9-10 March 2016, Athens, Greece
QUALICheck International Workshop on
summer comfort technologies in buildings

Overview of technological development in
passive cooling and high efficiency active cooling

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Content

• Introduction
• Shading
• Passive strategies: Natural Cooling Techniques
• Active strategies: Renewable Cooling
• Conclusions
Introduction

• At the beginning, in northern European countries, there was no cooling problem, in fact there was no cooling
• Standards only paid attention to the heating problem
Introduction

• As soon as the minimum requirements were more ambitious for reducing heating demand (consumption), cooling problem started to raise

• Now, even in the colder countries, there are cooling problems
Introduction

- In southern countries, we always have had the same problems for heating than for cooling, but also only heating was paid attention,
- In Spain, for instance, we inspired our old standard (1979!) in a German standard: no cooling at all
Introduction

• The first review, started at the end of past century, but published at 2006!, after the first EPBD, did pay the same attention to the heating than to the cooling, but buildings were constructed for the heating and protected from the cooling
Introduction

- Project ASIEPI: Assessment and improvement of the EPBD Impact (for new buildings and building renovation) (2007-2010)
- WP7 Stimulation of better summer comfort and efficient cooling by EPBD implementation:
  - Whereas in the past a major challenge was to keep our buildings sufficiently warm, recently and in new buildings the challenge is also to guarantee reasonable comfort conditions in summer with no, or at least minimum, cooling energy
Introduction

**Box 4 • Modern Building Energy Demand: less heating and more cooling**

In the past decades, thermal insulation of modern buildings has improved significantly. This has led to a lower heating demand and enabled the introduction of lower temperature heating, such that the use of ambient heat and heat pumps becomes feasible. On the other hand district heating systems become less attractive as less heat per consumer is purchased annually, though this can possibly be partly compensated for by an increase in use of floor space per consumer.

Insulation also can reduce the cooling demand in summer. Cooling demands have grown because of increased internal heat loads from computers and other appliances, more rigorous personal comfort levels, and more glazed areas on modern commercial and domestic building designs that increase the heat influxes (IEA, 2006c). The ratio of building surface to volume has also been rising, especially in the service sector and often in combination with glazed facades (IEA, 2005). In effect, modern building designs have increased the demand for cooling but reduced the demand for heat energy. This trend has been amplified by recent warmer summers in many areas, increased demand for comfort, particularly by those living in developing countries and economies in transition, and the recent availability of low cost, air-conditioning systems.

The reduction of heating loads should be encouraged as a positive aspect, but the increased application of conventional cooling equipment should be avoided. In order to decrease the cooling load, building design should focus more on the use of passive cooling options. The electricity peak load experienced in summer could then be reduced.

Deviations above (oranges) and below (blues) the average temperatures from 50 to 80

[YouTube video](https://youtu.be/gGOzHVUQCw0)
Introduction

A general recommendation for building design, could be:

– Build the building mostly for heating
– Protect the building from summer heat gains (*Shading*)
– Once the gains are there, modulate them (*Inertia*)
– Try to get ride of them with ventilative cooling (*natural cooling techniques*, night ventilation, hybrid night ventilation, forced night ventilation)
– If there is still heat to remove, **use active systems**:
   • Consider using **renewable** energy systems, and **efficient** active systems

In recent years, a lot of research, development and innovation has been devoted to these issues
Content

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Shading

- The best way to avoid cooling problems is applying solar shading:
  - Exterior solar shading
Shading

• The best way to avoid cooling problems is applying solar shading:
  – Exterior solar shading
  – Interpane solar shading
Shading

• The best way to avoid cooling problems is applying solar shading:
  – Exterior solar shading
  – Interpane solar shading
  – Interior solar shading (!)

marcarso-decoracion.com
The best way to avoid cooling problems is applying solar shading:

– Exterior solar shading
– Interpane solar shading
– Interior solar shading

Then, you can use Fixed, Movable, Manual or Automatic shading devices
Shading

• The best way to avoid cooling problems is applying solar shading:
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  – Interior solar shading
Then, you can use Fixed, Movable, Manual or Automatic shading devices

We will attend later a session devoted to solar shading...
Tools for evaluate the EPC, should pay attention to everything of these, (which would open to the QUALICHECK topics)
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Passive strategies: Natural Cooling Techniques

• Once the heat gain is in the building, we can try to modulate it, absorbing it in a massive wall, and then disipate it to a natural sink

• Phenomena to consider:
  – (Re)distribution of solar radiation
  – Inertia
  – Ventilation

• These topics have been studied very deeply...
Passive strategies: Natural Cooling Techniques

- Redistribution of solar radiation
Passive strategies: Natural Cooling Techniques

• Redistribution of solar radiation: it depends on the building inertia

Building inertia is dependent on the wall’s inertia, and the fraction of radiation impinging on every wall: which depends in turn on:

• period of the year
• Aspect ratios of the rooms
• Orientation of glazed areas
• Furniture position
Passive strategies: Natural Cooling Techniques

• Redistribution of solar radiation:
  - Change in orientation
  - Change in aspect ratio
Passive strategies: Natural Cooling Techniques

- Ventilation, night ventilation (natural or forced)

Effectiveness of Ventilation is dependent on the air movement around the walls (film coefficients!), and the inertia of the walls:

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Inlet air velocity (m/s)</th>
<th>Convective coefficient $hc,i$ (W/m²K)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wall 1</td>
<td>Wall 2</td>
</tr>
<tr>
<td>0.5</td>
<td>4.07</td>
<td>2.06</td>
</tr>
<tr>
<td>1.0</td>
<td>6.43</td>
<td>3.66</td>
</tr>
<tr>
<td>1.5</td>
<td>8.60</td>
<td>5.20</td>
</tr>
</tbody>
</table>
Passive strategies: Natural Cooling Techniques

- Ventilation, night ventilation (natural or forced)
Passive strategies: Natural Cooling Techniques

- Evaporative cooling
  - Direct
  - Indirect
- Passive downdraught evaporative cooling (PHDC)
- Roof based natural cooling strategies (RoofSol)
- Innovative systems: PCM associated to ventilation
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Active strategies: Renewable cooling

In the KeepCool project, *Promotion of sustainable cooling in the service building sector*, they recommended to follow, when possible, this decalog:

1. Define explicitly the thermal comfort objectives, using the *Adaptive Comfort* model where possible.
2. Intervene on the site layout and features which can affect summer comfort.
3. Control and reduce heat gains at the external surface of the envelope.
4. Control and modulate heat transfer through the building envelope.
5. Reduce internal gains.
6. Allow for local and individual adaptation.
7. Use passive means to remove energy from the building.
8. Use active solar assisted cooling plants.
9. Use high efficiency active conventional cooling plants.
10. Train building managers and occupants on how to use, monitor the performance of and adequately operate and maintain the building.

Let us see an example from solar absorption cooling system in Spain...

**Box 1 • Definition of Renewable Energy**

The IEA (2006e) defines renewable energy as *energy derived from natural processes that are replenished constantly*. This definition applies to a wide range of energy sources derived directly or indirectly from the sun including solar, hydro, wind, wave, biomass and ambient heat, but also includes non-solar sources such as geothermal, tidal and ocean currents.

Solar, geothermal and biomass can all be used as direct sources of heat (Box 2) and heat can also be extracted from the air, water or ground (Box 3). Heat can be used to drive absorption chillers for cooling. In addition any form of renewable-based electricity can be used to power heating or cooling appliances but these applications are not considered in this report.
Ratio Heating/Cooling energy demand for tertiary buildings in Spain
Heat for producing cooling by absorption systems

Mechanical vs. absorption chillers
Mechanical vs. absorption chillers
Almacenamiento térmico

Agua sobrecalentada
13 bar / 180º C

Máquina absorción de doble efecto

Intercambiador

Circuito de Agua refrigeración

Agua fría

gas natural

Sistema de control

Circuito secundario

Captador solar Fresnel

Agua sobrecalentada
13 bar / 165º C

Circuito primario

- Río Guadalquivir -
• Engineering School (main building): 35000 m²
Solar Cooling

Fresnel Solar Collector
• Absorption Chiller: BROAD BZH15

Double effect
H2O/BrLi
Nominal power: 174 kW
COP=1.34
PCM Storage Tank
Hidroquinone. Tpcm: 170°C
275 kWh
Monitoring and evaluation (2009)

Energy consumption by fuel source

Energy final produced (kWh)

- Solar: 11.31%
- Gas: 30.55%
- Electricidad: 58.14%

Porcentaje cubierto del total de refrigeración (822788 kWh)

Graph showing energy consumption by fuel source.
The use of the solar fraction concept to assess the climatic applicability of solar cooling
Active strategies: Efficient systems

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**Status of heating and cooling technologies today**

**Overview**

This roadmap covers several key building technologies for space and water heating, heat storage, cooling and dehumidification. They are:

- **Active solar thermal (AST)** can provide space and water heating, as well as cooling needs. This roadmap focuses on building integrated systems, but it can equally be used in district-heating schemes.

- **Combined heat and power** systems of building scale (1 kW to 1 MW) and "campus" scale (1 MW to 5 MW) are the focus of this roadmap. Traditional CHP systems are mature and a useful transitional technology, while micro-CHP, biomass CHP and even fuel cell systems (using CO₂-free hydrogen) may emerge as an important abatement option.

- **Heat pumps for cooling and space and water heating** are mature, highly efficient technologies that take advantage of renewable energy.

- **Thermal storage** includes sensible (hot water, underground storage) and latent (phase change ice storage, micro-encapsulated phase-change materials) and thermo-chemical storage. Thermal storage can maximise the energy savings and energy efficiency potential of other technologies, facilitate the use of renewables and waste heat, and improve flexibility, helping to minimise the overall system cost of the BLUE Map scenario.

Heat pumps, active solar thermal and CHP can all be installed in almost all building types to provide space and water heating. For cooling, active solar thermal and CHP require thermally driven chillers.

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6. Other technologies play an important, but smaller contribution and won’t be covered in this roadmap. These include efficient fossil fuel technologies, such as condensing boilers, biomass and biofuels.

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Conclusions

• It has been shown the evolution of the cooling demand in buildings, and passive and active techniques for removing it from the buildings

• The key statement from ASIEPI WP7, IEA and other documents, is considered a good summary of this slides:

  *Whereas in the past a major challenge was to keep our buildings sufficiently warm, recently and in new buildings the challenge is also to guarantee reasonable comfort conditions in summer with no, or at least minimum, cooling energy, if possible using renewable sources, and efficient systems*
Overview of technological development in passive cooling and high efficiency active cooling

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