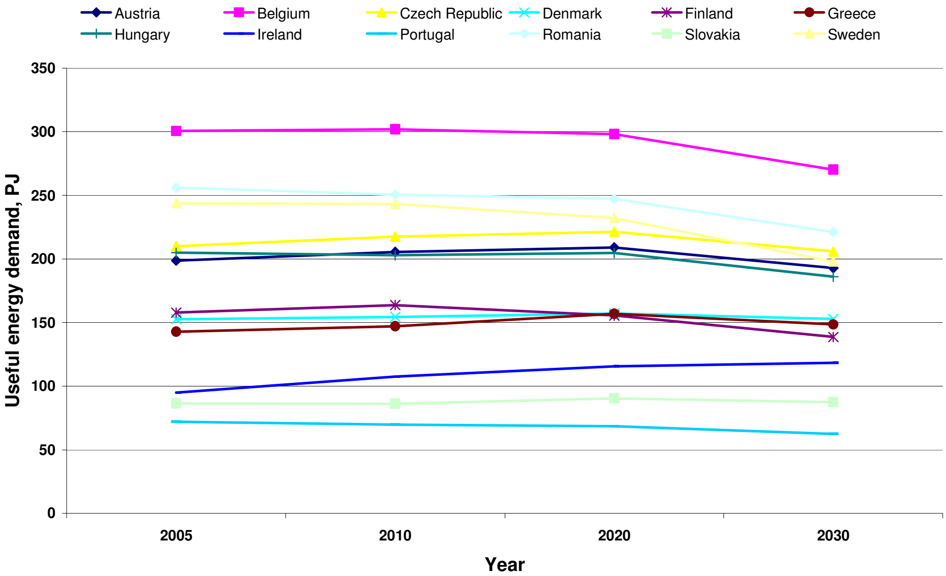

Figure 4.10b: Estimated useful heat demand in the residential sector. Medium -size residential sector

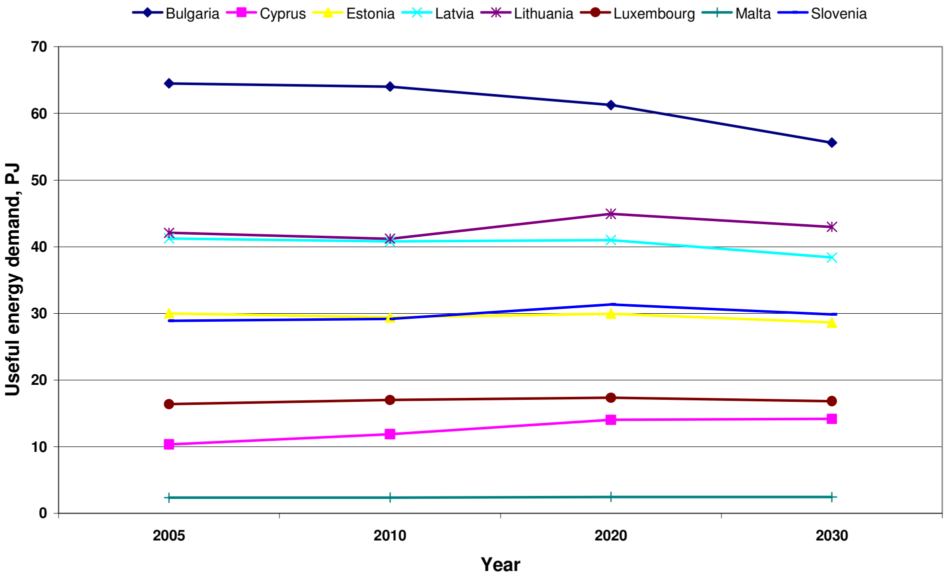

Figure 4.10c: Estimated useful heat demand in the residential sector. Small-size residential sector

5. Mapping – Service Sector

The service sector represents more than 70% of the GDP of OECD countries. It also accounts for 13% of total final energy consumption, behind transport, industry and households (which account for 37%, 25% and 21% of energy consumption, respectively) (Mairet and Decellas, 2009). Furthermore, the service sector is the most heterogeneous sector of the economy, made up of many small energy consumers. Thus, statistical assessment of this sector is complex and varies according to country.

5.1. General description of the sector

5.1.1. Breakdown of the service sector

The service sector includes subsectors such as all kinds of public and private offices, hotels, restaurants, shops, supermarkets, schools, universities, kindergartens, hospitals, swimming pools and various other services. Many types of buildings are represented which vary with regard to size, technical standard, building age, etc. International comparison limits the level of the decomposition, since the latter depends on the availability of detailed, harmonised data across all countries studied. The quality of decomposition results also depends strongly on how the sector is decomposed. Table 5.1 presents different decomposition patterns of the services sector that are currently used in Europe. Despite the fact that some general common areas are present in all systems, Table 1 demonstrates the discontinuities among the different systems implemented. As an example, in Germany (WZ system) the energy consumption of small firms and enterprises with up to 19 employees (small industrial enterprises) is assigned to the tertiary sector. “Agriculture and forestry/horticulture" and "military services" are also included in the tertiary sector. With regard to railways and airports, the total mobile energy consumption is allocated to the transport sector, but stationary energy consumption can is sometimes classified as belonging to the tertiary sector (Schlomann et al., 2009). Another example is the fact that education and research is not considered as a sub-sector in all systems.

Table 5.1 : Categorisation methodologies for the service sector

Reference		**(Mairet and Decellas, 2009)**	**(Mairet and Decellas, 2009)**	**(Scrase, 2000)**	**(Schlomann et al., 2009)**	**(Grube et al., 2007) ((Schleich, 2009)**
Source	**JRC[*]**	**CEREN[**]**	**INSEE[***]**	**AGEB, WZ 2003[****]**	**BERR[*****]**	**NACE[******]**
Information		**Official data on energy consumption of the service sector**	**National statistics published by the French statistical institute**	**Energy mass balances using energy consumption in the tertiary sector**	**Final energy consumption in the service sector, per sub sector, fuel, end-use**	**Statistical Classification of Economic Activities in the European Community**
Geographical Scope	**EU**	**FRA**	**FRA**	**GER**	**GBR**	**EU**
CATEGORIES	Shops	Wholesale/retail trade	Trade	Trade	Retail	Wholesale and retail trade
					Warehouses	
	Sports and recreation	Sport, culture and other recreational activities	Sport, culture and recreation services	-	Sport & Leisure	Other community, social and personal service activities
	Hospitals	Health and social services	Health and social services	Hospitals, schools, public baths	Health	Health and social work
	Hotels	Bars, hotels, and restaurants	Hotels and restaurants	Hotels, restaurants, NGOs	Hotel & Catering	Hotels and restaurants
	Restaurants					
	Offices	Offices and administration	Finance	Office like enterprises	Government	Financial intermediation
			Real estate			Real estate, renting and business activities
			Mail and telecommunication			
			Consultancy		Commercial offices	
			Operational services			
			Administration			
			Research and development			
	-	Education and research	Educational	-	Education	Education
	-	Transportation	Transportation	Airports	Communication & Transport	-
	-	-	-	Construction	-	-
	-	-	-	Food Industry	-	-
	-	-	-	Agriculture – crops and livestock	-	-
	-	-	-	Horticulture	-	-
	-	-	-	Textiles, clothing, freight forwarders	-	-
	-	-	-	Manufacturing		-

*Joint Research Centre of the European Commission , ** Centre for Studies and Economic Research in Energy, France, *** French statistical institute, France, ****German national energy balances (Arbeitsgemeinschaft Energiebilanzen) & German Classification of Economic Activities 2003 (Statistisches Bundesamt, Wiesbaden 2003), ***** Department for Business Enterprise & Regulatory Reform, UK ****** Statistical Classification of Economic Activities in the European Community

5.1.2. Performance Criteria

Although some minor differences can be found in different studies, there are three major common criteria that are used to evaluate the energy performance of the sector; i) productivity, ii) energy efficiency and iii) final energy consumption.

The ratio of total floor area to value added, accounts for the productivity of the service sector, (Mairet and Decellas, 2009). Changes in this ratio result not only from structural changes in the service sector (a shift from sub-sectors requiring large floor areas towards those that require little) but also from changes in productivity (a change, at constant structure, of the floor area needed to generate one unit of value added). This effect relies upon sharing over sub-sectors, and therefore is more accurate.

Likewise, the total energy consumption divided by an activity indicator is often considered an indicator of energy efficiency. Changes here result from a combination of multiple effects, (Mairet and Decellas, 2009):

- Technical progress effect (improvements in technologies),
- Behaviour effect (changes in the habits of users),
- Equipment rate effect (e.g. penetration rate of office equipment) and
- Substitution effect (e.g. changes in space-heating fuel mix).

The significance of above effects will differ between the sub-sector, depending on which kind of end-use energy is the most significant.

The evaluation of the final energy consumption per value-added ratio using the total aggregate energy consumption may simulate the impact of several factors. A more accurate quantification of the energy/activity indicator ratio therefore requires disaggregation by end-use.

5.2. Characteristic – Energy demand overview at EU level

This chapter attempts to describe the current overall situation in energy consumption and energy saving potentials for the services sector in the European Union. In 2007, the OECD total primary energy supply was 60127 TWh, with electricity production counting for 14% of it (10469 TWh) and heat production for 5% (3052 TWh) of the total demand (IEA 2011; IEA 2010). OECD energy consumption in 2030 is projected to be 6% higher than 2010, with growth averaging 0.3% p.a. to 2030. From 2020, OECD energy consumption per capita is on a declining trend (-0.2% p.a.). On the contrary, non-OECD energy consumption is projected to be 68% higher by 2030, averaging 2.6% p.a. growth from 2010, accounting for 93% of global energy growth (IEA world energy outlook 2010).

Electricity continues to gain an increasing share of final energy use in all EU countries, despite its use placing an extra burden on the energy economy and the environment. Electricity, which accounted for 36 % in 2000, is expected to have a share of more than 47 % of energy consumption in the service sector by 2030, (Grube et al., 2007). This long-term development makes it necessary to initiate increased measures to save electricity and to use it efficiently. Figure 5.1 presents the specific electricity consumption per sub-sector for several EU countries. Southern EU countries tend to show a much higher increase in electricity consumption and an alarming occurrence of summer peaks with precarious impacts on the stability of electricity grids. The cooled area in EU-15 countries, a large share of which comprises service sector offices and trade buildings, increased by more than 100 % between 1990 and 2000 and a further increase of 150 % is expected by 2020, (Grube et al., 2007). The nature of this increase (mainly in the commercial sector) represents also a great potential for implementation of district heating and cooling. If this increase of the cooling market share is supplied partly by DC systems based on waste heat and RES, this would results in significant social financial and environmental benefits.

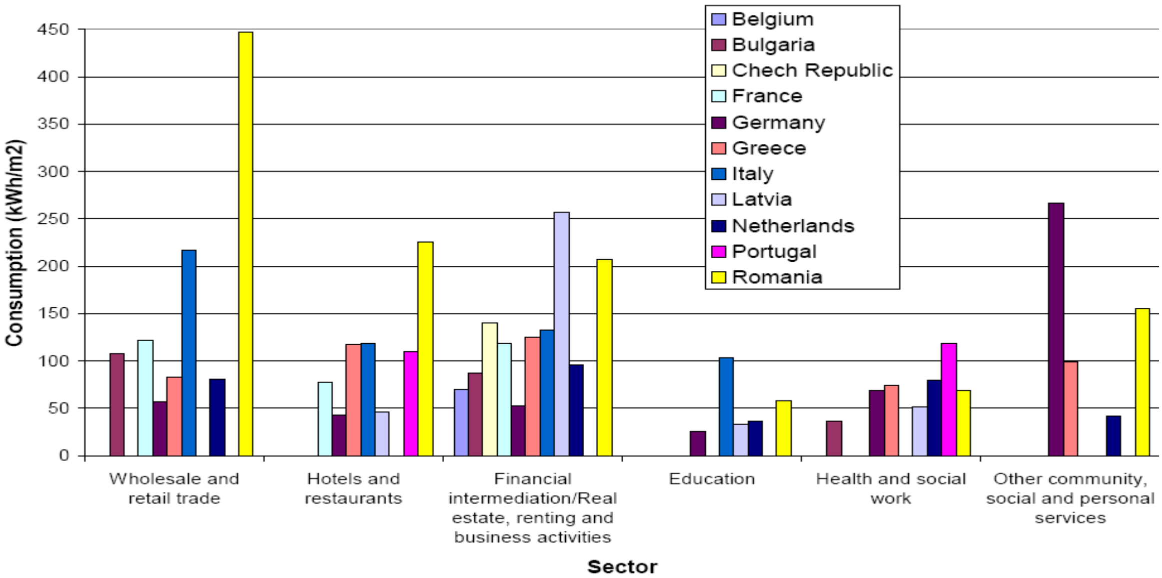

Fig. 5.1: Electricity consumption per sub-sector, (Grube et al., 2007)

Figure 5.2 presents the electricity consumption per end use for several EU countries. For many building managers, electricity consumption is a difficult area in which to identify saving potentials due to the complexity of end-uses which are mainly crosscutting technologies such as lighting, office equipment, information and communication, hot water production, ventilation, air conditioning, electric motors (pumps, elevators), and electric heating. A sector-specific use is the cooling and freezing, e.g. in supermarkets, hotels, and restaurants.

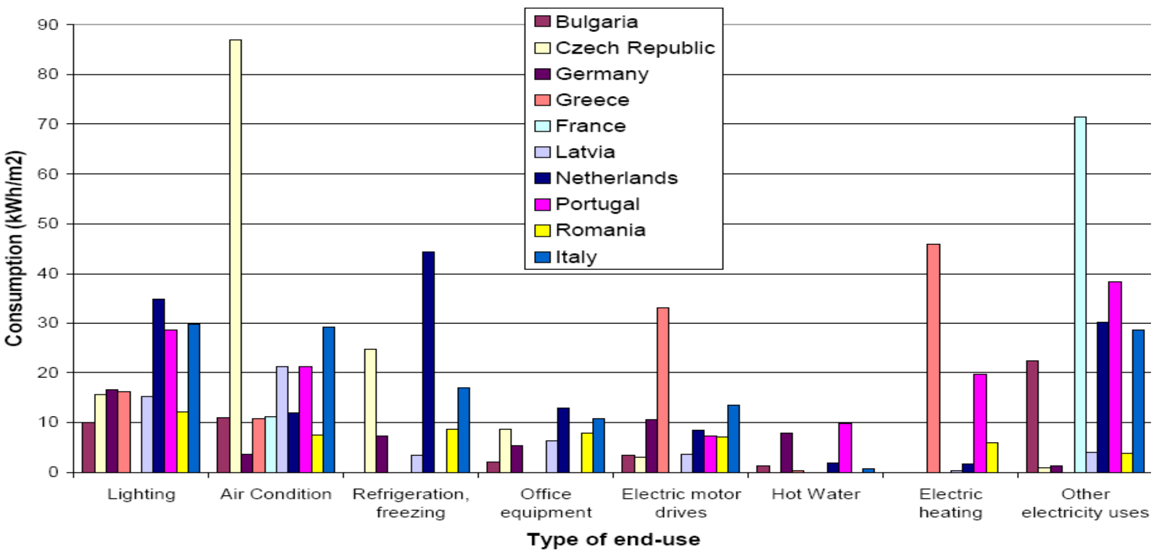

Fig. 5.2: Breakdown of electricity consumption per end use, (Grube et al., 2007).

Scrase (2000) and Schleich (2009) both show that there is large potential for efficiency improvements in electric appliances within the sector. The data situation on the stock and electricity consumption of buildings in the service sector is still insufficient even in Germany, where surveys on this issue were conducted for many years, (Schleich, 2009). In Switzerland, a study analysed building and organisational characteristics, energy-relevant decisions and the development of the electricity consumption in 100 office buildings over a decade. Among others, it revealed that the increasing efficiency of equipment was compensated by a more intensive use of equipment and new installations, e.g. IT infrastructure or air-conditioning. The electricity consumption structure is expected to change considerably over time due to technological developments and the purchase and use of appliances, (Scrase, 2000).

The estimated breakdown of useful energy demand for the service sector in EU-27 Members States is presented in Table 5.2. and Figure 5.3 presents the methodology employed. This table was constructed using the 2009 final energy data published by Eurostat, together with data on the ratio the final energy is used for thermal and electric energy purposes, the break down of the final energy use for each of the defined service sub-sectors, and finally the composition of the electric or thermal use in terms of the end use categories that were defined (Ecoheatcool WP1, 2005; Scholman et al., 2009; Astrom et al. 2010; Eurostat, 2011; EPA NR, 2011).

It should be noted here that due to the no availability of information for all MS, the countries were grouped based on topological and weather criteria in 5 groups, and the numbers of the leading group in terms of energy break down in thermal electrical, subsector and end use were used. These five groups are presented in Table 5.1:

Table 5.1: EU27 Member States Grouping

Group 1 : Central – East Europe	Germany Austria Bulgaria Slovakia Switzerland Poland Romania Hungary Czech Republic
Group 2: South Europe	Spain Portugal Malta Slovenia Cyprus Greece Italy
Group 3: Central Europe	France Belgium Luxembourg Netherlands
Group 4: North Europe	Latvia Lithuania Denmark Estonia Finland
Group 5: North Atlantic Europe	United Kingdom Ireland

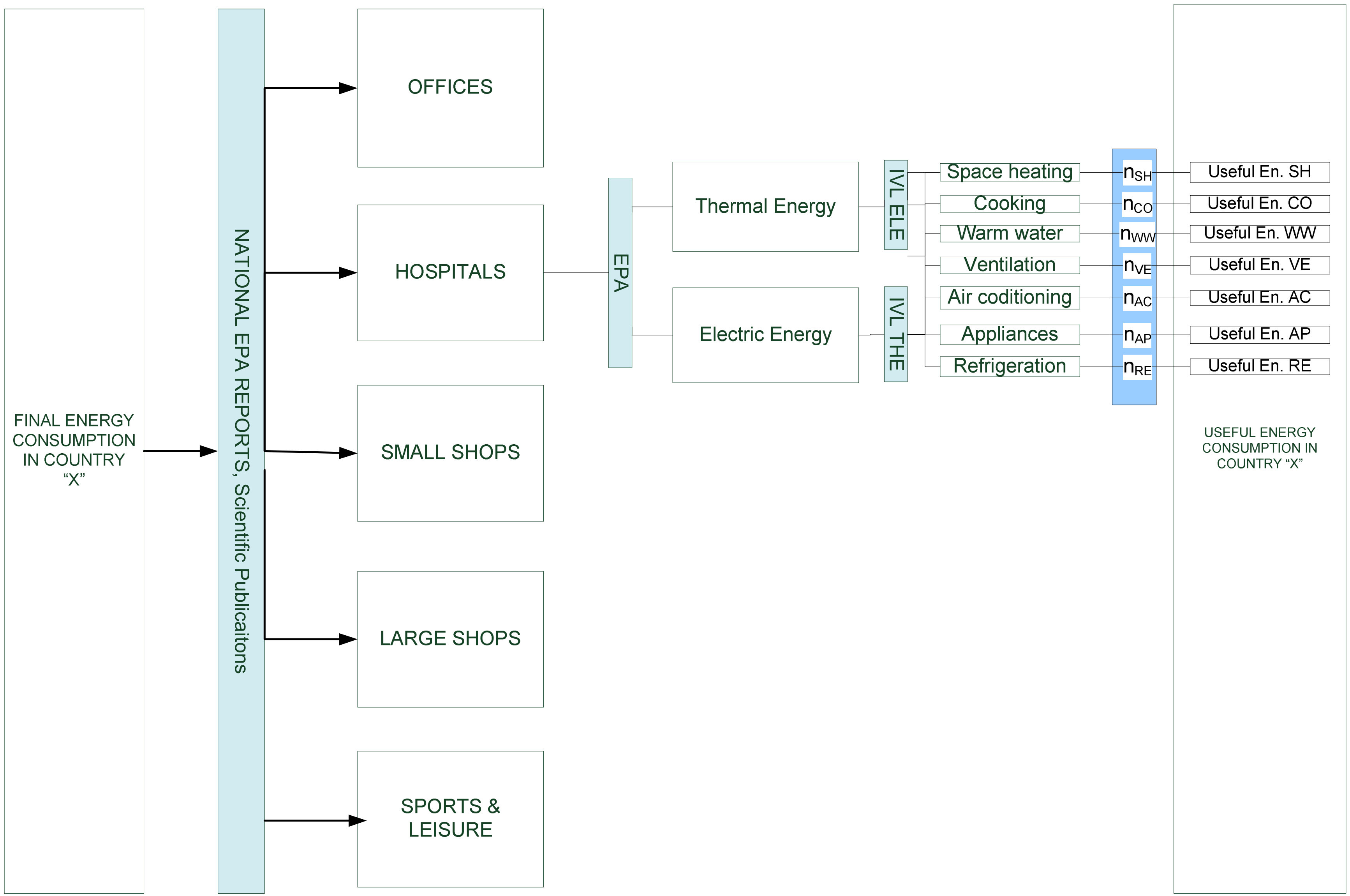

Figure 5.3. Methodology for the calculation of the estimated useful energy demand in the service sector of EU-27

Table 5.2. Breakdown of useful energy demand for the service sector in EU-27 in PJ for 2009

PJ	Hospitals			Hotels & Restaurants			Sport & Recreation			Shop - Large			Shop - Small			Offices			Total		
	Space Heating	Water Heating	Space Cooling	Space Heating	Water Heating	Space Cooling	Space Heating	Water Heating	Space Cooling	Space Heating	Water Heating	Space Cooling	Space Heating	Water Heating	Space Cooling	Space Heating	Water Heating	Space Cooling	Space Heating	Water Heating	Space Cooling
Austria	4,3	1,3	1,4	14,9	4,4	4,6	5,1	1,5	1,6	9,5	2,8	3,0	6,2	1,8	0,0	21,7	6,4	6,8	61,9	18,2	17,3
Belgium	10,6	2,7	2,0	15,8	4,0	2,9	7,6	1,9	1,4	8,7	2,2	1,6	8,7	2,2	0,0	30,2	7,7	5,6	81,7	20,7	13,5
Bulgaria	0,9	0,2	1,0	3,0	0,8	3,6	1,0	0,3	1,2	1,9	0,5	2,3	1,3	0,3	0,0	4,4	1,2	5,2	12,6	3,4	13,3
Cyprus	0,1	0,0	0,5	0,3	0,1	1,3	0,0	0,0	0,2	0,1	0,0	0,4	0,1	0,0	0,0	0,3	0,1	1,4	0,9	0,2	3,8
Czech Republic	4,0	1,1	1,3	13,6	3,7	4,6	4,7	1,3	1,6	8,7	2,3	2,9	5,7	1,5	0,0	19,9	5,4	6,7	56,6	15,2	17,0
Denmark	8,2	2,6	5,3	2,1	0,7	1,4	6,7	2,1	4,3	2,4	0,8	1,6	2,0	0,7	0,0	11,7	3,7	7,6	33,1	10,6	20,2
Estonia	1,7	0,5	1,1	0,5	0,1	0,3	1,4	0,4	0,9	0,5	0,1	0,3	0,4	0,1	0,0	2,5	0,7	1,6	7,0	2,0	4,3
Finland	4,0	1,2	8,0	1,0	0,3	2,1	3,2	0,9	6,5	1,2	0,3	2,4	1,0	0,3	0,0	5,7	1,6	6,8	16,1	4,6	25,6
France	47,4	13,7	30,5	70,5	20,4	45,4	34,0	9,9	21,9	38,9	11,3	25,1	38,9	11,3	0,0	134,8	39,1	87,6	364,4	105,7	210,6
Germany	33,6	8,8	20,8	115,3	30,2	71,4	39,5	10,3	24,5	73,6	19,3	45,6	48,1	12,6	0,0	168,1	44,0	104,0	478,2	125,1	266,3
Greece	2,2	0,9	5,1	5,9	2,4	13,9	0,8	0,3	1,9	2,0	0,8	4,6	2,4	0,9	0,0	6,5	2,6	15,3	19,7	7,9	40,7
Hungary	5,4	1,1	0,4	18,7	3,8	1,3	6,4	1,3	0,4	11,9	2,4	0,8	7,8	1,6	0,0	27,2	5,5	1,9	77,4	15,7	4,8
Ireland	2,2	0,7	1,7	3,2	1,0	2,5	1,2	0,4	1,0	5,5	1,7	4,3	2,3	0,7	0,0	10,0	3,0	7,9	24,3	7,3	17,4
Italy	27,5	7,3	19,3	75,1	19,8	52,7	10,0	2,6	7,0	25,1	6,6	17,6	30,0	7,9	0,0	82,6	21,8	57,9	250,3	66,1	154,6
Latvia	2,7	0,6	0,3	0,7	0,2	0,1	2,2	0,5	0,2	0,8	0,2	0,1	0,7	0,2	0,0	3,9	0,9	0,4	11,0	2,6	1,1
Lithuania	2,6	0,7	1,4	0,7	0,2	0,4	2,1	0,6	1,1	0,8	0,2	0,4	0,7	0,2	0,0	3,7	1,0	1,9	10,6	2,9	5,2
Luxemburg	0,4	0,2	0,0	0,6	0,3	0,0	0,3	0,2	0,0	0,3	0,2	0,0	0,3	0,2	0,0	1,2	0,6	0,0	3,2	1,7	0,0
Malta	0,0	0,0	0,2	0,1	0,0	0,5	0,0	0,0	0,1	0,0	0,0	0,2	0,0	0,0	0,0	0,1	0,0	0,5	0,3	0,1	1,4
Netherlands	19,5	5,0	6,4	28,9	7,5	9,6	14,0	3,6	4,6	16,0	4,1	5,3	16,0	4,1	0,0	55,4	14,3	18,4	149,7	38,8	44,3
Poland	7,0	1,9	4,8	24,2	6,4	16,5	8,3	2,2	5,7	15,4	4,1	10,5	10,1	2,7	0,0	35,2	9,4	24,1	100,2	26,7	61,6
Portugal	3,2	1,0	3,9	8,8	2,7	10,7	1,2	0,4	1,4	2,9	0,9	3,6	3,5	1,1	0,0	9,7	3,0	11,8	29,3	9,2	31,5
Romania	2,8	0,5	0,4	9,5	1,8	1,3	3,3	0,6	0,4	6,1	1,2	0,8	4,0	0,8	0,0	13,8	2,7	1,8	39,4	7,6	4,7
Slovakia	2,4	0,6	0,8	8,2	1,9	2,9	2,8	0,7	1,0	5,2	1,2	1,8	3,4	0,8	0,0	11,9	2,8	4,2	33,9	7,9	10,8
Slovenia	0,8	0,2	0,4	2,3	0,6	1,0	0,3	0,1	0,1	0,8	0,2	0,3	0,9	0,2	0,0	2,5	0,6	1,1	7,5	1,9	3,0
Spain	11,0	3,6	17,4	30,1	10,0	47,6	4,0	1,3	6,3	10,1	3,3	15,9	12,0	4,0	0,0	33,1	10,9	52,4	100,4	33,2	139,6
Sweden	19,2	5,6	12,7	5,0	1,5	3,6	15,6	4,6	10,3	5,7	1,6	3,9	4,8	1,4	0,1	27,3	8,0	18,0	77,6	22,6	48,5
United Kingdom	21,8	6,1	18,3	31,5	8,8	26,4	12,1	3,4	10,2	54,9	15,4	46,0	22,7	6,4	0,0	99,4	27,9	83,4	242,5	68,0	184,3
EU-27	**245,3**	**68,1**	**165,4**	**489,4**	**133,3**	**328,5**	**187,6**	**51,3**	**115,9**	**308,2**	**83,7**	**201,4**	**233,3**	**63,8**	**0,2**	**821,0**	**224,6**	**538,6**	**2284,8**	**624,9**	**1350,0**

Table 5.3: Useful Energy provided by District Heating and District Cooling in the European Services Sector in TJ for 2009.

TJ	Hospitals		Hotels & Restaurants		Sport & Recreation		Shop - Large		Shop - Small		Offices		Total	
	District Heating	District Cooling	District Heating	District Cooling	District Heating	District Cooling	District Heating	District Cooling	District Heating	District Cooling	District Heating	District Cooling	District Heating	District Cooling
Austria	2244	4	7710	13	2643	4	4920	8	3215	4	2244	6	22975	39
Belgium	380	0	566	0	273	0	312	0	312	0	380	0	2224	0
Bulgaria	360	0	1238	0	424	0	790	0	516	0	360	0	3689	0
Cyprus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Czech Republic	1218	0	4185	0	1434	0	2670	0	1745	0	1218	0	12469	0
Denmark	7747	1	2019	3	6288	1	2275	2	1921	1	7747	1	27997	8
Estonia	1236	0	322	0	1003	0	363	0	306	0	1236	0	4465	0
Finland	0	12	0	41	0	14	0	26	0	14	0	16	0	123
France	0	0	0	45	0	0	0	18	0	32	0	961	0	1056
Germany	6973	28	23964	98	8214	33	15291	62	9991	33	6973	39	71407	294
Greece	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hungary	664	1	2281	4	782	1	1455	3	951	1	664	4	6796	14
Ireland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Italy	286	16	780	53	104	18	261	34	312	18	286	21	2028	160
Latvia	1410	0	368	0	1145	0	414	0	350	0	1410	0	5097	0
Lithuania	2033	0	530	0	1650	0	597	0	504	0	2033	0	7347	0
Luxemburg	4	0	5	0	3	0	3	0	3	0	4	0	21	0
Malta	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Netherlands	3461	3	5147	10	2485	3	2838	7	2838	3	3461	6	20230	32
Poland	2077	0	7139	0	2447	0	4555	0	2976	0	2077	0	21272	0
Portugal	34	1	92	3	12	1	31	2	37	1	34	1	239	7
Romania	574	0	1973	0	676	0	1259	0	822	0	574	0	5878	0
Slovakia	613	0	2106	0	722	0	1344	0	878	0	613	0	6275	0
Slovenia	75	0	204	0	27	0	68	0	81	0	75	0	530	0
Spain	0	3	0	39	0	5	0	13	0	16	0	43	0	119
Sweden	14691	125	3829	431	11925	148	4315	275	3643	144	14691	151	53094	1274
United Kingdom	1498	0	2164	0	832	0	3769	0	1558	0	1498	0	11320	0
EU-27	**47577**	**193**	**66621**	**739**	**43090**	**230**	**47530**	**449**	**32959**	**267**	**47577**	**1249**	**285354**	**3127**

District heating is more suitable to provide energy for specific low temperature uses such as space heating and/or water heating. By comparing the findings presented in Tables 5.2 and 5.3, district heating derived energy covers between 4.6% to 18% of the useful energy needed in the different sub-sectors for space and water heating, with hospitals and sport and recreation facilities being at the high end of this margin, while in offices only 4.6% of the useful energy is covered. At the EU27 level, DH energy is just above 7% of the useful energy with the margin from 0% (7 countries) to just above 64% (Denmark) at the country level. For district cooling, the margin between the sub-sectors at the EU 27 level is between 0.1% - 0.2% of the space cooling useful energy demand, and spans between 0% (16 countries) to 2.6% (Sweden), and finally at the EU27 level, is 0.23%.

5.3. Country Specific Analysis

This chapter presents in more depth the current situation for 3 EU member states, namely the United Kingdom, France and Germany, which in total represent more than 20% of the European population and cover more than 35% of the area of Europe.

The service sector is a very diverse sector, which can be seen by the different national approaches when mapping the energy demand in the sector. The approaches differ both on how the sector is divided (offices, schools shops etc) and which end use types are mapped. Germany maps the end use energy based on which kind of energy that is needed (mechanical, low temperature etc), while France instead seem to start from the appliances.

5.3.1. France

In 2006, the French service sector represented 77% of value added and 76% of employment. On the other hand, with 263 TWh, the service sector only accounted for 14% of final energy consumption. Nevertheless, its rate of increase has been one of the fastest. Since 1973, the energy consumption of this sector has grown by an average of 1.5% per year; while French national energy consumption has only grown by 0.6% per year. Only the transport sector recorded a higher average annual growth rate (2%per year), (Mairet and Decellas, 2009).

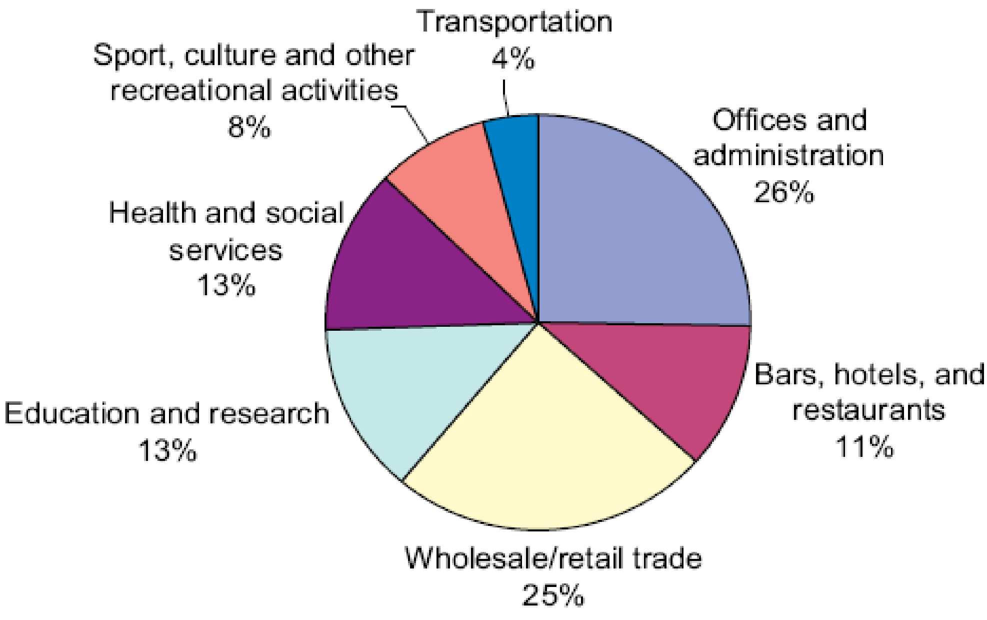

Fig. 5.3: Service sector energy consumption by sub-sector in France, 2001, (Mairet and Decellas, 2009)

As it can be seen in Figures 5.3 and 5.4, the two largest sub-sectors in terms of both floor area and energy consumption are wholesale/ retail trade and offices and administration. They alone represent almost half of energy consumption. The education and research sub-sector, although it accounts for 22% of the service sector floor area, only accounts for 13% of energy consumption, due to low energy needs, (Mairet and Decellas, 2009).

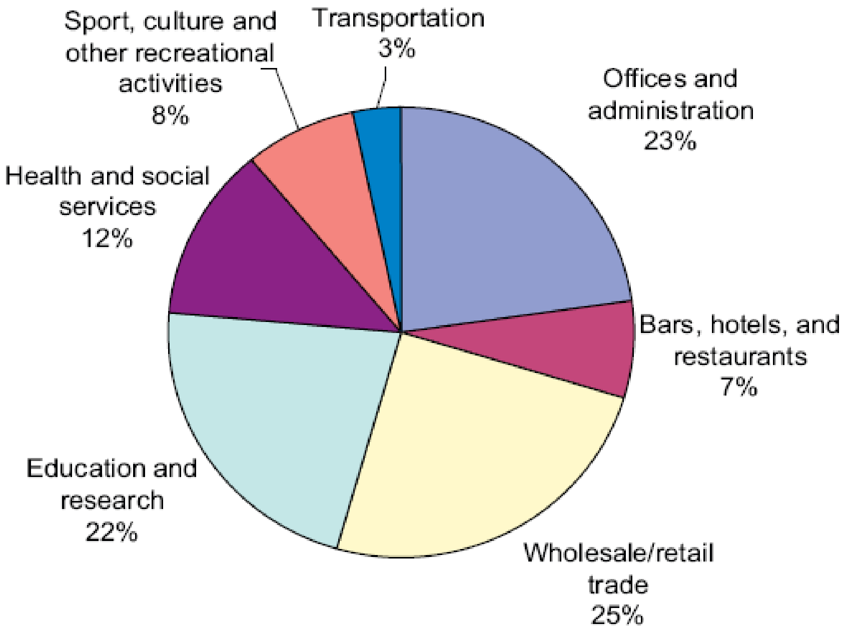

Fig. 5.4: Service sector floor area by sub-sector in France, 2001 (Mairet and Decellas, 2009).

Figure 5.3 shows the end-use structure of the energy consumption per sub-sector in 2001. More than half of service sector energy consumption was for space heating. Electric appliances accounted for 26% and air conditioning for about 5% of all the energy consumed. In education, the sub-sector with the lowest energy demand, space heating accounts for 75% of the energy consumption. While electric appliances have a particularly high share in the office and transportation sub-sectors, due to the massive use of information and communication technologies, and in the trade sub-sector, due to refrigeration and lighting demand. Cooking accounts for a major part of energy consumption in the bars, hotels and restaurants (hereafter ‘‘restaurant’’) sub-sector, but is nearly non-existent in the office and trade sub-sectors. Sub-sectors with housing/accommodation activities (health and social services (hereafter ‘‘health’’) and restaurant sub-sectors) have a high DHW need, (Mairet and Decellas, 2009).

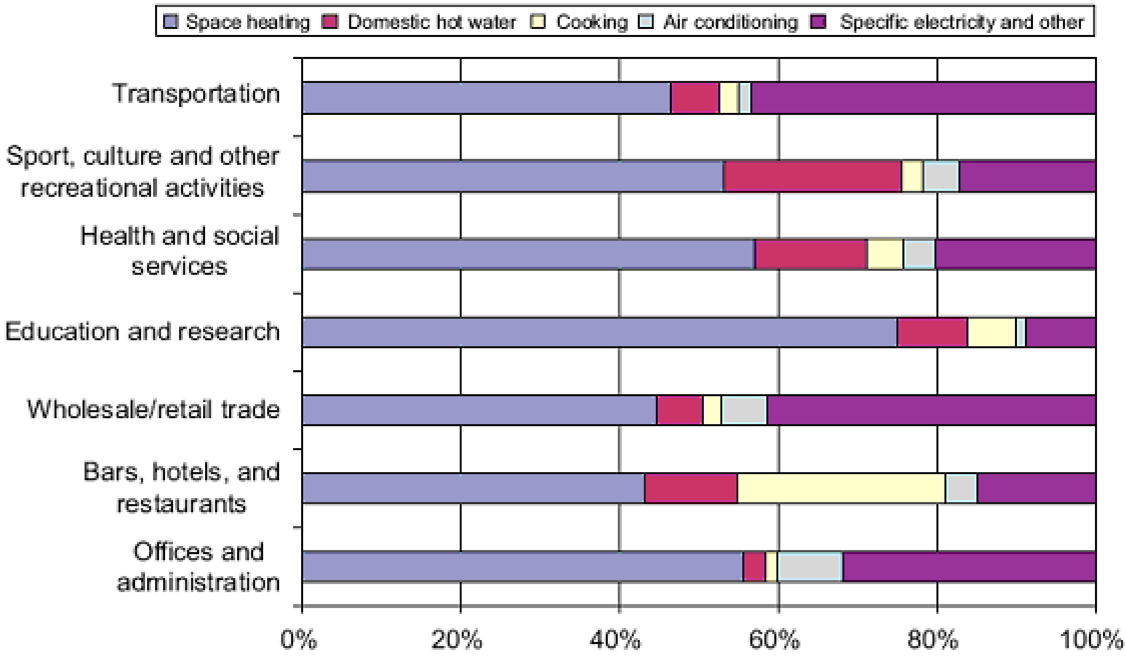

Fig. 5.5: Energy end-use by sub-sector for France, 2001, (Mairet and Decellas, 2009).

This end-use is also important for the sport, culture and other recreational activities sub-sector. Finally, air conditioning is especially widespread in the office and trade sub-sectors. Changes in the economic structure, end-use structure and fuel mix are just some of the factors affecting the aggregated energy consumption of the service sector. Over the period 1995–2006, energy consumption in the service sector grew by 18% (or 1.5% per year), (Mairet and Decellas, 2009). The main factor contributing to this change was the economic growth of the sector. The equipment rate effect (estimated for air conditioning only) also contributed to the increase in energy consumption. The impact of these effects, however, was mitigated by structural changes and productivity gains. Energy substitutions for space heating and improvements in intensity also helped to limit the growth in energy consumption.

Space heating

For space heating, the service sector value added was the major factor affecting energy consumption in France. Structural changes and improvements in intensity led to a reduction in space-heating energy consumption. The impact of structural changes was due to the declining weight of the sub-sectors that account for a major share of space-heating consumption (education, health and restaurant sub-sectors). The reduction in energy intensity was caused by improvements in insulation and heating systems. In new buildings, energy consumption per m^2 for space heating was 27% less than the average of existing buildings in 2006. The decrease in energy consumption can't only be explained by new buildings, when buildings constructed after 1995 only accounted for 13% of the total building stock. Renovation work in existing buildings may also have contributed to the decrease in energy intensity.

To a lesser extent, the fuel mix substitution resulted in lower final energy consumption mainly due to the change from domestic fuels to gas and electricity (space-heating equipment associated with these two energies exhibited better relative efficiency than domestic fuel). Finally, the productivity effect was marginal. Improvements in productivity in some sub-sectors (trade, sport, office, transportation) resulting in a lower energy consumption. The consumption increase is counterpoised by a decline in productivity in the other sub-sectors. Over the period 1995–2000, the growth of the service sector was the main factor in the increase of space-heating consumption. The energy consumption per value-added ratio was positive, compensated for by the structure and productivity effects. After 2000, the energy consumption per value-added ratio plummeted, offsetting the service sector value added. This may be the consequence of the reinforcement of thermal building standards in 2000. The largest energy consumption reductions were achieved in the office, education and health sub-sectors through energy substitutions and energy efficiency improvements.

On the other hand, for the trade sub-sector, despite consuming a great deal of energy for space heating, the effect from fuel mix substitution was negligible, whiles the energy consumption per value-added ratio was positive. This may be explained by a structural change within the trade sub-sector. This sub-sector includes not only sales floor area, but also warehouses, which are generally not heated. The increase in the share of sales floor area in this sub-sector may have led to an increase in the unit consumption for space heating not attributable to changes in energy performance. Finally, with respect to the sport sub-sector, the positive effect of fuel mix substitution is linked to growth in the market share of natural gas, whose unit consumption was higher for this sub-sector.

Electricity

Specific electricity consumption has increased rapidly, at the same pace as the output of the service sector. The service sector value added was the main factor driving this change whereas the impact of structural changes was negligible. The office and trade sub-sectors accounted for the major share of specific electricity consumption in the service sector. Productivity gains achieved in these sub-sectors helped to offset the growth of specific electricity consumption (a negative productivity effect). Finally, increasingly intensive use of specific electricity resulted in a positive energy consumption per value-added ratio. All sub-sectors except for transportation contributed to this increase. The energy consumption per value-added ratio was particularly high for the office and trade sub-sectors: increased use of office equipment in offices and of refrigeration and lighting in stores. Finally, since 2002, the energy consumption per value-added ratio has been relatively stable. It is likely that saturation of the office equipment rate has occurred in some sub- sectors. Therefore, the increase in unit consumption due to the growth in the equipment rate is compensated for by improved energy performance of equipment. In certain European Union countries, electricity intensity levelled off, or even declined, over the past few years.

Air conditioning

Air conditioning is the most rapidly growing end-use. The equipment rate effect measures the impact of the change in the air-conditioning rate on energy consumption. This was the most significant effect, which, combined with the service sector value added, and accounted for the high growth in air-conditioning consumption. Improvements in productivity, particularly in the office and trade sub-sectors, slightly limited this growth. Structure and energy consumption per value-added ratios had no impact on changes in energy consumption. The negligible energy consumption per value-added ratio resulted from contrasting changes between sub-sectors.

Domestic hot water

Domestic hot water energy consumption increased and the service sector value added was the main factor that led to this increase in DHW. This increase was counterbalanced by structural changes, due to the relatively low activity growth of the education, health and restaurant sub-sectors, for which DHW needs, were high. The productivity and energy consumption per value-added ratios played a less important role. The most important gains in energy efficiency were achieved in the transportation and office sub-sectors, but the sport sub-sector exhibited large positive energy consumption per value-added ratio. This sub-sector, which represents a low share in the value added and energy consumption of the service sector, is very heterogeneous, combining sporting facilities and cultural buildings, as well as sewage treatment plants. The estimate of the energy consumption per value-added ratio may potentially be influenced by a structure effect within that sub-sector.

Cooking

The restaurant, health and education sub-sectors accounted for about 80% of energy consumption for cooking in the service sector. The restaurant sub-sector was alone responsible for nearly 50% of this consumption. The decreasing weight of these three sub-sectors in the total value added of the service sector led to a large structure effect, which partially offset the service sector value added. The drop in the ratio of value added to floor area in these sub-sectors explained the positive productivity effect, which was counter- balanced by the energy consumption per value-added ratio. The energy consumption per value-added ratio resulted from improvements in energy efficiency in all sub- sectors, including the restaurant sub-sector, for which cooking is a major end-use.

5.3.2. United Kingdom

In UK, the rate of growth in energy consumption in the last 25 years has been approximately three times greater than in the domestic sector, and is projected to exceed growth in all other sectors except transport. The rate of increase equals or exceeds the growth in the contribution the sector makes to the UK economy. In the commercial services sector (private offices, retail, leisure, hospitality and warehouses), final energy consumption grew by 65% from 1973 to 1996, compared to only 1% growth in public sector services energy consumption. This rapid growth in commercial sector energy consumption reflects expansion in floor space, and increased heating, lighting, IT and air conditioning (A/C) loads in individual buildings, (Scrase, 2000).

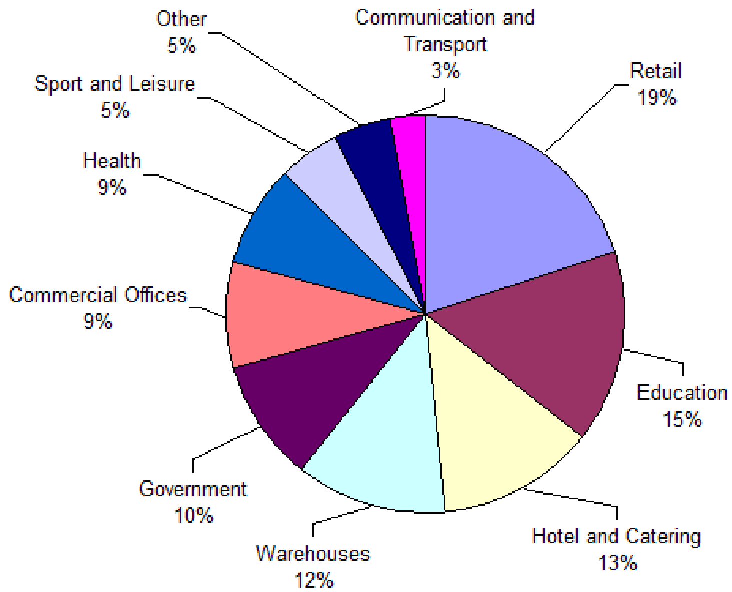

Fig. 5.6: Service sector energy consumption by sub-sector in UK, 2008, (UK NS., 2010)

The rapid increase in UK's service sector energy consumption has been particularly marked in the 1990s. Perhaps the most worrying trend is the rate of increase in electricity consumption in the service sector. While total energy use in the sector defined as 'other final users' by the DTI (i.e. public plus private services and agriculture) increased by 16.6% from 1973 to 1998, electricity use more than doubled. This reflects growing demand for high levels of illumination in the retail sector, the growth of A/C and use of IT equipment. In electricity generation almost two thirds of the input energy is lost as wasted heat. Because of the high electricity use in the service sector, conversion losses are higher in the service sector than any other. From 1970 to 1994 retail floor space increased by 54%, office floor space almost doubled, and warehouse space increased by a massive 114%.

The leisure industry is another sector in which similar trends are observed. This is the first sector in which an agreement has been made relating to energy use in buildings rather than in industrial processes. Furthermore, the vast majority of leisure businesses are small and medium sized pubs, restaurants and hotels, whereas the focus here is on barriers to energy efficiency in buildings that are owned primarily as investment assets. In the economy as a whole it is generally the case that new investments will be more energy efficient than the equipment that they replace. Boilers, car engines, household appliances and industrial machinery have all followed this pattern. This effect means that energy consumption normally rises more slowly than economic growth.

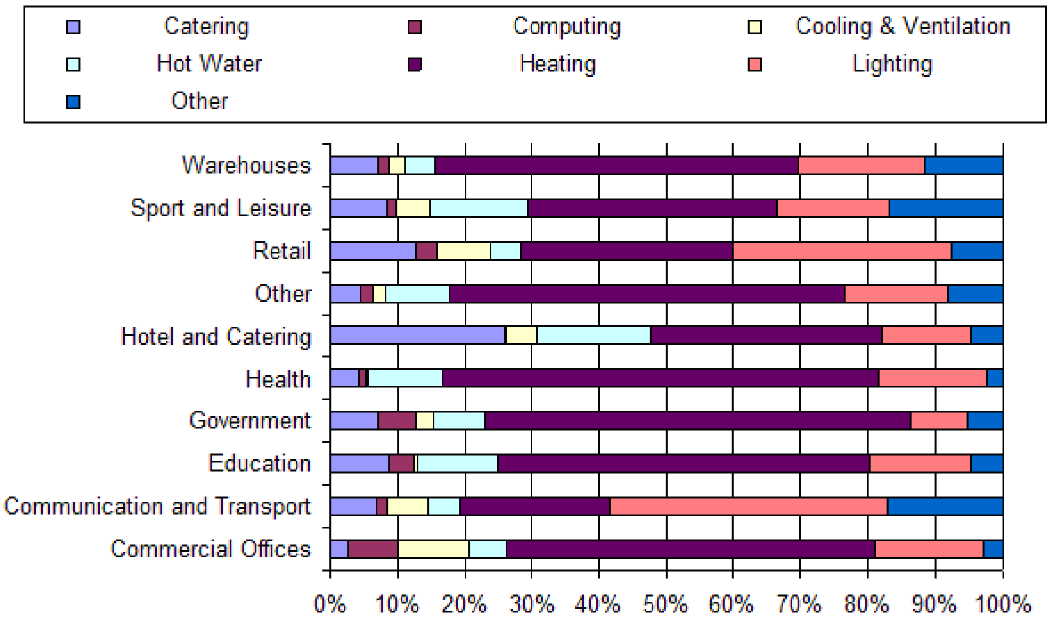

Fig 5.7: Energy end-use by sub-sector for UK, 2008, (UK NS, 2010).

Historical, energy has been used more efficient when the economy has been growing. However, many modern office buildings go against this trend, with newer designs often consuming more energy per square meter than traditional buildings. This effect is primarily because of the rising use of A/C, which typically (though not necessarily) reduces energy efficiency substantially. Over half of new offices and a third of new retail premises built in the 1990s had A/C. In the 1980s these proportions were 43% and 25%, and in the 1970s 36% and 22% respectively. If this trend continues, coupled with the rapid increase in floor area discussed earlier, energy consumption will continue on its rapid upward trajectory, outstripping growth in the contribution the sector makes to the economy.

5.3.3. Germany

The German commercial and services sector in 2006 accounted for about 16% of final energy consumption (1416 PJ) and 6.5% of direct CO_2-emissions in Germany(Schlomann et al., 2009). The share of energy costs is usually well under three percent of total costs. It consists of small industrial enterprises (with no more than 20 employees), all public and private services as well as the agricultural and construction sectors. Hence, the German commercial and services sector differs from the categories 'service sector', 'public sector' or 'service sector' usually found in United Nations or Euro stat energy statistics, (Schleich., 2009).

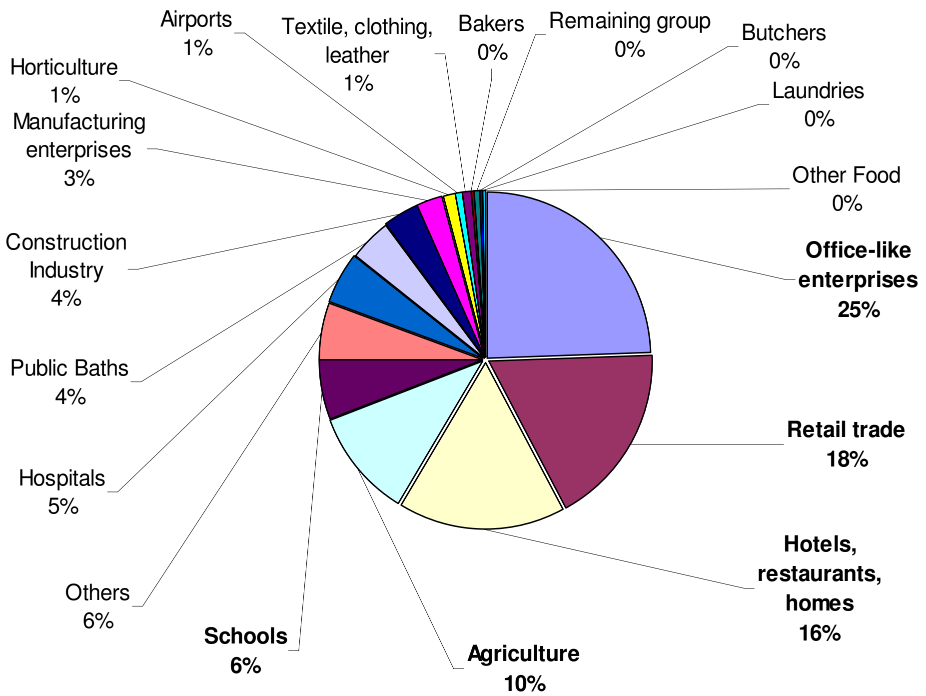

Fig. 5.8: Service sector energy consumption by sub-sector in Germany, 2006, (Schlomann et al., 2009)

Figure 5.8 presents the energy consumption per sub-sector of the German services sector, as described by the WZ code in table 1. Figure 5.9 presents the energy consumption per end use and sub sector. Bellow, definitions of each end use type:

Space heating

The electricity used for heating rooms as well as the amount of electricity resulting from the additional heat demand via fans and radiators. Fuel and district heat used for heating commercially used buildings.

Process heat

Electricity used for hygiene (hot water) and for thermal processes (heating, boiling, frying, melting, welding, tempering, drying etc.). The energy used to meet the hot water demand in the businesses for personal hygiene (hand washing, showering, bathing) and for process technology procedures (washing and cleaning, boiling and cooking, sterilizing, burning and welding etc.) as well as to meet the heat demand of swimming pools and under-glass constructions.

Cooling

The electricity consumption of stationary and mobile electrically-powered compressors for producing cold for central and decentralize air conditioning systems and space cooling as well as the gas used to operate absorption chillers for air conditioning commercial areas.

Process cooling

The power consumption of electrical chillers in cold stores, walk-in coolers of refrigerated display cases, freezers and fridges which are supplied by absorption chillers. The gas used by cold stores, walk-in freezers and cold stores, centrally supplied freezers, refrigerated displays, freezers and fridges supplied using absorption chillers.

Mechanical energy (power)

Electricity used to power machines and appliances excluding the consumption of compressors used for process cooling and to produce cold for air conditioning and space cooling. On top of this, the fuel used to power combustion engines in agriculture (tractors etc.), in the construction industry (to generate electricity and compressed air, for diggers and wheel loaders etc.), at airports (airplane tractors, buses etc.) and used for stationary purposes in businesses.

Lighting

Electricity used for lighting commercially used rooms and lighted open spaces, advertising and shop windows and street lighting/

Information and communications

The electricity consumption of appliances to obtain, process, disseminate, store and document information (computers, servers, printers, copiers etc.), for communications (telephones, mobile phone chargers etc.) as well as for cash registers etc.

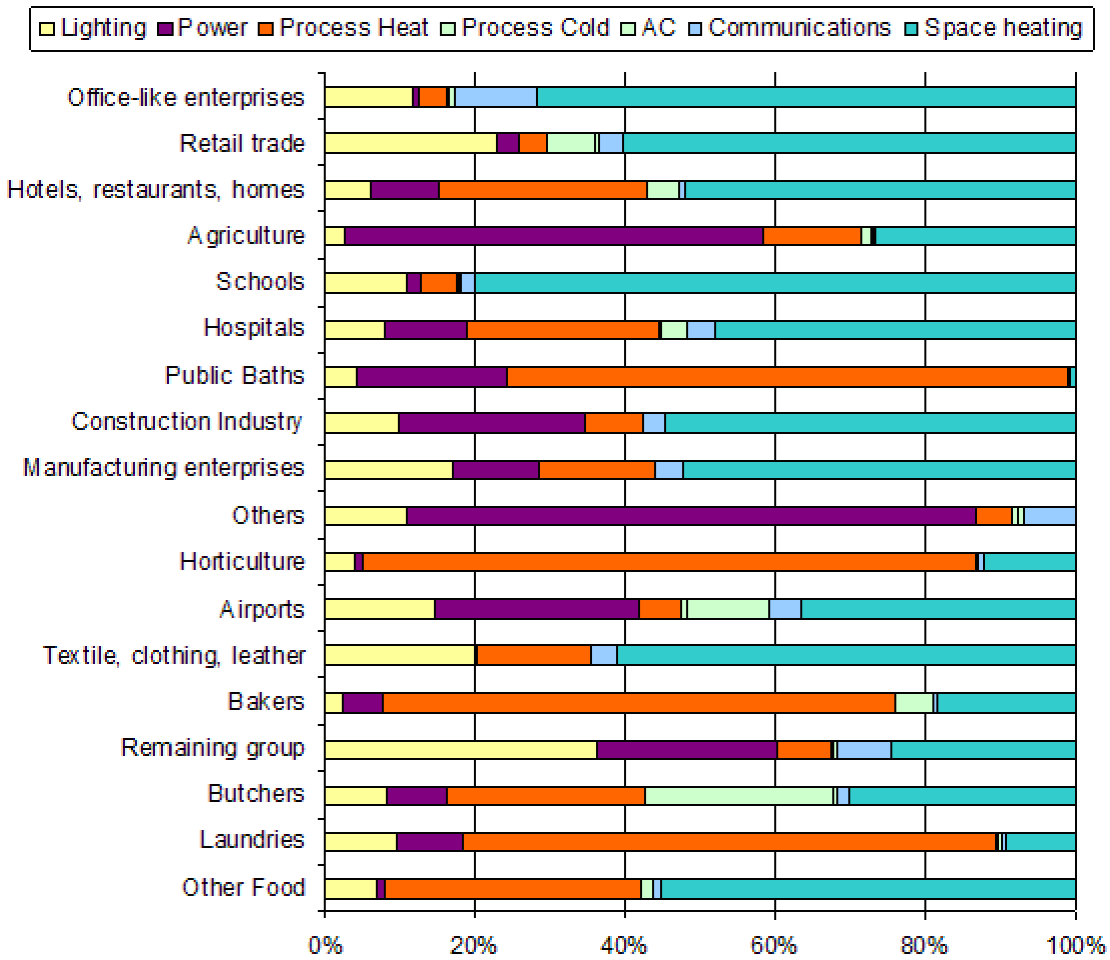

Fig 5.9: Energy end-use by sub-sector for Germany, 2006, (Mairet and Decellas, 2009).

The *construction industry* is a very heterogeneous sector with regard to company size and structure. Structural and civil engineering and prefabricated building are the main components of the building trade; plumbers/fitters and painters/varnishers are the biggest lines of business in the finishing trade. Energy consumption is split into space heating and production in the companies as well as numerous machines and appliances on building sites and building site traffic. As was to be expected, businesses in the main building trade operate many more energy-intensive appliances both within companies themselves and on the building sites. Almost all the appliances are electrically powered apart from forklift trucks and dump trucks. There are considerable problems with recording energy consumption in the construction industry, especially on building sites, e.g. for site electricity and heating containers, because the costs for these are borne by the building owner. It is also difficult to correctly split the diesel consumption of building site vehicles which is partly assigned to the tertiary sector and partly to the transport sector.

The industrial branches grouped together here under the heading of "*office-like enterprises*" cover a wide range of public and private services: banks and insurance offices, public utilities and other business services, some with an obvious office character such as lawyers, solicitors or tax advisors, but others with more energy-relevant aspects like waste disposal services, hairdressers, cleaning services or doctors. From the viewpoint of energy, however, most of these have similar structures. Space heating dominates followed by electricity applications for lighting, ventilation and air-conditioning, information and communication technologies. The share of air conditioned, cooled or ventilated rooms is around 10% on average in this group. About one third of the businesses with air conditioning or cooling have a central air conditioning system, two thirds have small units; mobile units are more common than split ones. The lighting system may be as old as 45 years; the average of 11.7 years is a bit lower here than in the other branches. In customer-occupied and office areas, the share of fluorescent and energy-saving lamps is relatively high at around 70%; halogen lamps are used especially in shop windows and open spaces. As expected, office-like enterprises have more office equipment than other branches of the tertiary sector; this is especially valid for banks, insurances and public institutions.

Metalworking, the automobile trade, wood, paper and printing businesses all count as *manufacturing enterprises*. Alongside general features such as heating, lamps, office equipment and ventilation and air conditioning, sector-specific process technologies play a greater role in this group, especially with regard to electricity. Fuels, in contrast, are predominantly used for space heating. Metal working encompasses heterogeneous industrial branches with different energy intensities. Relatively, mechanical and electrical engineering, locksmiths and welding shops, the production of medical and orthopaedic products and other metal products have the biggest shares in the tertiary sector. The variety of production technologies used is correspondingly large; most of these are electrically powered, e.g. compressed air production, moulding/shaping and separating. As well as for space heating, fuels are also used for processes involving heat treatments such as, e.g. hardening, tempering, welding etc. The automobile trade is made up of car repair garages, car dealers and mixed services. The main field of activity for the repair garages is motor mechanics followed by bodywork and paintwork. There are office and sales rooms on top of this. Electricity in these companies is mainly used for lighting, powering pumps and equipment as well as for compressed air for the repair and service areas. Wood and wood products covers the manufacturing of furniture (three quarters of those surveyed) and building components (11%), each with relatively little energy-intensive equipment; the other businesses are sawmills. Suction systems represent the biggest power consumers in carpentry/joinery with a share of approx. 40% in the total electricity consumption. In the paper and printing trade, the small enterprises comprise printers, bookbinders, copy services. Electricity is mainly used for printing machines followed by cutting, folding and stitching. Digital printing machines, compressed air, lighting, air conditioning and operating systems in standby-mode are also relevant.

Alongside offices, *wholesale and retail trade* is the largest branch in the tertiary sector with more than 5.5 million workers. There is a significant difference in energy consumption between food and non-food lines of business. The food trade has a high demand for refrigeration and freezing. But space heating demand is also a main energy consumer. Lighting represents a large factor in trade on the electricity side. The air conditioning of salesrooms also has a noticeable impact in food retailers. Although the number of retail trade businesses is declining as a result of the concentration process, the sales areas have been increasing for years which will probably influence energy consumption. Since the last survey, shop opening hours in Germany have increased slightly from Mondays to Fridays and significantly on Saturdays (21% more than eight hours compared to 8% previously). More and more grocers and food stores have areas where baked products and small snacks are served, which are equipped with ovens to bake or heat bread, meat and processed meat products. 24% of the businesses questioned have one or several ovens of this type. The energy demand of modern cash registers is also not negligible.

Hospitals, schools and public baths vary greatly with regard to energy and should therefore be regarded separately. Since the specific energy consumption based on the number of employees is limited in its meaningfulness in this sector, more suitable reference units – the number of beds, number of pupils/students and water volume - were used here. Hospitals are characterized by high space and process heat demand. The latter is particularly relevant if the hospital runs its own laundry. Apart from lighting, electricity is required mainly for ventilation and air conditioning. Schools are a very heterogeneous group ranging from kindergartens right up to universities. Space heating demand dominates the energy consumption here. Electricity is mainly used for lighting. The main distinction with regard to public baths is between indoor swimming pools and outdoor ones. "Leisure pools" represent a combination of the two which is becoming more common. A large share of the energy consumption in public baths is for the process heat used to heat the water, but also for space heating in indoor pools. Modern public baths are equipped with very complex building technology, mainly for ventilation, electrical engineering and pool technology which causes considerable electricity consumption. In addition, pools are also increasingly equipped with additional installations which are energy-intensive such as saunas, solariums, wellness and health-related areas, fitness rooms, restaurants etc.

The *hotel and restaurant* sector consists of catering and accommodation. It is true that, as a service sector, there are businesses of every size in the tertiary sector, but this area is dominated by small to very small enterprises. Space heating and thus fuel consumption is the most important in both sectors from the viewpoint of energy consumption. The second largest energy consumer after space heating is process heat for kitchens, mainly for cooking food, but also for heating food and keeping it warm, preheating and cleaning dishes. Electricity is also used mainly for cooking, followed by refrigerators/freezers, then for dishwashing, laundry and lighting. Refrigerators and freezers are becoming more significant because of the growing use of frozen products due to a greater flexibility. Lighting also plays a relatively important role for energy consumption.

Bakers and butchers are the main lines of business in the tertiary sector belonging to the food industry. Baking ovens have the biggest energy consumption in bakers. In the bakers covered here, which tend to be quite small enterprises, mostly discontinuous processes are used, e.g. rack ovens or deck ovens. Today outlets and production facilities including a retail outlet often have an electric oven directly in the salesroom to finish baking pre-produced raw pastries and rolls. Electricity is additionally used mainly for cooling devices. Comparatively low shares of electricity are accounted for by power applications (machines, e.g. to sieve, mix, knead and stir, as well as ventilation), lighting and hot water production. In butchers, the main consumption of energy is for producing sausages and processed meat products. Various heating processes are carried out in large cooking boilers and combi-ovens. Making raw sausages is done in maturing chambers and smokehouses. Production plants are mostly fuel-heated, fewer use electricity. The main electricity share is due to heating water, refrigerating and freezing. Electricity consumption for refrigeration and freezing is on the increase because more and more refrigerated and frozen products are being used or sold.

The group of *laundries* covers the entire textile cleaning industry, i.e. laundries, dry cleaners, textile rental services, dyeing works, ironing and rotary iron services. This is a comparatively energy-intensive sector. Energy is mainly used for heat processes: washing, drying, hot pressing/mangling, cleaning and ironing. The energy required for space heating is negligible. Due to the high demand for process heat, there is usually enough waste heat available to heat the production areas. Space heating is predominantly needed for separate rooms, e.g. sales, offices and canteens. The electricity demand comes from lighting to a lower extent, but is mainly due to the electric motors used to drive machines and provide ventilation.

Based on the number of workers, *agriculture* is quite an energy-intensive sector. This has to do with the low average number of employees per farm. The 116 agricultural enterprises questioned only have 3.4 workers on average, half of them actually only have one or two workers. Livestock farming has the biggest energy demand. Crop farming is not as energy-intensive with a few exceptions (grain drying), if the fuel consumption of farming vehicles is disregarded. The main electricity applications are power processes, mainly the ventilation of animal pens in intensive livestock farming, as well as for cooling milk. Process heat is needed for radiant heaters when rearing chicks and piglets. In horticulture, especially those enterprises with heated under-glass areas are very energy-intensive. Fuels are used to heat greenhouses; electricity is needed for lighting, ventilation and heating small areas of plants as well as for controlling automatic ventilation and irrigation processes.

5.4. Barriers to improvement

The estimated energy demand of the service sector in 2010 in the EU27 is 6233015 PJ (1731393 GWH) and is expected to increase by almost 4% by 2020, when technologies with improved efficiency are expected to have been implemented in the energy market. Nevertheless, existing studies found multiple types of significant barriers to energy efficiency improvements, (Schleich, 2009). They are mainly caused by socio-economic framework conditions in the sector, but also market failures, transaction costs, or imperfect information as well as market barriers on the supply side. Especially public organisations and companies which are not profit-oriented are characterised by a high level of barriers. One of the main important barriers is the lack of information about the patterns of energy consumption. This is partially due to missing metering devices and partially to organisational deficiencies such as failing to clearly assign the responsibilities for energy management and energy costs. Transaction costs including the costs of collecting, assessing and applying information on energy savings potentials, investments and organisational measures, as well as the costs of negotiations with potential suppliers, consultants or installers are prohibitive. Another problem is the shared responsibility between different departments, e.g. operating and purchasing departments. There is also a lack of sufficient market structures and access to energy service companies, energy consultancies, energy agencies, etc. Finally the end-users, i.e. the employees who do not pay the energy costs, are not usually motivated to save energy.

The leading role of the public sector to implement and promote energy efficiency improvement Measures, as required under the Energy Services Directive, 2006/32/EC can affect the overall efficiency of the energy use in the European energy sector. Public sector (including hospitals and educational institutions) consumes almost 13% of the final energy consumed in the German service sector (Schlomann et al, 2006); in UK this figure raises up to 19% (UK National Statistics, 2010); in France, over 20% of the workforce is employed in public sector, the figure is estimated to be over 20% (Mairet and Decellas, 2009). These examples clearly demonstrate that improving energy efficiency in the public sector will have a significant effect in the overall energy consumption in the service sector. Thus, speeding up the refurbishment rate of approximately 1.5% p.a. to 3% in the public sector is a feasible target that can have immediate positive results and will set an example for the other stakeholders of the service sector in Europe.

5.5. Result – The evolution of the demand

Figure 5.10 presents the evolution of the energy demand in terms of end use, for the European service sector, according to the PRIMES scenario (European Commission DG-ENER, 2010)

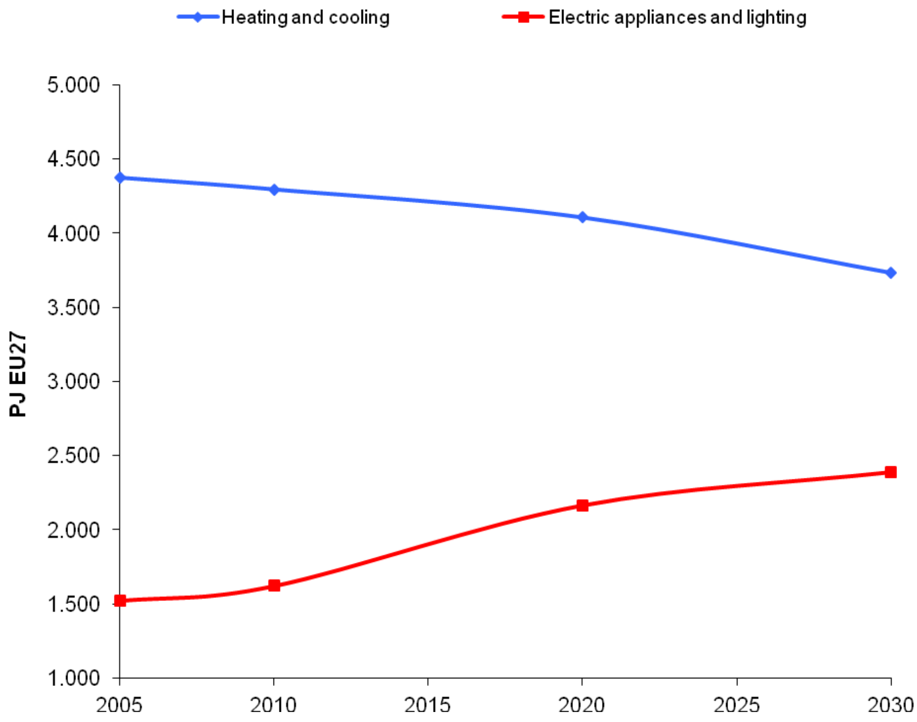

Figure 5.10: Evolution of the Energy consumption in the service sector by end use, in the EU27 group

The decrease in the demand for heating and cooling is mainly achieved by the construction of more energy efficient buildings and by the modification of the existing structures with energy saving measures (wall insulation, double glaze windows, window shades, etc.). This decrease does not translate to a decrease of the volume of the sector and this is shown by the increase in energy demand for electric appliances and lighting.

Figures 5.11 and 5.12 present the evolution of the energy demand separately for heating and cooling end uses. PRIMES model parameters for the evolution of the combined heating and cooling demand in the EU 27 were used to determine the evolution of heating and cooling separately. Results show that cooling demand in the EU 27 group is expected to grow with a pace of 0.85% p.a., whereas heating demand is expected to decrease annually by 1.57%. From the figures it can be conclude that the heating / cooling mix will shift from 66% heating and 34% cooling in 2005 it will end up to 52% heating and 48% cooling. This result together with the fact that currently almost all the individual cooling systems (i.e. excluding district cooling) are utilising electricity, demonstrates the need to shift to non electric cooling systems and more specifically district cooling networks, in order to tackle the increasing cooling demand while leveraging the electricity consumption of the sector.

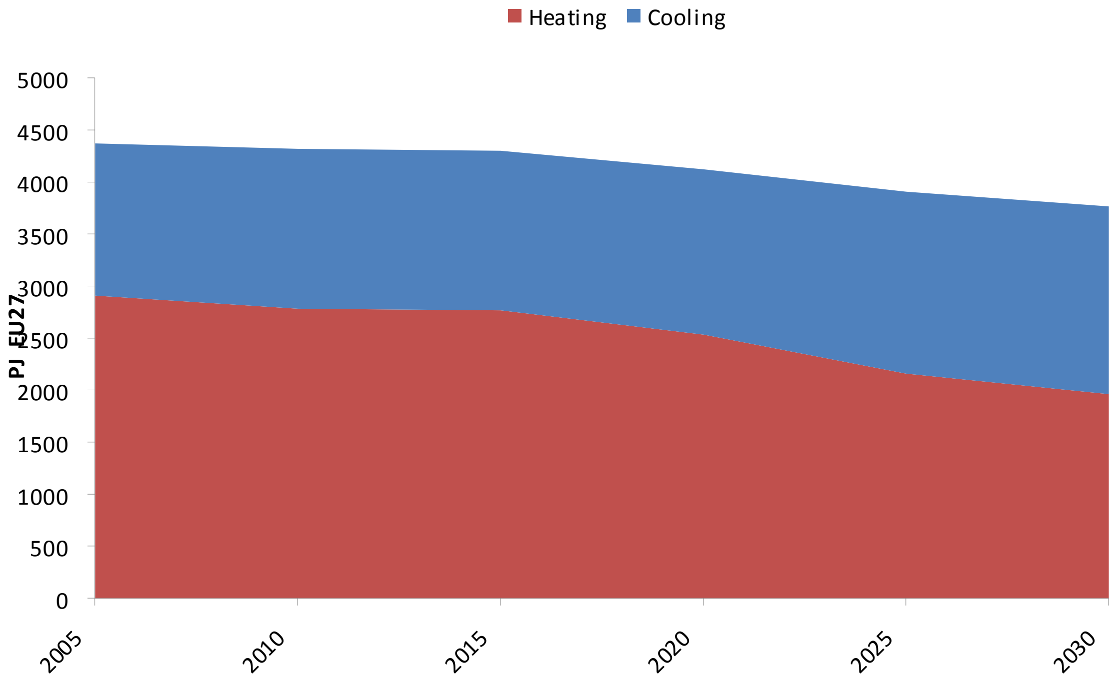

Figure 5.11: Evolution of heating and cooling demand in the EU27 service sector, based on the PRIMES model.

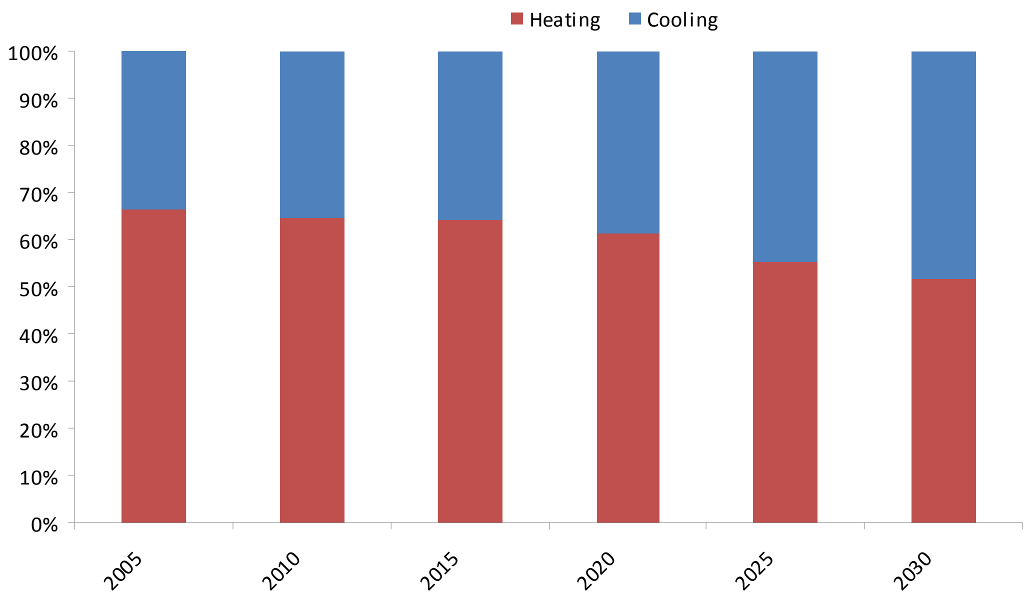

Figure 5.12: Evolution of the heating/cooling mix in the EU 27 service sector.

The evolution of the demand in the service sector is mainly affected by the sector growth in the specific country, which is translated to new office buildings and complexes, and in the efficiency improvement not only of the installed technology, but also because of the change in the policy of each company in terms of energy saving measures implemented (better insulation, motion sensor, automatic blinds and windows etc.). Figure 5.13 shows that within the EU27, three main service sector categories can be identified; one category includes the countries where the service sector is not only big but also mature (4a). Here we see a decrease in the energy consumption, primarily because the growth effect is small compared to the effect of retrofitting energy saving measures in the existing building stock. The next category is countries with intermediate sized service sector.

Some of the countries of this category are showing quite a noticeable in crease in their energy consumption (Romania, Slovakia, Czech Republic), which is a sign of the rapid growth of their services sector (4b). Finally, Figure 4c, represents the category of the small sized service sector countries, where again in some cases (Bulgaria) the increase in the energy demand shows the actual growth of the sector in the specific country.

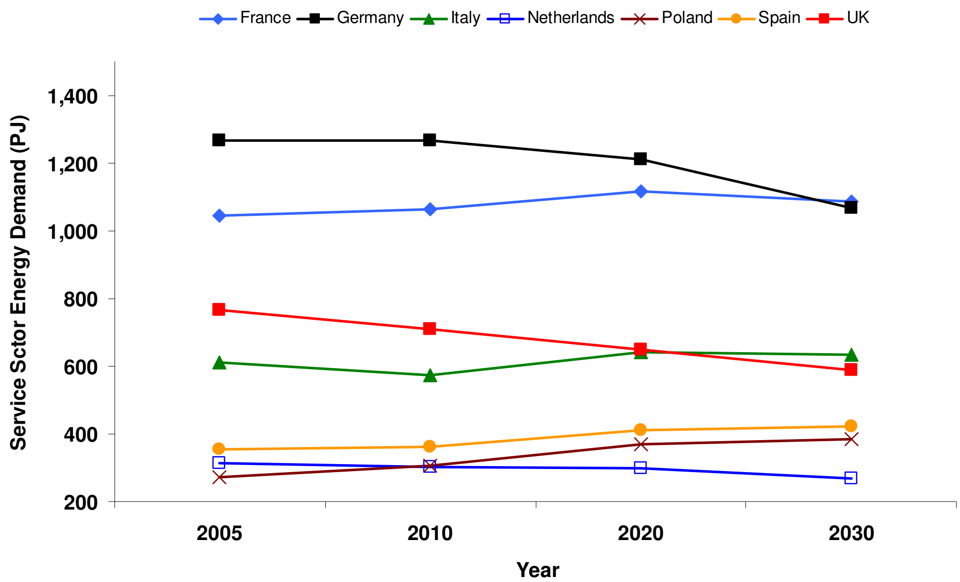

Figure 5.13a: Estimated useful heat demand in the service sector. Large-size residential sector

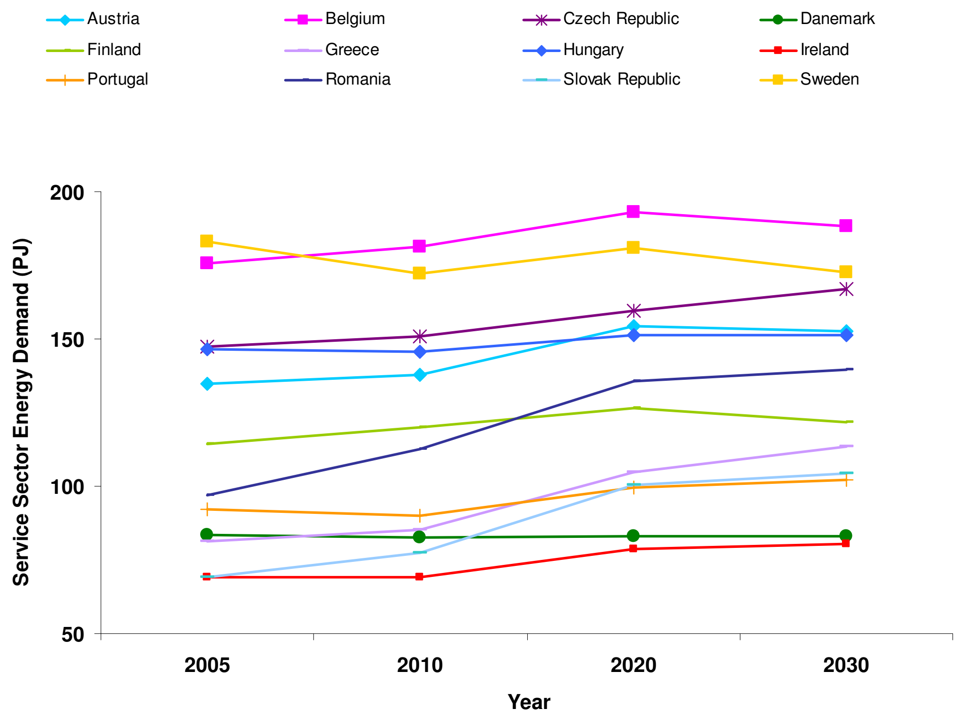

Figure 5.13b: Estimated useful heat demand in the service sector. Medium-size residential sector

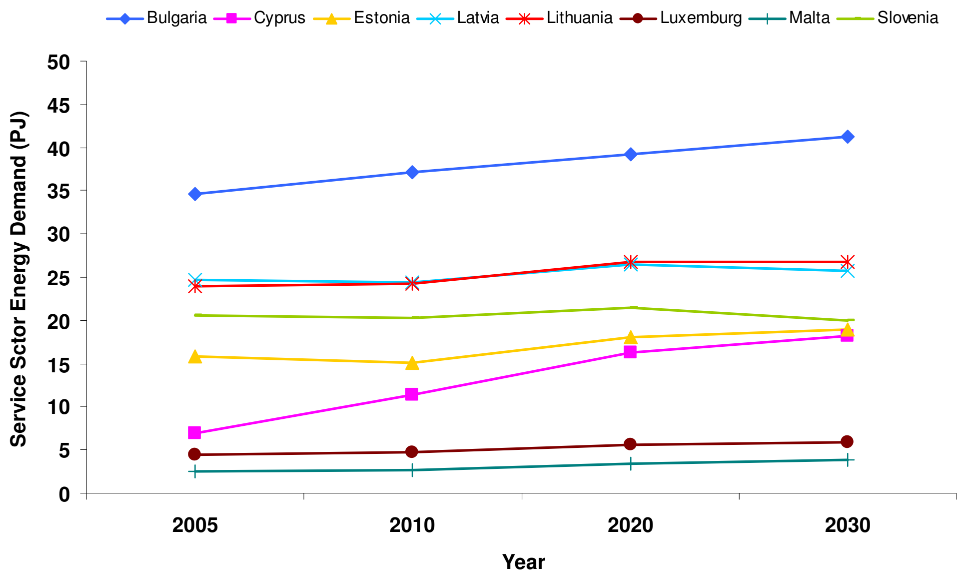

Figure 5.13c: Estimated useful heat demand in the service sector. Small-size residential sector

6. Conclusions

The objective of the report is to map the heat and cooling demand for the industrial, residential and service sector.

In the industrial sector, the estimated useful heat consumption for 2009 is 4434 PJ. The higher changes in the useful heat demand will take place in the high range of temperatures for the iron and steel industry and for the non-metallic mineral industry. However, there is a meaningful increase and decrease of the low and medium range of temperatures of the heat demand for the food, drink and tobacco industry and the pulp and paper industry, respectively.

In the residential sector, the estimated useful energy demand for space heating and for hot water is around 6766 PJ and 1555 PJ respectively. The estimated useful cooling demand is around 87 PJ which represents only 1% of the total demand. District heating covers around 8.7% of the useful energy demand for space heating and hot water in the EU in the residential sector. The differences among countries are very wide. It is possible to find cases where the contributions of the district heating to the demand does not take place as in Spain or cases where the weight of the district heating is relatively high as Denmark with a around 46%. The contribution of the district cooling is around the 4% all the total cooling demand in the EU27. For Spain, Italy and France, where cooling demand suppose around 68% of the total, the contribution of the district cooling only suppose around 0.03%, 2.4% and 0.02% respectively. The evolution of the demand in the residential sector is mainly affected by the sector growth in each country, which is translated to new buildings with better energy performances, and the refurbishment of old building with better insulated envelop and better technologies. In addition, changes in the building policy of the MS are a key point to promote of the measures to improve the energy efficiency of this sector. In general term, a reduction of the energy consumption takes place in all MS, although there some countries with a rapid growth as Ireland and Cyprus where construction sector suppose a high weight in their economies.

In the service sector, the estimated useful heating demand for space heating and for hot water is around 2284 PJ and 625 PJ, respectively. The estimated useful cooling demand is around 1350 PJ which represents only 30% of the total demand. District heating covers between 4.6% to 18% for space and water heating, with hospitals and sport and recreation facilities being at the high end of this margin, while in offices only 4.6% of the useful energy is covered. At the EU27 level, district heating energy is just above 7% of the useful energy if the sector, with the margin from 0% (7 countries) to above 64% (Denmark) at country level. For District cooling, the margin between the sub-sectors at EU 27 level is between 0.1% - 0.2% of the space cooling useful energy demand, and spans between 0% (16 countries) to 2.6% (Sweden), and finally at the EU27 level, is 0.23%. Similar to the residential sector, the evolution of the demand in the service sector is mainly affected by the sector growth in the specific country, which is translated to new office buildings and complexes, and in the efficiency improvement not only of the installed technology, but also because of the change in the policy of each company in terms of energy saving measures implemented (better insulation, motion sensor, automatic blinds and windows etc.). In the countries where the service sector is well developed a decrease in the energy consumption is observed. This is because the growth effect is small compared to the effect of retrofitting energy saving measures in the existing building stock, as in France or Germany. In the countries were the service sector is small or less mature, a rapid growth in the energy consumption takes place as in Romania or Slovakia

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Abstract

In order to fully understand the national potentials for cogeneration, it is essential to identify the existing and prospective demand of heat and cooling by sector. A study will be performed on a MS level to describe the demand of heat and cooling by different sectors (i.e. industrial, residential), demand types (different temperatures) and supply technologies.

This work aims to analyze the current situation and future trends of heat and cooling demand in the EU, as well as, the use and availability of industrial. Within each sector the demand will be presented for different segments. The focus is to map the demand of heat and cooling on temperature intervals possible to be supplied by district heating, district cooling or CHP. In order to capture the characteristics of heat, heat is split into different types; space heating, warm water, cooking, and industrial heat. For cooling, space cooling is the main type applicable to district cooling.

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