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European Temperate, Humid Continental Climate Building Stock facing the Change: Challenges to Face and Pathways to Go, Based on Austrian Experiences

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Abstract

Background: In Central Europe, houses without technical cooling outlived the 1906 invention of the chiller till today. ¹ Right now, both climate change and rising comfort expectations are pushing towards Air Conditioning. The paper highlights the challenge and introduces pathways to go.

Conclusion 1 “Go for Climate Sensitivity”. Even taking climate change into account, there still exist ways to create buildings without cooling, by carefully implementing shading and passive cooling. The principle of night ventilation is already well introduced, while the moderation of the outside micro climate gains growing importance.

Conclusion 2: “Adapt Standards and Laws”. There exist some legal relicts with very rigid maximum indoor temperatures. Those paragraphs lead to high tech building services equipment, which, once being installed, is excessively operated. Those laws have to be changed.

Conclusion 3: “Antiquate the idea of full indoor climate control”. The idea of creating a fully controlled indoor environment definitely has failed. The principles of adaptive comfort and of personal control of comfort parameters have to be adopted or reintroduced.

Keywords

Climate Change, Climate Sensitive Building Design, Adaptive Comfort, Passive Cooling

¹ Willis Haviland Carrier, U.S. patent No. 808897, Apparatus for Treating Air, January 2, 1906

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1. Central Europe's Climate Undergoing the Change

1.1. Temperate, Humid Continental Climate according to Koeppen

According to the Koeppen definition of Climate Zones, Austria belongs to the zone of, category Dfb.²

- > Main category “D, cold”: With the mean temperature of the hottest month of the year above 10°C and the corresponding mean temperature of the coldest month below 0°C.
- > Sub category “f, without dry season”.
- > Sub sub category “b, warm summer”. With more then four months where the mean temperature is above 10°C and with the mean temperature of the hottest month of the year below 22°C

1.2. Current Climate Conditions

Exemplarily the capital of Austria, Vienna is taken as the reference location for all further investigations. Vienna's climate is characterized by its significant winter, with roughly 3.500 heating degree days, by its, mild spring and summer and by a foggy autumn. There's precipitation throughout the year, in winter frequently as snow, at least so far. Humidity is moderate, with monthly mean values ranging from 6 g/kg to 11 g/kg. There's a significant seven-month heating period, lasting from beginning of October to end of April. There's no specific cooling period, with only 24 cooling degree days, again at least so far.

Long term weather data measurements have been taken since the mid 19th century by Austria's official authority, the Central Institute for Meteorology and Geodynamics (ZAMG).³ Based on these measurements Reference Years are derived according to EN ISO 15927-4 through the method of Finkelstein-Schafer.⁴ For description of the current climate situation, such a Test Reference Year is used, based on ZAMG temperature recordings from 1996-2005 and ZAMG radiation recordings from 1981-2000, published within the international climate database METEONORM.⁵ This data set is referred to as “current” within this paper in all later comparisons.

The following spreadsheets (Table 1 and Table 2) list basic climatic key figures of the current climate in Vienna.

Annual Mean Temperature	11°C
Heating Degree Days	3.542 Kd
Cooling Degree Days	24 Kd
Cooling Degree Hours	583 Kh

Table 1: annual climate key figures, Vienna, current

² M.C.Peel, B. L. Finlayson and T. A. McMahon, 2007

³ ZAMG, Central Institute for Meteorology and Geodynamics, Vienna, <http://www.zamg.ac.at/> (18.03.2010)

⁴ EN ISO 1527-4, 2005

⁵ METEONORM 6.1, Global Meteorological Database, 2009, <http://www.meteonorm.com> (18.03.2010)

Monthly Mean Temperatures

January	0°C
February	2°C
March	6°C
April	11°C
May	16°C
June	19°C
July	20°C
August	21°C
September	15°C
October	11°C
November	6°C
December	1°C

Table 2: Monthly Mean Temperatures, Vienna, current

A comfortable overview of the climatic conditions of a site or a region can be gathered from the psychrometric chart. It shows the state of moist air, displays the comfort zone and additionally indicates the link between outdoor climate conditions and favourable architectural design principles.

The following visualisation of the psychrometric chart was done by the authors, using the ZAMG climatic data set already mentioned and following the systematic approach of N. Lechner, published in “Heating, Cooling and Lighting”.⁶

Figure 1 displays the psychrometric chart, indicating favourable architectural design principles, without climate data. Figure 2 again displays the psychrometric chart, this time without labelling but showing the dust cloud of the climatic dataset from ZAMG already mentioned.

⁶ N. Lechner, 2001

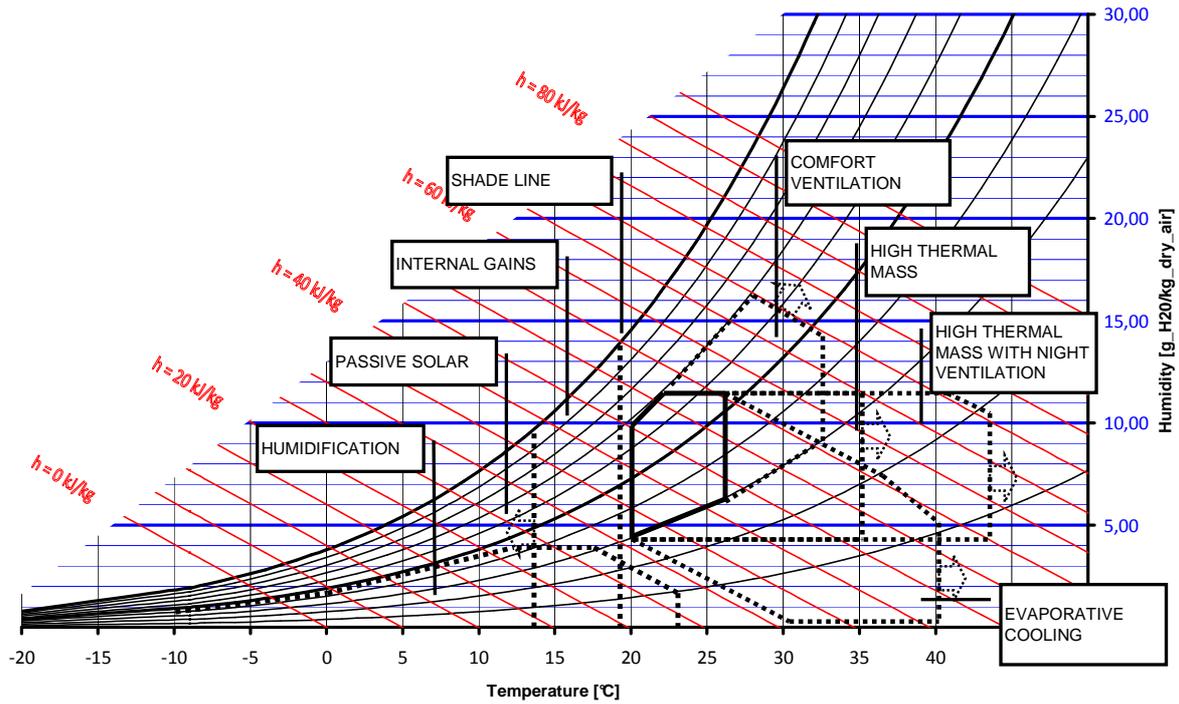


Figure 1: Psychrometric chart, without climate data, including labelling

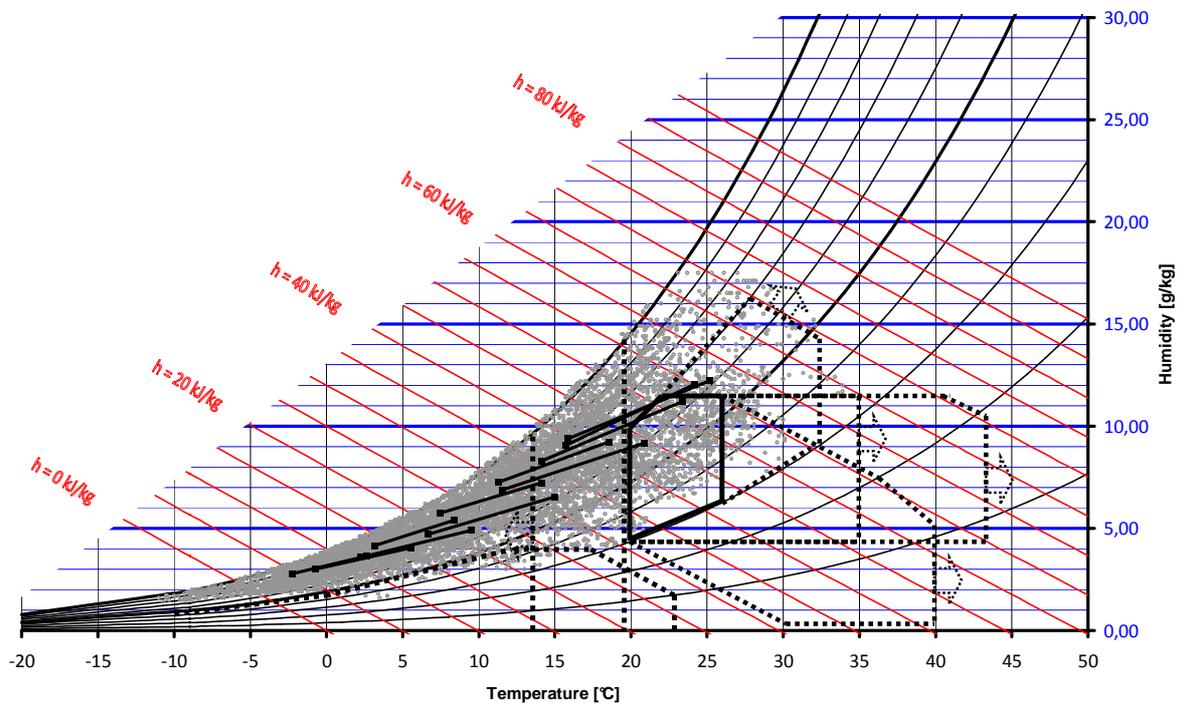


Figure 2: Psychrometric chart, Vienna, current

The psychrometric chart of Vienna's current climate, displays the temperature- humidity - combinations throughout the year by a cloud of dots, with one dot for each hour. Additionally there are indicators for the typical day-swing of temperature and humidity, displayed by black

lines between the monthly mean values of the hottest and the coldest hours of the day, with one line for each month. It can easily be recognised that Vienna's climate is dominated by temperatures below the comfort zone, with only isolated hours which might call for cooling. And there's a significant swing between day and night temperatures of around ten degrees, what makes thermal mass and night flush ventilation a favourable choice of passive cooling.

1.3. Recordings of Climate Change

Climate Change takes place. This is evident not only by prognosis but already from measurements.

The sad proof can easily be given by examining climate data measurements from history. The following comparisons are based again on ZAMG weather data measurements, this time using temperature measurements from 1961-1990 instead of 1996-2005 and radiation data measurements from 1981-1990 instead 1981-2000.

This older data set is referred to as "historic" within this paper in all later comparisons.

The shift both in monthly mean temperatures and in average daily peak temperatures within a month is visualised in the following chart (Figure 3).

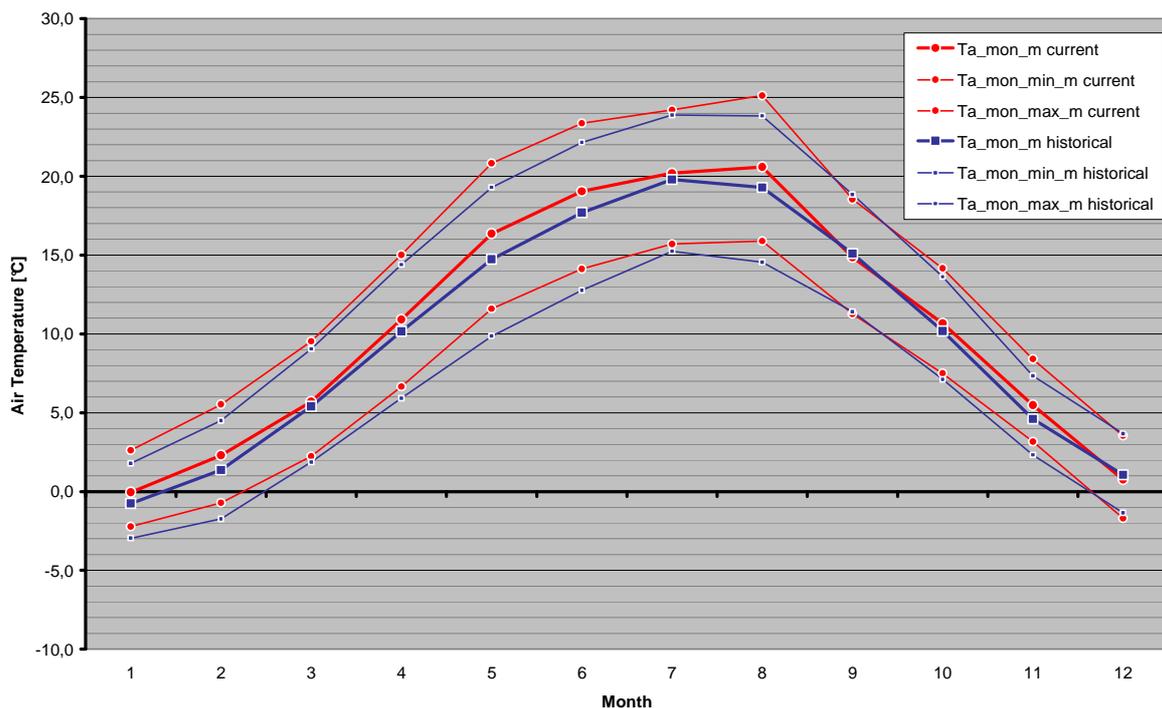


Figure 3: Monthly mean and daily peak temperatures, Vienna, current and historic

The bold lines represent the monthly mean temperatures, while the fine lines mark the characteristic daily maximum and minimum temperatures within each month. In blue colour the information is given for the historical climate data, while in red colour the graphs represent the recent climate data. It can easily be seen, that over a wide range of the year

shifts both in medium and peak temperatures up to one degree Celsius occur. Additionally the graph indicates that the warming effect seems to differ with the seasons.

A second way to visualise the warming which already took place within the only one generation time shift between the data sets of “historical” and “current” is the graph of the temperature exceedance statistics, as shown below (Figure 6).

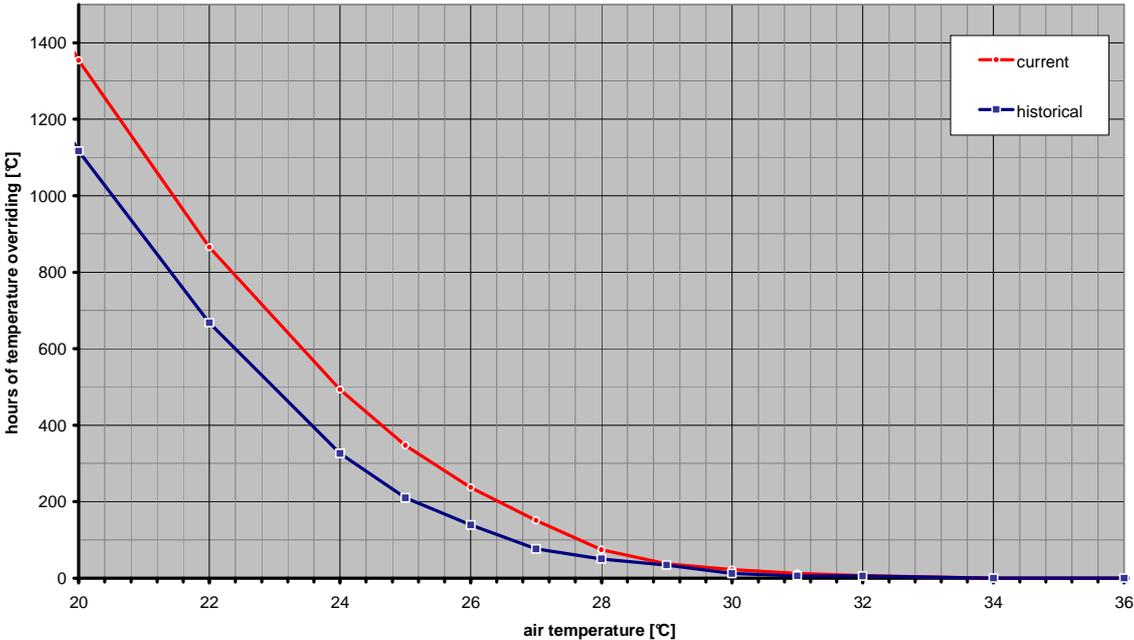


Figure 4: Temperature statistics, Vienna, current and historical

Displayed is the number of hours in which the air temperature exceeds a certain level, again in blue the historical data set and in red the current one. It is obvious, that there’s a shift towards more frequent occurrences of hot temperatures, which directly cause pressure towards mechanical air conditioning in buildings.

1.4. Predictions of Climate Change

There exists a large number of predictions of climate change on the worldwide scale, published and well documented by the IPCC⁷ in its reports.^{8,9,10,11} And there exists the international effort to take actions to limit the global warming to 2 Degrees Celcius. Not only

⁷ IPCC, Intergovernmental Panel on Climate Change, <http://www.ipcc.ch/> (17.03.2010)
⁸ IPCC, 1990
⁹ IPCC, 1995
¹⁰ IPCC, 2001
¹¹ IPCC, 2007

since the failure of the Copenhagen conference is there a strong doubt that this aim will be met.

On the regional scale predictions are much more difficult to generate and consequently are much rarer. Still they are of high importance, since regional effects of climate change with no doubt will differ significantly from the worldwide predictions. For example alpine regions are expected to undergo a much stronger warming process than lower or even coastal influenced regions.

In Austria, a three year research program on the predicted effects of climate change on a regional scale was finished in 2007 and made it possible for the first time to closely investigate consequences of climate change to various subsystems, such as the thermal performance of houses. The research program's name is reclip:more - Research for Climate Protection: Model Run Evaluation.¹² It was carried out by a consortium of Austria's best climate research centres, including again the national authority, the ZAMG, under the project management by the ARC systems research GmbH.¹³

Based on the still optimistic IPCC scenarios, reclip:more predicts two possible scenarios for Austrian Climate in 2050, further addressed as "prediction 1 (P1)" and "prediction 2 (P2)".

Both scenarios predict a mean temperature shift for eastern Austria by 2050, differentiated by seasons, as given in the following table.

	Prediction 1	Prediction 2
Winter:	+1.3°C (+2.3°F)	+1.8°C (+3.2°F)
Spring:	+1.8°C (+3.2°F)	+2.5°C (+4.5°F)
Summer:	+2.0°C (+3.6°F)	+2.5°C (+4.5°F)
Autumn:	+2.5°C (+4.5°F)	+3.0°C (+5.4°F)

Table 3: Regional Predictions of Climate Change, 2050, Vienna

Application of those predictions to the data set "recent" leads to climate situations visualised in the following tables and figures.

Figure 5 shows the shift both in monthly mean temperatures and in average daily peak temperatures based on the climate data sets "recent" and data set "prediction 1".¹⁴

¹² reclip:more, 2007

¹³ ARC systems research GmbH, <http://www.systemsresearch.ac.at/> (18.03.2010)

¹⁴ The scenario „prediction 2“ would roughly add another half degree temperature shift.

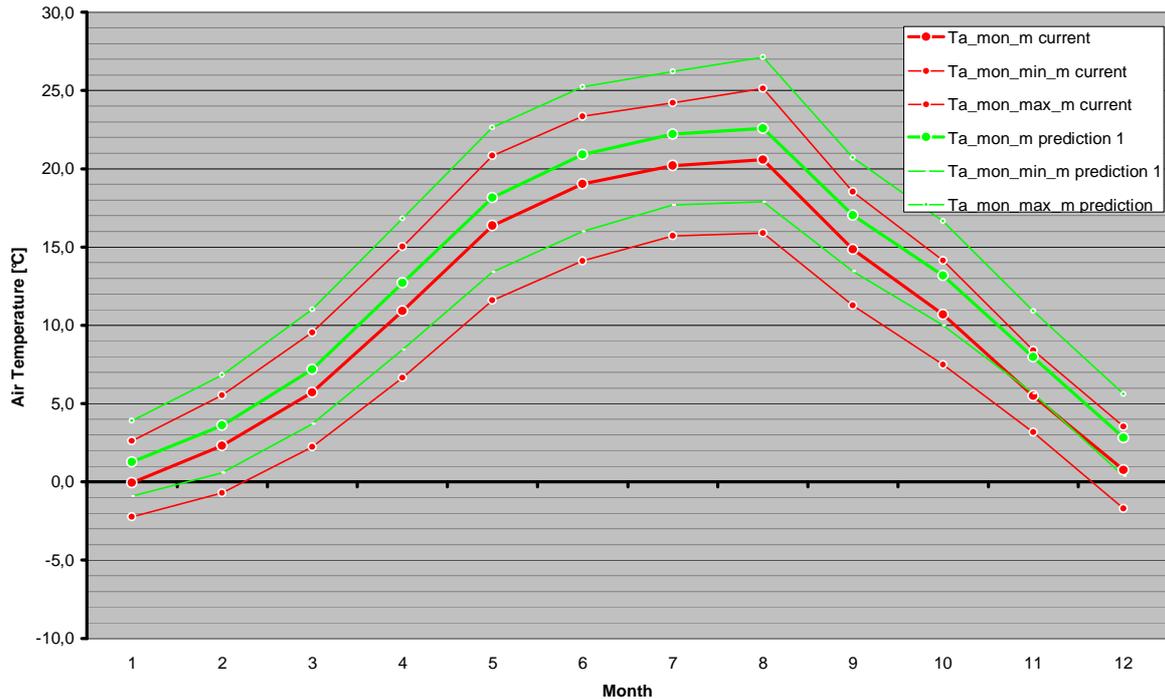


Figure 5: Monthly medium and daily peak temperatures, Vienna, current and prediction 1

Again the bold lines represent the monthly mean temperatures, while the fine lines mark the characteristic daily maximum and minimum temperatures within each month. In red colour the information is given for the recent climate data. In green colour there are the graphs for the optimistic predicted climate data (prediction 1). A shift of both medium and peak temperatures occurs in the range of 1,3 and 2,0 degrees Celsius.

Also the chart of the temperature exceedance statistics very descriptively shows the extent of climate change we are quite sure to be facing (Figure 6).

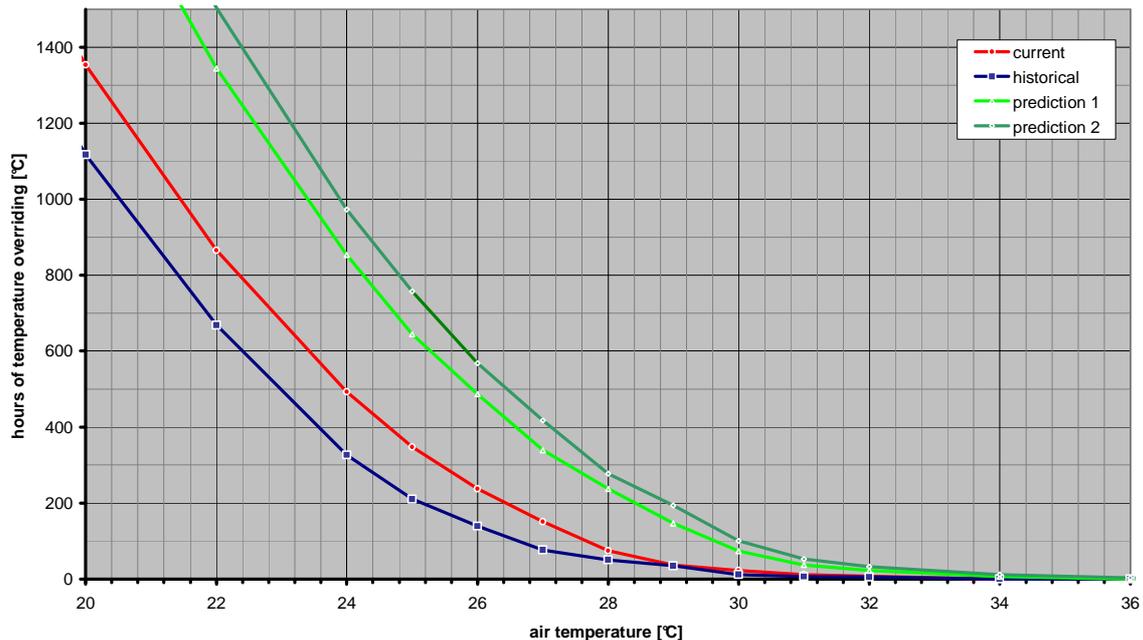


Figure 6: Temperature exceedance statistics, Vienna, historical, current and predicted

Additionally to “historical” and “current” now the temperature statistics of data set “prediction 1” and prediction 2” are displayed, showing the dramatic rise of the statistical annual number of hours with high temperatures.

This shift of temperatures has significant consequences on the thermal performance of buildings. They will be discussed in the following chapter.

2. Climate Change Putting Passively Cooled Buildings under Pressure

2.1. Traditional Climate Sensitive Design Principles in Austria

2.1.1. Heating

In the climate sensitive building tradition of Austria as a representative of European temperate, humid Continental Climate the number one concern always has been the protection from cold winter temperatures and winds. There are around 3,500 Kd Heating Degree Days. In history temperature zoning within buildings, integrating thermal gains from animals were essential design principles, followed by passive solar heating strategies, going along with improvements in glass.

Today U-values of opaque envelope elements of 0,35 W/m²K (R=2,9 m²K/W) are obligatory, with a strong movement towards the Passivehouse standard with U-values of around 0,10 W/m²K. Double-pane insulating glass is standard, with a U-value of 1,10 W/m²K with an increasing number of triple-pane insulating glasses with U-values down to 0,50 W/m²K.

Mechanical air ventilation systems with efficient heat recovery are right on the step of becoming standard.

Heating loads in new buildings range from 10 to 50 W/m², while heating demands can be expected in the range of 15 to 70 kWh/m²a.

2.1.2. Cooling

Technical cooling of buildings developed slowly in Austria. There are only 24 Kd Cooling Degree Days or 583 Kh Cooling Degree Hours. In this climate, there have always been sufficient design methods to keep a desirable summer comfort level by appropriate window design, shading, thermal mass plus night ventilation, amended by measurements of outdoor microclimate moderation.

Against this background, in residential buildings there never has been a need for mechanical cooling and still isn't. In fact, it is stated in our national building codes that a residential building has to be comfortable in summer without mechanical cooling.

Even office buildings kept generally passively cooled till international glass architecture made Air Conditioning inevitable, starting roughly from the 1960's. Today office buildings are constantly cooled and ventilated, with recent cooling loads from 30 to 100 W/m², resulting in cooling demands can be expected in the range of 20 to 60 kWh/m²a plus energy demand for dehumidification and humidification and running the mechanical components, what easily doubles the net demand.

Due to the frequent occurrence of significant hot summers and due to increasing comfort expectations the numbers of annually installed air conditioning systems rapidly grows.

2.2. Parameter Study on Correlations between Climate Change and Cooling Demand

There's a crucial influence of climate change on the need for mechanical cooling. So far even office buildings could reach acceptable summer indoor conditions without air conditioning. Though in most cases a moderate cooling load occurs, the consequences of not installing it have been tolerable in all cases where architecture contributed to the function. This is undergoing a systematic change now, what has been investigated by the authors within a parameter study, which is described in brief:

2.2.1. Objectives

The study investigates and highlights the influence of climate change on the heating and cooling demand of a typical office room. The objective is to point out, which changes in terms of need for cooling might occur to this room, which so far went off sufficiently without technical cooling.

2.2.2. Methodology

The research work is designed as a parameter study, based on

- (1) Definition of an exemplary room
- (2) Determination of climate change scenarios
- (3) Calculations of the heating and cooling demand and the heating and cooling heat load
- (4) Display of results as a set of significant key figures

2.2.3. Definition of an Exemplary Room

An office room with characteristic floor plan, floor height, building construction elements and parameters of usage is defined in accordance to ÖNORM B 8110-3¹⁵, the Austrian design code for the thermal summer performance of buildings.

- > length x width x height = 7.5m x 7.5m x 3.2m
- > one outside façade, oriented to the south, with a window proportion of 50%
- > facade and backside wall made of concrete, partition walls made of light weight constructions
- > insulation level of the building constructions according to European 1960's standards:
 $U_{\text{Wall}}=1.0 \text{ W/m}^2\text{K}$ ($R_{\text{Wall}}=1.0 \text{ m}^2\text{K/W}$),
 $U_{\text{Window}}=2.5 \text{ W/m}^2\text{K}$ ($R_{\text{Window}}=0.4 \text{ m}^2\text{K/W}$),
 $g_{\text{Window}}=0,76$
- > outside louvers with a shading coefficient of 0.26
- > Air Change Rate during occupancy periods 1,0 1/h; else 0,1 1/h;
with part-time summer natural ventilation at 1,5 1/h

Table 4: List of input parameters

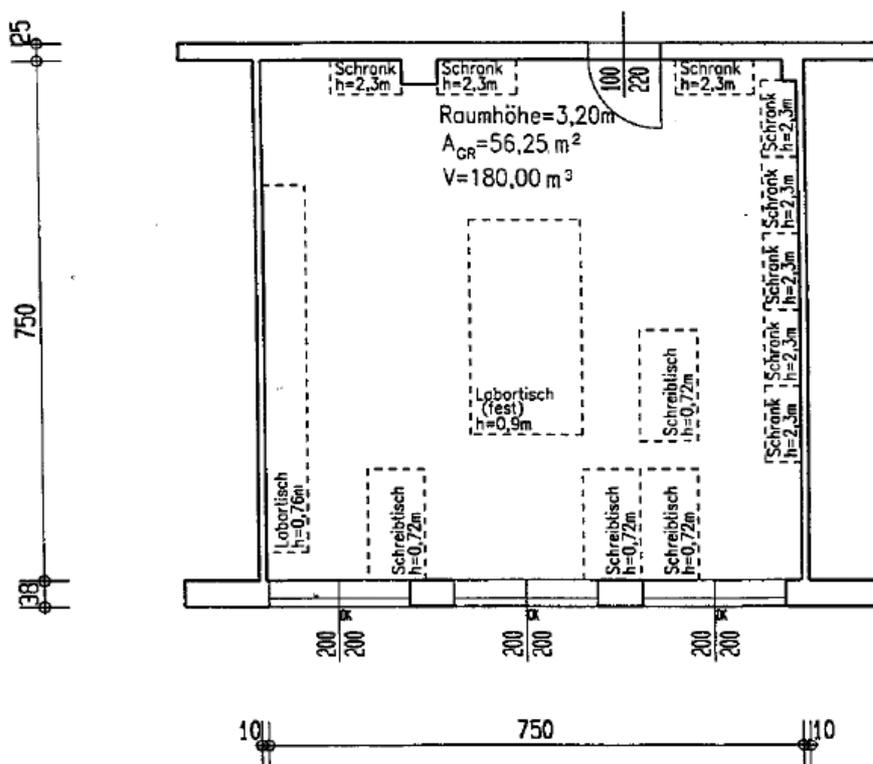


Figure 7: Floorplan of the investigated room

¹⁵ ÖNORM B 8110-3, 2001

2.2.4. Determination of Climate Change Scenarios

Climate data sets are derived as already described before:

For the recent climate the Test Reference Year from ZAMG is used.

For the 2050 scenario the predictions of reclip:more are applied to the Test Reference Year. The version with lower temperature changes is further on addressed as 'prediction 1' (P1) while the version with the higher temperature changes is named 'Prediction 2' (P2).

2.2.5. Calculation of the thermal performance

The analysis of the thermal performance is done by calculation of the heat balance of the room using the comprehensive dynamic building simulation tool TRNSYSlite.¹⁶ Using a single zone model of the room, the energy balance is calculated in steps of 20 minutes for varying weather conditions and varying usage conditions.

2.2.6. Display of results

A set of key figures is defined to describe the change of heating and cooling demand as well as the ability of the room to be run without technical cooling at all:

- > Heating Demand [kWh/m²]:
The calculated annual net heating energy, relating to the heated net floor area of the room, needed to keep the room at an air temperature of minimal 20°C (68°F)
- > Cooling Demand [kWh/m²]:
The calculated annual net cooling energy, relating to the heated net floor area of the room, needed to keep the room at an air temperature of maximal 26°C (79°F)
- > Heating Load [W/m²]:
Maximum net heating load needed to keep the room at an air temperature of minimum 20°C (68°F) relating to the heated net floor area of the room
- > Cooling Load [W/m²]:
Maximum net cooling load needed to keep the room at an air temperature of maximum 26°C (79°F) relating to the heated net floor area of the room.
- > 27°C temperature exceedance frequency [h]:
Number of hours within a one year period in which the indoor operative (!) temperature exceeds the reference value of 27°C (81°F).

Table 5: List of key figures to describe the results of the survey

¹⁶ TRNSYSlite 4.0.27, Transsolar, Stuttgart

2.2.7. Results

The results of the parameter study show clearly that the predicted regional climate change scenarios significantly affect the heating and cooling demand of the analysed office room. See the following table (Table 6) and charts (Figure 8 and Figure 9).

	current	prediction 1		prediction 2	
Heating demand	23 kWh/m ²	19 kWh/m ²	-17%	16 kWh/m ²	-30%
Cooling demand	1 kWh/m ²	9 kWh/m ²	+900%	12 kWh/m ²	+1.200%
Heating load	22 W/m ²	20 W/m ²	-9%	18 W/m ²	-18%
Cooling load	33 W/m ²	39 W/m ²	+18%	42 W/m ²	+27%

Table 6: Effects of Climate Change: List of results

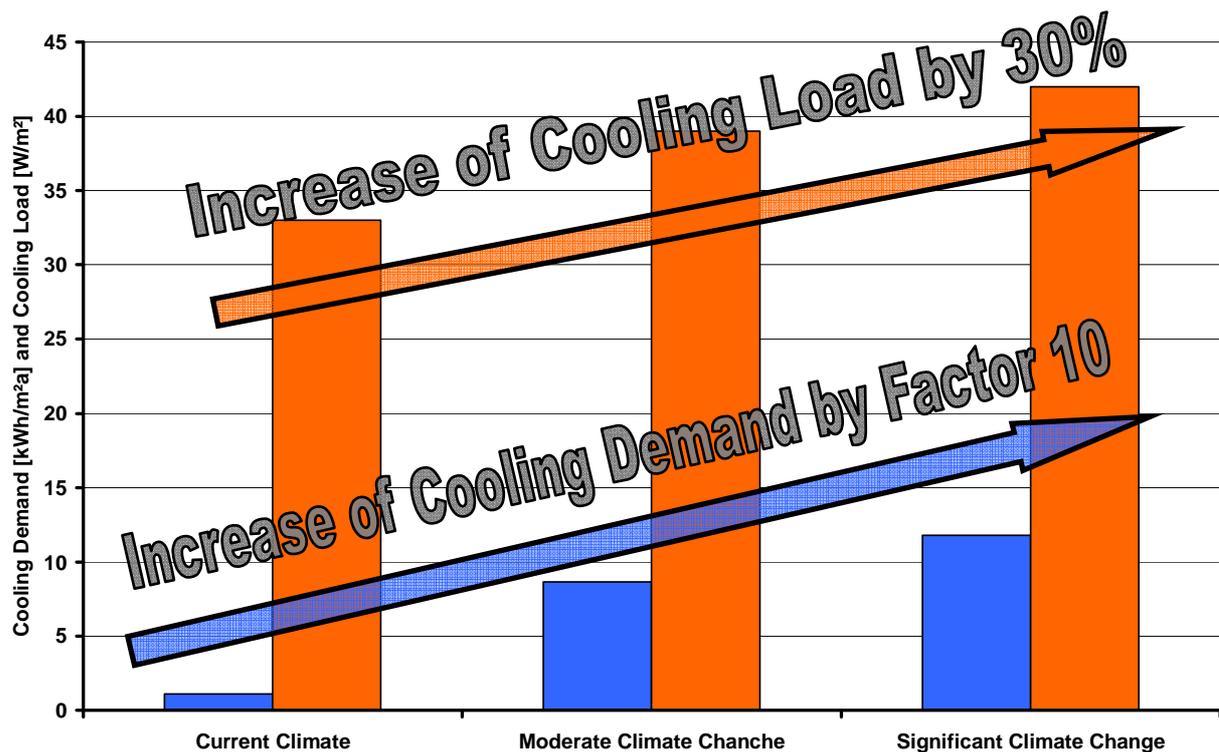


Figure 8: Effects of Climate Change on the Cooling Load and Cooling Demand

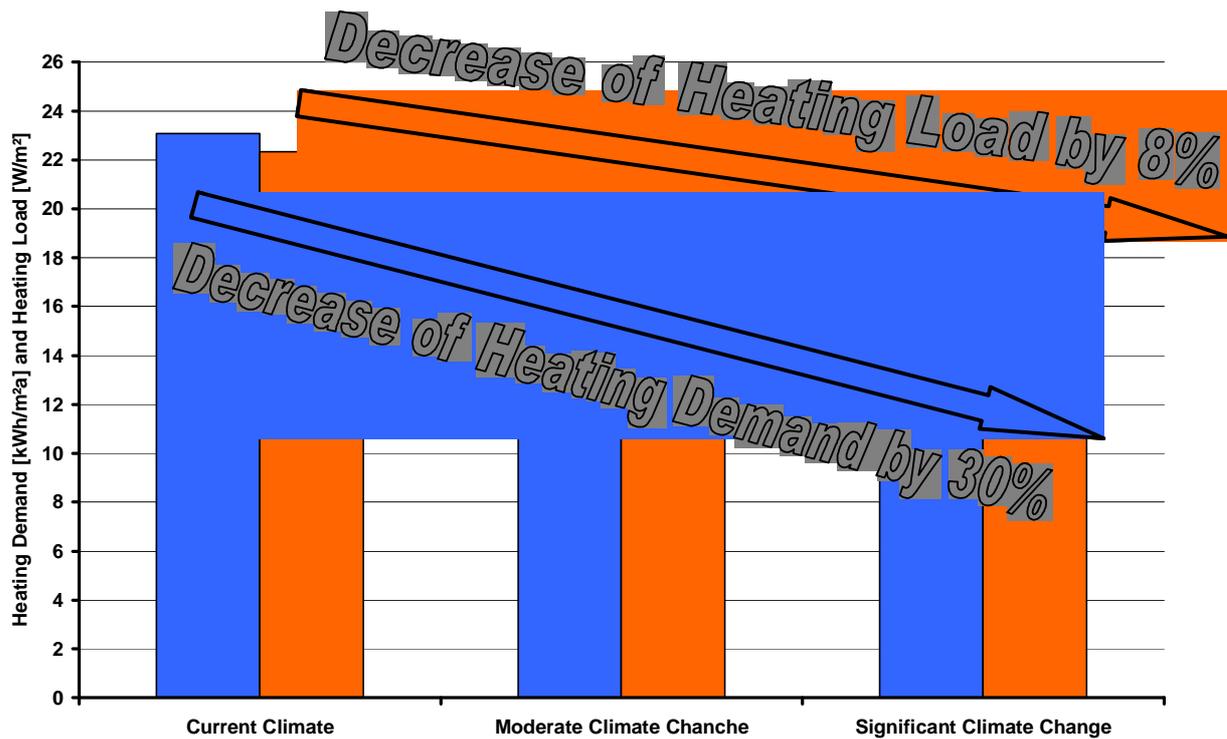


Figure 9: Effects of Climate Change on the Heating Load and Heating Demand

The 27°C (81°F) temperature exceeding frequency rises from 329 h to (P1) 1.063 h (+223%) or to (P2) 1.303 h (+296%)

In short, there are two distinctive results:

Heating demand drops moderately. Cooling demand rises excessively. The sum of both rises.

Heating load drops slightly. Cooling load rises moderately. The sum of both rises.

Cooling demand not only rises, but newly occurs. It has to be pointed out, that Central Europe with its temperate, humid continental climate till nowadays has every chance to create buildings that perform well without any technical cooling, just using elements of climate conscious architecture and of passive cooling. We must react to climate change and adopt our design principles. Otherwise climate change will make us lose this opportunity of running buildings without technical cooling.

The sum of heating load and cooling load increases. The loads for heating and cooling are in general proportional to the investment costs. Climate change therefore will not only cause higher running costs but also higher investment costs for building service installations.

3. Conclusions / Advices

3.1. Adapt Design Principles to meet Climate Change

3.1.1. General Objectives

Central Europe is in danger to lose the benefit of a non-air-conditioned building stock. Both climate change and a general increase of comfort expectations are the driving parameters.

With architectural design, construction and building service engineering that serve the principles of climate responsive design the challenge can be met to keep buildings comfortable without air conditioning.

Building design rules which are written down in national and international standards should be adapted to the climate change scenarios as soon as possible. That's valid even for recently introduced standards such as the EPBD.¹⁷

3.1.2. Shading and Daylighting

Shading will become of major importance. It will have to be developed from only glare protection to a true sunlight blocking function, such as traditionally applied in Mediterranean regions. Residential houses shall get equipped with really heavy shading devices to lock the sun out during those times of the day when rooms aren't occupied.

Parallel to the strong need for shading the quality of daylighting has to be watched and addressed. A sensible positioning and sizing of windows, together with a wise choice of indoor colours and corresponding floor plans will be necessary to bring thermal and visual qualities together.

3.1.3. Thermal Mass, Night Flush Ventilation and Comfort Ventilation

Thermal Mass plus Night Flush Ventilation have been most favourable Passive Cooling strategies in the Area of Austria, respectively of Vienna. Facing Climate Change the night temperatures rise, in town areas significantly supported by heat island effects. Therefore the possible contribution of traditional night flush ventilation drops.

The authors are convinced that it will be a necessary step to adopt comfort ventilation into our buildings, at least during the afternoon hours. This would need a real change of paradigm, followed by developing new design rules, since the Austrian design principle so far was to achieve lower temperatures indoors than outdoors and therefore close the room against outside climate and only introduce hygienic minimum ventilation.

3.1.4. Floor Slab Cooling, Earth Cooling, Phase Change Materials

There are a number of hybrid cooling technologies, which gain importance if Passive Cooling alone won't do the job. In Austria there are already a remarkable number of positive experiences with floor slab cooling. Best choice is to run it via Earth Cooling, even without a need for a chiller running. Phase Change Materials are a promising development, but so far there are still significant challenges left, not only economically, but physically, too.

¹⁷ EPBD, 2002

3.2. Learn about mixed mode buildings

We will have to learn about time and learn to differentiate between periods of a day where there has to be mechanical cooling and other periods of a day where the building is left over to passive cooling. That, again, will need a change of paradigm, since today AC-systems, once installed, tend to be used excessively, 24 hours a day.

3.3. Implement a legal environment for climate sensitive buildings

To make the passive cooling choice the easy choice, legal restrictions against such buildings have to be changed, e.g. standards that call for strict temperature limits or other strict comfort parameters throughout the year.

The most famous one is ISO 7730, defining the three categories of thermal comfort from A to C, defined by the maximum range of PMV.¹⁸ ISO 7730 is incorporated into the Austrian Standards system ÖNORM and therefore is a basis of national design decisions.

Category A: $PMV \leq \pm 0,2$; Category B: $PMV \leq \pm 0,5$; Category C: $PMV \leq \pm 0,7$

That leads to a range of operative temperature that is influenced not only by radiative and air temperature but additionally clothing level, activity, air speed and humidity. By definition of ISO 7730, the maximum operative summer temperatures range between 26,6°C (category A) and 28,0°C (category C), assuming typical European office circumstances.¹⁹ ISO 7730 applied to humid Continental Climate in fact is not too bad, but it's missing an adaptive quality.

ISO 7730 proved to work well in air-conditioned buildings. But it was found out to call for much too strict comfort benchmarks in buildings without AC. Application of the ISO 7730 therefore lead to Air-Conditioning in the huge majority of buildings, what has to be questioned.

There already is an answer to the question, and that could be EN 15251, again incorporated into the Austrian national standards system ÖNORM.²⁰ It defines indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics. EN 15251 differentiates comfort criteria between buildings with and without mechanical cooling. For buildings without mechanical cooling and with personal access to windows, blinds and vents it introduces the adaptive comfort model of ASHRAE 55, what really can be regarded as a breakthrough towards a sensible comfort parameter definition. Maximum operative temperatures are linked to the rolling mean temperature. Vienna's today's summer climate is characterized by rolling mean temperatures of around 20°C, with rare peaks up to 23°C, what results in acceptable maximum operative temperatures of 27,5°C (category 1) to 30,5°C (category 3).

The following chart (Figure 10) shows a one year run of the current hourly temperatures (light blue), the daily mean temperatures (dark blue), the daily rolling mean temperature (red) and the two limits for comfortable indoor temperatures according to the adaptive comfort model of EN 15251 (orange).

¹⁸ ISO 7730, 2005

¹⁹ Clo=0,5, met=1,0, r.H.=50%, v=0,1m/s

²⁰ EN 15251, 2007

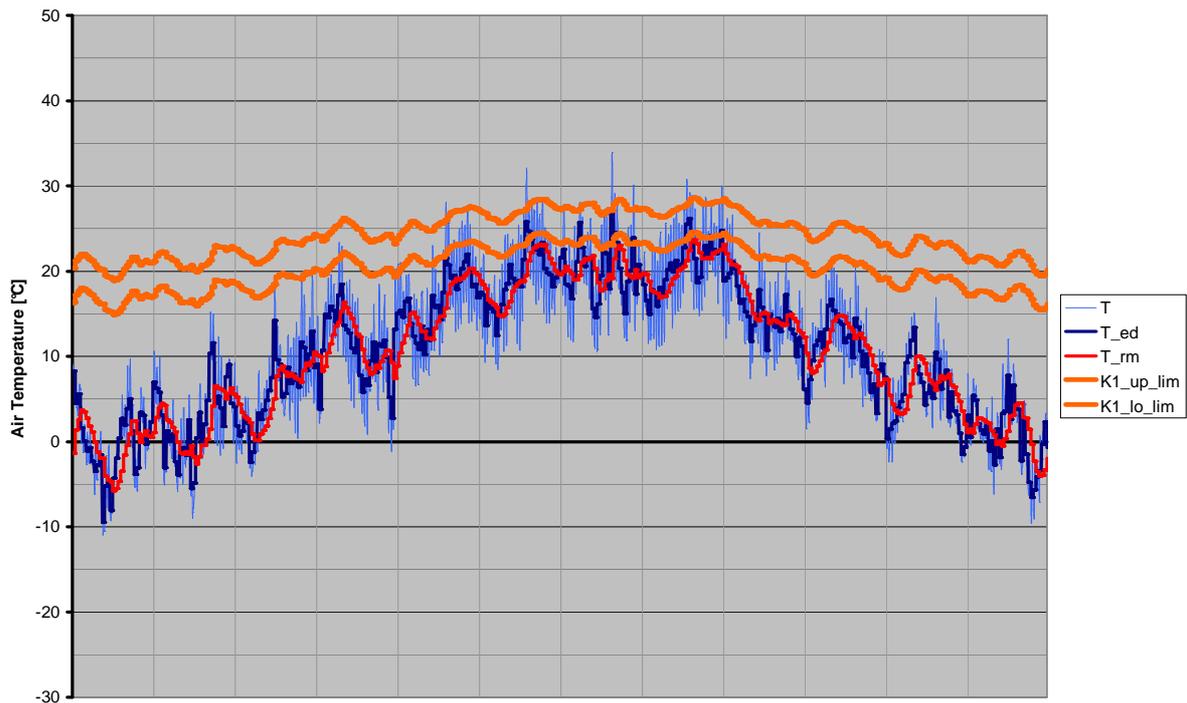


Figure 10: Comfort limits according to EN 15251, adaptive comfort model, Vienna, current

Again, climate change will do its job and will rise the peaks of the rolling mean temperature in Vienna up to 25°C, allowing corresponding maximum operative temperatures of 29°C (category 1) to 31°C (category 3).

Such indoor temperatures may be regarded as high, compared to air-conditioned buildings with fully controlled indoor environment. On the other hand it has to be understood that a comfort perception like this is reality in millions of houses which have no air conditioning. The adaptive comfort model is officially introduced with EN 15251, but it hasn't made its way into architectural and building services design so far. To the Authors it seems of crucial importance to raise awareness within the Architects and Building Services Engineers towards this standard and towards the chance to leave the pathway of too strict comfort benchmarks behind.

Last not least, a close look national legal frameworks, dealing with the employees' safety and health is necessary. Quite often are some definitions on temperature and humidity benchmarks included. And frequently those parameters are driven by the spirit of the seventies. One example is the "Deutsche Arbeitsstättenrichtlinie", ASR 6.²¹ In this code, the recommended maximum of operative temperature is defined with 26°C, allowing only temporal exceeding. Such rigid codes have to be changed.

²¹ ASR 6, 2001

3.4. Antiquate full indoor climate control

Last not least: Antiquate the idea of full indoor climate control. It's just an engineer's dream, without too much connexion to real life. Real life is about survival and sustainability. We may allow our built indoor environments to change a little bit with daytime and seasons. There's nothing wrong with that. Application of the adaptive comfort model will be a step towards the right direction.

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