Cooling buildings: tailored or ‘prêt-à-porter’ solutions?

E. de Oliveira Fernandes
Faculdade de Engenharia da Universidade do Porto, Portugal

ABSTRACT

Cooling buildings, more than a generalized need, is a reason for concern because of a paranoia provoked *inter alias* by an aggressive marketing of HVAC, relatively inexpensive equipment and the anticipation stimulated by the media of climate change effects. But, as a matter of fact, there are many and, in some cases, sound reasons for cooling buildings.

The purpose here is to propose to discuss the cooling issue starting from the point that there is not a general need for cooling everywhere in the World. If there are regions where cooling is absolutely necessary, that doesn’t necessarily mean air conditioning. The most universal truth in cooling is that the solution shall be tailored for each particular case.

1. INTRODUCTION

Cooling buildings means the generic set of processes or techniques to control the maximum temperature (air and radiant) indoors. Associated to that objective, the eventual reduction of the relative humidity in the air can also be found.

The need for those control processes can be due to the outdoor climate conditions, mainly through the incoming air but, also, for an excess of an undue impact of solar radiation, or be determined by internal sources of heat and moisture. Heat gains through the envelope do not have to be considered as a cause here as, in principle, they must be properly controlled by the architecture (building orientation, shading) and the construction (shading, insulation) of the envelope. In some cases the control variable can only be the temperature while, for others, both temperature and moisture need to be monitored and controlled.

Keeping the temperature indoors lower than a certain level is not an objective of recent times. Concepts of comfort and of health indoors were very limited centuries ago. Nevertheless, a simple overview of examples of vernacular architecture illustrates how the objectives of comfort led to solutions of high sophistication. The history registers very creative ideas for that purpose illustrated by the many examples that vernacular architecture generated through the ages excelling in solutions of avoiding/preventing and/or attenuating/delaying the temperature rise indoors. The basic three strategies combined or not, were:

- shading,
- thermal mass,
- natural ventilation.

Architecture, construction and materials were used taking those strategies very seriously. The historic compact cities of Yemen (Fig. 1) or the heavy massive houses of the Mediterranean basin, just to refer those two cases, are brilliant


Figure 1: Yemen: lessons on cooling from the past.

examples of that. That is the message conveyed to us by the geography, i.e., by the interaction of man through the history with the region, the place and the climate.

The expected results, however, were not a preset guaranteed temperature, independent of the hour of the day or of the day of the year. The temperature indoors was certainly the result of a compound of effects in which the impact of the local climate was not the least factor. Several studies conducted in the last century led to the conclusion that the fluctuations of the outside temperature not only could influence the mean level of temperature indoors as it could also establish a rather stable ‘temperature platform’ for a model of thermal comfort indoors. That would lead to the important and strategic concept of adaptive comfort.

The humidity could be reduced by natural ventilation if it was the solely result of the occupancy or of any activity generating humidity indoors. On the contrary, the problem of high humidity in the air couldn’t be solved that simply if the moisture was entering the building with the incoming air from outside. That is why the most remarkable examples of cooling passive techniques are probably in climatic zones of dry and hot climates.

The changes that happened meanwhile regarding just the perception of the need or, even, the actual need for cooling buildings, since those times in the past to nowadays, are not due to the climate. This can be said, despite local changes in the micro-climates, as it is the case of the heat islands effect in the urban environment, or of the global climate change whose effects are claimed to be detected almost everywhere.

The change on the need for cooling (perceived or actual) is, to a large extent, due to the life style expressed mainly by the extension of our living indoors, where we spent probably more than 90% of our time; the clothing habits; and the fitness of building construction in general to the climates where it is built. The latter was very well characterized by Prof. Rafael Serra from Politecnica of Barcelona who referred to those buildings as ‘performing worse than the climate: warmer in summer and colder in winter’. But other changes, in particular for office buildings, result from the intensity of activities conducted indoors such as the generation of heat and moisture due to the occupants and to the equipment including the artificial lighting. This major contribution of the activities indoors requires a special approach of the cooling issue despite the outdoor climate conditions. That may explain, to some extent, the expansion of air conditioning even in climates where the pair temperature/relative humidity would not require it.

New challenges emerge, as the use of energy for air conditioning occurs mostly in peak electricity hours and periods in the year (summer, for instance), contributing itself significantly for those peaks. The latter correspond to the most expensive periods for electricity production and could, one way or another, be partially attenuated by a better energy management. This is also a sensitive reason for being careful with the diffusion of air conditioning and for thinking in depth what to do about cooling. It is not only the challenge of overcome the energy availability in peak hours or the energy cost, but it is also the problem of finding solutions for the drawbacks of most of the final energy still in use in this oil culture that will last for one more century, at least. The demand side management in this particular energy use for comfort in buildings is definitely one of those solutions.

For the cases with low internal gains, where the intensity of the use of the building is not very intense, the precautionary principle advises to keep basically the older strategies, even if better refined. The abundance of simulation and calculation tools these days are not meant to change the physics of the phenomena but to be able to better interpret and anticipate them and, then, to enhance the natural performance of buildings.

The purpose of this paper is to discuss the issue of cooling buildings and how to address the issue in relation to the building itself, its functions and its climatic context. Being aware of the pressure that has been put on the market towards the diffusion of air conditioning systems and the push by the news on the media about the effects in the temperatures rise due to the heat islands effect in cities and the climate change process, the purpose is to approach the issue from a methodological perspective. No reference will be made to the specific technologies that can be used for the mechanical cooling, even when the latter is renewable based.

2. COOLING BUILDINGS: THE ISSUE

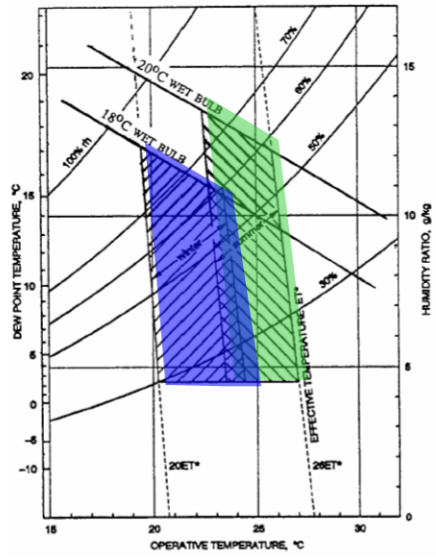
Cooling buildings is a process or a technique that aims at controlling indoor environments to keep the temperature and the relative humidity below certain limits. The causes that determine the need for cooling may come either from the outdoor climate or from the internal loads or from both. The need for cooling, in what regards the humans – other objectives, like preservation of materials or products have their own rationale – comes from the occupants perception, which, incorporating ultimately also cultural and other psychological related influences, is expressed by the concept of thermal comfort. Thermal comfort is defined as the ‘condition of mind that expresses satisfaction with the thermal environment’ (ASHRAE, 2001). Besides the parameters that characterize the indoor climate (air temperature and radiant of the surfaces; relative humidity; quality and velocity of the air and ventilation rate), the two other critical parameters are related with the occupants themselves, namely, the levels of activity and of clothing.

The first question at this point is to clarify if it makes sense today to establish a difference between cooling and air conditioning. If that difference is recognized to be valid, then it is relevant to distinguish both conditions when it comes to define and elaborate on strategies.

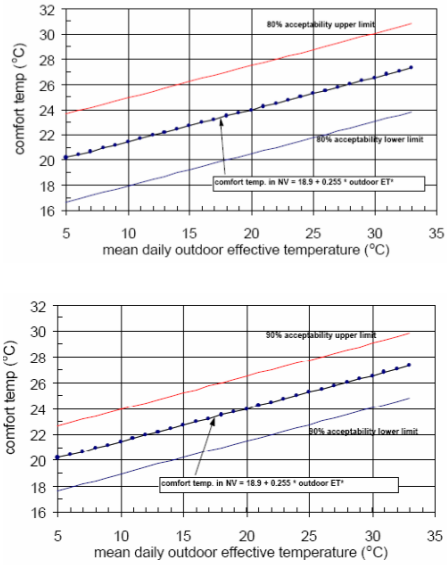
Yet there are two comfort concepts which are definitely the driving engines for the two types of option for cooling that are open towards the future:

- *Thermal comfort model* by Prof. O. Fanger (Fig. 2a) (Fanger, 1972). Its requisites are founded on experimental studies with people in air conditioned rooms leading to comfort levels according to some accepted percentage of dissatisfied occupants. It is thus a concept with the underlying assumption that air conditioning is going to be used. The two zones for winter and summer imply the recognition of several factors other than thermal ones.
- *Adaptive comfort model* (Fig. 2b) (de Dear and Brager, 1998). It was established on the basis of 21000 measurements, mostly in offices. It is adequate to non air conditioned buildings or spaces and it establishes two sets of temperature limits corresponding to 80% and 90% of acceptability putting into relationship the actual indoor air temperature with the average outdoor temperature of the last month.

The issue of cooling buildings assumed a total new character when the target became a preset temperature guaranteed, independently of the climatic conditions outside and of the inter-



(a)



(b)

Figure 2: Thermal comfort models: a) O. Fanger’s; b) Adaptive model.

nal sources, whenever a particular effect was wanted in a given way at a particular time. Air conditioning is the process of guaranteeing the control of maximum temperature and maximum relative humidity together with other concomitant specific objectives of ventilation, including air renovation rates and air cleaning. Air conditioning implies a temperature set point which by definition is not going to mean comfort for all. Therefore it leaves always some room either for complains or for individual adjustments namely with the clothing level. It is the cooling with rather low operative temperatures that makes typical the sweater indoors in the USA in summer time (Fig. 3) which need shall, of course, be cause for reflection.

Air conditioning is a sophisticated mean of environmental control, easily controllable by electronic and other high tech means. However, it is based on the use of probably unnecessary quantities of energy, most likely not incorporating a great share of renewable primary energy forms. As an exclusive sophisticated technique, air conditioning installation should ask for more restricted and well characterized conditions of use.

On the contrary, the adaptive model expresses the concept that backs the traditional approach of passive cooling and we will refer to it from now on just as cooling when there will be a need to contrast with air conditioning. Under this perspective cooling will be a basic need to be fulfilled preferably through natural means, playing with the architecture, the construction and fabrics, in tune with the soundest sustainable concepts applied to energy. It supposes flexibility of the occupants by some personal interactivity playing with clothing and building dedicated features (shading, ventilation, etc.). After the obvious adjustment of clothing level, literally the second human skin, other interactions with the building itself, of housekeeping type, may become naturally necessary such as operating windows, curtains and shutters and promoting ventilation. Only once this process has been gone through and the need for commercial energy is proved to be necessary, it shall be provided by auxiliary means.

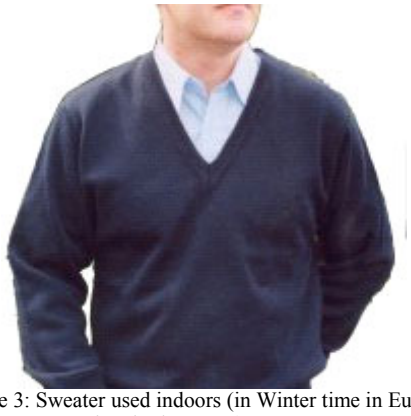


Figure 3: Sweater used indoors (in Winter time in Europe and in Summer time in the USA!).

3. STRATEGIES FOR COOLING

The XXI Century starts at the climax of the air conditioning paranoia. The figures show almost 100% air conditioned office buildings (65% for residences) in Japan and a little less in the USA (80% and 85% respectively). In Europe the figures are much lower (<27% offices, <7 % residences) but according with the market and the fashion all reasons seem to be good to push air conditioning. Air conditioning technology is good, of course. That is not the issue. But, with the help of a metaphor, the some way that no medicine is good for all kinds of illnesses, air conditioning should be used only when adequate. Furthermore, the air conditioning has not only advantages. Some of its drawbacks are more than likely to occur as well. Results of a European Audit, in 1992, extended to 56 offices around Europe showed air conditioning systems as the source for around one third of the indoor air pollution. As an ‘add on’ type of technology in the building for controlling the indoor environment, the approach to air conditioning should, precisely, take into account that simple fact: it is an ‘add on’ that might not be needed or could be avoided.

In such a context, the strategies for cooling buildings have to respond to a certain number of preliminary issues to prevent from embarking in procedures that are against rationality:

- First of all, the rationality intrinsic: As buildings are energy systems themselves, entitled to create spaces with specific environment and energy requirements the potentialities of each system, i.e., of each building, must be explored in a coherent and consistent way;
- Secondly, the rationality that justifies for

each case the choice of the comfort and health requirements. The fact that the ASHRAE Standard 55/2004 (ASHRAE, 2004) admits the use of adaptive comfort model for non air conditioned buildings and define comfort criteria for those buildings creates already a wide field for options;

- Thirdly, the rationality that implies the respect for the concept of sustainability in what regards the building and all natural resources involved: productivity (comfort and health) of workmanship, energy and environment. It is known that workmanship is the most costly production factor, much more than energy or even property. But, how are we all sure about the specific requirements for each work environment in a particular cultural and climatic context?

Once respected the criteria for rationality above the conditions to proceed are assured. Now it is necessary to elaborate the check list of the critical questions in order to verify when and how air conditioning shall be used.

The critical questions are:

- Is health and comfort definitely dependent on air conditioning? If the answer is yes, does it happen everywhere? And, does it happen all the time for all conditions? In some cases, if air conditioning has to be installed for cooling it can also be used in the winter season for heating. Thermodynamics, with the reversible cycle in machines such as heat pumps – among others means – allows perfectly for it. But, is that an excuse for installing air conditioning when only one of the functions may be needed?
- Does it make sense to design and build new urban sites and buildings and spaces based on the general principle of the availability and use of air conditioning without questioning its need?
- Being aware that the straight forward sequence from the brief to the building design through construction till the building occupation is not respected all along for every building; and that seldom the design is adjusted to climate or to the function; and that the function may change during the construction and utilization of the building, what cost may represent all those intermediate changes, in particular, those ending up by late solutions of air conditioning, when a better designed and planned building could have been built?
- Knowing that air conditioning is dependent on auxiliary energy, is there an acceptable rationale to refrain on air conditioning buildings just to reduce energy uses? If air conditioning was not considered, what would be the price regarding the productivity loss?
- Is the design of buildings without air conditioning a non remediable expression of a restriction and socially not acceptable as if, regarding quality and status, it could not be considered a first class building?
- Aren't concepts such as 'healthy buildings' and 'sustainable buildings' reducing the internal loads and putting forward additional criteria of rationality in what regards cooling /air conditioning?

From those questions, taking into account the current status of knowledge, adopting principles of precaution and bearing in mind the modern trends towards sustainability, the strategies could be formulated, probably, in a quite straight forward manner (Fig. 4):

1. The building must be designed for a given purpose (comfort or other). The purpose can be understood with some flexibility in the sense that a building is in reality a cluster of spaces, each one with its own specific requirements in such a way that sometimes the differences among two spaces in the building are more significant than between the two and outside.
2. It must be kept in mind that most of the cooling needs are more related to the activities indoors than to the local climate.
3. The use of air conditioning must be technically justified in each building. The adapta-

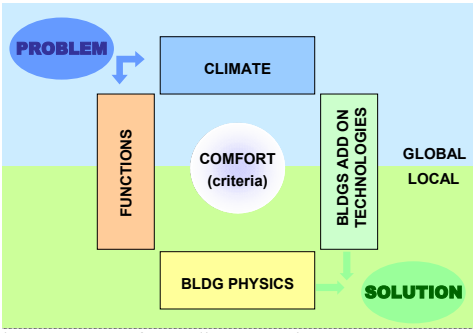


Figure 4: Frame for cooling strategies.

tion of existing buildings to different purposes must be carefully planned also from the indoor climate perspective.

4. Even the actual impact of the local site on cooling load of the building shall be anticipated in urban and landscape terms.

So, as it is illustrated in Fig. 4, the cooling issue can be summarized in the following way: a given cooling problem characterised by some functions to be fulfilled in a given climate, has to deal, first of all, with the building physics and, in a second stage, involves more specific (active) technologies. The solution must fulfil three main criteria: to provide 'comfort' according to the model adopted and to assure global and local environment (related to the nature and quantity of energy used).

The climate introduces a background condition that is determinant for air conditioning if it is hot and humid. Otherwise there is always room for other considerations.

4. CONCLUSIONS

Cooling is always an option to be considered but air conditioning is not always a need.

The most trivial cooling approach is to use the building itself during the design phase to promote natural cooling technologies. In some cases, however, the cooling needs are such that they call for the more sophisticated solutions. That shall be anticipated and the case must be studied carefully. A design thought for passive cooling for instance will be surely less appropriate for an efficient air conditioning. All to say that there is not a 'prêt-à-porter' solution for cooling, even if the option is air conditioning. The problem of air conditioning is clearly, at first, a question of identifying the specific conditions on which its use is absolutely needed. The same applies, at a more natural level, for passive cooling even if assisted with mechanical ventilation.

But, is there truly a need for 'air conditioning'? The answer in absolute terms is, of course, yes. There are new concepts of comfort; new life styles; new ways of organizing work; new 'occupants' in the office liberating heat at a higher rate than persons themselves, such as computers, etc. etc. Clearly, the first set of arguments lay on the functions and, therefore, on service and occupants needs. But there are also reasons associate with the climate. In some climates, the simultaneous high temperatures and relative humidity values cannot be overcome in terms of comfort without the recourse to the air conditioning.

Nevertheless, the answer 'yes' given above needs to be nuanced in very clear terms. So, the final answer, shall be

- *'yes'*, definitely in some cases where high temperatures and high relative humidity levels are present indoors; both can be due to the climate conditions but they can also derive from the type of occupation and utilization of *the space;*
- *'maybe'*, in some cases where very strict indoor environment conditions are required such as museum rooms, etc., but the climate doesn't impel to it;
- *'no'*, in more cases than currently thought, as a consequence of effects such as fashion, status, marketing, bad architecture, inappropriate use of the building or, even, all together.

There are, then, opportunities for the 'yes' and, by extension, for the 'maybe' cases, while the 'no' cases must be identified in a clear way. This, not because someone wants to impose comfort restrictions of whatever kind on his fellows citizens but because it is quite easily demonstrated that such option is not the right one to be generalised.

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