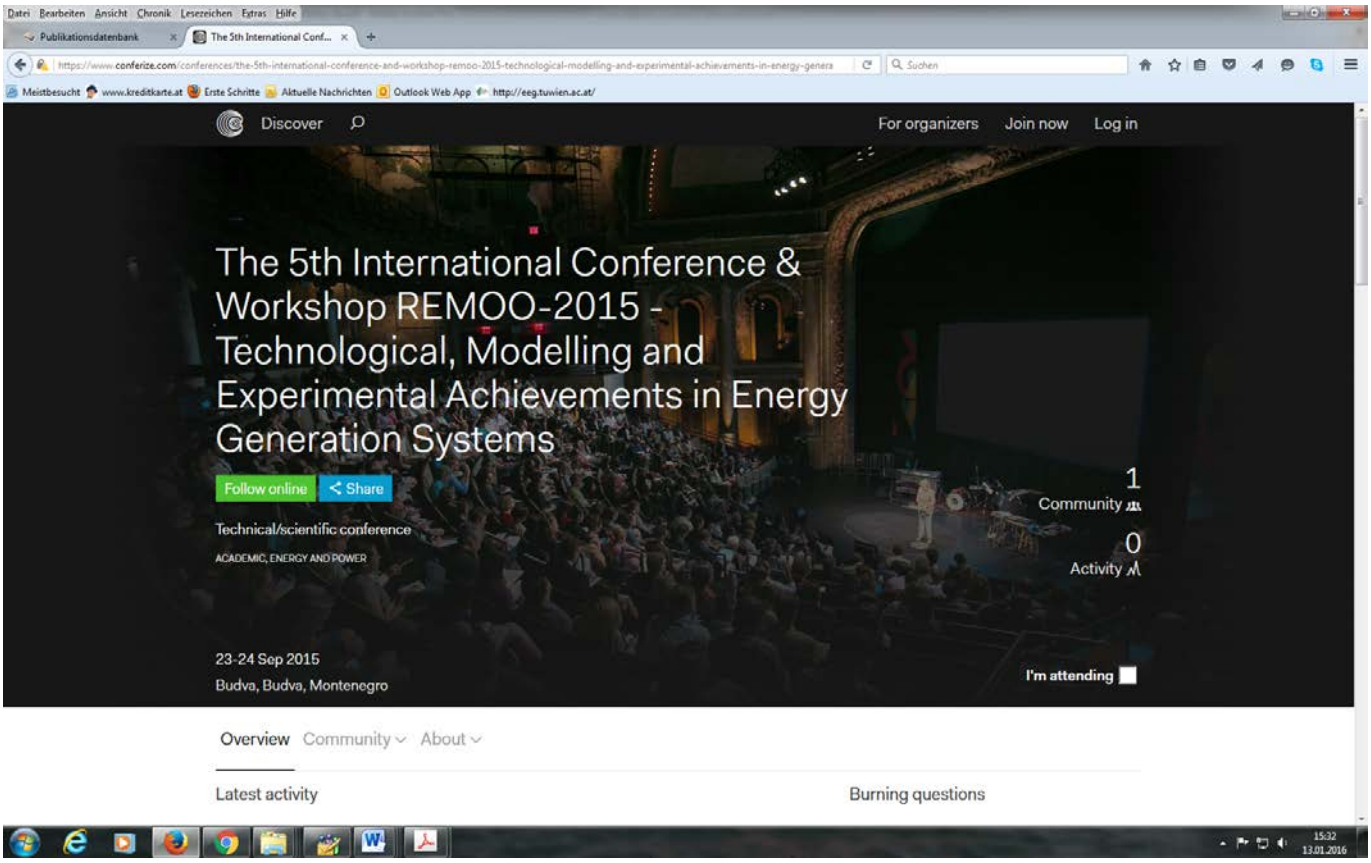
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ASSESSMENT OF THE SPACE HEATING AND COOLING MARKET IN THE EU28: A COMPARISON BETWEEN EU15 AND EU13 MEMBER STATES

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Abstract

The aim of this investigation is to fill in the knowledge gaps of the space heating and cooling market in Europe. While the space heating market is already well researched, there is a lack of information concerning air-conditioning. Following a bottom-up approach, data of the actual space heating and cooling market are collected and analysed. Next, air-conditioning market information was retrieved through a top-down approach and compared with bottom-up acquired data. Results indicate the energy consumption for space cooling in the EU28 to be almost 70 TWh/y, while the European Commission underestimates this value by approximately 60-70%. According to the findings from the bottom-up approach, the ratio between total potential and existing energy consumption is around 9:1 for air-conditioning and almost 1:1 for space heating. The EU15 is responsible for practically the entire space cooling consumption (~93%) of the EU28, with about 63 of the total 68 TWh/y. In contrast, the whole potential of recent member states comes out to be enormous, around four times its present energy consumption for air-conditioning. The space heating market is almost fully saturated, whilst the space cooling market in Europe is characterized by a high potential for growth, especially in households.

Keywords

Space heating, air-conditioning, potential, market, Europe

1 Introduction

By 2020, the EU is aiming to decrease greenhouse gas emissions to 20% below 1990 levels. The energy produced by renewable energy sources (RES) is expected to be 20%. Additionally, a 20% upgrade of energy efficiency is foreseen [1].

The primary energy consumption in Europe amounts to around 1800 Mtoe/y in 2010. This is mainly caused by different types of heating and cooling applications (almost 900 Mtoe/y, not only related to building´ space heating and cooling but also industrial heat), followed by transportation and electricity with about 540 and 360 Mtoe/y respectively. Buildings account for around 720 Mtoe/y. The majority of energy consumption within the European building stock is attributed to space heating (SH) and space cooling (SC) purposes [2-7].

In recent years, the 28 EU member states invested a lot to quantify the energy consumption of the different sectors [8-11]. However, almost no data is available for the air-conditioning (AC) part. A proper investigation to determine this type of information has not been carried out yet.

The majority of the data collection focused on the experience of preceding investigations. Especially, the "ARMINES - Mines de Paris/Mines Paristech Graduate School" was involved in a number of publications and projects to investigate the present topic, such as the EECCAC (Energy Efficiency and Certification of Central Air Conditioners) report [12]. A number of other relevant sources were used: the Intelligent Energy Europe project SOLAIR (Solar Air-Conditioning), the Sixth Framework Programme project POLYSMART (Polygeneration with advanced small and medium scale thermally driven air-conditioning and refrigeration technology) and the International Energy Agency project ANNEX 34 (Thermally Driven Heat Pumps for Heating and Cooling) [13-15].

The indicated exemplary data sources provide information for SH, SC and domestic hot water (DHW) preparation, related energy demand and consumption values and market figures within Europe. However, a clear picture of the AC market in the EU is missing.

Domestic hot water preparation issues have been treated as well, because their needs are covered by the same kind of equipment as SH.

Through a bottom-up approach, SH, SC and DHW preparation demand and consumption data has been analysed in the residential and service sectors of the EU15 and the remaining EU13 member states. Additionally, following a top-down approach, the EU28 AC consumption has been investigated and set against the respective bottom-up approach´s results.

Principal complications faced during this study are: the fact that the terms energy demand and consumption are erroneously used interchangeably and only laboriously obtainable data are available for the European SC market.

Chapter 2 explains in detail the information collection and analysis processes used. In chapter 3, the energy demand and consumption in the residential and service sectors has been subdivided into the SH, AC and DHW preparation categories. Due to the disparate information availability between the EU15 and EU13 nations, these two agglomerations has been analysed separately in a first step: within section 3.1 and 3.2 respectively. Comparison, discussion and conclusions regarding energy consumption for all three fields (SH, SC and DHW preparation) of the EU28 residential and service sectors are provided as well in chapter 4.

2 Methodology

The data regarding specific energy demand and consumption for SH, AC and DHW preparation (kWh/m² y) was collected, divided by member states (EU28) and ordered within the households and service sectors. Energy for appliances was excluded by the survey (e.g. cooking).

Concerning the collected information, it is important to distinguish between energy demand and consumption. The energy demand is the net energy requirement to cover SH and SC needs. In contrast, the energy consumption represents the energy input at the devices required to satisfy the demand. As such, the two quantities differ by disparate conversion factors [16]. Therefore, concerning SH and DHW preparation, because the efficiency of boilers is < 1 (0.8-0.9 for currently installed technologies in Europe), the energy consumption data is higher than the energy demand.

The energy efficiency ratio (EER) for electrically driven SC equipment is > 1 (around 2-3 for currently installed technologies within the EU). Because of that, the energy consumption for AC is lower than the SC demand [17]. It has to be mentioned that only the comparison of SH and SC demand is correct, while electricity consumption (in heat pumps and air-conditioners) can only be fairly compared with fuel consumption (e.g. gas in a gas boiler) if an adequate conversion into primary energy terms is performed. This is because the two energy carriers have a different content of grey

energy when employed by the final consumption. The primary energy (usually expressed in terms kWh or toe) accounts for the consumption of fossil resources, providing a basis for clear comparison of different energy carriers.

The heated and cooled floor area, as well as the whole floor area in the residential and service sectors, was identified for the different EU member states.

In the case of graphs shown with a unit of kWh/m² y (figures 1, 3, 6 and 8) the average line is obtained by weighting the mean of the single nations´ energy demand and consumption on the heated or cooled floor area of the respective country. In the case of DHW preparation the entire floor area is taken into consideration (figures 1 and 6).

In the charts shown with a unit of kWh/inhabitant y (figures 2 and 7), the average line is obtained simply by calculating the mean of the energy demand and consumption values for the different EU15 and EU13 countries. The following values with a unit of kWh/inhabitant y (residential sector) or kWh/employee y (service sector) mainly indicate the specific energy use habits of the inhabitants or employees in the various EU15 and EU13 member states.

The columns given in kWh/inhabitant y have been calculated by dividing the energy demand or consumption per application type (SH, SC or DHW preparation) in TWh/y by their respective amount of occupants within the households sector (figures 2 and 7).

In figures 4, 5, 9 and 10, the columns of total SH and SC per country in TWh/y have been obtained by multiplying the average energy demand and consumption per country in kWh/m² y with the respective heated or cooled floor area in million square meter (Mm²). These show the related distribution of the energy demand and consumption among the EU15 and EU13 nations. The potential SH and SC demand as well as consumption were identified using the same calculations, with total floor area instead of conditioned floor area. Therefore, the technical potential has been calculated.

Following values regarding DHW preparation demand and consumption per member state in TWh/y have been calculated by multiplying the average DHW preparation demand and consumption per country in kWh/m² y with the respective entire households or service sector floor area of each country in Mm².

For the SH and DHW preparation part, sufficient information is available, whilst there is a lack of data concerning SC. On the other hand, information with regard to the energy consumption for AC in the EU is difficult to collect. At the moment, a huge amount of data concerning the AC market in Europe is based on estimations [18-20].

Not all collected information has been used to form the statistics. Data which lie outside a range of plus or minus one standard deviation around the average of the respective data pool have been discarded. Due to the impossibility of creating complete energy statistics by collecting climate corrected information, this type of data has been excluded by the investigation. Values characterized by a reference year more than a decade ago have not been taken into consideration. Specifically, the data used to create the following figures and tables covers the period of 2005-2015.

In the following statistical figures, with a unit of kWh/m² y, the numbers straight over the top of the columns indicate the amount of information utilized to calculate the values for each column, the error bars show their standard deviation and the percentages above their coefficient of variation (CV). In the case of charts with a unit of TWh/y, the percentages at the top of the columns indicate the CV of the data used to form the respective columns and the error bars represent their standard deviation.

Within chapter 4 of the present investigation, solely energy consumption and not energy demand was considered. Main reason for this is the shortage of energy demand information for the EU13, making it impossible to compare the EU15 and EU13 member states. For the EU13 countries solely

energy consumption and not energy demand was utilized. All available energy consumption data is considered and in the case, only energy demand values are available, these have been transformed into energy consumption. Space heating and DHW preparation demand information was transformed into energy consumption by dividing with a value of 0.85 (average efficiency of currently installed boilers within the EU = 0.85) [17]. Space cooling demand data was transformed into AC consumption by dividing with a value of 2.7 (actual average seasonal energy efficiency ratio in Europe = 2.7) [12], [20-24].

The seasonal energy efficiency ratio (SEER), not EER, was used for this calculation, because it reflects the real consumption conditions of the AC equipment for the SC season over a year. In contrast, the EER is measured under rated load conditions [12], [25-31]. The SEER indicates the whole heat amount removed (Q) from the conditioned space during the entire annual AC season, divided by the entire work input (W - electricity) of the SC machinery during the same season [25]. See Eq. (1).

$$SEER = Q_{cold,\ season}/W_{electricity,\ season} \quad (1)$$

Due to the aforementioned shortage of information, the whole energy consumption indication, given in TWh/y, for the EU28 service sector includes solely offices for the EU13. However, EU office buildings have the highest entire SC energy consumption ratio of the European building stock [32-34]. With regard to the EU13 nations, no calculations with a unit of kWh/employee y were performed, because it is not meaningful to determine the habits of the work active population per EU13 member state, while considering only the offices instead of the whole service sector. If the whole energy indication of the various EU15 and EU13 sector could not be calculated, due to a lack of data (e.g. entire SH consumption of the EU13 office sector), related values were excluded from final calculations.

3 Results

3.1 Space heating, space cooling and domestic hot water preparation demand and consumption of the residential and service sectors (EU15)

Figure 1 shows the relation between SH and DHW preparation demand of the residential sector in kWh/m² y between the different EU15 nations.

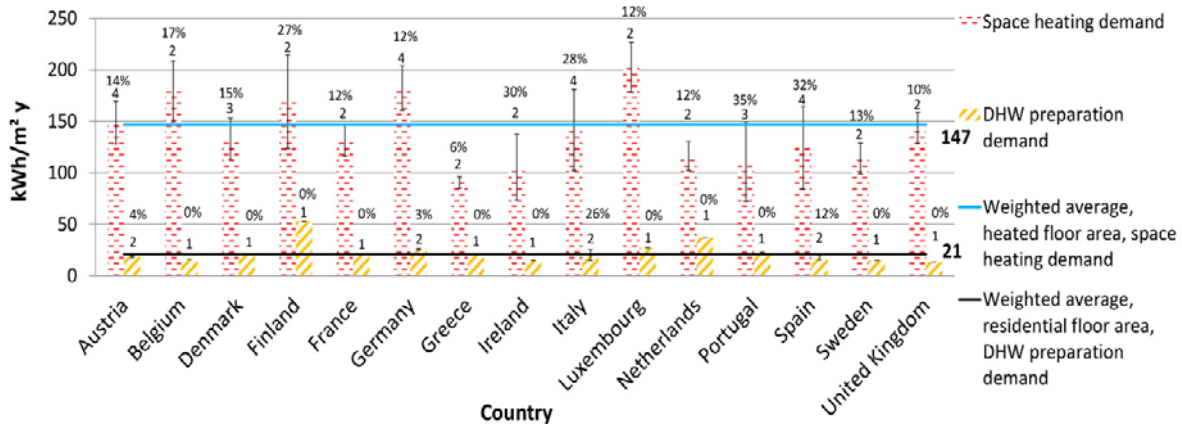

Figure 1: Space heating and domestic hot water preparation demand per country, residential sector, kWh/m² y [4], [12-15], [26-29], [35-37]

The average demand for SH and DHW preparation in the residential sector, comes out to be about 147 and 21 kWh/m² y respectively. This results in a proportion of about 7:1. The respective SH consumption appears to be just slightly higher: 156 kWh/m² y.

Figure 1 shows a certain homogeneity regarding the SH demand per country. Member states with colder climates demonstrate more SH demand than nations with warmer climates. Of all states, Luxembourg has the highest value. It also is characterized by low energy prices and the highest purchasing power per person [38-39]. The CV percentages shown in Figure 1 demonstrate that the selected data to form the bars are rather similar. The average value is around 18%.

Regarding the DHW preparation, Finland returns the highest number (53 kWh/m² y). The Netherlands also shows a huge value (37 kWh/m² y). One possible explanation for the high energy demand by the Dutch, is a high utilization of electricity for DHW preparation [40].

Analysing the data published within the past decade shows a reduction in specific residential SH and DHW preparation for all EU15 countries. The same applies to respective data within the service sector of the old EU member states.

The energy demand for SH in the residential sector of the EU15 is around 1863 TWh/y. In comparison, the energy demand for DHW preparation of the same sector is about 331 TWh/y. Hence, a relation of approximately 6:1 emerges.

If the energy use habits of the different EU15 citizens are compared concerning the SH and DHW preparation demand, an even wider gap results. See Figure 2.

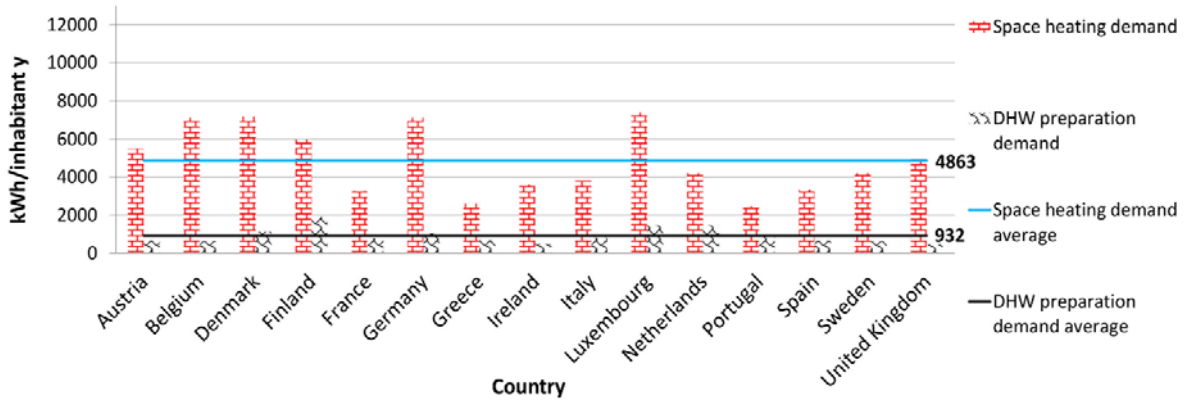

Figure 2: Space heating and domestic hot water preparation demand per country, residential sector, kWh/inhabitant y [4], [12-15], [26-29], [35-37]

The mean value concerning the energy demand for SH in the residential sector is about 4863 kWh/inhabitant y. If this value is compared to the average number of the energy demand for DHW preparation of the residential sector (~932 kWh/inhabitant y), the number for SH is more than five times higher than that for DHW preparation.

The highest SH demand value in Figure 2 is again given by Luxembourg. Moreover, the bar for France appears relatively smaller in Figure 2 compared to Figure 1 for the same kind of application. French dwellings are typically smaller than the EU15 mean; France has about 89 m² average floor area per apartment and the EU15 mean per living unit is around 93 m² [41].

The respective value within the service sector amounts to approximately 4120 kWh/employee y. If this number is compared with the corresponding average value of the residential sector a reduction of ~15% in the service sector is recognizable.

The focus goes to the comparison between SH and SC demand in kWh/m² y. See Figure 3.

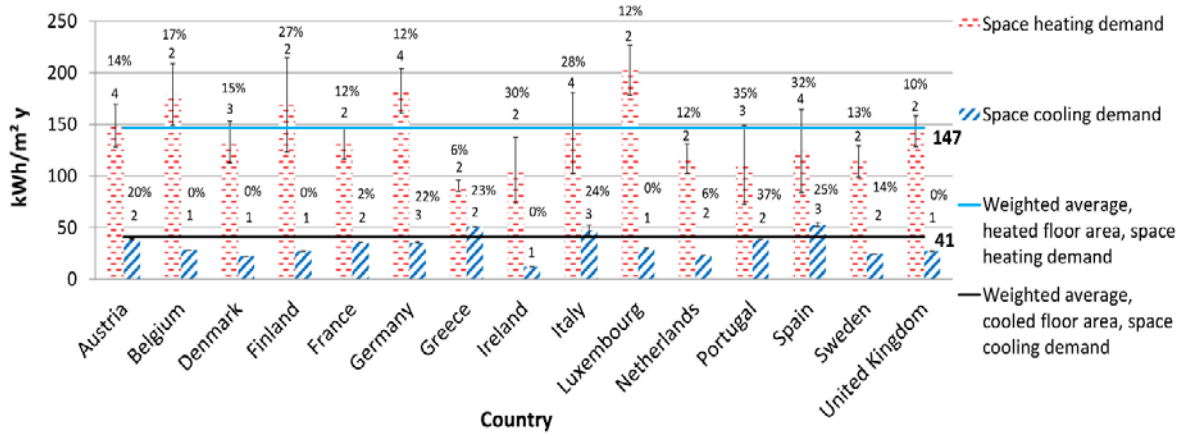

Figure 3: Space heating and cooling demand per country, residential sector, kWh/m² y [4], [12-15], [26-29], [35-46]

The SH and SC demand of the residential sector, results to be 147 and 41 kWh/m² y respectively. The resulting proportion is around 3.5:1.

In comparison to SH demand, the scenario for SC changes completely. The countries located in warmer regions of the EU15, show a higher demand for SC application and the other way around.

Surprisingly Luxembourg, United Kingdom and Belgium show relatively high values for AC application. These reach almost the number of France.

For SC demand, the average CV percentage is quite small, with an average of about 12%.

In contrast to SH, when analysing the different data published within the past ten years, an increase in the residential specific AC demand is evident in all EU15 countries. This also applies to the values for the tertiary sector within Western Europe.

If the SH and SC demand of the residential sector are compared between the different EU15 member states, with a unit of TWh/y, an even larger proportion between these emerges ~78:1 (about 1863 TWh/y of SH demand and around 24 TWh/y for SC).

If the energy use habits of the different EU15 citizens are compared regarding the SH and SC demand again a wide gap results.

Compared to the average value of SH demand purposes in the residential sector (about 4844 kWh/inhabitant y) the respective energy demand for AC is around 93 times lower.

The focus goes to a comparison between the SH and potential SH demand and SC and potential SC demand per member state in the residential sector of the EU15, with a unit of TWh/y. See Figure 4 and 5.

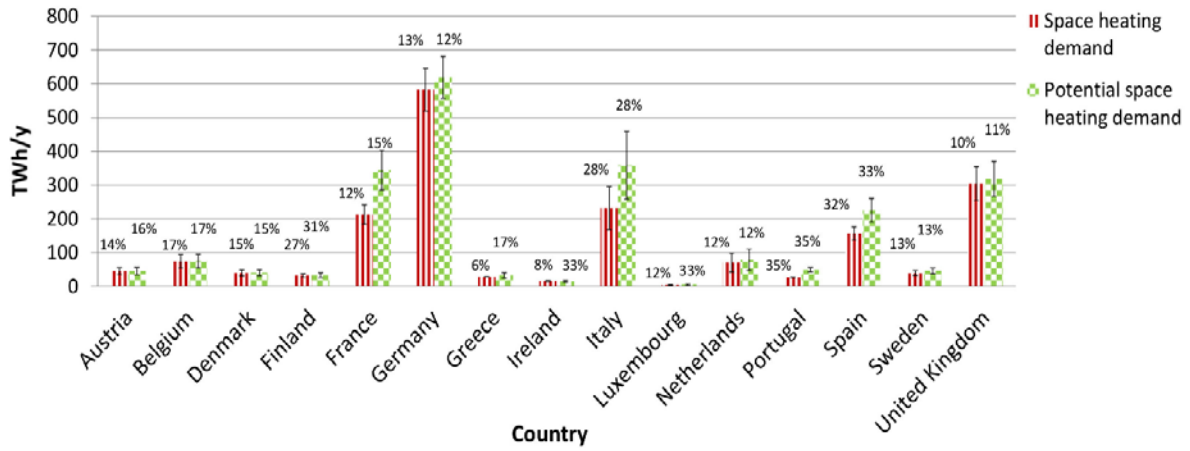

Figure 4: Space heating and potential space heating demand per country, residential sector, TWh/y (as not visible in the graph above: space heating demand and potential space heating demand of Luxembourg = 4 and 6 TWh/y respectively) [4], [12-15], [26-29], [35-37]

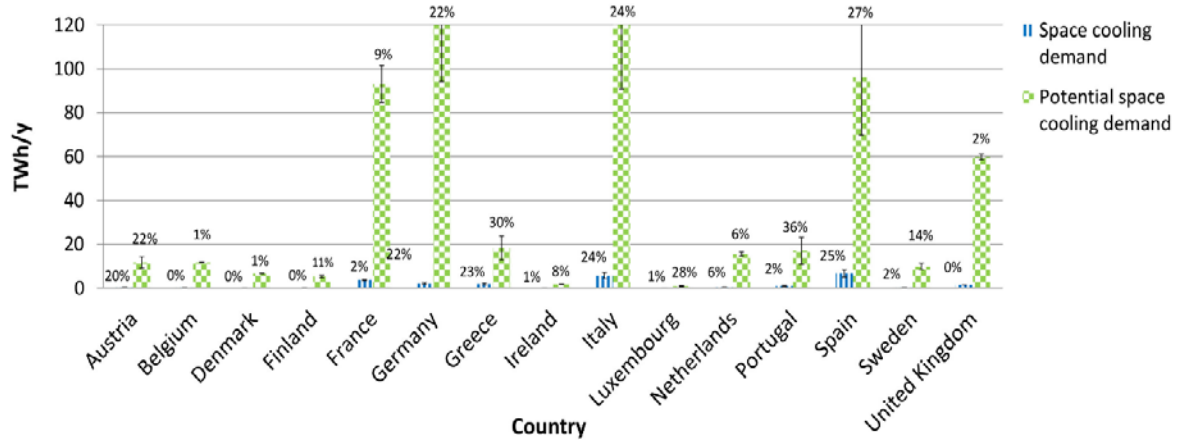

Figure 5: Space cooling and potential space cooling demand per country, residential sector, TWh/y (as not visible in the graph above: space cooling demand of Austria, Belgium, Denmark, Finland, Ireland, Luxembourg, Netherlands, Portugal and Sweden = 0.3, 0.3, 0.1, 0.2, 0.05, 0.006, 0.4, 0.9 and 0.2 TWh/y respectively; potential space cooling demand of Germany and Italy: 120 TWh/y both) [4], [12-15], [35-37]

If the differences between the energy demand and potential energy demand are compared in the two graphs above, the mismatch results to be higher at the AC sector: 422 TWh/y for the SH and 563 TWh/y for the SC sector.

Especially the proportion between the total SC and entire potential SC demand is much larger than the related SH indications: around 1:1.23 for the SH and 1:24 for the SC sector.

If the same comparison is carried out for the service sector, the difference results to be higher at the SC sector again: for around 299 TWh/y. Especially the proportion between the whole AC and entire potential SC demand in the service sector is much larger than at the SH sector, about three times more.

Hence, in total (residential and service sector) the potential AC demand results to be higher than the potential SH demand in the same sector for a value around 440 TWh/y.

The whole energy demand (residential and service sector) of the total SH, SC and DHW preparation has to be taken into account as well. The highest position is held by SH with approximately 2514 TWh/y, followed by DHW preparation with around 331 TWh/y and AC with about 149 TWh/y. Thus, the SH is almost eight times larger than the DHW preparation and nearly 17 times higher than the SC portion.

As already mentioned above, the SC sector shows the largest whole energy demand potential of these.

Tables 1 and 2 summarize and complete the actual and potential values of energy demand and consumption for SH, AC and DHW preparation in the residential and service sectors of the EU15.

Table 1: Space heating, space cooling and domestic hot water demand and consumption, bottom-up approach, actual values, residential and service sectors (EU15), TWh/y [4], [12-15], [35-37]

Bottom-up approach results, actual values (EU15), TWh/y				
	Residential sector		Service sector	
	Demand	Consumption	Demand	Consumption
Space heating	1863	1982	651	NA
Space cooling	24	17	125	NA
Domestic hot water preparation	331	409	NA	NA

Table 2: Space heating, space cooling and domestic hot water demand and consumption, bottom-up approach, potential values, residential and service sectors (EU15), TWh/y [4], [12-15], [35-37]

Bottom-up approach results, potential values (EU15), TWh/y				
	Residential sector		Service sector	
	Demand	Consumption	Demand	NA
Space heating	2285	2421	651	NA
Space cooling	587	425	424	NA
Domestic hot water preparation	331	409	NA	NA

Like shown in Table 1 and 2, the potential of the EU15 member states is enormous, exceeding its present energy demand for AC applications by seven times. The ratio between the potential and present energy demand in the residential sector is more than 20 times that ratio for the service sector.

3.2 Space heating, space cooling and domestic hot water preparation demand and consumption of the residential and office sectors (EU13)

Figure 6 shows the relation between SH and DHW preparation consumption of the residential sector in kWh/m² y between the different EU13 nations.

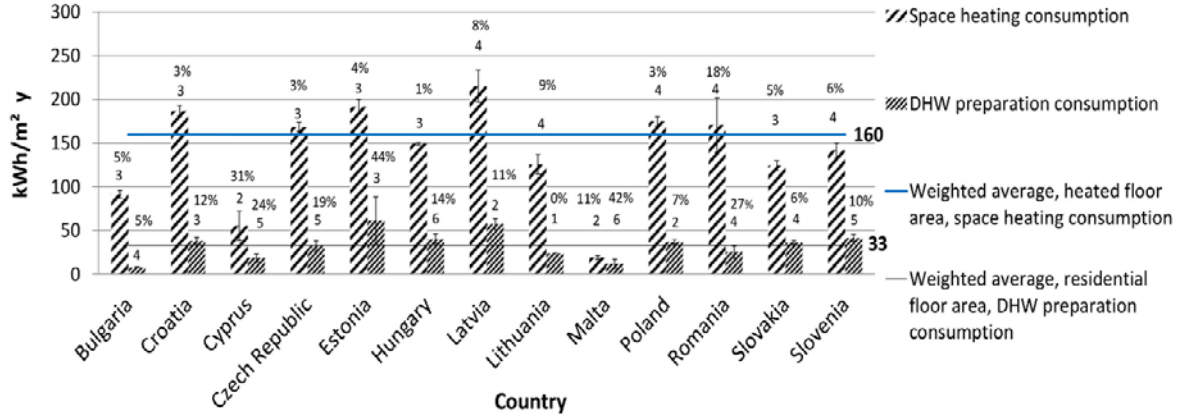

Figure 6: Space heating and domestic hot water preparation consumption per country, residential sector, kWh/m² y [4], [11-15], [37]

The mean consumption for SH and DHW preparation purposes in the residential sector, results in about 160 and 33 kWh/m² y respectively. This is a proportion of about 5:1.

With regard to SH consumption in Figure 6, again a certain homogeneity per country is given. Furthermore, the countries in warmer climates clearly show lower SH consumption values.

The highest value for SH consumption is given by Latvia, and the lowest one by Malta with approximately 215 and 19 kWh/m² y respectively. Possible reasons for Latvia´s high value include cold climatic conditions, and the deterioration of its building stock [47-48]. Moreover, Malta´s low value is a result of its warm climate [21], [47-51].

From the average CV percentage shown for SH consumption in Figure 6, it is visible that the selected data to form these bars is very similar. The average CV is around 9%.

As was already the case for the EU15, the specific SH and DHW preparation consumption data in the residential sector show a reduction for all EU13 counties during the past decade. The same applies to respective data within the service sector within the new European member states.

As already mentioned, the energy consumption for SH in the households sector of the EU13 is around 438 TWh/y. In comparison to that, the energy consumption for DHW preparation of the same sector is almost 92 TWh/y. Hence, the relation between SH and DHW preparation is approximately 5:1 again.

If the energy use habits of the different EU13 citizens are compared regarding the SH and DHW preparation consumption, once more a wide gap emerges. See Figure 7.

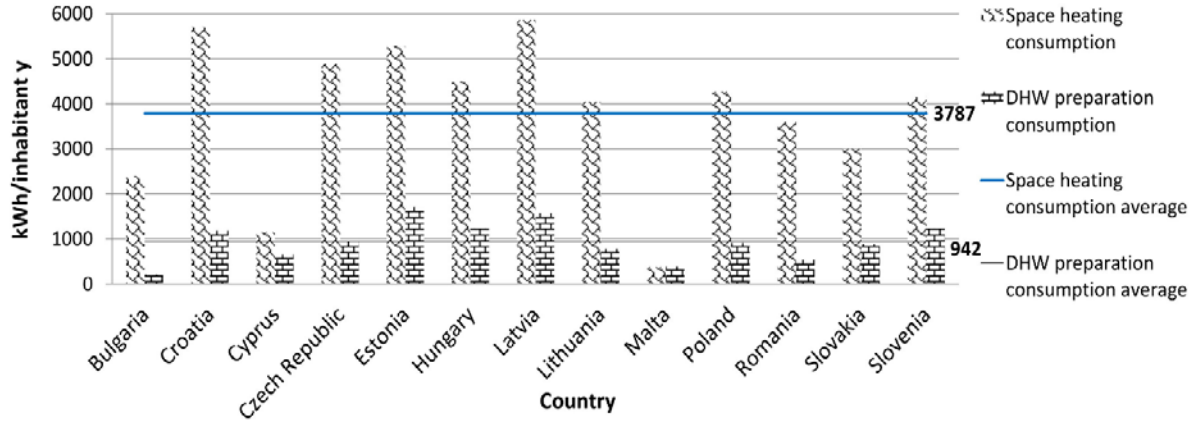

Figure 7: Space heating and domestic hot water preparation consumption per country, residential sector, kWh/inhabitant y [4], [11-15], [37]

The average value concerning the energy consumption for SH in the residential sector of the EU13 member states is about 3787 kWh/inhabitant y. If this value is compared to the mean value of the energy consumption for DHW preparation consumption of the same sector (~942 kWh/inhabitant y), the number for SH is more than four times larger than that one for DHW preparation.

Attention now turns to the comparison between SH and SC consumption in kWh/m² y. See Figure 8.

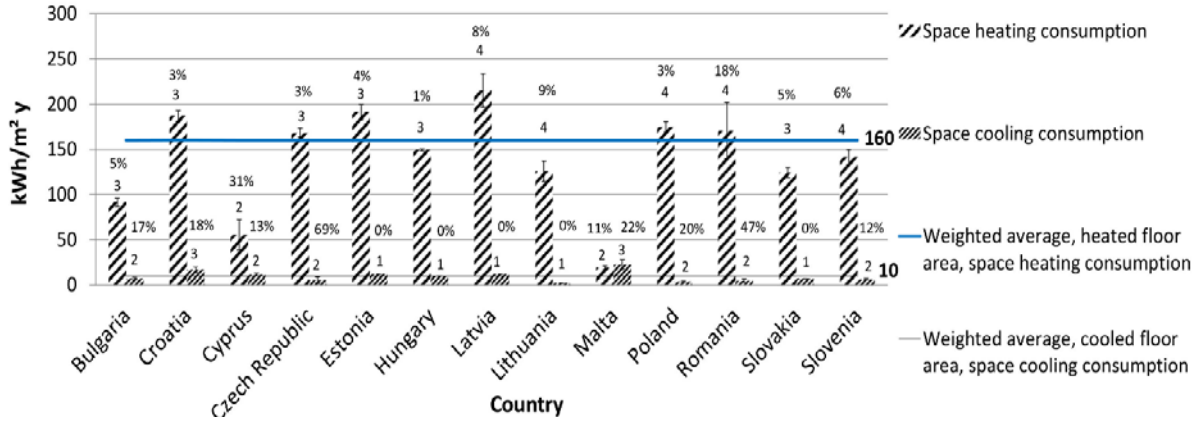

Figure 8: Space heating and cooling consumption per country, residential sector, kWh/m² y (as not visible in the graph above: space cooling consumption of Lithuania = 0.4 kWh/m² y) [4], [11-15], [21], [27], [37]

The average SH and SC consumption of the residential sector, results to be 160 and 10 kWh/m² y respectively. The resulting proportion is enormous: ~16 to 1.

The situation for SC is completely different than the scenario for the SH consumption. The countries in warmer climates show higher SC consumption, and the countries in cooler climates demonstrate lower SC consumption. There are three exceptions: Estonia, Latvia and Hungary. Those three EU13 member states are located in rather cold climatic zones of Europe, and show SC values exceeding the respective weighted average given in Figure 8 [49-50].

In the case of SC consumption, the average CV percentage is quite small, with an average of 15%.

Like seen in the EU15, the specific SC consumption data in the residential sector of the EU13 member states registers an increase over the past ten years. This statement is also valid for the respective information concerning the service sector of the new EU member states.

If the SH and SC consumption of the residential sector are compared between the different EU13 member states with a unit of TWh/y an even larger proportion between these emerges: 438:1 (about 438 TWh/y of SH consumption and around 1 TWh/y for SC).

If the energy use habits of the different EU13 citizens are compared regarding the entire SH and SC consumption again a wide gap comes out.

Compared to the mean value of SH consumption purposes in the residential sector (about 3787 kWh/inhabitant y) the energy consumption for AC in the residential sector in kWh/inhabitant y results to be around 51 times lower.

The focus goes to a comparison between the SH and potential SH consumption and SC and potential SC consumption per country in the households sector of the EU13, with a unit of TWh/y (Figure 9 and Figure 10).

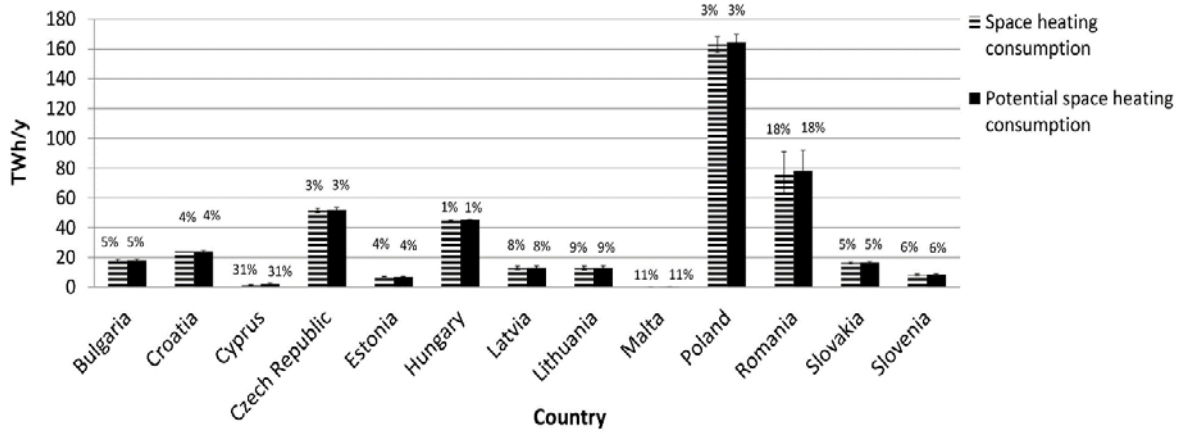

Figure 9: Space heating and potential space heating consumption per country, residential sector, TWh/y (as not visible in the graph above: space heating consumption and potential space heating consumption of Cyprus and Malta = 1.3, 0.2 and 2.2, 0.3 TWh/y respectively) [4], [11-15], [27]

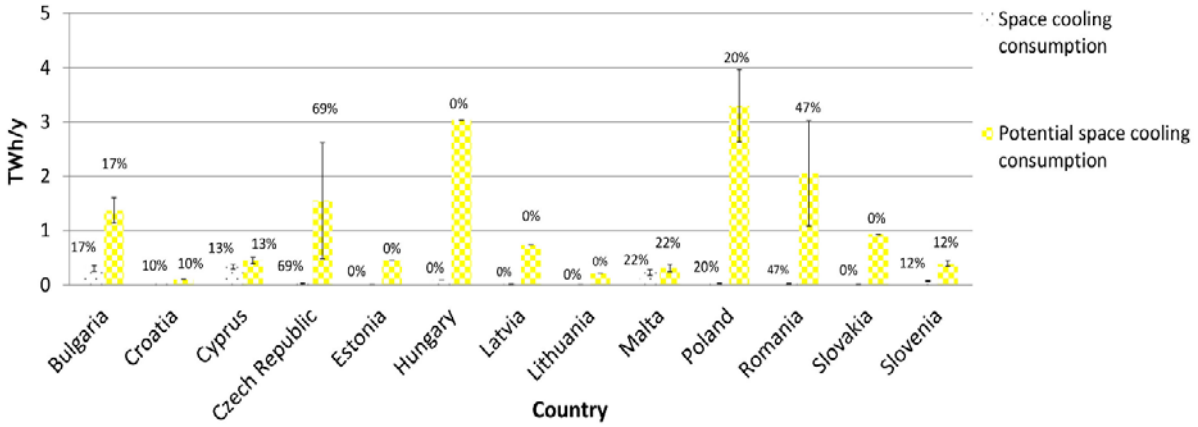

Figure 10: Space cooling and potential space cooling consumption per country, residential sector, TWh/y (as not visible in the graph above: space cooling consumption of Croatia, Czech Republic, Estonia, Latvia, Lithuania, Poland, Romania and Slovakia = 0.01, 0.02, 0.002, 0.01, 0.001, 0.002, 0.01 and 0.1, TWh/y respectively) [4], [11-15], [21], [27], [37]

If the difference between the energy consumption and potential energy consumption are compared in the two graphs above, the resulting mismatch is higher for the SC sector: 5 TWh/y for the SH and 14 TWh/y for the SC part.

Especially the proportion between the whole SC and total potential SC consumption is much larger than that one of the SH sector: around 1:1.01 for the SH and 1:15 for the SC sector.

Hence, the potential AC consumption of the residential sector within the EU13 results to be higher than the potential SH consumption in the same sector for a value of around 9 TWh/y.

The entire SH, SC and DHW preparation consumption in the residential and office sectors of the EU13 has to be taken into account too. The highest position is again kept by SH with approximately 438 TWh/y, followed by DHW preparation with around 92 TWh/y and AC with about 5 TWh/y. Thus, a relation of almost five times is given between SH and DHW preparation and almost 88 times between SH and SC.

As mentioned above, like it was already the case within the EU15, also here the SC sector shows the highest total energy consumption potential of these.

Tables 3 and 4 summarize and complete the actual and potential values of energy consumption for SH, AC and DHW preparation in the households and office sectors of the EU13.

Table 3: Space heating, space cooling and domestic hot water consumption, bottom-up approach, actual values, residential and office sectors (EU13), TWh/y [4], [11-15], [21], [27], [37-53]

Bottom-up approach results, actual values (EU13), TWh/y		
	Residential sector	Office sector
	Consumption	
Space heating	438	NA
Space cooling	1	4
Domestic hot water preparation	92	NA

Table 4: Space heating, space cooling and domestic hot water consumption, bottom-up approach, potential values, residential and office sectors (EU13), TWh/y [4], [11-15], [21], [27], [37-53]

Bottom-up approach results, potential values (EU13), TWh/y		
	Residential sector	Office sector
	Consumption	
Space heating	443	NA
Space cooling	15	6
Domestic hot water preparation	92	NA

As shown in Table 3 and 4, the potential of recent member states is enormous, exceeding its present energy consumption for AC applications by approximately four times. The ratio between the potential and actual energy consumption in the residential sector is more than 13 times that ratio for the office sector.

4 Discussion and conclusions

Space cooling accounts for an important part of the European Union households' energy consumption and is particularly meaningful for its service sector.

According to the bottom-up approach´s results, the ratio between total potential and existing entire energy consumption for air-conditioning is ~9:1. The potential energy consumption for space cooling exceeds the respective actual value by an enormous number of approximately 535 TWh/y, which corresponds to almost eight times the actual air-conditioning energy consumption.

European space cooling consumption quantification, following a bottom-up approach, shows a value of around 68 TWh/y. The mentioned air-conditioning indication significantly exceeds the European space cooling market information acquired by top-down values from the European Commission (2009 and 2012 for both last named sources). It estimates between 19 and 39 TWh/y [34], [43], [53]. Various documents confirm the range provided by the European Commission. For example, Kranzl et al. 2014 name the European Union air-conditioning consumption to reach a value of almost 30 TWh/y [54].

In contrast, a number of further top-down gathered data indicate the space cooling branch in Europe to be around 55 and 88 TWh/y: e.g. Marinhas 2010, Constantinescu et al. 2006 as well as Weiss and Biermayr 2009 respectively [55-57].

Other indications, collected by the top-down approach, show the European Union air-conditioning market to be significantly larger, exceeding the last mentioned space cooling consumption information for about two to three times. For example, Boermans T. et al. 2015 indicates the air-conditioning consumption in Europe to be approximately 130 TWh/y [58]. Kalz and Pfafferott 2014 quantify the space cooling consumption in the European Union by almost the same size and Sanner et al. 2011 characterize the air-conditioning consumption in Europe by more than 170 TWh/y [59-60]. Dalin 2006 estimates a number of almost 250 TWh/y [18].

If the entire space cooling consumption is compared between the EU15 and EU13 member states, interesting facts emerge. The EU15 is responsible for practically the whole air-conditioning consumption (~93%) of the EU28, with about 63 and 68 TWh/y respectively. In contrast, a number of sources indicate the EU15 air-conditioning market to be around 80% of the total European one [1], [2], [12]. For the EU13 service sector only the offices portion was analysed. However, offices are characterized by the highest entire space cooling consumption of the European service sector [32-34].

Europe´s specific air-conditioning consumption (residential and service sectors) has constantly increased during the past decade. A huge discrepancy emerges if the space cooling consumption is compared between the EU15 and EU13 member states in the households sector. The EU15 air-conditioning consumption accounts for about 30 kWh/m² y, while the respective value in the EU13 is approximately 10 kWh/m² y.

If the residential space cooling consumption is compared between the EU15 and EU13 an enormous mismatch comes out, with 17 and 1 TWh/y respectively. Principal reason for this is the minor diffusion of air-conditioning applications within the EU13.

Surprisingly, Cyprus shows the highest residential space cooling consumption value of the EU13 with about 0.3 TWh/y and is highly ranked within the EU28 as well - in fourth position together with Portugal, which has about ten times more inhabitants [18]. Primary reason for that is the high percentage of cooled floor area in Cyprus´ households: more than 74% [26]. The elevated specific value for air-conditioning purposes in Cyprus contributes to that point as well.

Specific space heating consumption (residential and service sectors) is characterized by a constant decrease during the past ten years in Europe. Interesting facts emerge if the specific space heating consumption are compared between the EU15 and EU13 member states in the residential sector. There are very similar weighted averages, with 156 and 160 kWh/m² y for the EU15 and EU13 respectively.

In Europe, the entire potential energy consumption for space heating purposes is almost equal to its actual one: around 1.2:1. The European Union´s energy consumption is mainly marked by space

heating with a value of at least 3169 TWh/y. The EU15 residential space heating consumption exceeds that one of the EU13 by about 1544 TWh/y, with around 1982 and 438 TWh/y respectively.

A wide gap appears, when the specific space heating use habits of the different EU15 and EU13 citizen are compared in households. Approximately 5457 kWh/inhabitant y for the EU15 and 3787 kWh/inhabitant y for the EU13 space heating consumption are revealed. Main reason for that is the lower economic availability in the EU13 countries [39]. The average space heating consumption of the EU28 member states is approximately 4681 kWh/inhabitant y.

Indication for domestic hot water preparation consumption differs with 26 kWh/m² y for the EU15 and 33 kWh/m² y for the EU13. Prime reasons for this are relatively colder climatic conditions in the EU13 and more energy efficient boilers allocated in the EU15 [12], [24], [31], [61-66].

The same comparison regarding domestic hot water preparation consumption values shows a mismatch of around 317 TWh/y, with approximately 409 TWh/y and 92 TWh/y for the EU15 and EU13 respectively.

The ratio of potential and actual domestic hot water preparation consumption is 1:1 in Europe with 501 TWh/y each, as it has been assumed that the consumption of domestic hot water preparation is given for the whole residential and service floor area.

With regard to the habits of occupants and their impacts on domestic hot water preparation consumption, a difference of around 13% emerges with around 1079 and 942 kWh/inhabitant y for the EU15 and EU13 respectively. This higher domestic hot water consumption for the EU15 seems to be in contradiction with its more efficient boilers mentioned above. A possible reason for the greater energy consumption of domestic hot water preparation within the old European Union member states could be a higher amount of litres domestic hot water utilized within the households of Western Europe.

One member state has to be pointed out concerning the analysed market of the EU13: Poland. Poland´s position within the EU13 has a number of similarities to that of Germany within the EU15. Concerning energy consumption, Germany and Poland result in having the highest values in the absolute majority of cases, with usually approximately 1/3 of the entire energy consumption per type (space heating, air-conditioning and domestic hot water preparation). The economic situation of a country has an influence on its whole amount of energy consumption as well. In terms of gross domestic product, Poland and Germany are the largest economies within their respective European countries´ agglomerations [18], [39].

Regarding the total energy consumption (residential and service sectors) of space heating, space cooling and domestic hot water preparation within the entire EU28, the highest position is held by space heating with approximately 3169 TWh/y, followed by domestic hot water preparation with around 501 TWh/y and air-conditioning (68 TWh/y). Thus, a relation of approximately six times is given between space heating and domestic hot water preparation and around 46 times between space heating and space cooling.

Not all collected information appear to be trustworthy - even if the mentioned data has been retrieved from reliable sources solely. For the space heating and domestic hot water preparation part, sufficient information is available; for the air-conditioning one, a major lack of information exists.

The space heating market is practically fully saturated, while the space cooling market is characterized by a huge potential, especially in the households sector.

For the EU15, much more data has been found than for the EU13. This especially concerns the energy consumption for air-conditioning purposes. In particular, the information collected for the EU13 cooled floor area was only laboriously obtainable and its reliability has to be further investigated. Thus, it is recommended to analyse the European space cooling consumption and

related cooled floor area in more detail, with major focus on tertiary buildings and particular attention to the EU13.

The energy efficiency of buildings as well as the different building typologies have a major influence especially on space heating and cooling consumption in the residential and service sectors. Because of this fact, it has been decided to extend the carried out investigation, taking into account the differences of the European building stock.

Another improvement suggestion regards the comparison of European Union countries´ building energy demand for space heating, space cooling and domestic hot water preparation without the influence of the climate condition - calculating climate corrected energy demand values. This transformation could be based on the specific energy demand of the single nations in the European Union. Mean heating degree days of the single European counties (or regions) and average heating degree days from all 28 European Union member states might be gathered from Eurostat statistics for the time range of 2000 to 2009 [67]. By doing so, the performance of the building stock allocated within the different European Union nations can be differentiated, considering the specific climate conditions.

It would be interesting to find out to what extent the air-conditioning market in Europe is of importance concerning employment, its contribution to the European Union´s gross domestic product and how this market evolves, once the economic crisis is over.

Acknowledgements

Our gratitude goes to Prof. Herbert Braun and Prof. Herbert Weingartmann (University of Natural Resources and Life Sciences, Vienna) for the scientific supervision of the present investigation. We are thankful to Prof. Tobias Pröll (University of Natural Resources and Life Sciences, Vienna) and Dr. Raphael Bointner (Vienna University of Technology) for the corrections of the present study. Finally, we would like to bring our deepest appreciation to Dr. Ulrich Oberegger Filippi (EURAC research) for the calculations carried out together.

Nomenclature

AC	Air-conditioning
CV	Coefficient of variation
DHW	Domestic hot water
EER	Energy efficiency ratio
E.g.	Example given
kWh	Kilowatt hours
M	Million
m^2	Square meter
NA	Not available
SEER	Seasonal energy efficiency ratio
SC	Space cooling
SH	Space heating
RES	Renewable energy sources
Toe	Tonnes of oil equivalent
TWh	Terawatt hours
W	Work
Q	Heat flux
y	Year

Synonyms

Actual	Real, present
Air-conditioning	Space cooling
EU15	Old European Union member states, Western Europe
EU13	New European Union member states
Residential sector	Households sector
Service sector	Tertiary sector
Total	Whole, entire

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