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Introduction

The use of solar thermal energy for air-conditioning in hot and sunny climate is a promising new application of solar thermal collectors in buildings. The main advantage is that in solar air conditioning applications cooling loads and solar gains occur at the same time and on seasonal level.

In Brazil the energy demand for refrigeration and air-conditioning correspond to approximately 15 % (134 TWh/year) of the total country energy use [1].

Around 48% of energy is consumed in commercial and public buildings due to air conditioners, usually by driving electrical vapour compression chillers [2].

Solar cooling has the potential of significantly reducing the electricity consumption, contribute fossil energy saving and electrical peak load reduction. The solar array yields thermal load reduction of the building. Furthermore it contributes in a positive way the urban microclimate through absorbing the solar irradiation on the roofs. Last but not least Solar cooling decrease the ecological footprint of tropical cities due to achieving carbon emission reduction and using environmental friendly refrigerants.

Figure 1.1 shows a Hotel in Japan which is using solar energy for providing HVAC and domestic hot water. The solar array provides shading. All of the mechanical equipment is underneath the array.

Figure 1.1 - Okura Act City Hotel in Hamamatsu, Japan. This building was designed with Solar energy in mind [3].

Many of the huge agglomerations, such as Rio de Janeiro and São Paulo, are located in or at the boundaries of the inter-tropical zone and additionally in developing countries. Figure 1.2 shows a comparison of global climatic map with the population distribution.

The climatic advantages in the Tropics have led to the highest density of population highest population growth [4].

More than a third of the world's population live between the Tropic of Cancer and the Tropic of Capricorn. The Tropical belt has become the most densely populated and thus poorest region of the planet. Latin American and the Caribbean are the most urbanized regions in the World [5].

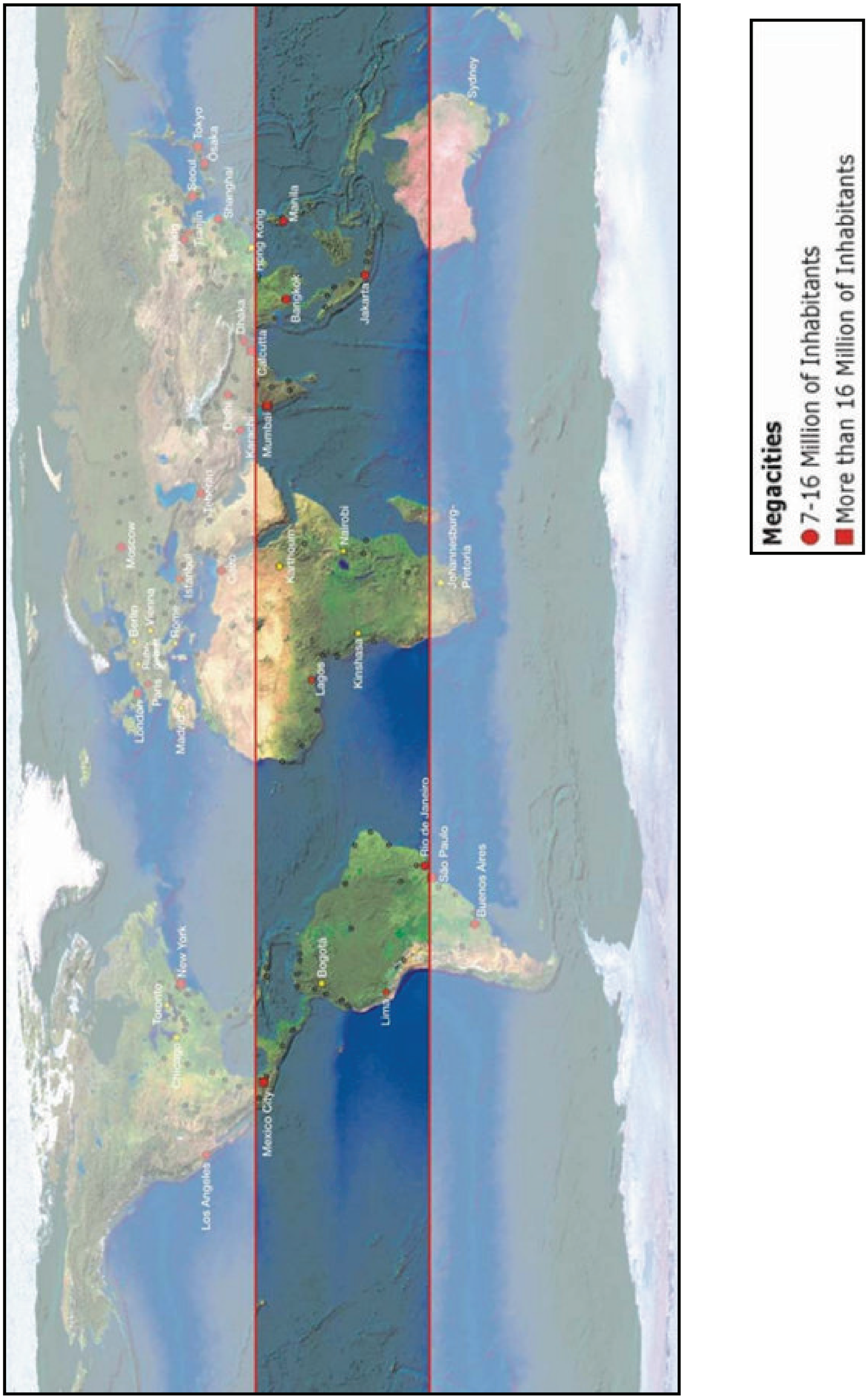

Figure 1.2 - Megacities of the tropical Belt (modified) [4].

In tropical latitudes, the impact of urban climate is associated to more negative effects on thermal comfort and the energy consumption of buildings than in the cities of the temperate climate zones, due to higher solar radiation income [6].

On the existing high temperatures in the tropical occurs an further temperature increase by the formation of the so called 'urban heat island' in created mainly by the lack of vegetation, into the environment conducted waste heat (e.g. due to the heat rejection of air-conditioning) and by the high solar radiation absorptance of urban surfaces.
Predicted climate changes due to anthropogenic emissions will cause also an increase in mean atmosphere temperatures and atmospheric IR radiation [7].
Taking all these facts into account the cooling demand increases and in future more and more buildings will be air-conditioned. For these reasons the country's energy consumption increases mostly due to in the "small" and "medium" range less-efficient applied split air-conditioners and package systems. Figure 1.3 shows a typical building in Brazil with applied split air-conditioners.

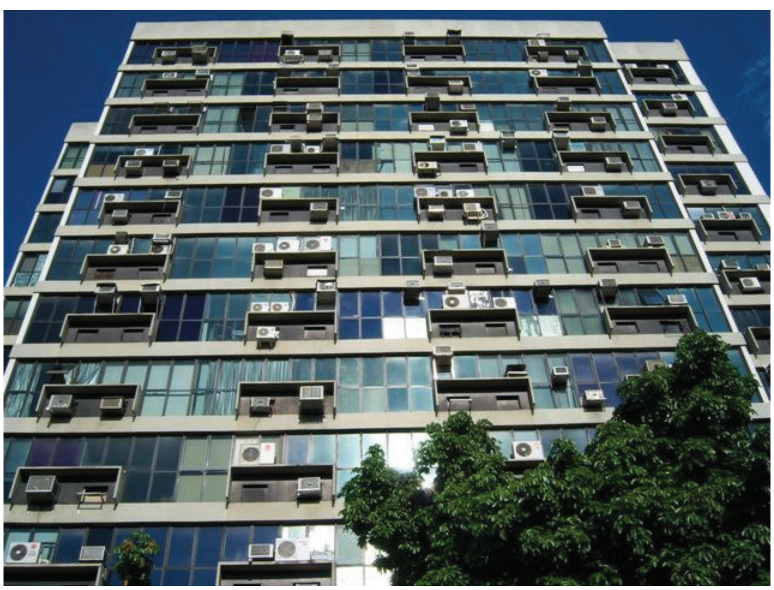

Figure 1.3 - Applied electrically driven compression air-conditioning at a commercial building in Rio de Janeiro - Brazil.

The annual growth in Brazil of the cooling and air-conditioning market in terms of capacity is expected the range of 4.5 GW/y (1.3 million TR/y) [1].

This corresponds to the sales rate of room split air-conditioners and package systems for capacities < 5 kW for South America in 2008, published by JARN [8].

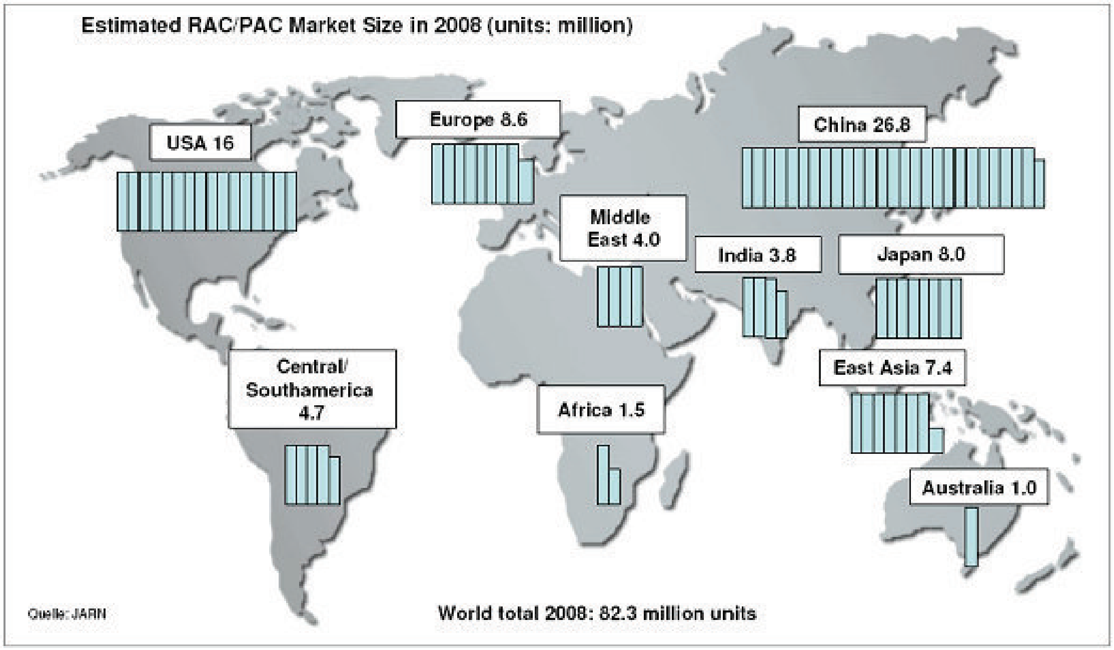

Figure 1.4 - World market sales rate in 2008 of split air-conditioners and package systems in the capacity range < 5 kW (1.42 million TR). Source: JARN

In hot and humid regions the use of free cooling techniques are limited and can not guarantee that the indoor comfort will be fulfilled all the time. To contribute a sustainable urban development in Brazil, another energy-efficient cooling technology must be implemented – the solar cooling.

By the growing environmental concerns and consistent effort in research and product development the interest in solar air-conditioning technology has increased in the last years. All over the World solar-assisted Air-Conditioning demonstration projects are showing that the technologies are mature.

Until now, there is not a pilot project for solar air-conditioning of buildings in Brazil.

The Eletrobrás/PROCEL (Brazilian electricity Conservation Program) will establish a centre for energy efficiency education in Guaratinguetá at the University UNESP (Universidade Estadual Paulista) and has the intention to equip the auditorium with a solar air-conditioning system.

The Project will be, likely realized in cooperation with the GTZ (german technical cooperation) within the framework of the GTZ energy program for the purpose supporting regenerative energies and energy efficiency in Brazil.

For the appropriate design of such a solar cooling system, the building must be simulated by using local meteorically data to determine the correlation between solar gain and cooling load.

Furthermore it must be analyzed which solar cooling technology is suitable under the specific climatic conditions and if the alternative technology can compete economically with conventional split air-conditioners.

The basis of this work is primarily a GTZ commissioned technology study “solar cooling in Brazil” developed by Fraunhofer Institute of Solar Energy Systems ISE (Germany).

The thesis is organized into the following main chapters:

The next chapter starts with a critical overview on existed solar cooling technologies and their scope regarding the climate conditions in Brazil. It describes the fundamentals of solar building cooling, function and their benefits. In these chapter will be principally discussed the use of open cycle processes (DEC) and Photovoltaic driven compression chillers in comparison to sorption chilled water systems. Summarized, it intended to give the reader an introductory technical background. It is followed a practical relevant case study.

Chapter 3 includes the main focus of this work. First it informs about the intended pilot-project in Guaratinguetá and gives some background knowledge regarding building cooling and air-conditioning. It describes the building and the energy simulation program Helios-PC which is used to simulate its thermal behaviour. The next steps in this chapter are as follows:

- Comparing of different in Brazil available solar collectors
- Simulation of Correlation Solar gain / cooling demand
- Choice and design of the appropriate solar cooling technology
- Assessment of the economically viability in comparison to conventional compressor Split Air-conditioning. Including the Assessment of two different Back-up possibilities for Solar-assisted Air-Conditioning System: a) back-up with Split Air-Conditioning b) thermally back-up with Gas
- Environmental benefits

Beside the Simulation and Design of solar cooling system it shows how the cooling demand (thermal load) of the building could be reduced by changing the indoor set temperature within the Brazilian standards (PNB-10) and by using building insulation.

Finally Chapter 4 Conclusion and Recommendations presents the results obtained and concludes the study, adding some general recommendations on solar-assisted air-conditioning.

1.1 Objective

The goal of this work is to verify if solar-assisted air-conditioning in the "medium" capacity range can already be an alternative energy saving technology for building air-conditioning in Brazil. In this context a Case Study - Auditorium in Guaratinguetá - will be done, thus the following necessary question can be answered:

- Which technology can be used and is available?
- Which is the best system for the given application under the conditions of the specific-site?
- How is the correlation between solar gain and cooling demand?
- Is the use of solar-assisted air-conditioning feasible for the building?
- Which cold distribution is suitable under the specific climatic condition (hot and humid climate)?
- Which solar collector is the most cost-effective on the Brazilian market?
- What dimensions of the solar collector area and other system components results the best energy cost performance?
- Is another ecological and economical alternative feasible for example active night-cooling?
- How can the high investment cost of solar cooling system be decreased?
- How it's possible to decrease the cooling demand of a building and hence the cooling capacity of the solar cooling system, which leads to lower investment cost?
- Which back-up system is under the local energy prices (gas/electricity) appropriate?
- Can solar assisted air conditioning already compete economically with in the "small" and "medium" cooling capacity range often applied conventional compressor Split Air-conditioning Systems?