# MAN & CLIMATE – ARE WE LOOSING OUR CLIMATE ADAPTATION?

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**Abstract -** As part of a bigger research project in the area of comfort due to natural ventilation in the hot and humid climate, the deviation from the Thermal Comfort Mean (on the ASHRAE scale)for locals in the hot-humids was checked for a school with air-conditioning. Due to various publications by different authors a clear deviation was expected, presuming the typical acclimatization of residents in this climate. The results were quite surprising: the average of all deviations came close to zero, with a very slight difference between male and female students. The question was now, why this group of students in Rio de Janeiro show a comfort sensation like that of people in temperate climates. Therefore a second analysis was carried out, based on a questionnaire, which asked the participants for the average daily stay in air conditioned spaces. The result was an average of a daily 23% without air-conditioning, which means, that more than ¾ of the day these participants stayed in air-conditioned spaces. The long term effect of this de-acclimatization means a considerably higher energy consumption of the building stock in the near future.

## 1. Introduction

The energy consumption of inhabitants in tropical countries is generally much lower (see table 1) than in temperate climates (see Fig. 1, 2). One of the reasons is obvious: to survive energy is not necessarily important in the tropics – living (without comfort!) - up to a skin temperature of 35 C. Under humid conditions the comfort by high temperatures can be improved by ventilation or wind speed $v$ ($0 < v < 3.5$ m/s). Only rich people or office workers have – if power is there - the possibility to use air-con for comfort improvements (to lower the temperature, the relative humidity and increase in offices the productivity). For air-con offices the North Americans postulate (horrible) 19°C room temperature in summer times. In the Asian territories one can see this in case where in offices the temperature is especially realised for North Americans and Europeans, while in buildings the local people live and work with a good efficiency > 28 C.

## 2. One Comparison Rio de Janeiro/Cologne

*Rio de Janeiro (22° South):* The natural climate conditions are hot-humid, but using the passive techniques to solve the comfort problems, there is only 3 % of the year when air-con is needed; the other comfort improvement measures could be obtained : 61% by ventilation, 15% by thermal mass and solar heating and 20% of all the outdoor conditions are perfect without any additive measure (Lamberts, 1997). Thus as can be seen in former times most buildings are comfortable in summertime only through the use of ventilation. Thanks to strongly increased traffic noise and building density development, comfort by ventilation is no longer feasible in many places. So air-con set out to conquer the hot-humid world, if the budget is there for investment and daily use. However only a insignificant part of the apartment inhabitants can spent the money for air-con (e.g. in Brazil 8% of the flats are air-

conditioned). Offices and other workplaces have air-con for comfort improvements and good work results. In Tab. 1. the effect of energy consumption is shown for the City of Rio de Janeiro by the power demand of the different user groups. Residential consumption is – only use of power for light und electrical appliances - the smallest, commerce is with air-con, computer etc. and light, the middle, but industry uses the most energy in kWh/m²*a for all possibilities of energy use.

Tab 1. The today energy consumption coupled on different buildings types in Rio de Janeiro

| Buildings | % of total building area[6] (IPLANRIO) | mean m²[7] (IPLANRIO) | kWh/m²a (LIGHT) |
|---|---|---|---|
| Residential | 66.92 | 74.9 | 54.13 |
| Industrial | 5.72 | 1253.3 | 519.46 |
| Commerce | 12.90 | 156.3 | 213.33 |

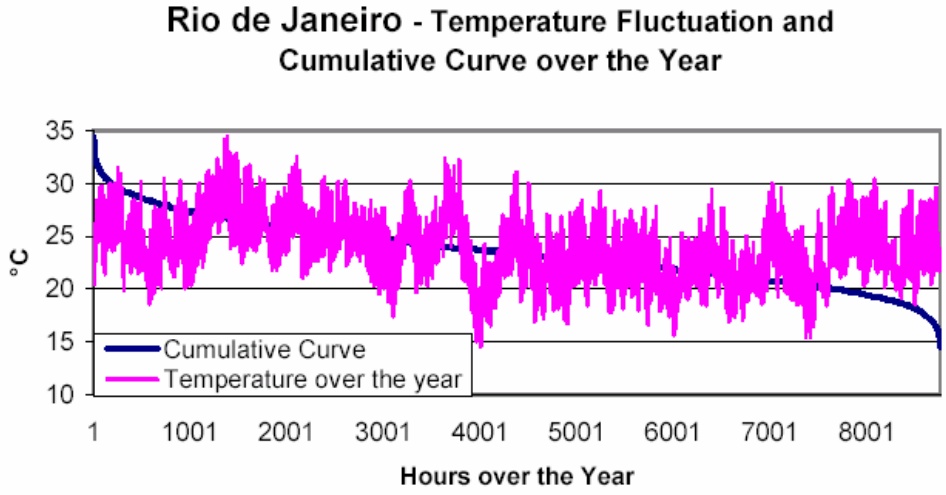


Fig. 4. Cumulative and fluctuation curve of the outdoor temperature in Rio de Janeiro (Data Meteonorm (Meteotest); 32 h > 32°C; 180 h > 30°C; 684 h > 28 °C; 1820 h > 26°C; 3608 h >24°C; 5819 h >22°C; 7626 h > 20°C

*Cologne (51 North)* Although Cologne lies under the golf stream influence the climate is still that of moderate cool.

So the heating season starts 1st of October and ends 31st of March. In former times (up to the 60´s) the German people lived in only one heated room and then at the end of the 70´s they began investing in central heating systems and spent a little money for energy. Beginning, in 1970, with the 1st oil crisis and an average annual consumption for heating of 440 kWh/m², the energy saving legislative started. Down now with the latest legislation, which took effect in February 2002, to 40 kWh/m² annual consumption (a reduction of 90 % in ~ 30 years). The mean value over all buildings in 2001 was ~ 190 kWh/m²a. With a better insulation of all house components the energy amount decreases for heating. The insulation level has thus increased from a standard of 4 cm now to a modern level of ~ 15 cm, while the window U-Value came from ~ 3 down to 1.1 W/m²*K

[6] Residential = 42% apartments, 23% houses, 12% low cost, 12% plots, 11% others; Industrial = all types; Commerce = 35% offices, 16% storages, depots, 13% schools, 9% hotels, 9% hospitals, 5% traffic stations, 4% restaurants, 4% banks, 4%offices, 3% clubs, 1% service stations, 1% cinemas

[7] Total area divided through numbers of flats/companies/

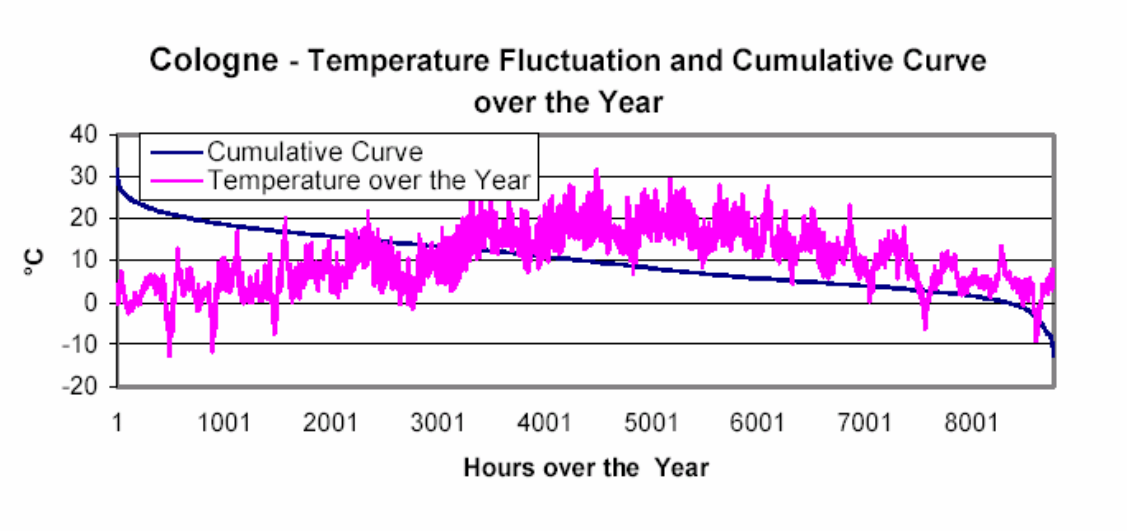


Fig. 5. Cumulative and fluctuation curve of the outdoor temperature in Cologne (Data Meteonorm (Meteotest); 15 h > 28 °C; 167 h > 24 °C; 688 h > 20 °C; 1990 h > 16 °C; 3590 h >12°C; 5052 h > 8°C; 6937 h > 4;8320 > 0°C

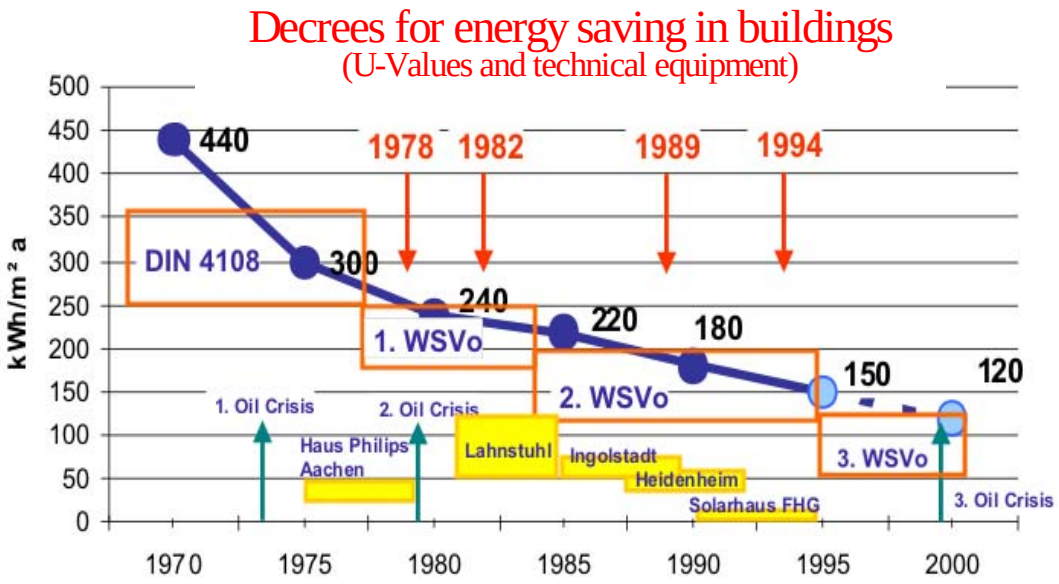


Fig. 4. Mean end energy (kWh/m²a) used for heating in Germany 1960 until 2000

## 3. Comfort sensation in schools with air-conditioning

As part of a bigger research project in the area of comfort due to natural ventilation in the hot and humid climate (Grimme et al., 2002), the deviation from the Predicted Mean Vote (PMV) for locals in the hot-humids was checked for a school with air-conditioning. Due to various publications by different authors (Bravo, 2000, MacFarlane, 1958, Nicol, 2000) a clear deviation was expected, presuming the typical acclimatization of residents in this climate, as seen by tests on adapted persons (Grimme et a. 2002). Figure 5 shows all the 884 data over a period of up to 39 days under similar weather conditions. An example of the indoor conditions is given in figure 6. The results in the air-con school room were quite surprising: the average of all deviations came close to zero, with a very slight difference between male and female students. If one computes the average total deviation, this is only 0.05. The deviation from the Thermal Comfort Mean (on the ASHRAE scale) can be designated as

insignificant. Now divide up one the group the probands in masculine and feminine on, those show as a average total deviation for the feminine probands a value of 0.1; for the group of the masculine a value results of –0.05.

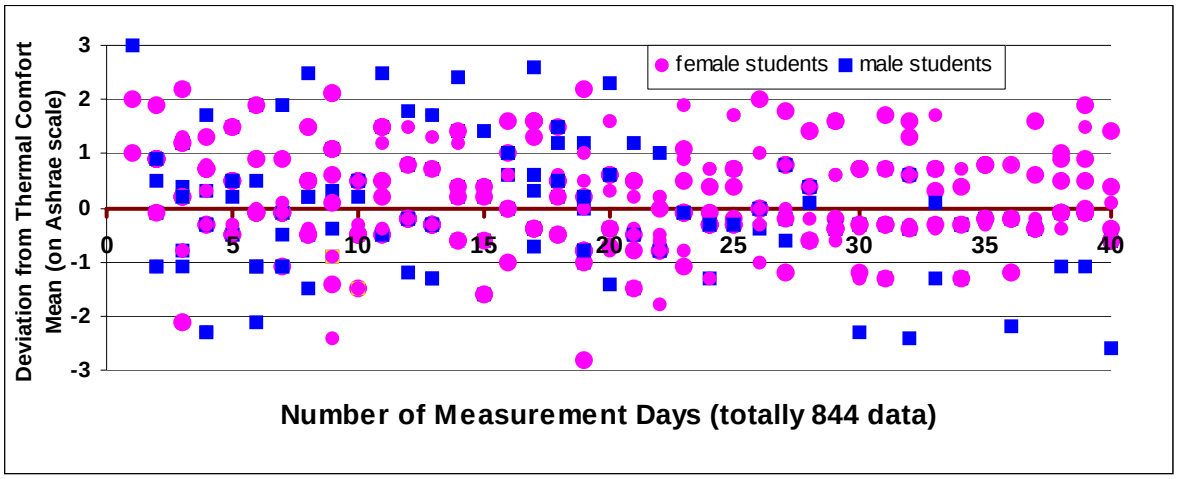


Fig. 5. Thermal Comfort-Deviation (on Ashrae Scale) over 18 female, 12 male probands in an air-con high school room for a period >13 < 39 days and 3 measures, total 844 data, under similar weather conditions

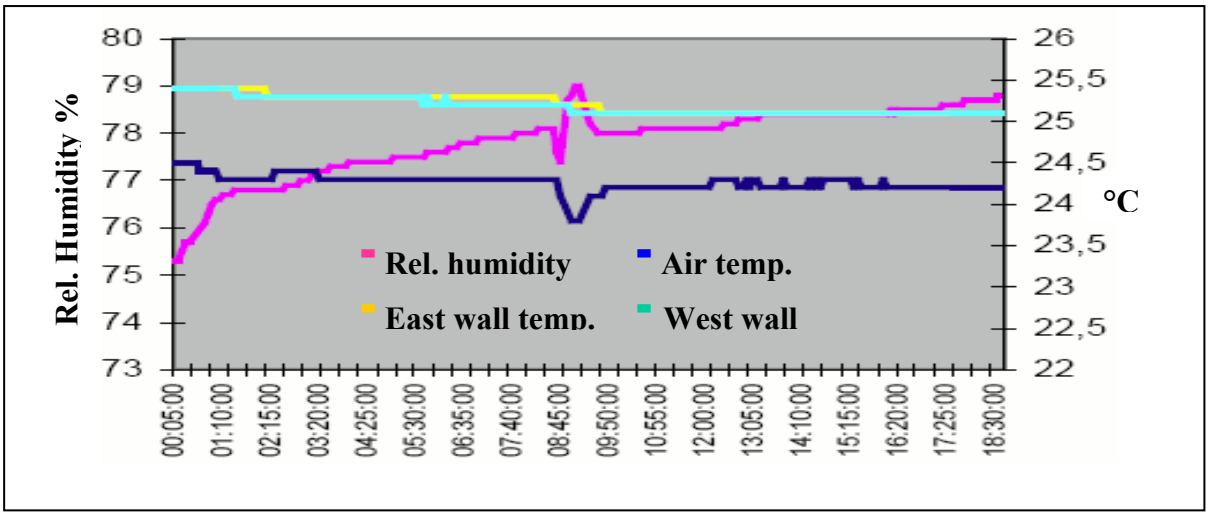


Fig. 6 Measured conditions for the 06/26/02 in the school room used by the probands

## 4. Air conditioning in daily life and its effect on the climate adaptation

The question was now, why this group of students in Rio de Janeiro show a comfort sensation like people in temperate climates. Therefore a second analysis was carried out, based on a questionnaire, which asked the participants for the average daily stay in air conditioned spaces. The result (see Fig. was an average of a daily 23% without air-conditioning, which means, that more than ¾ of the day these participants stayed in air-conditioned spaces. Only 5 of all 32 probands spend less than 12 hours with air-con!

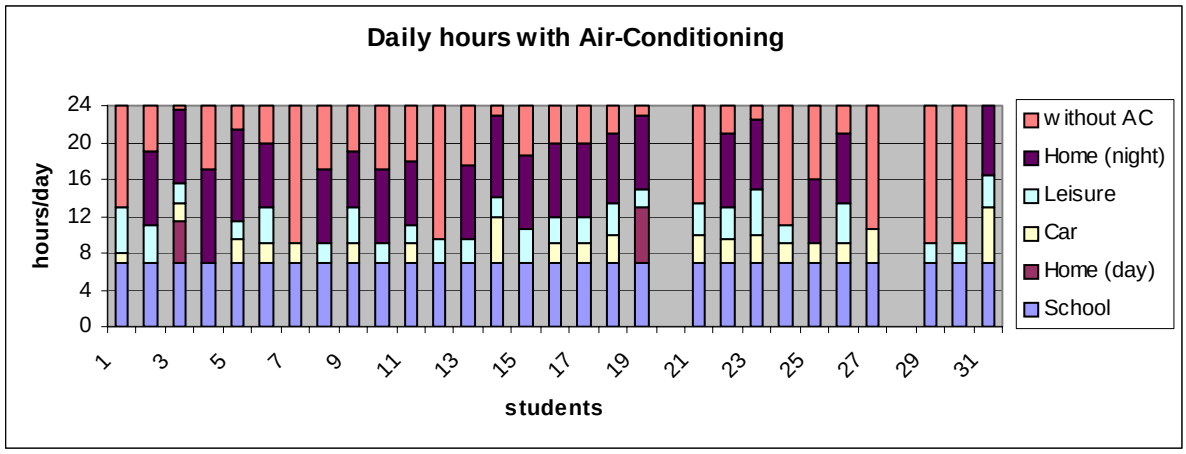


Fig. 7. Daily hours in air conditioned rooms – results from Rio de Janeiro

The long term effect of this de-acclimatization means considerably higher energy consumption in the present building stock under the present circumstances (availability, investment, income, cost of maintenance and use). Only with intelligent solutions for the buildings (see Fig. 8) and trained, respectively climate adapted users (they have to live with higher room temperature) can such a horrible energy scenario be overcome. Another example can be a green roof: the effect is not only positive in the microclimate (evaporation cooling, retention of rain water, roof shading), but also in dust catching and noise protection, as well helps for longer lifetime of the roof sealing.

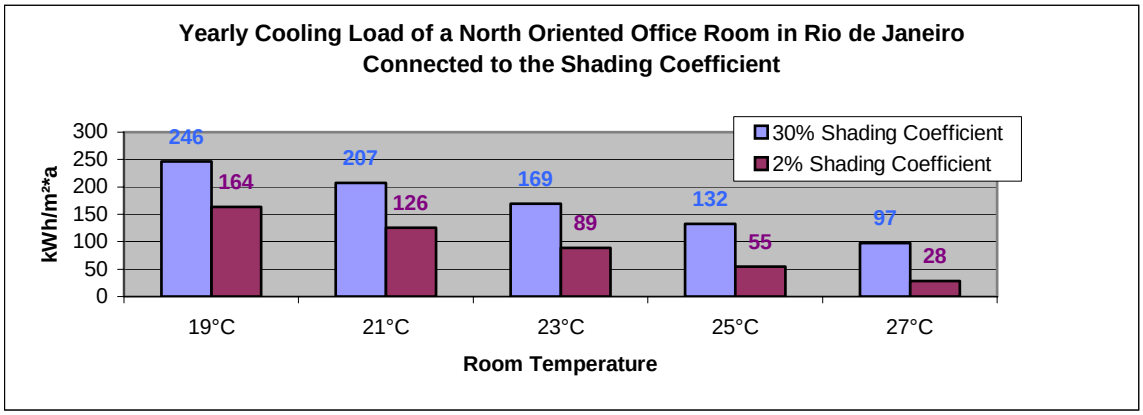


Fig. 8. Yearly cooling load of a north orientated office room in Rio de Janeiro – Influence of accepted maximum temperature and shading coefficient (Laar)

## 5. More wealth – more comfort – more costs

An increasing income in a population generally is followed by an increasing demand of comfort. In Germany, as in many other countries in temperate climate, the only heated room in most buildings was the kitchen or a combined living room. The rest of the rooms were not heated and therefore freezing cold in winter. To warm the bed, a hot stone or a hot-water bottle was put into the bed some time before its use. Central heating, which means the heating of all rooms, was only introduced in the early 60´s of the last century, gradually substituting the ovens fired with coal. Today >85% of all apartments are equipped with this system, which meant a sharp increase in the energy demand per square meter. Only improving the energy efficiency of the buildings could curb this tendency. However in Germany the yearly rate of new energy saving buildings is very low and the total energy saving is only very slowly moving to a lower (rsp. better) level. The comfort temperature is always increasing, starting

from 18°C and now reaching 21°C (up to 23°C in some rooms). International building codes have a minimum of 19°C irrelevant of location and this is used in most cases as the design temperature; for Brazil 23 to 25 C are used for air-con design.

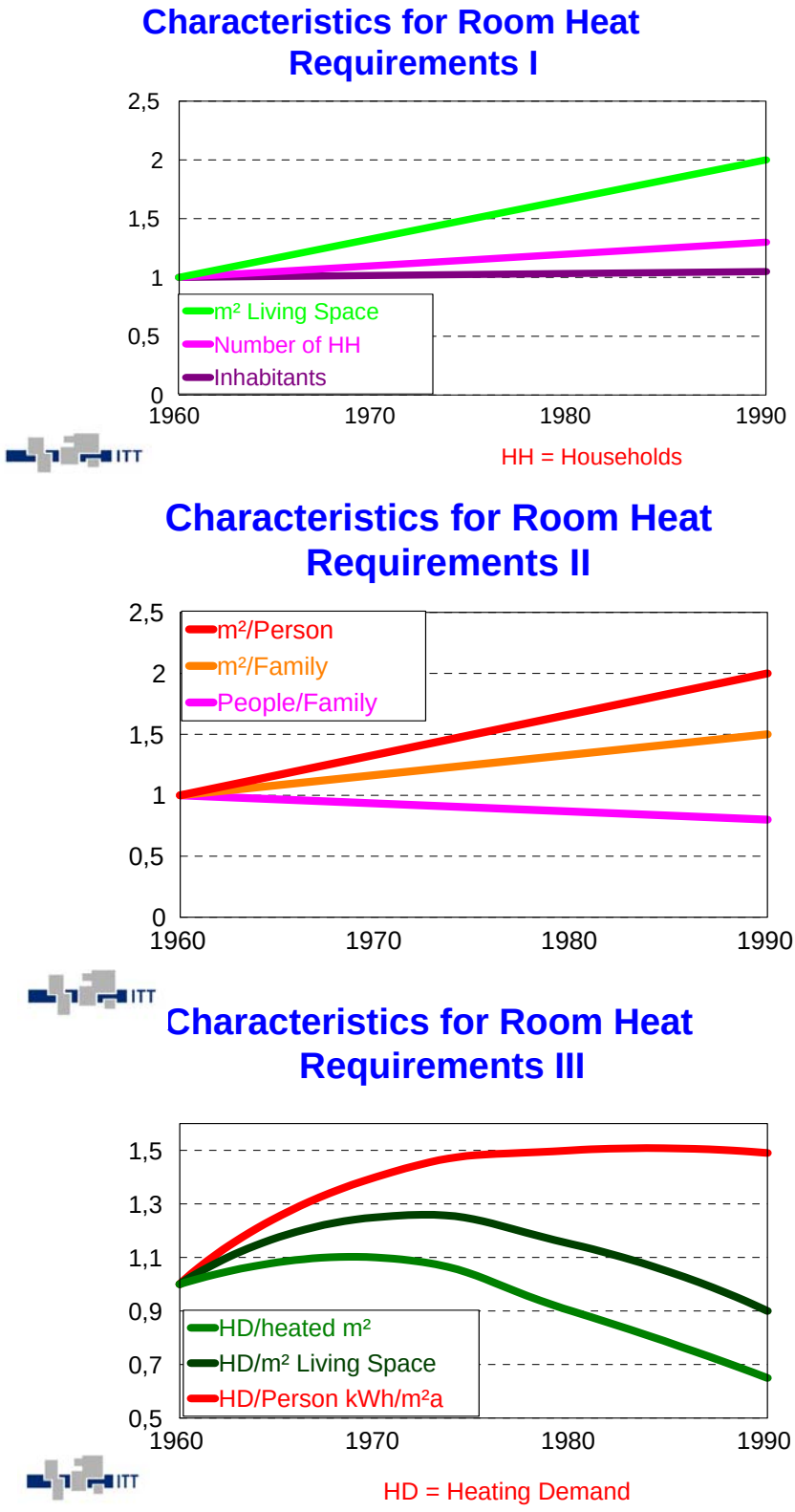


Fig. 9. Characteristic developments in Germany for room heat requirements (total living space, number of households, inhabitants; m²/person, m²/family and people/family; heating demand/m² and family and people/family)

While the use of energy improved significantly in the last decades since the first oil crisis in 1970, the energy consumption per capita is still on a high level (see Fig. 9). The reason lies in the increase of square meter per person, driven through the demographic change of the population - more one and two person households -, and a general tendency towards bigger apartments. Taking in to account that the over the last decades increased room temperature level, starting in the early 50´s with 18 C, now 21 up to 23°C is quite normal (having in mind that 1 K higher heat season room temperature brings a additive demand of 10 % of the total demand). So the people in the moderate climate loose a big part of their winter adaptation/acclimatization. The improvement of energy efficiency in the building stock was "eaten up" almost completely due to these tendencies. The rate of energy saved as a whole through energy saving in new buildings is so low that the new buildings can not decrease the losses due to the older buildings.

## 6. Conclusion

The tendencies of energy consumption in residential buildings in the tropics seem to be quite clear: based on the results of this project and with the general tendency of more comfort in more rooms, the energy consumption will rise sharply, as soon as the economic situation of the population or part of the population improves. Having in mind: The context of the study of thermal comfort in hot-humid climate is the multi-billion dollar air conditioning (AC) industry (turnover $28bn in equipment alone) (Nicol, F. 2003). It is here that the vicious circle is started! As People are able to afford modern houses thy are more and more able to confine to national building codes. More than often these national codes follow closely the European/North American standards. The temperature levels for human comfort are thus set at low levels relative to those of the Tropics. To realize these standards air-con is unavoidable. These people living under such conditions lose thus their natural climate adaptation. This results in the need for ever constant air-con. Resulting in the human loss of climate adaptation and the fact that air-con is seen as a living statement of health. So under both climates (moderate and hot-humid) a clear loss of the proven climate adaptation can be quite clearly seen.

The only possible strategy to curb this increase is the bio-climatic approach in architecture and urbanism. Special solutions for microclimate improvements being among others the green roof under hot-humid climate which proved expedient against ground sealing. With an integrated approach it is possible to provide comfort without the use air conditioning or - in the case of buildings with a high internal load – minimize the energy consumption through air conditioning (Laar 2002).

## Bibliography

Bravo, G. et al, 2000 Sensación térmica y confort en condiciones cálidas y húmedas. Proceedings COTEDI 2000. Maracaibo/Venezuela, 2000

Grimme, F. W., Laar, M. Moore, Chr.. 2002, Ventilation dependent comfort under tropical conditions, AiF-project, final report (in German language)

IPLANRIO 1996, Anuario estatistico da cidade do Rio de Janeiro; Prefeitura da Cidade do Rio de Janeiro

Laar, M., 2002, Energy Efficient Urbanism & Architecture / A Questão da Eficiência Energética na Arquitetura e no Urbanismo. In: Sustainable Revitalization of Tropical Cities/Revita-lização Sustentável de Cidades Tropicais. Ed.. M. Laar & K. Knecht/InWEnt, Rio de Janeiro/ Berlin, 2002

LIGHT 1997, Boletim estatistico de mercado, Ano 4, no 27

Lamberts, R., et al. 1997, Eficiência Energética na Arquitetura. PW Editores, São Paulo 1997

MacFarlane, W. V., 1958, Thermal comfort zones. Architect Sci Rev, 1:1-14, 1958

Meteotest, 1999, Meteonorm Version 4.0

Nicol, F., 2000, International Standards don’t fit tropical buildings: what can we do about it?

Nicol, F., 2003; The dialectics of thermal comfort, inaugural lecture, February 2003

Proceedings COTEDI 2000. Maracaibo/Venezuela. 2000

Techem Service AG, 2001, Energie-Kennwerte. Hilfen für den Wohnungswirt, Ausgabe 2001