Sustainable Buildings in the Tropics

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Abstract

Sustainable buildings in the tropics are becoming a mayor issue today. The zone between the tropic of cancer and the tropic of Capricorn encloses approximately 50.000 km² of land, around 1/3 of the earth's landmass. The population in the tropics is still increasing constantly, already accounting for 1/3 of the world population.
Many of the 100 countries, which count at least partly with a tropical climate, are on the threshold to become an industrialized country. Others will follow soon. So a sharp, prosperity induced increase in energy consumption will occur. While the actual energy consumption per capita in Africa and Asia is around 0.5 tons of oil equivalent (toe) and in Latin America around 1 toe, the per capita consumption in Europe is around 3.5 toe and in the USA almost 8 toe. The implications of the European or American way of live applied to the whole world are obvious.
Many projects to reduce the energy consumption in industrialized countries are under way, with quite some success. This paper will focus on ways to reduce energy consumption in buildings in the Tropics, like shading, daylighting and natural ventilation, for instance. It will also give some figures on the impact of different measures.

1. INTRODUCTION

Architecture and urban design have an important impact on the energy efficiency and sustainability of societies. In Florida/USA, example for a developed tropical state, 47% of the total energy consumption is used in buildings and 35% in transport, which can at least partly be influenced by urban design. More than 90% of the energy used is electric energy (FSEC, 2002). In Brazil, example for an emerging country, 42% of the electrical energy is consumed in buildings (Lamberts *et al*, 1997).
Now all countries in the tropics do have a long history of sustainable buildings: the vernacular architecture. The hot and dry regions with hot days and cold nights developed over centuries a perfect balance of shading and daylighting, natural ventilation and heat storage. In the hot and humid regions natural ventilation and shading systems were perfectly adapted to the local climate.
With the introduction of air conditioning systems, architecture became obviously independent from climate: the pure aesthetics became prevalent, most "clearly" expressed in the form of fully glazed office buildings. Architecture lost its sustainability. The direct effects on energy consumption can be observed all over the world: the average energy consumption of office buildings in Rio de Janeiro is around 340 kWh/m² a (Lamberts *et al*, 1997), the average consumption in ASEAN countries ranges between 200 and 300 kWh/m² a (Levine *et al*, 1992).
The private consumption is stepping up also, with still an enormous potential to grow: in Brazil the share of air conditioning in the total energy consumption in private households is 7%, with a market saturation of only 6% (Januzzi & Schipper, 1999).
A lack of proper legislation in many countries aggravates this problem even more: investments in the sustainability of the buildings is neglected in favour of "show effects" like, for example, the affluent use of expensive natural stones.

Latest own research results for Rio de Janeiro as a case study indicate a enormous potential in energy savings in offices.
While the principal concepts are very similar for residential and commercial buildings, the approaches are different. In residential buildings the low-tech approach will prevail for the vast majority of the buildings, due to the cost structure and a more active user behavior. In commercial buildings a more technical approach seems to be more successful, taking into consideration a generally higher initial investment and a more passive user behavior.

1.1 Thermal comfort in the hot & humid tropics

To provide thermal comfort for the user of a building is fundamental. Without it, the body gets stressed and the efficiency of the immune system suffers significantly. The human organism gets prone to diseases. ISO 7730 as well as ASHRAE use the results of an extensive research carried by Fanger to define thermal comfort. These definitions serve well for temperate climate for which it was developed. However its use in the tropics has to be questioned: while ASHRAE accepts some form of acclimatization by specifying a higher temperature range for summer (t = 22.5 to 26°C at 60% RH), some recent studies indicate an even higher average comfort temperate for the hot & humid tropics: in naturally ventilated buildings in Maracaibo/Venezuela the average operative comfort temperature found was 29.6°C (Bravo et al, 2000), in Bangladesh the comfort operative temperature for natural ventilated building and a clo-factor of 0.5 was 28.9°C (Kumar, 1999). An adaptation of the human body to higher temperatures seems to be obvious, while we feel still a certain lack of research tackling this question to the point, where a concrete formula can be introduced. Meanwhile the prevailing air conditioning temperature is between 19°C and 22°C in most office buildings in the tropics, while at the same time the outside temperatures are around 30 – 40°C. The thermal stress for the human body by changing from one ambience to the other is well known and probably the main reason the frequent - almost epidemic - summer flu in tropical cities. The implication on the energy consumption created by these very low indoor temperatures are shown in figure 1. The general parameters used in these simulations are defined in the chapter “Potential in Energy Saving in Office Buildings”.

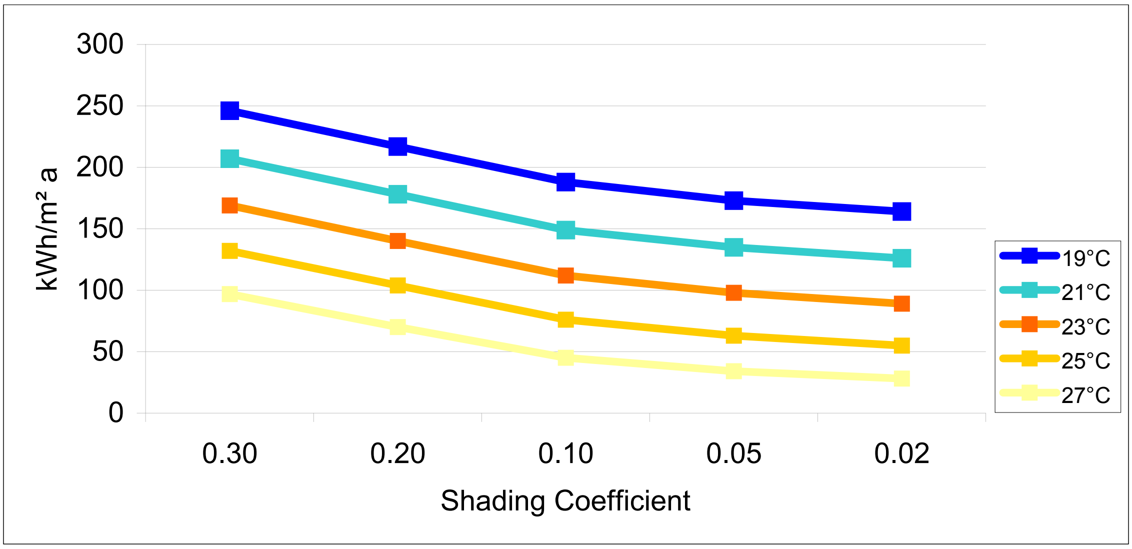

Figure 1 - Cooling Load in Dependence of Room Temperature (sensible Heat)
(for Rio de Janeiro - Office Building - North Facade- own HELIOS-Simulations)

1.2. Natural ventilation

Natural ventilation in combination with an optimisation of the microclimate (and shading) was always the main feature of vernacular architecture in the hot & humid tropics. Air movement is known to

improve significantly the thermal comfort sensation (see figure 2). To guarantee a proper ventilation, a sustainable planning starts already on the urban scale: ventilation "canyons" have to be created in the urban master plan and a improvement of the microclimate can be achieved by landscaping measurements, lowering the air temperature and the potential radiation in the IR-range by shading and evaporative cooling. It also should provide ventilation channels towards the buildings. The building layout decides the efficiency of natural ventilation – a stretched building with big apertures toward the predominant wind direction and cross ventilation provides good thermal comfort conditions for residential buildings.
For office buildings the layout is more challenging, due to the relatively big internal load and their sensitiveness to stronger breezes. Nobody likes to see his office papers flying around. Anyway, first examples of naturally ventilated office buildings are available, like, for example, the UMNO-Building in Penang/Malaysia, designed by Ken Yeang. The architect uses wind wing walls to catch and redirect the wind into the building. Another possibility might by the solar chimney, which is still under development for a use in the tropics.

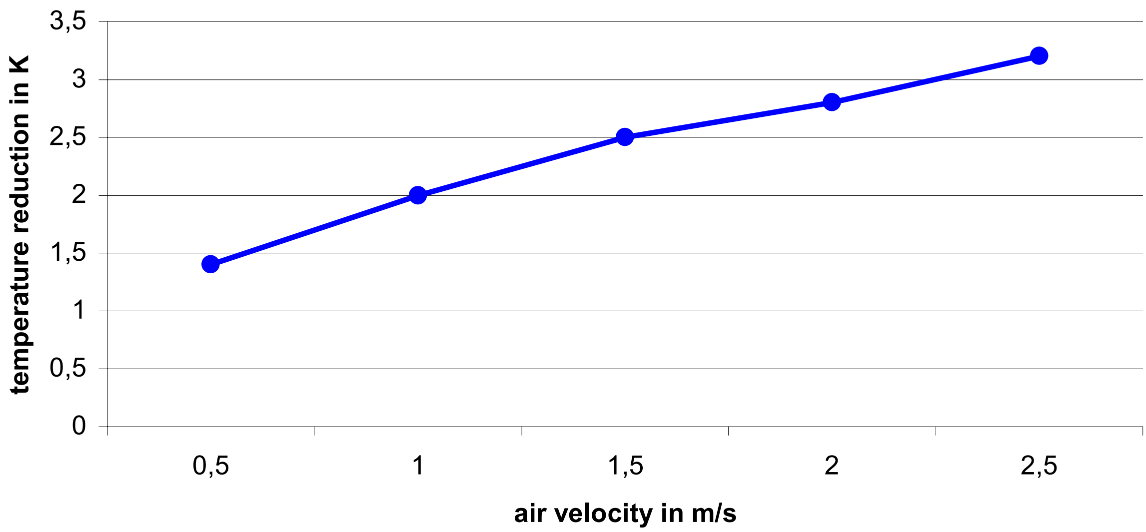

Figure 2. Improvement of Thermal Comfort Sensation by Natural Ventilation in the Hot & Humid Tropics (Sharma, 1977)

So natural ventilation has a huge potential - yet not fully developed - lowering the consumption of energy for air conditioning significantly.

1.3. Shading

The importance of shading in the tropics is already well known and was always a major issue in the vernacular architecture in the tropics. Figure 3 quantifies the impact of shading on the thermal load of an office building in Rio de Janeiro. It compares the performance of different glazing: unshaded, shaded against direct radiation and shaded against direct and diffuse radiation. The results provide an idea about the relevance of the transmission compared to the radiation. The simulation was carried out with HELIOS for a north façade in Rio de Janeiro. No internal loads were considered.

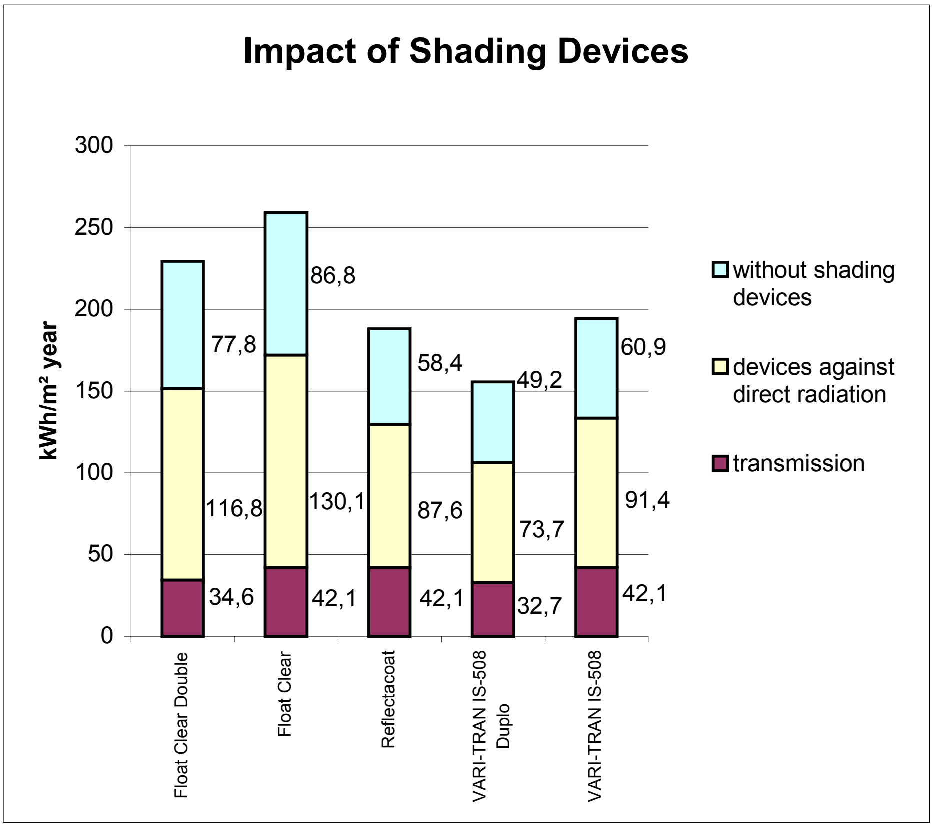

Fig. 3 Cooling Load with different kinds of shadings (Laar & Grimme, 2000)

The results demonstrate clearly the importance of shading devices and the relatively small impact of double glazing on the overall heat load.

1.4. Daylighting and Daylight Control Systems

Daylighting in the Tropics is a relatively new topic with an excellent potential: the day length in tropical latitudes has a very small variation in the course of the year, from 0 minutes (day length 12 hours at the equator on both dates, the 21st of June and 21st of December) to a maximum of 90 minutes at the Tropic of Cancer and Capricorn. Therefore the daylight offer covers the demand for the core hours of office buildings quite well. Recent research results point out, that habitants of the Tropics are adapted to higher illuminance and luminance levels and therefore the visual comfort parameter for the tropics have to be adapted accordingly (Laar, 2001). Different daylighting systems are available, from simple fixed systems like lightshelves and fins to high sophisticated ones with one or two axis tracking systems. Due to the thermal aspect of daylight, an isolated daylighting systems would also work as a heating system, which is not very desirable in the Tropics. A balanced system with daylight guiding and shading elements has to be composed – a Daylighting Control System.
Beside the efficiency aspect for daylighting and shading several other factors have to be considered, like maintenance effort, running costs, available workmanship etc. (Laar (2), 2001).
Some own first results on the efficiency of daylighting control systems, based on simulations run over a year with hourly data for Rio de Janeiro, are quite promising: the use a proper daylight control systems can reduce artificial lighting by 60 – 80%, at the same time cutting down the cooling load of the building.

1.5. Potential of Energy Saving in Office Buildings

Offering concrete data about the supposed energy consumption of a "typical" building is quite risky: there are many parameters involved and it is almost impossible to describe all of them in one paper. Anyway, it is also import to get an idea of the potential of energy saving to be obtained with an improved building layout and the use of efficient technology. The results shown for an office building in Rio de Janeiro where obtained through different simulation tools: METONORM provided the weather data on an hourly basis, HELIOS calculated the transmission, RADIANCE the obtained illuminance level, TAKO and TAKO-Cool the daylight autonomy and the thermal load due to radiation respectively. The energy for dehumidification was calculated by LEF, a program based on the enthalpy between the outdoor and the desired indoor air humidity. The internal load is composed of office worker (10 W/m²), workstations (10,6 W/m²), and a artificial lighting system with daylighting sensors (15 W/m² installed): The typical office room is 5,0 m wide and 10,0 m deep. Different daylighting control systems were tested, the shown result is based on the average mean of the 4 best systems. The maximum acceptable indoor air temperature is 24°C and the maximum relative humidity is 70 %. The relation between main office space and secondary space (corridors etc.) is 70:30. The thermal load of the secondary space is composed of artificial lighting (15 W/m²). There is no shading of the building by other elements, like neighbouring buildings, vegetation or topography. Transport energy for air conditioning is included in this calculation. The energy consumption for vertical transport (elevators etc.) has not been considered,.
The results are promising: the calculated energy reduction is around 63%, compared to the actual energy consumption of office buildings in Rio de Janeiro.

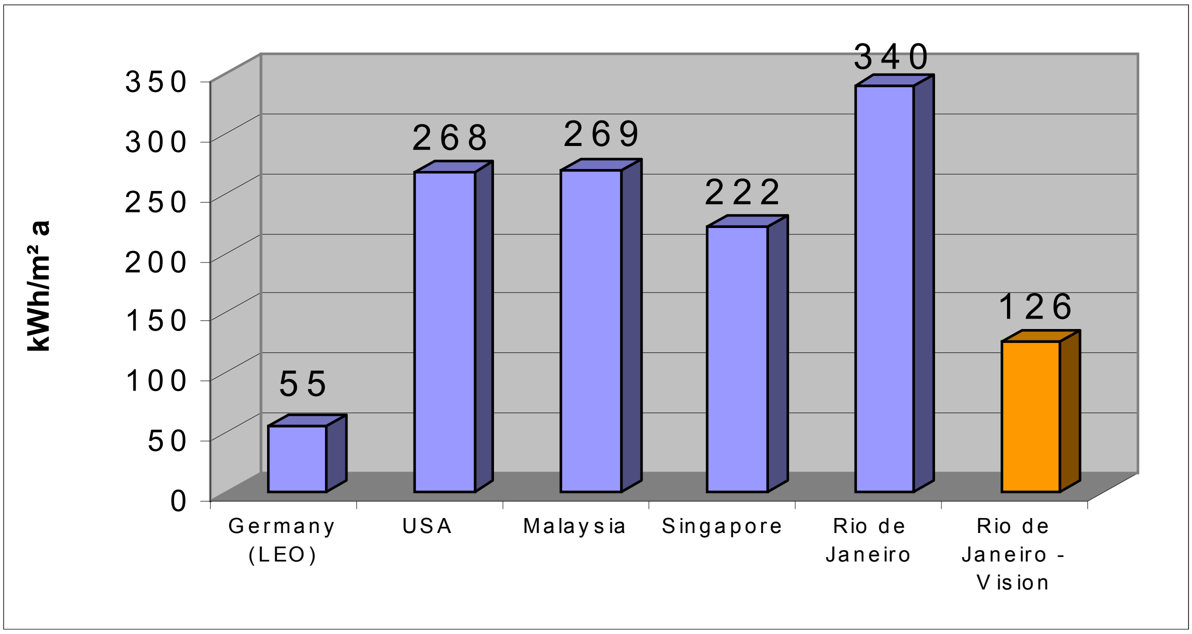

Figure 4 – Average Energy Consumption in Office Buildings (Lamberts et al, 1997), (Levine et al, 1992)

Further improvements can be achieved through natural ventilation and innovative air conditioning systems, as well as through a more efficient office equipment.

1.6. New regionalism

To progress in the area of sustainable development we have to change our paradigm of architecture. What we need is a new architectural approach, the "New Regionalism": respecting climate and culture of the region and therefore creating an ecological and cultural sustainability in the built environment. Instead of the international style, which respects neither climate nor the regional culture, we have to join our forces in order to use the positive aspects of the globalisation: international cooperation in research and development, speeded up by largely improved communication tools. The aim to avoid faceless and resources devouring cities can be achieved only in cooperation, respecting ones own (which often is the major problem) and the cultures of other people. Some good examples of modern, regional architecture can already be found in Australia and Malaysia, for instance.

2. CONCLUSION

We already do have a lot of solutions ready to be implemented in order to achieve a much better sustainability. In some areas research and development work has to be done yet.
To achieve a major change in the existing paradigm towards sustainability in the built environment we need action in various areas:

- Improvement in the formation of future architects and engineers, beginning with interdisciplinary projects already at the faculties
- Prototypes and pilot projects for research and development as well as for proving to investors and planners that these new ideas really work. This is definitely a government duty
- More international cooperation to benefit from already available knowledge in other countries and to join forces to develop new and to improve existing solutions

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