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Impact of climate change on energy demand in the Swiss service sector - and application to Europe

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Abstract

The short-term dependency of energy demand for space heating on winter temperature in the Swiss commercial sector is well understood. This provides a basis for estimating the effect on demand of longer term changes in temperature, such as those reported for the period 1970-2003 (Hofer, 2003) and the further warming of several degrees C expected in the coming decades (Hohmann/Neu, 2004). Energy demand for space cooling is at present small and variations in summer temperature are hardly detectable in the national electricity demand pattern. But due to higher internal loads, fashionable glass facades and increasing comfort levels, the cooled floor area is steadily increasing. Events like the summer of 2003 are accelerating this trend and the specific energy demand for cooling. It is important, therefore, to develop a better understanding of the relationship between summer weather conditions and energy demand for cooling.

In this paper we explore possible changes in heating and cooling demand in the Swiss commercial sector over the next 30 years, taking account of the expected temperature increase and the evolution of the stock of buildings and their equipment. Two principal scenarios are evaluated: a reference case in which temperatures remain constant; and a second case in which temperatures increase. For heating demand, changes in specific energy consumption are evaluated; for cooling demand, specific energy demand and floor area equipped with cooling equipment are varied.

Although the principal focus of the work is on Switzerland, it is possible to extend the analysis to other parts of Europe. Energy consumption data for the commercial sector is sparse, particularly for cooling, but simulations have been used effectively in this context. (Adnot et al., 1999 and 2003). For much of Europe, we conclude that likely increases in cooling energy demand due to global warming will be outweighed by reductions in the need for heating energy. There is likely to be a net increase in demand for electricity in all but the most Northerly countries, however, and in the South a significant increase in summer peak demand. Depending on the generation mix in particular countries, the net effect on carbon dioxide emissions may be an increase even where overall demand for delivered energy is reduced.

1. Introduction

The short-term dependency of energy demand for space heating on winter temperature in the Swiss commercial sector is well understood. This provides a basis for estimating the effect on demand of longer term changes in temperature, such as those reported for the period 1970-2004 (Hofer, 2003) and the further warming of several degrees C expected in the coming decades (Hohmann/Neu, 2004). Energy demand for space cooling is at present small and variations in summer temperature are hardly detectable in the national electricity demand pattern. But due to higher internal loads, fashionable glass facades and increasing comfort levels, the cooled floor area is steadily increasing. Events like the summer of 2003 are accelerating this trend and the specific energy demand for cooling. It is important, therefore, to develop a better understanding of the relationship between summer weather conditions and energy demand for cooling.

In this paper we explore possible changes in heating and cooling demand in the Swiss commercial sector over the next 30 years, taking account of the expected temperature increase and the evolution of the stock of buildings and their equipment. Two principal scenarios are evaluated: a reference case in which temperatures remain constant; and a second case in which temperatures increase. For heating demand, changes in specific energy consumption are evaluated; for cooling demand, specific energy demand and floor area equipped with cooling equipment are varied.

The first part of the paper (energy demand in Switzerland) is largely based on the ongoing elaboration of new energy scenarios for Switzerland (Aebischer/Catenazzi, 2006). Two of the authors (BA and GC) acknowledge the financial support of the Swiss Federal Office of Energy.

2. The reference scenario

2.1 Brief description of SERVE04

SERVE04, CEPE's energy demand model for the service sector developed in the nineties and used on behalf of the Swiss Federal Office of Energy by CEPE in the current elaboration of new energy scenarios for Switzerland, is described in detail by Aebischer et al. (1996) and Aebischer (1999). The structure is mainly a widely-used bottom-up approach (figure 1).

Figure 1 Bottom-up approach used in the energy demand model SERVE04

$$\text{energy} = \sum_{i\,k} \text{quantity}_{i\,k} * \text{specific demand}_{i\,k}$$

i, k : economic sector, sub-sector, energy vector

- quantity : floor area (t, t', t'')
- specific demand : energy demand per m^2 (t, t', t'')

t, t', t'' : year of construction, year of 1^{st} and 2^{nd} refurbishment

For the electricity demand this simple approach is extended to include the observed increase of electricity demand due to structural changes within the economic sub-sectors (Aebischer/Spreng, 1994; Aebischer et al., 1994). Wherever possible this observed increase in electricity demand of 1,5% per year on average due to structural changes inside the sub-sectors is accounted for in the model by a relative increase of activities (floor area) characterised by higher specific electricity services. Examples of activities with higher electricity services are the modern retail stores with a large assortment of deep frozen food displacing more and more traditional corner shops ("Mom and Pop" stores) or large office buildings (with mechanical ventilation) including staff canteen and server room. In sub-sectors where this structural change could not be accounted for by changes in specific activities we assume an ongoing increase of electricity demand due to this structural change, but the increase of 1,5% per year observed in the eighties/early nineties is adjusted in proportion to the ratio of the actual increase of value added to the increase of value added in the eighties/early nineties. The observed electricity demand 1990-2004 in the Swiss service sector is rather well described by this model.

2.2 Major assumptions and inputs for the reference scenario

Conditioned floor area for heating and cooling
Reference floor areas are given 1990 to 2035 by Wuest&Partners (2004) for typical buildings (offices, schools, hospitals and others). CEPE used these areas and estimates of the projected number of full time equivalent employees compiled by Ecoplan (2005) to assign areas to economic activities. Overall conditioned floor area is estimated to rise by 26% between 2005 and 2035 (i.e., averaging 0,7% per year). The largest increase is in the health and remaining sectors (31%), followed by trade (24%), and the lowest in the banking and insurance sector. The growth of floor area is to a large extent due to the increase in floor area per full time equivalent employee, which rises between 2005 and 2035 by around 23%. Assuming that the relationship between employed persons and full time equivalents

develops as in the years 1991 to 2003, the area requirement per employed person increases by 9% from 2005-2035.

Heating heat requirement in new buildings
The average heat requirement in a typical new service sector building was assumed to reduce at an annual rate of 1,8% per year, following that of multi-family houses (Hofer, 2005). This rate of improvement is based on the expectation of steadily reinforcement of building standards by the cantons and of the uptake of low energy buildings.

Energy efficient refurbishment
Based on consideration of 25-year refurbishment cycles of building components starting in 1980 and considering that only 50% are energetically improved (Jakob/Jochem, 2004), it was calculated that the annual rate of refurbishment affected 1,9% of total floor area in the late 1990s, reducing to 1,3% in the year 2035, by which time 72% of the floor area existing in 1980 would have been fully refurbished at least once. This was calculated to result in an average reduction in energy requirements of 50 MJ/m^2 per refurbishment cycle.

Heating system efficiency
The average efficiency of boilers was calculated to increase from around 73% in 1980 to around 98%, for gas-fired boilers, and around 94%, for oil-fired boilers, in 2035. This was calculated using the results of a study by Jochem/Jakob (2004), carried out in co-operation with representatives of the oil and gas industries.

Sources of heat in new and existing buildings
In 1985 approximately 70% of the total floor area in the services sector was heated by oil. In new buildings that proportion had dropped to around 40%, about the same as for gas. By 2035, the oil heated proportion is expected to decline gradually to around 35% and all other sources of heating to rise, except for electrical resistance heating. The proportion using heat pumps is expected to double between 2005 and 2035. In existing buildings, fuel oil is being replaced at a rate of rather more than 1% of total oil heated floor area per year, particularly by natural gas and wood, while electrical resistance heating is predominantly being replaced by natural gas and heat pump heating systems.

Structural change within economic sub-sectors
The impact on electricity demand of the structural change within the sub-sectors is (wherever possible) accounted for by the changing distribution of buildings characterised by varying electricity services. The evolution of the distribution of these buildings in the period 1980 to 2000 was chosen in such a way that the estimated increase of electricity demand by the structural change was reached. Future values are derived by assuming a continuation of trends in social and economic development since the 1980s.

Electricity demand in new and refurbished buildings
Target electricity consumption in new buildings is generally between 20% and 40% below the average in existing buildings of comparable functionality. Starting from the year 2000 these targets reduce by 0.5% annually. In the year 2000 roughly 20% of the new buildings reach these targets. It's assumed that this ratio reaches 35% in 2010 and 80% in 2035. For the refurbishment of existing buildings, it is assumed that half of the reduction in the new buildings is reached on average. Refurbishment is expected to take place at a rate approaching 4% per year, which is twice as fast as that assumed for refurbishment of the building shell.

2.3 Energy demand in the reference scenario

Energy demand for room heating, warm water preparation and some process heat is steadily declining by about -0,2% per year resulting in 2035 in a reduction of -6% compared to 2005. On the contrary, electricity demand is growing at a rate of 0,9% (figure 4). The demand in 2035 is 32% higher than in 2005. The electricity produced in Switzerland is quasi CO_2 free. Under the assumption that this is still the case in 2035, then the CO_2 emissions of the service sector are declining faster than the heat demand, mainly due to the substitution of oil by gas and other energy carriers. In 2035 the reduction reaches -17% with respect to 2005.

3. The climate change scenario

We investigate the energy effects of continuous global warming, defined by the climate change scenario. The various political and socio-economic reactions that accompany continuous global warming over the next thirty years are beyond the scope of this sensitivity analysis. We assume that the societal, economic and technical circumstances and developments remain unchanged from our reference scenario. It is also not feasible to investigate the effects on the many end uses of energy and electricity. For the purposes of this paper, we focus on the two most obvious and likely most sensitive areas, heating and cooling.

3.1 Weather characteristics under the climate change scenario

Temperature and radiation are used to describe the weather under continuous global warming conditions. We assume the following increases of the average daytime temperature and radiation:

- +1 °C in the months from September to May,
- +2 °C from June through August,
- +5% solar radiation.

For the years 2005-2035 we apply a linear inter-/extrapolation.

3.2 Demand for heating energy under the climate change scenario

We use the correction factors calculated by Hofer (2005) to quantify the effects of these new weather data on the demand for heating energy. These factors are based on degree days[1] and radiation values. This method is the same as correcting for the average of observed historical energy demand under variable weather conditions. Hofer produces correction factors for twelve building types.

The increase of the average daytime temperature by 1°C from September to May and by 2°C from June through August leads to a reduction of average heating degree days of 11%, comparable to the very warm winter months in 1994.

The demand for heating decreases continuously compared to the reference scenario and by 2035 is 13% lower (figure 4), and the CO_2 emissions are accordingly lower as well. In this calculation, the inventory of buildings remains unchanged relative to the trend development.

3.3 Electricity demand for cooling under the climate change scenario

Before we can examine how much the electricity demand for cooling is affected by an increase in the average temperature and radiation, we must first estimate the electricity use for air conditioning under the reference scenario. For this, assumptions[2] about the cooled space and the specific energy use for air conditioning in the service sector must be made. Table 1 shows estimates of the floor area for different types of buildings and different economic sectors that are partially and fully air conditioned (cooled).

In order to estimate the cooled areas, we postulate that “high tech” areas tend to be fully air conditioned, while “medium tech” spaces tend to be partially air conditioned. This results in an estimate that of the total occupied floor area, 20% is fully and another 20% partially air conditioned, a plausible estimate when compared with those of other European countries. Offices show a significantly lower percentage of air conditioned areas than in 100 office buildings examined in detail in 1990. Of those 100 buildings, 24% (accounting for 40% of the area) were fully air conditioned, 28% (32% of energy-demanding space (EDS)) were partially air-conditioned, and the other 48% (28% of EDS) were not cooled at all (Aebischer, 2005). We expect significantly lower percentages for the entire office area within the service sector, since an unknown (but certainly large) number of office spaces are not situated within office buildings, but in other structures such as apartment buildings.

[1] Degree days are calculated as the sum of the daily differences between a “base temperature” and mean external temperature. Different definitions of degree days are used by different authorities; the definitions used in this paper are given in section 4.
[2] There are no representative data for the service sector as a whole as to the air-conditioned space, the installed cooling capacity or the electricity requirements for cooling.

Table 1 Fraction of heated floor area for different types of buildings and different economic sectors that are partially and fully air conditioned (cooled).

	2000	2005	2015	2025	2035
	Fraction of floor area				
Office buildings					
not cooled	47%	43%	33%	23%	14%
partially cooled	31%	35%	41%	48%	55%
fully cooled	22%	23%	26%	29%	32%
Retail stores					
not cooled	50%	47%	41%	35%	30%
fully cooled	50%	53%	59%	65%	70%
Hotels and restaurants					
not cooled	59%	55%	47%	39%	32%
partially cooled	30%	34%	40%	45%	51%
fully cooled	10%	11%	13%	15%	17%
Education					
not cooled	90%	89%	86%	83%	81%
partially cooled	6%	7%	9%	11%	13%
fully cooled	4%	4%	5%	6%	6%
Health care					
not cooled	65%	64%	62%	60%	58%
partially cooled	32%	33%	34%	35%	36%
fully cooled	3%	3%	4%	5%	6%
Other activities					
not cooled	50%	50%	50%	50%	50%
partially cooled	25%	25%	25%	25%	25%
fully cooled	25%	25%	25%	25%	25%
Total service sector					
not cooled	61%	59%	54%	49%	44%
partially cooled	20%	22%	25%	27%	30%
fully cooled	19%	19%	21%	23%	25%

Source: CEPE/Amstein+Walthert, CEPE

The specific electricity use for cooling (including chilling, control of humidity and pumps and fans used in distribution) in office buildings is based on the above-mentioned 100 office buildings. A special analysis (Aebischer, 2005) produced the following values:

- 23 MJ/m2.year (6.3 kWh/m2.year) for partially air conditioned office buildings,
- 96 MJ/m2.year (26.7 kWh/m2.year) for fully air conditioned office buildings.

These results correspond well to simulation calculations (Adnot et. al., 2003) for office buildings under similar climatic conditions (figure 2). As with the other technologies, we are assuming an “autonomous” annual reduction of the specific energy requirements by –0.5%.

For calculating the specific electricity use in the other building types and economic sectors, we apply Adnot’s (2003) simulation calculation. This leads to the following values (relative to the office buildings): trade = 129%, hospitality sector = 68%, schools = 100%, health sector = 116%, other sectors = 100%.

Based on these assumptions, the electricity requirements under the reference scenario for indoor cooling are shown in table 2.

Table 2 Electricity demand for cooling (including de-/humidification and distribution) of the commercial buildings in reference scenario, in TJ per year

	TJ per year				
	2000	2005	2015	2025	2035
Office buildings	1062	1196	1465	1714	1922
Retail stores	1055	1173	1387	1561	1691
Hotels and restaurants	133	149	179	204	225
Education	116	138	181	214	238
Health care	198	222	262	297	326
Other activities	900	937	963	968	953
Total service sector	3463	3815	4437	4957	5356

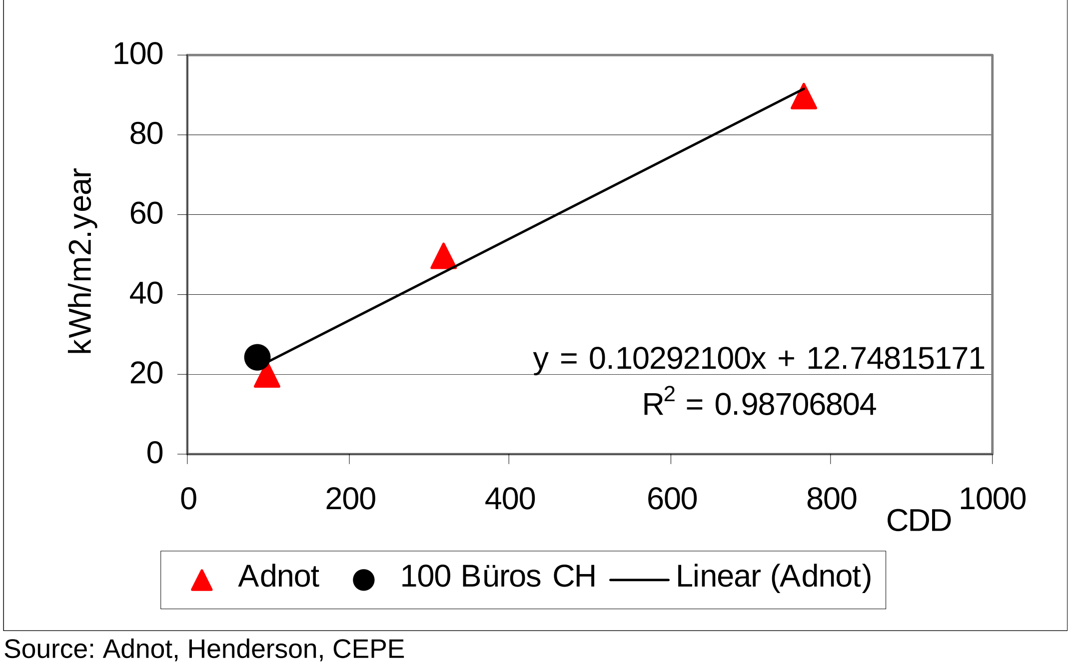
Source: CEPE

The percentage of the calculated electricity requirement for air conditioning relative to the overall electricity use is 5.9% in 2000 and 6.5% in 2035. Relative to the electricity use for climate and ventilation according to SIA 380/4, it comes to 24% in 2000 and 26% in 2035.
In order to arrive at a value for the electricity requirements for cooling under the climate change scenario, two factors must be taken into consideration:

1. higher specific electricity use due to higher average temperature, and
2. rapid increase of partially and fully air conditioned spaces.

The fit of the specific usage values for cooling office buildings in London, Milan, and Seville, as simulated by Adnot (2003), to the Cooling Degree Days[3] (CDD) (calculated by Henderson (2005) for this study) results in a very good linear dependence: Electricity use = 0.1029*CDD + 12.7481. The empirical usage rate for the 100 office buildings in Switzerland lies very close to this line as well (figure 2).

Figure 2 Electricity demand for cooling, in kWh/m2.year, of office buildings in London, Milano and Sevilla (= Adnot) in function of the Cooling Degree Days (CDD) in these locations. The linear fit of these three points is rather good R2 = 0.99. For comparison we show also the measured value of fully air conditioned office buildings in Switzerland (100 Büros CH).

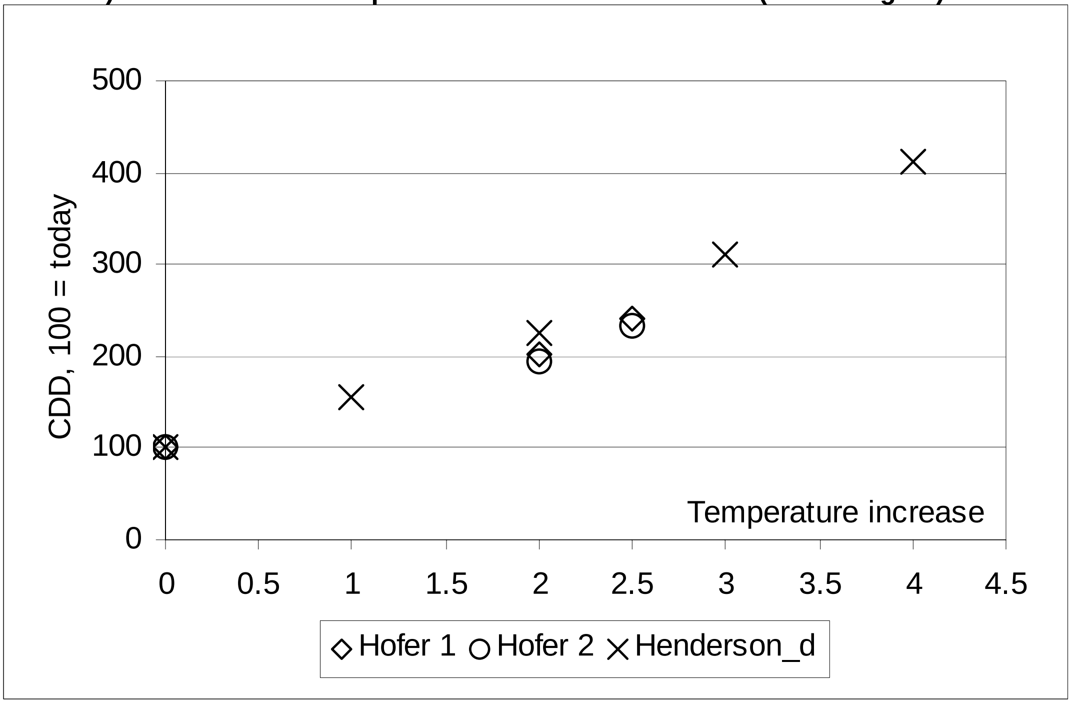


Source: Adnot, Henderson, CEPE

[3] Calculated to a base temperature of 18.3°C

We also apply this linear dependence when calculating the higher electricity usage under the climate change scenario. Depending on the method used, it is possible to arrive at two different results when the Cooling Degree Days are calculated for a temperature increase of 1°C from September to May, and of 2°C from June to August (figure 3). For 2035 we use the average of the two values computed by Hofer (2005): An increase of CDD by 199% between now and 2035. Based on the above formula, specific electricity consumption due to higher temperatures is 46% higher in 2035. The increase in specific demand – relative to the reference scenario – is computed by a linear interpolation between 0 in 2005 and 46% in 2035.

Figure 3 Relative change of Cooling Degree Days (100 = mean temperature today in Switzerland) in the case that temperature increases in summer (June–August) between 1 and 4 °C.



Source: Adnot, Henderson, CEPE

The second factor, namely the rapid increase of partially and fully air conditioned spaces, leads us to the ad-hoc assumption that by 2035 half of the spaces that appear as non-cooled under reference scenario will be partially air conditioned. Further, we estimate that half of the partially air conditioned spaces under reference scenario will be fully so by 2035.[4]

After determining these two factors, it is now possible to calculate the electricity demand for cooling under reference scenario_climate_warmer. Compared to reference scenario, we see an increase of 115% (table 3). Roughly 40% result from the higher specific requirements of the spaces that are already air conditioned under reference scenario. 20% are due to an increase of partially, 40% are due to an increase of fully air conditioned areas and the higher specific consumption for cooling these spaces relative to the trend scenario. The total demand is therefore 7.5% higher in 2035 (figure 4). In 2035, the percentage of electricity requirements for cooling as a part of overall electricity demand for the service sector grows from 6.5% under reference to 13.1% climate change. Relative to the electricity consumption for climate/ventilation according to SIA 380/4, the percentage grows from 26% under reference to 44% under climate change.

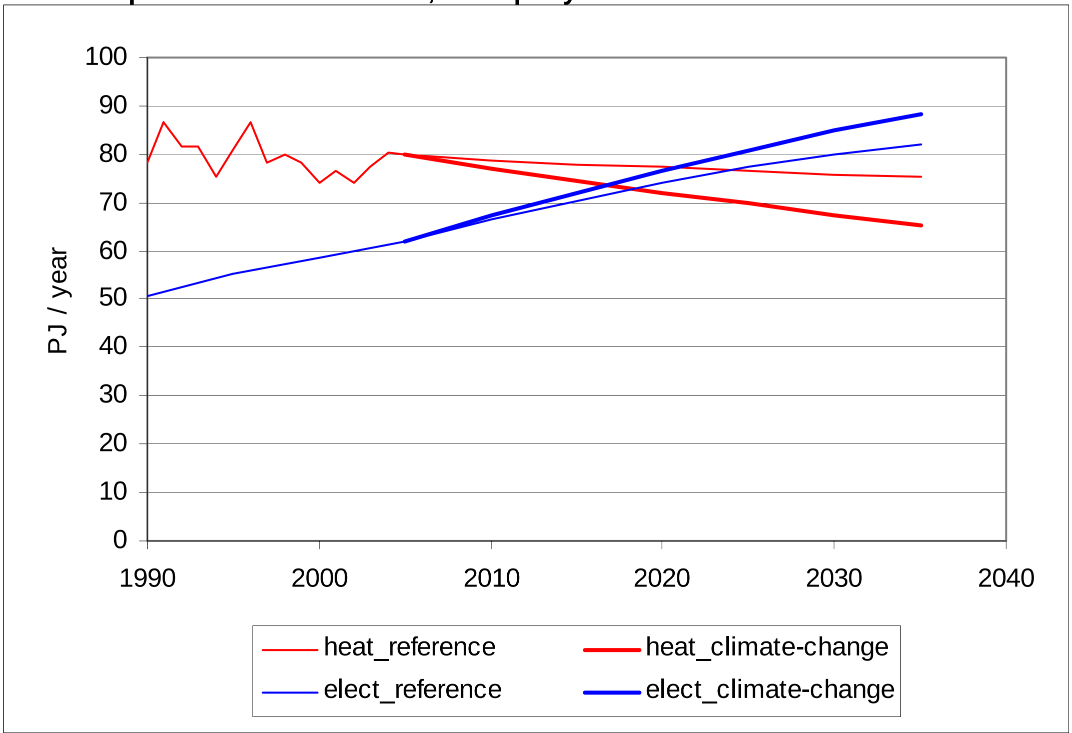
[4] This assumption was made together with Prognos AG which is coordinating the perspective studies. It is reasonable when one posits, as we do, that the climate change scenario refers to a continuous, evenly distributed temperature increase, and that there will not be another (or several) “Summer 2003” over the next few years. We believe that an accumulation of heat waves, even lasting only 1-2 weeks, would quickly lead to overall partial or full air conditioning.

Table 3 Electricity demand for cooling (including de-/humidification and distribution) of the commercial buildings in climate change scenario and variation in 2035 relative to the reference scenario, in TJ per year

	TJ per year					Variation in 2035
	2000	2005	2015	2025	2035	relative to ref.
Office buildings	1062	1196	1977	2972	4144	116%
Retail stores	1055	1173	1642	2126	2591	53%
Hotels and restaurants	133	149	268	416	592	163%
Education	116	138	341	591	881	270%
Health care	198	222	466	779	1149	252%
Other activities	900	937	1322	1744	2184	129%
Total service sector	3463	3816	6018	8628	11540	115%

Source: CEPE

Figure 4 Heating energy demand and electricity demand in the reference scenario with constant mean temperatures and in the climate change scenario with continuous increasing mean temperature and irradiation, in PJ per year



Source: CEPE

4. Implications for energy demand and CO_2 emissions in Europe

The approach used to evaluate impacts of climate change on energy demand for heating and cooling, described in detail the sections 3 for Switzerland, was applied to different climate zones in Europe. In this section we present the resulting impact on CO_2 emissions due to the climate change induced changes in heating and cooling demand in this different climate zones in function of two parameters:

- the fuel-mix for heating purpose and
- the CO_2 content of electricity.

Heating degree days (HDD) and cooling degree days (CDD) for mean climate conditions for the period 1961 to 1990 (“HDD$_{_mean}$” and “CDD$_{_mean}$”) were calculated using temperatures obtained from

Meteonorm[5] for 8 European locations and for Florida, which is noted for its high cooling loads. HDD were calculated according to the standard Swiss definition[6], using a base of 20°C with a cut-off temperature of 12°C. CCD were calculated to the ASHRAE definition[7], using a base of 18.3°C with no cut-off. Heating and cooling degree days for warming climate conditions (“$HDD_{\_warmer\_climate}$” and “$CDD_{\_warmer\_climate}$”) were calculated with the following simplified assumptions for all locations:

1. temperature increase of +1 °C in the months from September to May
2. temperature increase of +2 °C in the months from June to August.

The relative variations of heating degree days are highest for warm climates and the variations of cooling degree days are largest for cold climate zones (Table 4, first part)

Specific final energy demand per m^2 of heated area “$H_{\_location}$” for room heating and for preparation of sanitary water and process heat in these 9 locations was determined by the very rough approximation shown as formula (1), where $H_{\_CH}$ and $HDD_{\_CH}$ are the specific energy demand in Switzerland[8] of 153 $kWh/m^2.a$ and the mean heating degree days in Switzerland of 3514 degree days and the parameter “$a_{\_CH}$ ” is the fraction of heat demand in Switzerland that varies proportionally to the number of heating degree days, approximated by the fraction of total heat demand which is not used for sanitary water and process heat. The specific heat demand for sanitary water and process heat is supposed to be equal to 16 $kWh/m^2.a$ - independent of climatic conditions.

$$H_{\_location} = H_{\_CH} + H_{\_CH} * a_{\_CH} * (HDD_{\_location} / HDD_{\_CH} - 1) \qquad (1)$$

The heat demand in the case of higher mean temperatures is calculated analogously by formula (1).

Electricity demand for cooling per unit of cooled floor area (m_c^2) in the different locations was either taken from Adnot et al. (2003) or calculated with formula (2) determined by a linear fit to Adnot’s simulation results for locations in temperate and Mediterranean cities (Figure 2).

$$El_{\_location} = 12.74815171 + 0.102921 * CDD_{\_location} \text{ , in } kWh/ m_c^2.a \qquad (2)$$

The calculated specific energy demand for heating (including preparation of sanitary warm water and process heat) and cooling of commercial buildings in the 9 locations and the relative variations in the case that temperatures increase vary considerably (Table 4, second part).

In order to determine the total variation of electricity for cooling we have to evaluate the increase of cooled floor area due to climate change. We assume that in 2030 100% of the floor area is using heat (heating and/or sanitary water and process heat), but that with no climate change only a fraction is cooled. With increasing temperature this fraction of cooled floor area is increasing and the variation of electricity demand for cooling shown in the second part of Table 4 is also increasing. The fraction of cooled floor area (partially cooled is taken as half the area is cooled) in Zurich is assumed to be the same as in Switzerland altogether (section 3): 40% in the case of no climate change and 59% if the temperature increases by 2 °C in summer. These fractions for the other locations are rough guesses (Table 4, third part). The specific energy demand for cooling per unit of total floor area (m^2) of the commercial sector (and not just per unit of cooled floor area, m_c^2) is of course lower – except for Florida, where we assume that all the floor area is cooled) - and the relative increase of electricity for cooling is higher due to the increase of cooled floor area (Table 4, third part).

[5] Meteonorm is a global climatological database, containing data from 7,400 weather stations around the world. It includes a synthetic weather generator that can generate hourly time series corresponding to "typical years" from monthly values of all parameters using a stochastic model. (www.meteotest.ch)

[6] SIA Standard 381/3: Heating degree-days in Switzerland, Swiss Association of Engineers and Architects (in German), Zurich, Switzerland, 1982.

[7] ASHRAE Fundamentals Handbook 2001 (SI Edition). Chapter 31: Energy estimating and modeling methods, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, GA, 2001.

[8] Mean value in 2005 of all buildings in the commercial/building sector.

Table 4 Heating and cooling degree days for today's weather conditions ($HDD_{\_mean}$ and $CDD_{\_mean}$) **and in the case of a climate change with mean temperature increase of +2 °C in summer and +1 °C in winter** ($HDD_{\_warmer\_climate}$ and $CDD_{\_warmer\_climate}$)**; and specific heating** ($H_{\_mean}$) **and cooling** ($El_{\_mean}$) **energy demand per unit of heated** (m_h^2) **and cooled** (m_c^2) **floor area (2005**[9]**) for today's weather conditions and variations for increasing temperatures; fraction of cooled floor area in 2030 without** ($\%cooled_{\_mean}$) **and with** ($\%cooled_{\_climate\_warmer}$) **temperature increase and specific heating** ($H_{\_mean}$) **and cooling** ($El_{\_mean}$) **energy demand per unit of total floor area** (m^2) **for today's weather conditions and variations for increasing temperatures.**

	Florida	Athens	Murcia	Milan	London	Berlin	Zurich	Copen-hagen	Stock-holm
$HDD_{\_mean}$	28	696	1035	2797	2904	3436	3571	3847	4406
$HDD_{\_climate\_warmer}$	10	502	797	2526	2561	3126	3200	3459	4036
Variation	-64%	-28%	-23%	-10%	-12%	-9%	-10%	-10%	-8%
$CDD_{\_mean}$	2219	1061	766	319	63	119	88	26	52
$CDD_{\_climate\_warmer}$	2644	1337	1021	504	147	229	190	81	122
Variation	19%	26%	33%	58%	133%	92%	115%	212%	135%
$H_{\_mean}$, $kWh/m_h^2.a$	17	43	56	125	129	150	155	166	187
Variation	-4%	-18%	-16%	-8%	-10%	-8%	-9%	-9%	-8%
$El_{\_mean}$, $kWh/m_c^2.a$	241	122	90	50	20	25	22	15	18
Variation	18%	23%	29%	38%	43%	45%	48%	37%	40%
$\%cooled_{\_mean}$	100%	90%	80%	60%	40%	40%	40%	40%	40%
$\%cooled_{\_climate\_warmer}$	100%	95%	90%	75%	59%	59%	59%	59%	59%
$H_{\_mean}$, $kWh/m^2.a$	17	43	56	125	129	150	155	166	187
Variation	-4%	-18%	-16%	-8%	-10%	-8%	-9%	-9%	-8%
$El_{\_mean}$, $kWh/m^2.a$	241	110	72	30	8	10	9	6	7
Variation	18%	30%	45%	73%	109%	112%	116%	100%	104%

Source: Degree days calculated from data obtained from Meteonorm; other data from CEPE

In order to make a realistic balance of decreasing CO_2 emissions for heating purposes and increasing CO_2 emissions for cooling we would not only need detailed information about the CO_2 content of heating energy and of the electricity used for cooling in the year 2030, but also about the CO_2 content of the avoided heating energy and of the additional electricity used for cooling due to higher temperatures. This will be done by CEPE in a coming research project. Here, we do a simple sensitivity analysis in order to get a feeling about the possible variation due to different fuel choices. In order not to confuse the reader, we do not use any geographic names, but characterise the different locations by their CDD only.

The fuel mix for heating is characterised:

1. by the fraction of electricity in the total final energy demand for heating ("**little**" = 10%; "**much**" = 50%) and
2. by the CO_2 content of the remaining (non-electric) fuel mix used for heating (0.2 Mt CO_2 per TWh corresponding approximately to the CO_2 content of natural gas; 0.3 Mt CO_2 per TWh corresponding to CO_2 content slightly above the one for light fuel oil)

For the CO_2 content of electricity we use the two extremes:

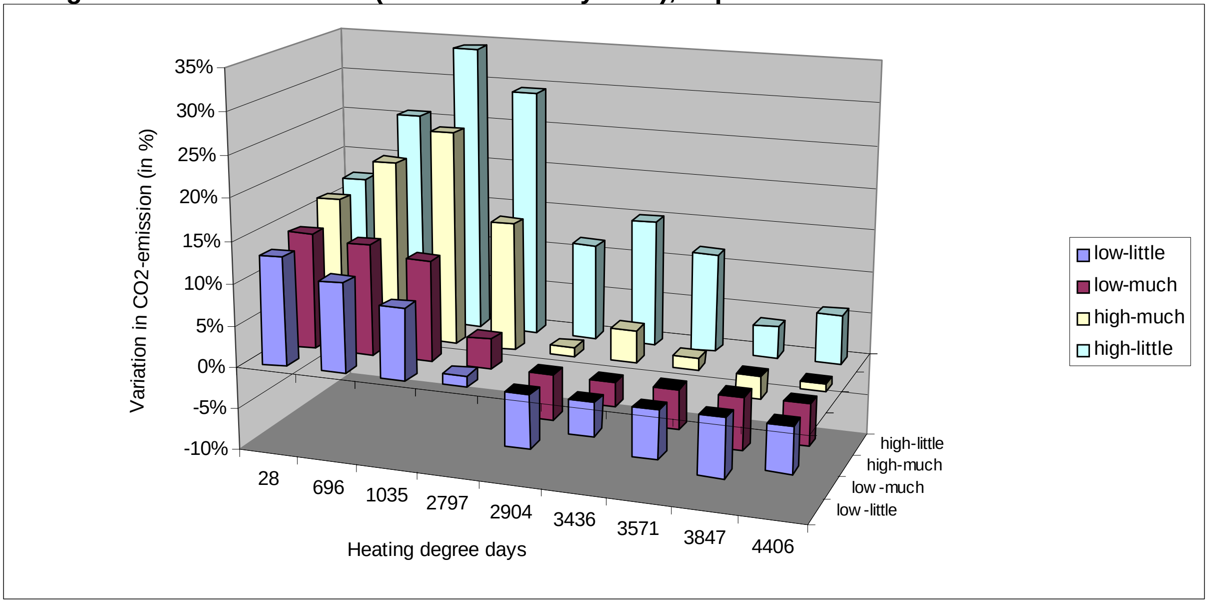
[9] Using today's values for evaluations in 2030 is acceptable for our purpose to investigate relative variations in CO_2 emissions, as long as energy efficiency is improving at a similar pace in the heating and in the electricity domain.

1. **high** CO_2 content (1 Mt CO_2 per TWh corresponding to electricity produced by coal fired power plants)
2. **low** CO_2 content (0.1 Mt CO_2 per TWh corresponding to electricity produced 90% CO_2 free)

The main outcomes can be summarized as follows (Figures 5 and 6):

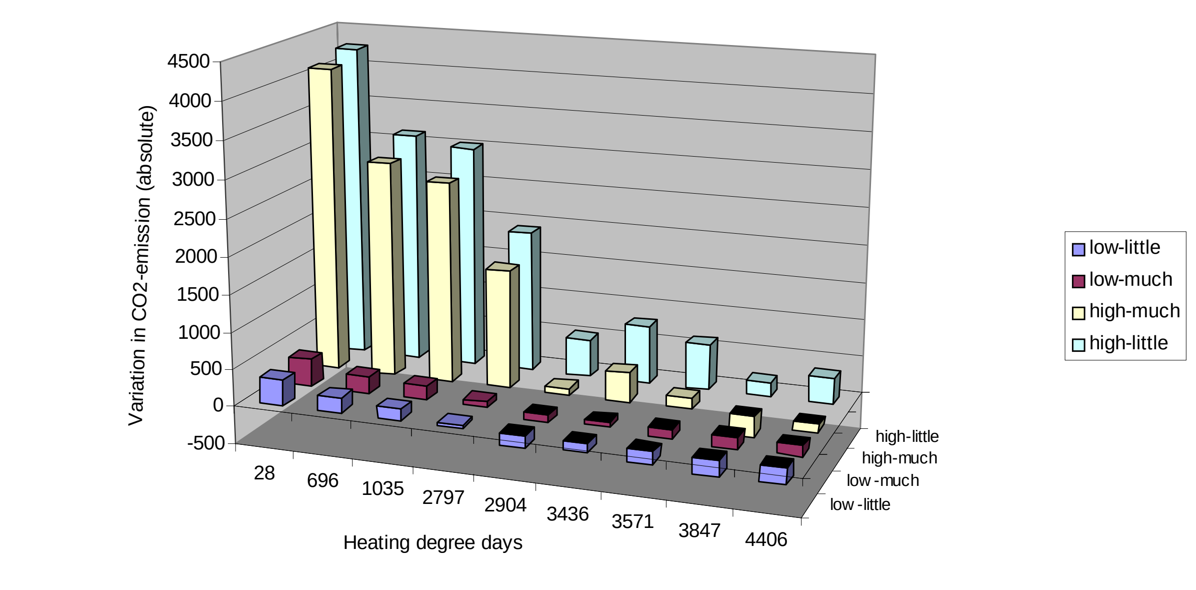
- The results depend only weakly on the CO_2 content of the non-electric fuels for heating. We present the results of the fuel mix with 0.2 Mt CO_2 per TWh corresponding approximately to the CO_2 content of natural gas.
- In warm climates, there is a large increase in terms of relative CO_2 emissions in the case **low** and very large increase in the case **high**. The fraction of electricity used for heating has a significant effect, except for the warmest locations. In absolute terms the increase is, not surprisingly, much higher in the case of **high**.
- In cold climates, the variations are in relative and in absolute terms significantly lower than in warm climates. Except in the case of high and **little**, the CO_2 emissions are always reduced by a temperature increase. The fraction of electricity used for heating has a significant influence in the case of **high**.
- In temperate climates, the situation is qualitatively very similar to the situation in cold climates, except in the case **high** and **much**, where the reduction of CO_2 emissions in the cold climate is changed into an increase of CO_2 emissions. In particular, there is:
    - a substantial reduction of CO_2 emissions in the case **low** almost independent of the fraction of electric heating;
    - a substantial (slight) increase of CO_2 emissions in the case **little** (**much**) and **high**
- The large differences between the locations HDD=2797 and HDD=2904 with rather similar heating degree days is due to the large differences in the cooling degree days.

Figure 5 Changes in relative CO_2 emission from heating and cooling due to climate change in different locations (characterised by HDD), in percent



Source: CEPE

Figure 6 Changes in absolute CO_2 emission from heating and cooling due to climate change in different locations (characterised by HDD), in arbitrary units



Source: CEPE

5. Discussion and conclusions

Detailed studies of long term temperature records show that temperatures in Switzerland rose by around 1.3 K during the 20th century, approximately twice as fast as mean global temperature, with most of the increase occurring in the last three decades. The trend towards higher temperatures is expected to continue, and may be expected to lead to a reduction in the need for heating in winter and increased need for cooling in summer. In this paper we explore the impact of a temperature increase of 1K in winter and 2K in summer on energy demand for heating and cooling and the induced CO_2 emissions. A change of this magnitude reduces HDD by about 10% for most locations in Europe. For CDD, the change is much more dramatic in relative terms, in many cases leading to more than double the present levels.

The reduction in HDD and the increase in CDD will tend to have opposing effects on energy use and CO_2 emissions. Increases in CCD are likely both to cause an increase in both energy use in buildings that already have cooling and in the fraction of total floor area that has mechanical cooling. Even a relatively modest increase in summer temperature may therefore lead to a doubling of cooling energy requirements compared to what would be needed if there is no temperature increase.

The net effect on energy use and CO_2 emissions depends on the balance between the effects on heating and cooling needs. For Switzerland, heating accounts for vastly greater energy use and CO_2 emissions than does cooling, as it does throughout North West Europe. Consequently, the effect of large percentage increases in cooling demand can be outweighed by much smaller percentage changes in heating demand. Another important factor affecting this balance is the relative CO_2 intensity of the electricity and heating fuels supplied to buildings. We found, therefore, a very large increase in CO_2 emissions where both summer temperatures and the CO_2 intensity of electricity are high.

Policy measures to reduce cooling energy demand may be aimed both at reducing the number of installations and at reducing energy use in buildings that have cooling capacity installed. The former is arguably the more effective in countries with cooler summers, and is most applicable for new buildings and major refurbishments, where intervention is possible at the design stage. Minimisation of summer cooling requirements is already encouraged by building regulations in some countries, including Switzerland and the UK. Our results suggest, however, that for Switzerland the present focus on avoiding mechanical cooling may need to be supplemented by emphasis on the design and effective operation of cooling systems. The avoidance strategy will remain viable, however, for the northerly maritime areas (including Ireland, the UK and Scandinavia).

Improvements to the efficiency of air conditioning equipment have been the subject of two EU SAVE projects – EERAC and EECAC – which have provided a basis for further intervention, including labelling and minimum efficiency standards. Legislation arising from Article 9 of the Energy Performance of Buildings Directive, which will to come into force in EU countries in 2006, is expected to lead to better maintenance and more appropriate installations of air conditioning equipment in future.

Rising peak demand in summer is an area of particular concern for policy makers. In Switzerland and other countries with moderate summer temperatures, this will not be significant unless the use of air conditioning increases by a very large factor. In the Mediterranean countries, however, it is a problem that needs immediate consideration both for generation and distribution capacity. The EERAC study found that, in countries with summer peaking, additional investment in generation, transmission and distribution may be needed as a result of growing air conditioning loads. The difficulties experienced in recent years in meeting peak loads in California are of interest and may offer lessons for Europe. Wilson et al, 2002, gave estimates of the contribution of air conditioning to the peak demand experienced in 2002. Commercial sector air conditioning was estimated to account for 15% (7000 MW) of the total peak load, with residential air conditioning contribution a further 14%.

In all European countries, it is clear that the design of buildings should no longer be based on past climatic data but should instead take account of expected changes during the planned life of the building. Frank (2005) shows how energy simulation can be used to assess impacts on particular building types and the benefits of particular technical measures, such as night ventilation. More use of building energy simulation should be made for individual buildings in order to take best advantage of opportunities for minimising cooling load through design features.

While becoming more conscious of the need to avoid (where possible) and minimise cooling demand, it is important that policy makers do not lose sight of the continuing need to reduce heating demand, especially in Northern Europe. Even for Southern Europe, where awareness of cooling demand is already strong, heating demand is likely to remain significant and should not be forgotten, especially if it is met by electricity to a significant extent.

Energy statistics in many European countries fail to distinguish energy used for cooling. While this may have been justified in the past by the relative insignificance of cooling in terms of total energy delivered, it is no longer the case. Bodies responsible for the collection of energy statistics should be encouraged to develop methods for collecting and presenting the relevant data.

References

Aebischer, B., G. Catenazzi, 2006. Energieverbrauch der Dienstleistungen und der Landwirtschaft. Ergebnisse der Szenarien Ia und Ib und Entwurf der Ergebnisse von Szenario II. Bundesamt für Energie, Bern, Stand 6. 1. 2006 http://www.energie-schweiz.ch/imperia/md/content/statistikperspektiven/34.pdf

Aebischer, B., 2005. Spezialauswertung der Daten in Weber (2002). CEPE internal report.

Aebischer, B., 1999. Analyse und Entwicklung des Energieverbrauchs im Dienstleistungssektor. In "Energie, Wirtschaft, Nachhaltigkeit", R. Meier, M. Renggli, P. Previdoli (Hrsg.), Verlag Ruegger, Chur/Zürich (ISBN 3 7253 0665 6)

Aebischer, B., J. Schwarz, D. Spreng, 1996. Perspektiven der Energienachfrage des tertiären Sektors für Szenarien I bis III 1990-2030. Bundesamt für Energie, Bern, Oktober

Aebischer, B., D. Spreng, 1994. Entwicklung des Elektrizitätsverbrauchs im Dienstleistungssektor einer grösseren Stadt. Sozioökonomische Energieforschung, BEW, Januar

Aebischer, B., J. Mutzner, D. Spreng, 1994. Strombedarfsentwicklung im Dienstleistungssektor. Bulletin SEV/VSE 16/1994

Ecoplan, 2005. Branchenszenarien Schweiz. Langfristszenarien zur Entwicklung der Wirtschafts-branchen mit einem rekursiv-dynamischen Gleichgewichtsmodell (SWISSGEM). Bundesamt für Energie, Bern, März http://www.energie-schweiz.ch/imperia/md/content/statistikperspektiven/38.pdf

Adnot et al., 1999. Energy Efficiency of Room Air-Conditioners (EERAC). A study for the Directorate General for Energy (DGXVII) of the Commission of the European Communities, Paris, May

Adnot et al., 2003. Energy Efficiency and Certification of Central Air Conditioners (EECCAC). A study for the D.G. Transportation-Energy (DGTREN) of the Commission of the E.U., Paris, September

Frank, Th., 2005. Climate change impacts on building heating and cooling energy demand in Switzerland. Energy and Buildings 37 (2005) pp 1175-1185

Henderson G., 2005. Cooling degree days, communication per E-Mail, 12. Juni

Hofer, P., 2005. Der Energieverbrauch der Privaten Haushalte 1990 – 2035. Bundesamt für Energie, Bern http://www.energie-schweiz.ch/imperia/md/content/statistikperspektiven/33.pdf

Hofer, P., 2003. Einfluss von temperatur- und Globalstrahlungsschwankungen auf den Energie-verbrauch der Gebäude. Bericht für das Bundesamt für Energie, Basel, 6. Juni

Hohmann R. and U. Neu, 2004. Klimaentwicklung in der Schweiz bis 2050. Ein kurzer Überblick. OcCC im Auftrag des Bundesamtes für Energie, Bern, Januar http://www.energie-schweiz.ch/imperia/md/content/statistikperspektiven/6.pdf

Jakob M., Jochem E., 2004. Erneuerungsverhalten im Bereich Wohngebäude, Schweizerisches Status-Seminar "Energie- und Umweltforschung im Bauwesen", Tagungsband 13, BFE, Bundesamt für Energie, Bern, 31. August
http://www.cepe.ch/download/staff/martin/ErneuVerhaltWohnGeb_StatusSeminar2004.pdf

Jochem, E., M. Jakob (Edts.), 2004. Energieperspektiven und CO_2-Refuktionspotentiale in der Schweiz bis 2010. Energieeffizienz sowie Substitution durch Erdgas und erneuerbare Energien. vdf Verlag, Zürich (ISBN 3 7281 2916 X)

Wilson, J., A. Rosenfeld and M. Jaske, 2002. Using demand responsive loads to meet California's reliability needs. Proceedings of the ACEEE Summer Study on the Energy Efficiency of Buildings, Asilomar, California, 18-23 August 2002, pp 5.305 – 5.316.

Wuest&Partners, 2004. Zukünftige Entwicklung der Energiebezugsflächen. Perspektiven bis 2035. Bundesamt für Energie, Bern, Juli http://www.energie-schweiz.ch/imperia/md/content/statistikperspektiven/5.pdf