Impact of climate change in the tertiary sector of Europe (EU27+2)[1]

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Abstract

To estimate the impact of climate change on the tertiary sector on the European level, its energy demand is modeled for 29 European (EU27+2) countries for two different scenarios, namely a base case scenario with past climate conditions and warmer climate (WC) with T increase between about 1.5°C and 3°C, depending on country and month. A bottom-up model was used that differentiates for each of the countries between five main sectors, namely finance, retail, education, health, hotels and restaurants, and a residual sector. Main drivers of the model, namely the amount of heated and cooled floor area and the specific energy demand for different types of energy services, are on the one hand derived from historical data and from projections from the literature, and on the other hand estimated by dynamic building simulation model runs. For two different climate scenarios, the specific energy demand is simulated for representative building types of different European locations. The simulations differentiate between the main types of energy services, namely lighting, ventilation, cooling, heating and other thermal applications, and reveal the impact of climate change to the energy demand. Due to the warmer climate, non-electricity fuel energy demand which is dominated by space heating in most sub-sectors, is reduced by 16% in 2050, and electricity demand is increased by 7% (by about 300 PJ). As such, the impact of warmer climate is lower than the “regular” electricity demand increase between 2005 and 2050 due to cooling which is estimated to about 500 PJ in the base case (from 310 to 830 PJ).

Introduction

As pointed out by Varga and Pagliano (2006) and referring to forecasts of the IEA Future Building Forum and of Adnot (e.g. Adnot, 2003), one of the fastest growing sources of new energy demand is cooling. This increase is related to bad building design (e.g. missing solar protection), increasing internal heat loads of electric office equipment and lighting and comfort needs that are translated to inappropriate thermal requirements Varga and Pagliano (2006). An increasingly warmer climate will amplify this trend and thus will impact significantly on the energy demand of the building sector in Europe. This impact can be structured into two main components, namely a direct physical impact and a socio-economic impact. The first mentioned impact refers to increase of specific energy demand of buildings with installed cooling systems which due to additional heat load and to a decrease of heating energy demand (Frank, 2005, Christenson Manz et al., 2006). The secondly mentioned impact refers to a changed behavior of investors and building users leading to a more pronounced diffusion of cooling systems and devices in the building stock.

For three reasons, the tertiary sector is particularly relevant regarding the impact of climate change. First, the energy and especially the electricity demand of this sector is one of the fastest growing and thus increasingly contributing to the problem. Second, efficiency potentials and hence CO2 mitigation potentials are particularly large in this sector. Third, the buildings of the tertiary sector are much more vulnerable to a changed (warmer) climate and hence adaptation measures are particularly relevant, both due to physical reasons (e.g. high internal loads, less air exchange through windows as compared to residential buildings, specially during the night) and due to impacts on indoor comfort conditions and ultimately on productivity (Aebischer, Jakob et al., 2007).

In this paper we study the impact of warmer climate conditions on the level of individual non-residential buildings (section 1) and on the level of the tertiary sector as a whole (section 2). As such, this paper contributes to the EU project ADAM (Adaptation and Mitigation) which seeks to find the optimal balance between adaptation and mitigation measures which is essential for an economically

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efficient response of tackling the climate change problem. The two scenarios presented in this paper serve as a reference for one or two mitigation scenario studies in the ADAM project.

Methodology

To estimate the impact of climate change on the tertiary sector on the European level (EU27+Norway and Switzerland), a two stage approach is followed. Each of the two stages is performed both with base case climate data (1982 to 1999) and with warmer climate (WC).

- First, building physics models are run to estimate specific energy demand for various building types.
- Second, an energy bottom-up model is used to project the energy demand of the sector as a whole, using input data of the first stage.

In the first stage energy demand and the indoor climate conditions are estimated by using a dynamic building simulation model (IDA-ICE) for some representative building types for different European climate zones. Simulation results are differentiated between the main types of energy services, namely lighting, ventilation, cooling, heating and other thermal applications, and will reveal the impact of climate change to the specific energy demand and on the need for building adaptation measures to ensure acceptable comfort conditions for building occupants.

In the second stage, the energy demand of the tertiary sector is bottom-up modeled up to 2050 for two different scenarios, namely a so-called base case scenario with current climate conditions and a reference scenario with warmer climate. For each of the European countries, the bottom-up model differentiates between five main sectors, namely finance, retail, education, health, hotels and restaurants, and a residual sector. Main drivers of the model are the conditioned (heated and possibly cooled) floor area and the specific energy demand for different types of energy services. The basic structure of the bottom-up modeling approach can be described as follows:

$$Energy\ demand = \sum_{i,k,e} FA_{i,k,e} \cdot specific\ energ\ demand_{i,k,e} \qquad (1)$$

where *FA* denotes the conditioned floor area, *i* the economic sector or sub-sector, *k* the energy type and *e* the type of energy service (e.g. heating, cooling) respectively. Both floor area and specific energy demand are changing over time. Drivers of the floor area are projections regarding value added, productivity progress (value added per employee) and assumptions regarding floor area per m^2 (see Jochem et al., 2007 for more details). The floor area, i.e. the building stock of the service sector, is further decomposed into buildings with different degree of energy services (e.g. with or without central or room air conditioner). Specific energy demand input data are on the one hand derived from historical data, and on the other hand derived from the results of the first stage.

To facilitate the data transfer between stage 1 and stage 2, results regarding specific energy demand values are related to heating degree days (HDD) and cooling degree days (CDD). Heating and cooling degree days are based on the difference between a reference value of 18°C and the average outside temperature (approximated as mean between minimum and maximum daily temperature) if the latter exceeds or falls below the defined threshold T (HDD: 15°C, CDD: 18°C).

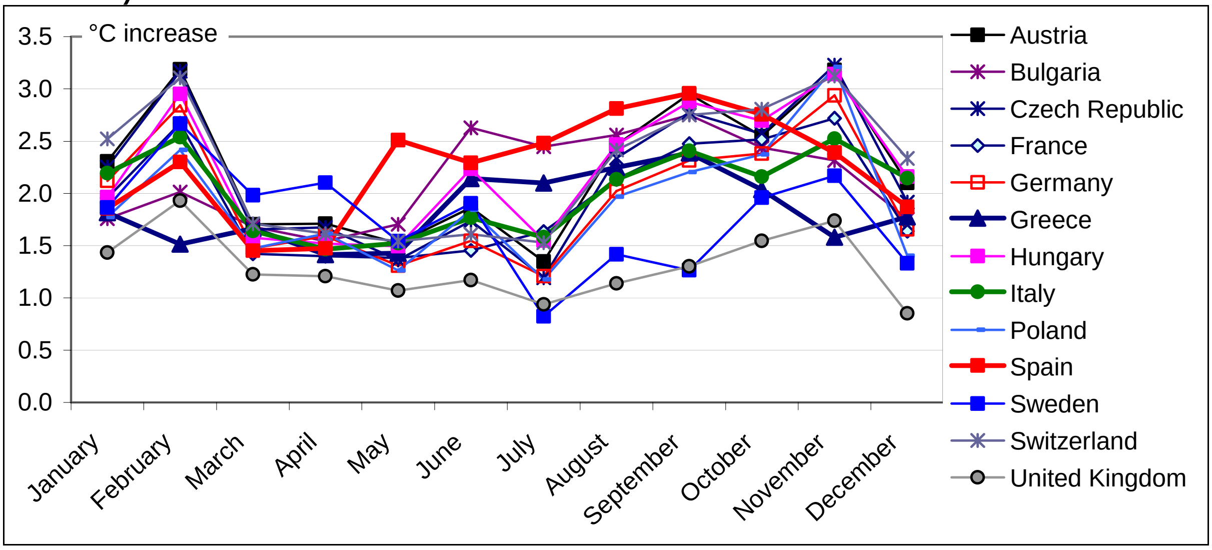
The warmer climate impacts on the energy demand in two ways. First, the share of cooled floor area is assumed to increase with warmer climate and second, the specific energy demand of cooled floor area is assumed to increase with warmer climate. The relation between climate and the share of cooled floor are is based market data and projections of the cooling market in Europe, based on findings of a study for the DGTREN of the EC (Adnot et al., 2003) and on preparatory studies of the ECODESIGN Lot 10 (Riviere, Adnot et al. 2007), particularly on Task 2 Economic and Market analysis. Second, the specific energy demand per square meter of heated and cooled floor area is affected by climate changes. This relation is based on own building model simulation results and is backed up with evidence from the literature, e.g. Riviere, Adnot et al. (2007), Cartalsi, Synodinou et al (2001), Frank (2005) and Aebischer et al (2007).

Temperature and degree days of the two underlying climate scenarios

Two climate scenarios are defined: a base case (BC) and a warmer climate (WC) scenario. HDD and CDD of the base case climate scenario were calculated for 39 locations[2] in 23 different countries using typical meteorological year (TMY)[3] hourly data from IWEC weather stations (as published on the website http://www.equaonline.com/iceuser/). Each of the EU27 plus Norway and Switzerland is represented by one or a weighted average of several IWEC weather stations.

HDD and CDD of the warmer climate (WC) scenario are calculated by using hourly T data of the base case scenario to which monthly average T differences between the considered modeling year (2005 to 2050) and the average of 1980 to 2000 were added, specifically for each country. These monthly T differences stem from simulation results of the climate model IMAGE. The underlying simulation runs were performed by Isaac et al. (2008) within the ADAM project. All of these monthly differences are positive for all countries and all months and vary mostly between 1.5°C and 3°C for 2050. For almost all European countries, increase is lowest in spring (see Figure 1). In southern Europe, largest increase is in late summer whereas in mid, central Europe largest increase is rather in winter.

Figure 1: Assumed increase of monthly T in the warmer climate scenario for 2050 (selected countries)



Source: own representation (based on Isaac et al., 2008: increase btw. 2050 and average 1980-2000)

Assumptions of the WC scenario are summarized as follows:

- Average T increase is uniform for every month, but different for each country (Figure 1).
- Monthly increases are superposed by an additional daily variation of the temperature, assuming a sin function of the form $0.5 * \sin\left\{\left(\frac{t+6}{24}\right)2\pi\right\}$ °C (2)
- No change in direct and global radiation (from climate models it is unclear whether radiation would rather decrease due to more clouds or rather increase) and relative humidity

At first it is interesting to note that the impact of the above temperature change assumptions do not have a linear impact on both heating and cooling degree days, nor in relative nor in absolute terms. In relative terms, HDD and CDD are changed increasingly with lower initial values, following a concave

[2] Vienna (AT), Brussels (BE), Copenhagen (DK), Helsinki (FI), Paris, Marseille (FR), Berlin, Bremen, Frankfurt, Munich, Koeln, Stuttgart (DE) Athens, Thessaloniki (GR), Dublin, Kilkenny (IE), Milan, Rome, Naples (IT), Nancy (FR, also used for LU), Amsterdam (NL), Coimbra (PT), Madrid, Sevilla (ES), Stockholm (SE), Birmhingham, London (UK), Larnaca (CY), Prague (CZ), Debrecen (HU), Kaunas (LI), Warsaw (PL), Bratislava (SK), Ljubljana (SL), Bergen, Oslo (NO), Geneva (CH), Bukarest (RO), Sofia (BG).

[3] Up to 18 years of weather data of the period 1982–1999 were processed by ASHARE using Hall's method, see ASHRAE (2002).

course. Heating degree days are lowered by about 25% to 30% in South Europe, and by about 15% to 20% in the remainder of Europe (see Table 1). In relative terms, cooling degree days are affected most strongly in Scandinavian and Northern-Continental Climates (up to +100% and even more), but much less in Southern Europe (+35% to 62%).

Heating and cooling degree data can be categorized to different regions within Europe. Regarding cooling degree days (CDD), five regions can be discerned (see Table 1). Regarding heating degree days (HDD), the regions South-East and Mid-West could be summarized, but North and North-West should still need to be distinguished.

Table 1 Selected locations for which building simulations are performed

European Region	Location, country	Heating degree days (*)			Cooling degree days (*)		
		Base	WC	Change	Base	WC	Change
South	Athens, Greece	1027	724	-29%	1089	1472	35%
	Rome, Italy	1391	960	-31%	604	912	51%
	Marseille, France	1630	1180	-28%	597	871	46%
	Madrid, Spain	1840	1395	-24%	595	961	62%
South-East	Debrecen, Hungary	3078	2489	-19%	288	504	75%
	Sofia, Bulgaria	2989	2467	-17%	247	506	105%
	Vienna, Austria	3114	2495	-20%	228	408	79%
Mid-West	Berlin, Germany	3088	2477	-20%	159	269	69%
	Paris, France	2562	2031	-21%	142	289	104%
North-East	Warsaw, Poland	3557	2958	-17%	88	172	95%
	Prague, Czech Rep.	3644	2936	-19%	80	169	111%
North	Stockholm, Sweden	4261	3647	-14%	28	68	142%
North-West	Birmingham, UK	3008	2555	-15%	20	45	118%
EU27+2	Weighted average	2813	2270	-19%	228	375	65%

(*) Sum of the differences (absolute value) between the daily mean temperatures and the balance temperature (18°C) of those days with daily mean temperature below (HDD) and above (CDD) threshold T (15.0°C for HDD, 18.0° for CDD)

Source: Own categorisation and calculations using data from http://www.equaonline.com/iceuser/ (based on ASHRAE 2002) and from Isaac et al. (2008).

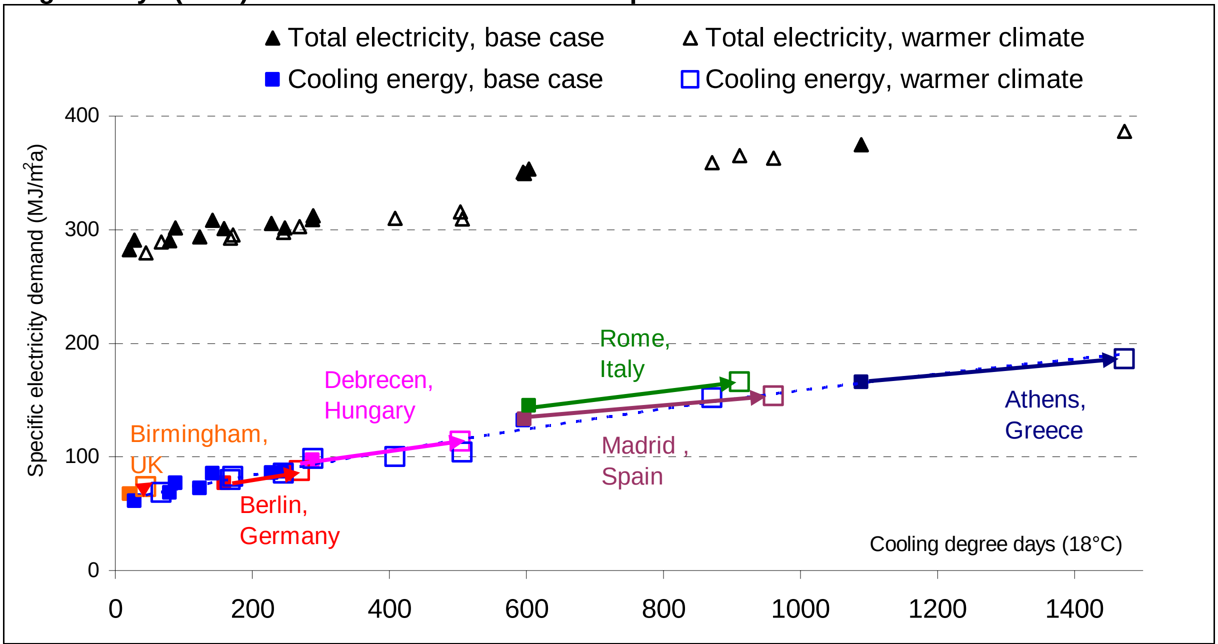
Impact of warmer climate on the level of individual buildings

Specific energy demand for lighting, ventilation, cooling, appliances, heating and other thermal applications is modeled for different building types and locations in Europe. Some 14 locations are chosen to cover both the relevant regions in terms of the energy demand of the tertiary sector and to cover the range of occurring climate in Europe.

Impact on Cooling Energy

Choosing a new office buildings with high internal loads and a rather large glazing proportion as an illustrative example, it can be stated that the electricity demand for cooling increases with increasing CDD, not linearly, but with decreasing gradient (see Figure 2), as is for CDD change rates as a function CDD. Note however that growth rates are increasing: a doubling of the CDD from 20 to 40 increases cooling energy demand by 4%, from 40 to 80 by 7%, and from 640 to 1280 by 37%. Since relative changes in CDD follow an opposite pattern (see Table 1), the impact of warmer climate on specific cooling electricity is quite similar across regions: between 13% (Warsaw) and about 20% for locations as different as Birmingham, Stockholm, Zurich, Berlin, Warsaw, Prague, Sofia, Debrecen (Hungary), Madrid, Marseille, Rome, Paris. It is also worthy to note that in this type of building there is a non-negligible cooling demand even in locations with very low or zero CDD. Its value amounts to about 60 MJ_e/m^2a, which is equivalent to a thermal load of about 110 MJ_{th}/m^2a. In absolute terms, total specific electricity demand of southern regions is clearly above the average of all locations. High cooling energy demand is partially, but not fully, compensated by low lighting energy demand due to more daylight availability. Except southern regions, most of Europe faces similar specific electricity demand: 280 to 310 MJ/m^2a in the base case and 300 to 330 MJ/m^2a with warmer climate.

Figure 2: Cooling and total electricity demand of new office buildings as a function of Cooling Degree Days (CDD) for different locations in Europe.



Source: own calculations (simulation model IDA)

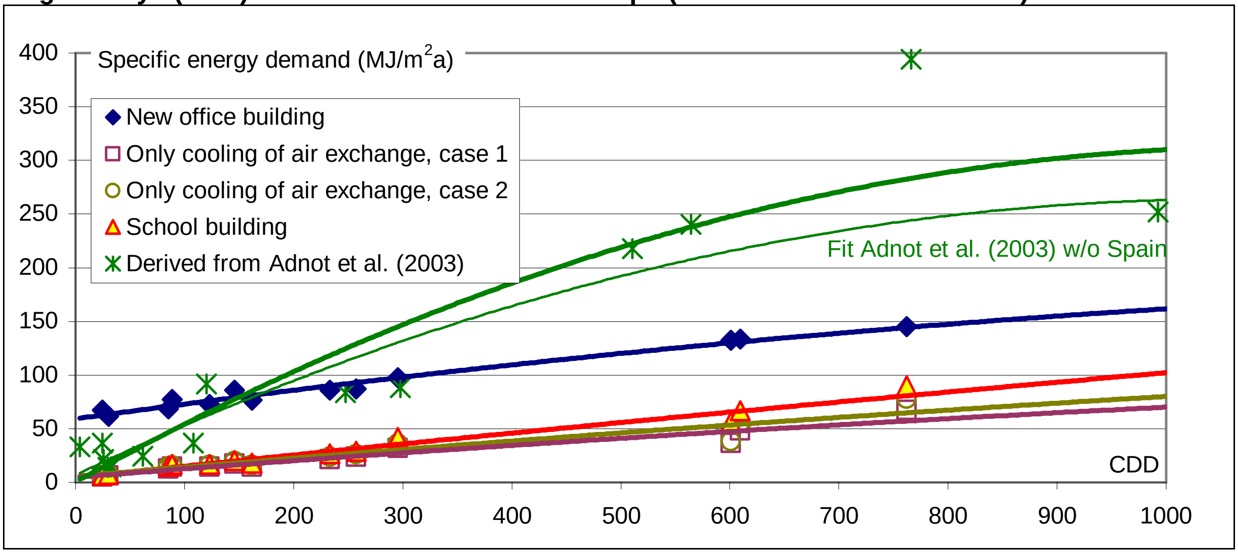
Depending on the building type, its cooling concept and mode of operation, specific energy demand for cooling varies considerably, as also pointed out by Adnot et al. (2003), Volume 1, p. 16. Indeed, specific cooling energy demand of certain buildings in locations such as London with almost zero CDD might be higher than cooling energy demand of other building types in locations such as Milano with about 350 CDD (note that the impact of warmer climate on CDD is much smaller for most European regions, see Table 1).

Similarly, the impact of warmer climate for a given location (e.g. Switzerland) can be quite different depending on the building type considered. The climate impact on the cooling energy demand (in absolute values) is much smaller (10 to 25 MJ/m^2a) than the impact of the building type which ranges from 5 to more than 100 MJ/m^2a of electricity for cooling, see Aebischer, Jakob et al. (2007). This means that even with warmer climate, cooling energy demand can be reduced substantially if building and cooling concepts are adjusted accordingly. Particularly it can be reduced below the demand of many cases with today's climate. In other words: impacts of targeted energy efficiency measures may be of larger magnitude as compared to climate change impacts.

Another parameter that determines the electricity demand for cooling and that could be affected by changed outdoor conditions is the yearly averaged coefficient of performance (COP). It could be both de- or increased. An argument for an increase would be the economics of energy-efficiency (the higher the electricity demand the more energy-efficiency improvements get economic). Arguments for a decrease would be sub-optimal design of heat exchangers, less operation hours with moderate outdoor temperature. Since it is unclear which of the argument would dominate, it is assumed that the annual COP of cooling systems is constant between the two climate scenarios (an average value of 2.5 was assumed). This approach allows for a ceteris paribus study of the impact of changed outdoor temperature, i.e. regardless any change in HVAC efficiency. Also it is assumed that indoor set point T would not change with warmer climate: a set point temperature of 26°C was assumed in both cases. Moreover, control strategies, for instance of solar protection elements, are assumed to be constant.

Figure 3 displays results obtained from IDA-ICE simulations of three different types of office buildings and one type of school buildings. Each building case was simulated for fourteen different locations in Europe for the two climate cases. For the sake of readability, only the results of the base case are displayed in Figure 3 as the results of the WC scenario follow the same pattern. For comparison, also the results of Adnot et al. (2003), are included in the graph. Similarly to the case of heating, the slope of fitted (quadratic) functions is the lower the more energy-efficient the considered building types and cooling systems and concepts are. In the case of our own simulations, assumptions are valid for rather efficient concepts (adjusted air exchange rate, room-set-point T of 26°C) which might not be fully achieved in practice, especially not in the case of old buildings and cooling systems. This also explains the difference to the results of Adnot et al. (2003) which are presumably representing not only new buildings and optimized practice (note for instance, that set-point T lower than 26°C, e.g. 23°C would increase cooling energy demand by several ten of percentage-points), but the building stock as a whole.

Figure 3: Specific electricity demand for cooling of various buildings as a function of Cooling Degree Days (CDD) for different locations in Europe (base case climate scenario).



Source: Adnot et al. (2003), own calculations (simulation model IDA), CDD derived from ASHRAE (2002) and Isaac et al. (2008).

Impact on Specific Heating Energy Demand

Specific heating energy demand (SED) is increasing more or less linearly with increasing HDD (see Figure 4) which allows for fitting linear functions of the type of equation (3). Note, that heating is only needed in situations with HDD of more than about 500 °Cd. Indeed, due to solar and internal heat gains, heating is not necessary even if daily average outdoor temperature is – to a certain extent – distinctively lower than desired indoor temperature,[4] which implies negative b_{EE}. The slope m_{EE} of the linear fits depends on the energy efficiency of the assessed buildings.

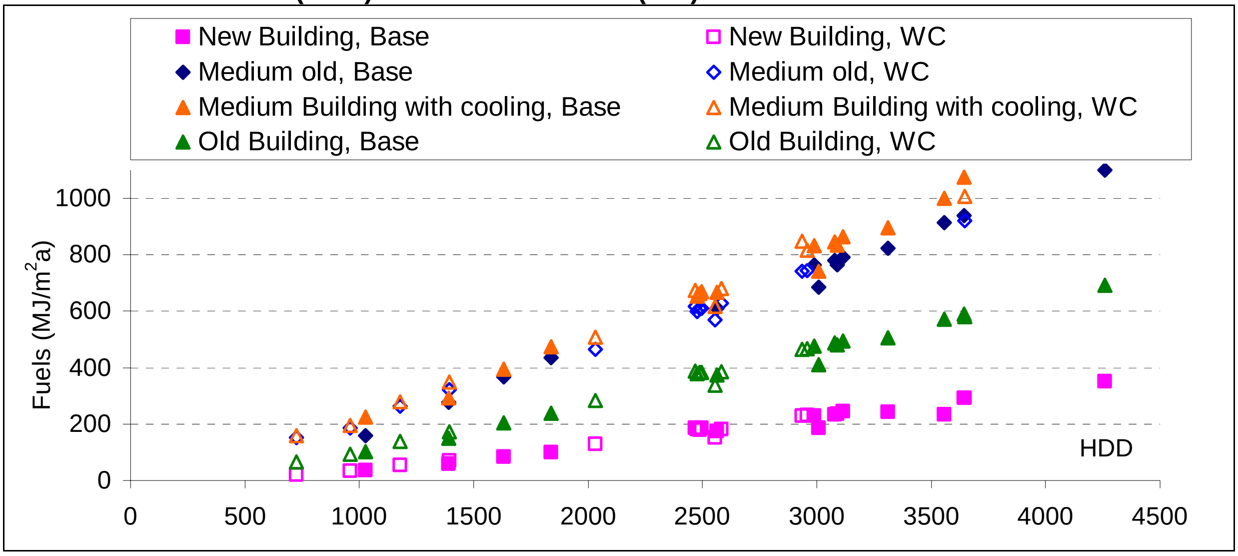
$$SED_{EE} = b_{EE} + m_{EE} * HDD \quad (3)$$

m_{EE} obtained from fits to results of buildings simulation runs with IDA-ICE and calculations according to the Norms SN EN 832 or SIA 380/1 range between 0.17 and 0.2 in the case of non-insulated multi-family house type buildings (depicted as “old buildings” in Figure 4), between 0.25 to 0.28 in the case of medium-old buildings with ventilation systems and about 0.1 in the case of new office buildings with adjusted ventilation rates (SED expressed in MJ/m²a and HDD in Kd). In the case of very energy-

[4] This is also the reason why other HDD definitions with lower thresholds would be more appropriate (e.g. HDD are 0 for all days with average T above 12°C).

efficient buildings that follow the German Passivehouse or the Swiss Minergie-P standard, m_{EE} can be even lower than 0.025.

Figure 4: Impact of warmer climate on fuel energy demand of office buildings as a function of HDD for the base case (base) and warmer climate (WC) scenario.



Source: own calculation, using simulation model IDA, HDD according to Table 1.

Impact of warmer climate on the level of the tertiary sectors of Europe

Main driver of the bottom-up model in terms of quantity is the energy floor area, which is determined by the number of employee (derived from value added per sector and productivity progress, adopted from the economic model E3ME) and their projected specific floor area. The current state of the floor area is derived from the ODYSSEE database and from statistical data of the number of employee per sector and per country. For each sector, a long term saturation level is assumed (see Jochem et al. 2007 for details). In some sectors, the floor area per employee rather decreases (e.g. office space) whereas in others it increases (e.g. commerce where less and less personal per square meter of sales area is needed) which entails a structural change between the sub-sectors.

Specific energy demand per unit of floor area (SED) of the model base year is derived from the ODYSSEE database. To project the specific energy demand in 2050, assumptions on the technical progress and on the “income” elasticity of the specific energy demand (dSED/SED / dVA/VA) where “income” is expressed in value added (VA) are made (see Jochem et al. 2007 for details). These assumptions are made on the level of the previously mentioned six sub-sectors.

To model the impact of warmer climate, specific electricity and non-electricity (fuels) demand are disaggregated into space-cooling and other electricity services and into space heating and “process” heat energy respectively. It is assumed that space-cooling and space heating varies with climate, whereas process-cooling (for instance to cool products), other electricity services and process heat is assumed to invariant to climate change. Process heat as defined in this paper includes all thermal heating energy services expect space heating such as hot water, laundry and other washing services, cooking, etc. The share of process heat varies between the sub-sectors and ranges from roughly 10 percent (trade, finance, administration, education), 25% (health) to about 50% (hotels, restaurants).

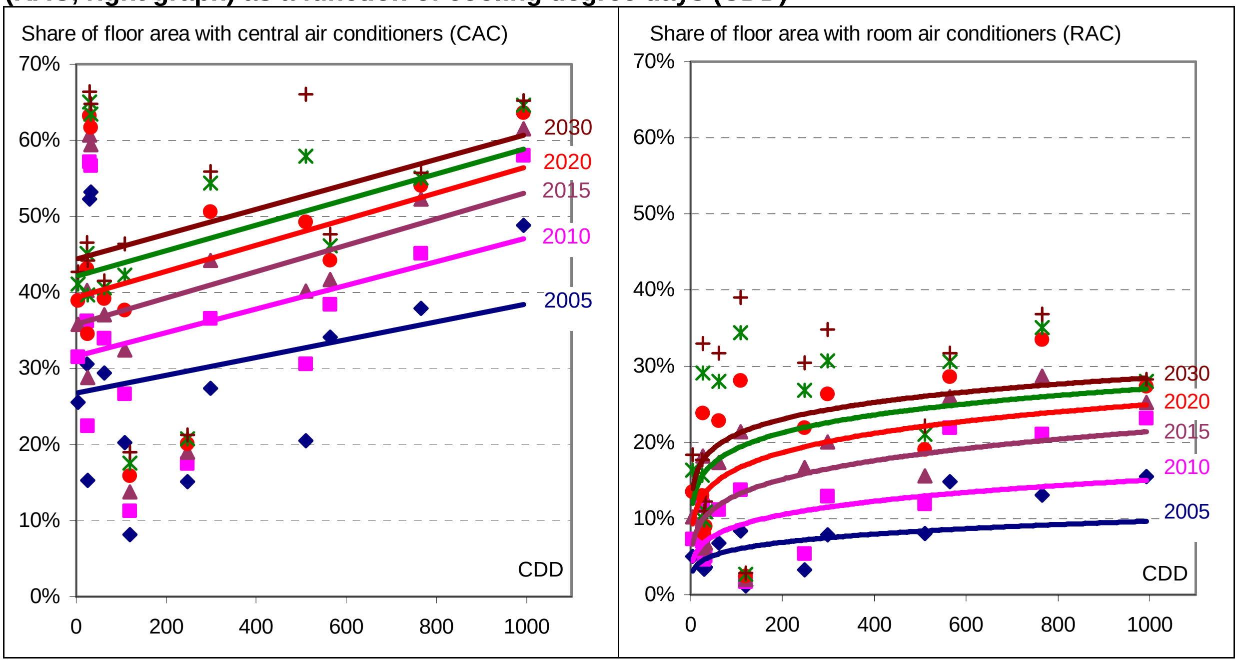
Assumptions and results regarding the impact of WC on the share of cooled floor area

As opposed to the case of heating where 100% of the occupied floor area (FA) is heated, significantly less the 100% of the FA is cooled and/or ventilated. Empirical evidence regarding the quantitative relevance of central air conditioning (CAC) or by room air conditioners (RAC) can be found in two studies DGTREN of the EC, namely in Adnot et al. (2003) in Riviere, Adnot et al. (2007). The amount of cooled FA was obtained by dividing their results regarding installed power by specific values of installed capacity per square meter (W/m^2). These values, which are country and building type specific, were adopted from Riviere, Adnot et al. (2007), Task 4. If ideally dimensioned or chosen, these values range typically between 70 and 130 W/m^2 (in the case of cooling only air conditioners). However, in practice, cooling systems and devices are often over dimensioned. For CAC, a factor of over dimensioning of 1.5 and for RAC a factor of 2 is assumed. These factors might seem high; note however that shares of cooled FA of more than 100% would be obtained with lower factors.

The country specific shares of cooled floor area are obtained by dividing the obtained cooled floor area by the countries' total modeled floor area. For the model base year (2005), these shares range between about 20% to about 35% for most of the countries north of the Alps (a noticeable exception is Germany with only 9%) and between 50% and 65% for the Mediterranean countries. Hence, even with CDD close to 0, a noticeable share of office and other space of the tertiary sector is either central air conditioned or equipped with RAC.

Next to empirical evidence regarding the to-date levels of cooling devices, both mentioned DGTREN studies performed projections up to 2020 and up to 2035 respectively. These projections are based on a cohort approach and a Bass diffusion model which is adjusted to past sales data (see Rivière Adnot et al. 2007). The thereof derived cooled floor area was related to the total floor area of the model base year 2005. The so-obtained shares of cooled floor of the different European countries and years are then related to country specific CDD data. In the case of CAC linear models of the form $Share_{CAC}=m_Y*CDD_{Base}+b_Y$ are fit for each model year *Y* and in the case of RAC a power models of the form $Share_{RAC} = m_Y*CDD^{by}$, see Figure 5.

Figure 5: Shares of central air conditioning (CAC, left graph) and of room air conditioners (RAC, right graph) as a function of cooling degree days (CDD)



Source: Adnot et al. (2003), Isaac (2007), Jochem et al. (2007), own calculations

The impact of warmer climate was modeled separately for CAC and for RAC. In the case of CAC, $S^C_{CAC,WC}$, which denotes the share of FA cooled with CAC of country C in the case of warmer climate (WC) of a given model year Y, is obtained by equation (5), where m_Y is the slope of a given model year Y which was obtained from the linear regression. In the case of RAC, the share of cooled FA was obtained by equation (6). Hence, in both cases, the individual share of each country was taken as a starting base to which was added the mean impact of WC obtained by the regression models.

$$S^C{}_{CAC,WC} = S^C{}_{CAC,PC} + m_Y * (CDD^C{}_{WC} - CDD^C{}_{Base}) \quad (5)$$

$$S^C{}_{RAC,WC} = S^C{}_{RAC,PC} + m_Y * (CDD^C{}_{WC})^{bY} - m_y * (CDD^C{}_{Base})^{bY} \quad (6)$$

From the slopes and the course of the power functions (Figure 5) and the change of CCD due to warmer climate in Table 1 on the one hand and from the differences between the different model years on the other hand it can be concluded that current trends as projected by Adnot et al. (2003) and Rivière, Adnot et al. (2007) have a stronger impact than the assumed climate change. Indeed, total shares of CAC and RAC increase by typically 25% to 40%-points between 2005 and 2030 whereas the additional increase due to warmer climate typically amounts to 1% to 3% in the case of the countries north of the Alps and to 3% to 5% in the case of the Mediterranean and South-Eastern European countries. Further increases are expected up to 2050 (see Table 2).

Table 2 Resulting cooled floor area of the Service sectors of Europe (EU27+2) for 2005, 2020, 2035, and 2050 (Billion m^2) and relative changes

		Base Case						Warmer Climate (WC)						WC/Base		
	2005	2020	2035	2050	2020/ 2005	2035/ 2005	2050/ 2005	2020	2035	2050	2020/ 2005	2035/ 2005	2050/ 2005	2020	2035	2050
Mediterr., SE EU	0.82	1.77	2.30	2.52	2.2	2.8	3.1	1.83	2.40	2.71	2.2	2.9	3.3	1.04	1.05	1.08
Rest of EU27+2	1.39	3.31	4.61	5.18	2.4	3.3	3.7	3.39	4.76	5.47	2.4	3.4	3.9	1.03	1.03	1.06
Total EU 27+2	2.20	5.08	6.90	7.70	2.3	3.1	3.5	5.22	7.16	8.18	2.3	3.2	3.7	1.03	1.04	1.06

Source: Calculations by the authors, based on data from Adnot et al. (2003), Rivière, Adnot et al (2007), Isaac et al. (2007), ASHRAE (2002) and Jochem et al.(2007), [last updated 23 July 2008].

For Europe as a whole (EU27+2), the amount of cooled floor area in absolute terms roughly triples up to 2035 (Table 2), whereas in relative terms it roughly doubles (from 31% to 63% in the base case and to 65% in the case of warmer climate), as can be derived from Table 3. Note that the relative increase between 2005 and 2035 is higher in the case of the more northern countries as these countries start from a quite low level (in 2005, only about 25% of the floor area are cooled which is about half of the respective share in the southern countries. Up to 2050, almost hundred percent of the floor area of the service sector in the Mediterranean and South-East European countries is assumed to be cooled and also in the rest of Europe, the share of cooled floor area reaches about 70%.

Table 3 Resulting cooled floor area as share of total floor area of the Service sectors of Europe (EU27+2) for 2005, 2020, 2035, and 2050

		Base Case			Warmer Climate (WC)		
	2005	2020	2035	2050	2020	2035	2050
Mediterr., SE EU	0.48	0.78	0.85	0.88	0.81	0.89	0.95
Rest of EU27+2	0.25	0.47	0.56	0.61	0.48	0.58	0.64
Total EU 27+2	0.31	0.54	0.63	0.68	0.56	0.65	0.72

Source: Calculations by the authors, based on Table 2 and Jochem et al.(2007), [last updated 23 July 2008].

Assumptions regarding the impact of WC on the <u>specific</u> energy demand for cooling

Resuming the finding of the respective previous section (Figure 3), it is assumed that the specific energy demand (SED^C_Y) for cooling of country *C* of a given year *Y* is the sum of the country's Base SED and the difference of a function which is quadratic in CDD and which is evaluated at the year Y and the Base period, see equation (7). Due to technical progress it is assumed that the coefficients of the mentioned quadratic function change over time. Indeed, due to structural changes (increasing share of new buildings) and retrofit of existing cooling systems one can assume that the impact of warmer climate gets weaker and weaker (as in Figure 3, the slopes of new buildings is less step than the to dates average). In Table 4 the assumed coefficients for the years 2005 and 2050 are displayed. For in between model years, outcome of equation (7) is interpolated between 2005 and 2050.

$$SED^{C}{}_{Y,WC} = SED^{C}{}_{Base} + \left[a_i * (CDD^{C}{}_{Y,WC})^2 + b_i * (CDD^{C}{}_{Y,WC})\right] - \left[a_i * (CDD^{C}{}_{Y0,Base})^2 + b_i * (CDD^{C}{}_{Y0,Base})\right] \qquad (7)$$

Table 4 Coefficients of Equation (7)

	a_i	b_i
Model base period (i=1)	-0.000230	0.5
Time horizon of model 2050 (i=2)	-0.000015	0.2

Source: Assumptions of the authors [last updated 22 July 2008].

Note that in both cases, a techno-economic progress that increases the energy-efficiency of providing cooling services by 0.5%/year was assumed which results in an EE improvement of 20% up to 2050.

Assumptions regarding the impact of WC on the specific heating energy demand

Equations (3) and (4) and respective coefficients (Table 5) describe the adopted model that relates specific energy demand for heating purposes to HDD. In accordance to the results of the building physics simulation model it is assumed that the slope m_{EE} is maximal in the case of non-retrofitted existing buildings and minimal in the case of buildings that comply with the German Passivehouse or the Swiss Minergie-P standard. The coefficients of buildings of sectors and countries with intermediate energy-efficiency (EE) are interpolated within these two boundary cases. Hence, as the average building stock is being retrofitted between 2005 and 2050, impact of warmer climate is steadily decreased as m_{EE} decreases.

$$SED_{WC} = SED_{PC} + m_{EE} * (HDD_{WC} - HDD_{PC}) \qquad (4)$$

Table 5 Coefficients of Equation (3)

	b_{EE}	m_{EE}
EE = existing building stock without retrofit	-70	0.20
EE = well insulated buildings	-30	0.05
EE = best practice (equivalent to the German Passivehouse or the Swiss Minergie-P standard)	-25.0	0.023

Source: Assumptions of the authors [last updated 22 July 2008].

In the case of no climate change (base case, present climate), non-electricity SED decrease from the current levels in all sectors with the exception of the commerce/trade sector where a decrease is detected only after a period of growth (by 15% up to 2020, see Table 6). As a result of technical progress, non-electricity SED in 2050 is expected to be 20% to almost 30% below the level of 2005 (except commerce/trade: only 8% lower). In the case of warmer climate, non-electricity SED decreases significantly more, namely by about 25% to more than 40% (commerce/trade only by 21%). Hence, in 2050 non-electricity SED of the WC scenario is between 10% and 20% below the scenario for which no climate change was assumed. Note that the impact of warmer climate differs between sectors as there are structural differences between northern and southern European countries.

Table 6 Resulting non-electricity specific energy demand (in MJ/m²a) of the Service sectors of Europe (EU27+2), weighted average of EU 27+2) for 2005, 2035, and 2050 and relative change

		Base Case						Warmer Climate (WC)						WC/Base		
	2005	2020	2035	2050	2020/ 2005	2035/ 2005	2050/ 2005	2020	2035	2050	2020/ 2005	2035/ 2005	2050/ 2005	2020	2035	2050
Commerce, Trade	530	610	569	486	1.15	1.07	0.92	577	510	408	1.11	0.98	0.79	0.95	0.90	0.84
Finance	643	556	505	467	0.87	0.79	0.73	523	448	388	0.83	0.71	0.62	0.94	0.89	0.83
Hotels, restaurants	761	700	654	608	0.92	0.86	0.80	674	609	548	0.90	0.81	0.73	0.96	0.93	0.90
Education	308	262	232	217	0.85	0.76	0.71	241	198	171	0.80	0.66	0.57	0.92	0.85	0.79
Health	678	596	553	520	0.88	0.82	0.77	565	500	446	0.85	0.75	0.67	0.95	0.90	0.86
Other	458	415	386	359	0.91	0.84	0.78	387	337	292	0.86	0.75	0.65	0.93	0.87	0.81

Source: Jochem et al.(2007), complemented and calculated by the authors [last updated 28 July 2008].

Results regarding the aggregate electricity demand of the Service sectors of Europe

In the Base Case with present climate, electricity demand is expected to increase by about 50% to 60% up to 2050 (Table 7). In the warmer climate scenario, the increase is slightly higher, namely by about 10%-points. In 2050, electricity demand is 7% higher in the warmer climate scenario than in the base case (about 1% already occurred between the base case and the year 2005). A noticeable difference can be discerned between on the one hand the Mediterranean and South-Eastern European countries and the rest of the European countries on the other hand. For the former, the difference between the base and the WC scenario is 16% whereas for the rest of the EU27+2 countries it is only 3% in 2050.

Table 7 Resulting total electricity demand of the Service sectors of Europe (EU27+2) for 2005, 2020, 2035, and 2050 (PJ) and relative changes

		Base Case						Warmer Climate (WC)						WC/Base		
	2005	2020	2035	2050	2020/ 2005	2035/ 2005	2050/ 2005	2020	2035	2050	2020/ 2005	2035/ 2005	2050/ 2005	2020	2035	2050
Mediterr., SE EU	659	894	1070	1141	1.36	1.62	1.73	960	1183	1321	1.43	1.76	1.97	1.07	1.11	1.16
Rest of EU27+2	2194	2806	3286	3302	1.28	1.50	1.51	2851	3368	3412	1.30	1.53	1.55	1.02	1.02	1.03
Total EU 27+2	2853	3700	4356	4444	1.30	1.53	1.56	3810	4551	4733	1.33	1.58	1.65	1.03	1.04	1.07

Source: Calculations by the authors [last updated 26 July 2008].

The difference between the two scenarios is caused by the different development of electricity demand for cooling. Whereas in the base case, cooling electricity increases from 310 PJ to about 830 PJ, which represents an increase of +170%, it increases from 330 PJ in 2005 to slightly more than 1100 PJ which represents an increase of +240% (see Table 8).

Table 8 Resulting electricity demand for cooling of the Service sectors of Europe (EU27+2) for 2005, 2020, 2035, and 2050 (PJ) and relative changes

		Base Case						Warmer Climate (WC)						WC/Base		
	2005	2020	2035	2050	2020/ 2005	2035/ 2005	2050/ 2005	2020	2035	2050	2020/ 2005	2035/ 2005	2050/ 2005	2020	2035	2050
Mediterr., SE EU	228	470	575	572	2.1	2.5	2.5	536	688	751	2.2	2.9	3.1	1.14	1.20	1.31
Rest of EU27+2	81	194	257	260	2.4	3.2	3.2	238	339	370	2.7	3.9	4.2	1.23	1.32	1.42
Total EU 27+2	310	664	832	832	2.1	2.7	2.7	774	1027	1122	2.3	3.1	3.4	1.17	1.23	1.35

Source: Calculations by the authors [last updated 26 July 2008].

As already stated above there is a noticeable difference the Southern countries and the rest of the EU27+2 countries. First of all, the share of electricity demand for cooling as compared to total electricity demand is larger already today: it is 35% in the Southern countries, but only 4% in the other countries and only 11% in the European average, see Table 9. Moreover the share of the Southern countries increases much more distinctively, namely by 15% to 20%-points whereas in the other countries it increases only by 5% to 7%-points.

Table 9 Resulting electricity demand for cooling as share of total electricity demand of the service sectors of Europe (EU27+2)for 2005, 2020, 2035, and 2050

		Base Case			Warmer Climate (WC)		
	2005	2020	2035	2050	2020	2035	2050
Mediterr., SE EU	0.35	0.53	0.54	0.50	0.56	0.58	0.57
Rest of EU27+2	0.04	0.07	0.08	0.08	0.08	0.10	0.11
Total EU 27+2	0.11	0.18	0.19	0.19	0.20	0.23	0.24

Source: Calculations by the authors, based Table 8 and Jochem et al.(2007), [last updated 24 July 2008].

Finally, it can be stated that the share of electricity demand for cooling first increases, but then decreases again, particularly in the base case, but to a minor extent also in the WC scenario. First, this is due to stronger saturation phenomena in the case of cooling (particularly regarding the share of cooled floor area, see Table 3 in the previous section) as compared to other types of electricity demand. Second, a stronger techno-economic progress was assumed in the case of cooling (0.5%/year) as compared to other electricity services (0.2% to 0.5%, see Jochem et al. (2007).

Results regarding the aggregate fuel energy demand of the Service sectors of Europe

The aggregate energy demand of the Service sector as a whole is obtained from the sumproduct of the floor area per sector (Jochem et al., 2007) and the specific energy demand inputs (Table 6). In the base case, non-electricity fuel energy demand is increasing by 38% up to 2035, but only by 28% in the warmer climate scenario (Table 10). Due to technical progress, a decrease up to 2050 is then expected in both cases. In relative terms, the impact of warmer climate is slightly larger in the case of the Mediterranean and South-Eastern (SE) European countries as compared to the rest of Europe. This is due to a larger relative change of HDD (see Table 1 above). As can be expected the total of the EU27+2 countries is dominated by the non-Mediterranean and non-South-Eastern (SE) countries. Due to the warmer climate, total non-electricity fuel energy demand which is dominated by space heating in most sub-sectors, is reduced by 16% in 2050 as compared to the base case and by about 14% as compared to 2005.

Table 10 Resulting total non-electricity fuel energy demand of the Service sectors of Europe (EU27+2) for 2005, 2020, 2035, and 2050 (PJ) and relative changes

		Base Case)						Warmer Climate (WC)						WC/Base		
	2005	2020	2035	2050	2020/ 2005	2035/ 2005	2050/ 2005	2020	2035	2050	2020/ 2005	2035/ 2005	2050/ 2005	2020	2035	2050
Mediterr., SE EU	599	765	877	843	1.28	1.46	1.41	710	780	679	1.22	1.34	1.16	0.93	0.89	0.81
Rest of EU27+2	3056	3771	4171	3784	1.23	1.36	1.24	3559	3799	3188	1.19	1.27	1.06	0.94	0.91	0.84
Total EU 27+2	3656	4535	5048	4627	1.24	1.38	1.27	4268	4579	3868	1.19	1.28	1.08	0.94	0.91	0.84

Source: Calculations by the authors [last updated 28 July 2008].

Discussion and outlook

Electricity and other energy demand of the tertiary sectors of the European countries are expected to increase considerably up to 2050 in both the base case and warmer climate, namely by more than 25% (base case) and by about 10% (warmer climate) in the case of non-electricity fuels and by more than 50% in the case of electricity. Due to the warmer climate, non-electricity fuel energy demand of Europe which is dominated by space heating in most sub-sectors, is reduced by 16% in 2050 as compared to the base case and by 14% as compared to 2005, and electricity demand is increased by

7% (by about 300 PJ). Depending on the future primary energy intensity of electricity generation, these results imply either a slight improvement or a slight worsening.

Note that in the case of electricity the impact of WC in 2050 is lower than the “regular” demand increase between 2005 and 2050 due to cooling which is estimated to about 500 PJ in the base case (from 310 to 830 PJ). However, it should be noted that electricity demand due to cooling might increase considerably more if the share of cooled floor area approached saturation not only in the case Mediterranean and SE EU countries, but also in the case of other countries which in terms of energy demand are of higher relevance. Particularly, heat waves could accelerate the purchase of room air conditioners. Moreover, electricity could be increased due to the use of reversible appliances which are installed for cooling intentions, but would be also in their heat mode.

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