International Workshop

« Efficacité Energétique des Bâtiments Publics »

Refroidissement nocturne des bâtiments publics: comparaison de différentes techniques et stratégies

Night Cooling of public buildings: comparison of different techniques and strategies

LASH - DGCB

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Aim of research

BRE office

Watford

Analysis and evaluation of potentialities of thermal mass activation systems in buildings for the reduction of energy consumptions and power demand in summer period and for the improving of indoor thermal comfort.

Libera Università di Bolzano

Background

- The three principal parameters affecting the efficiency of night ventilation NV are:
  - The night temperature difference between indoor and outdoor environment

    ⇨ *Climatic conditions*
  - The air change rates per hour

    ⇨ *Electrical consumptions*
  - The thermal storage capacity of buildings

    ⇨ *Building Thermal Mass*

Background

Usually the massive buildings present best environmentally performances compared to light buildings. But only a very slow thickness of the mass of the building participate to the energy balance..

The thermal mass activation systems consist of the utilization of a thermo vector, air or water, managed to optimize the exchanges between the building mass, viewed as a storage, and the environment

TMA systems examined

The thermal mass systems considered are:

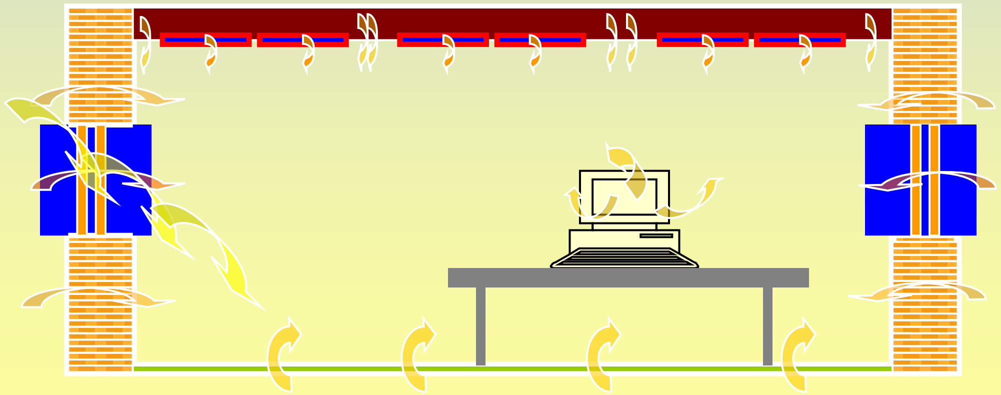
1. Massive buildings (high mass vs low mass)
2. TABS:
   - 2.1 Airborne Thermal Mass Activation
   - 2.2 Waterborne Thermal Mass Activation
3. Phase Change Materials:
   - 3.1 Passive PCM (wallboards)
   - 3.2 Activated PCM (ventilated systems)

Dynamic Modeling Technique

Dynamic Models built in Simulink Environment

- Finite Differences
- Deeply description of envelope
- Deeply description of HVAC\ventilation system
- Energy balances differential equations with explicit solution:

$$T_a(i+1) = T_a(i) + \Delta T_a(i)\big|_F + \Delta T_a(i)\big|_C + \Delta T_a(i)\big|_{E.W.} + \Delta T_a(i)\big|_W + \Delta T_a(i)\big|_{S.H.} + \Delta T_a(i)\big|_{I.H} + \Delta T_a(i)\big|_V$$



Inputs/Outputs of the model

Inputs consist of:

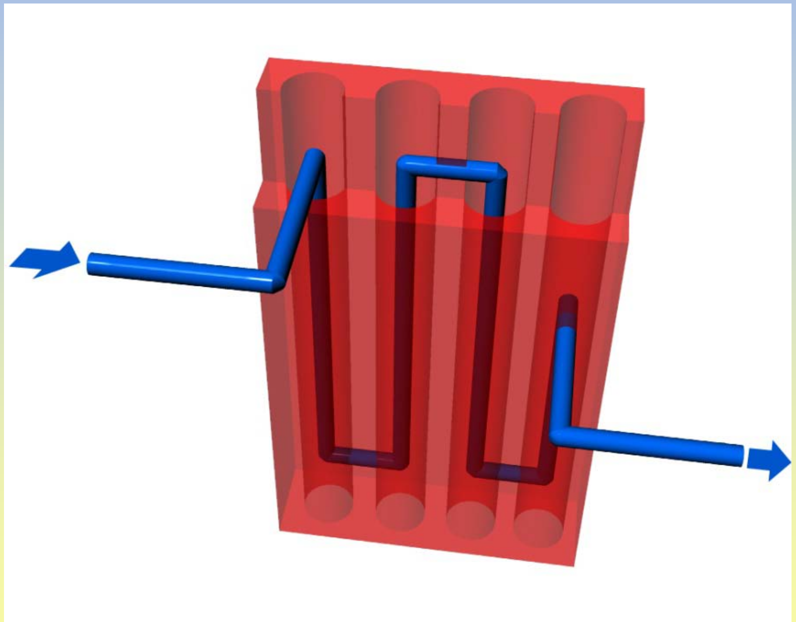
- Detailed thermo physical description of the environment
- HVAC\ventilation system description
- Hourly Climatic conditions
- Occupation profile

Outputs consist of:

- Temperatures Time profile of each surface involved in the energy balance
- Temperature and humidity of indoor air, ventilation air
- Energy demand of the environment
- Energy consumptions/ Power demand of HVAC system

Hollowcore Ventilated ceiling

Outdoor air, before entering the rooms flows through 29 meters inside a ceiling concrete slab



During the day:

- outdoor air is pre-cooled by means the thermal exchange with the slab

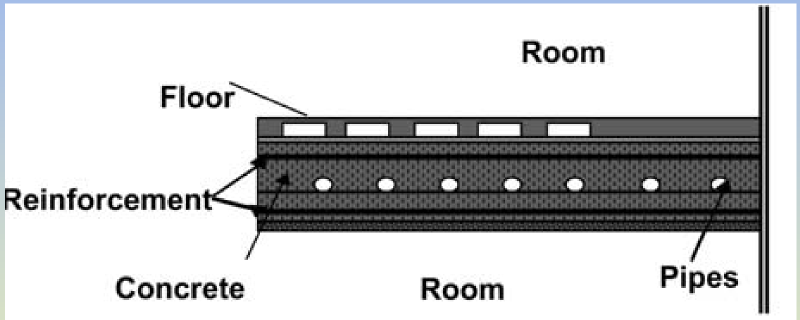
During the night:

- the ceiling is refreshed by means the thermal exchange with the outdoor air

Waterborne Activation

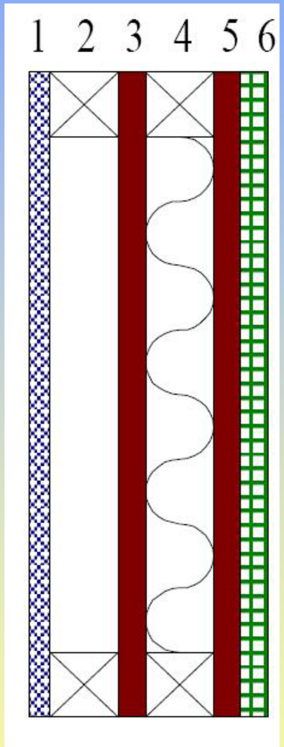
The floor is equipped with embedded pipes for circulation of water.

Circulation of water has not only a direct cooling effect, but also reduces the peak load and transfers it outside the period of occupancy.



The water flows inside the ceiling slab through a long pipe. Water temperature is among 15°C, so that capable to take over the heat of picked up by the ceiling without problem of moisture

PCM Wallboards



1. Particle board
2. Air
3/5. Plywool
4. Insulation
6. PCM layer

➢Passive utilization of PCM:

the PCM layer is supposed to work all the day between the solid and the starting of the melting phase

➢Sponge effect:

A PCM layer can be used to riproduce the effect of the concrete in light envelopes, acting as a sponge.

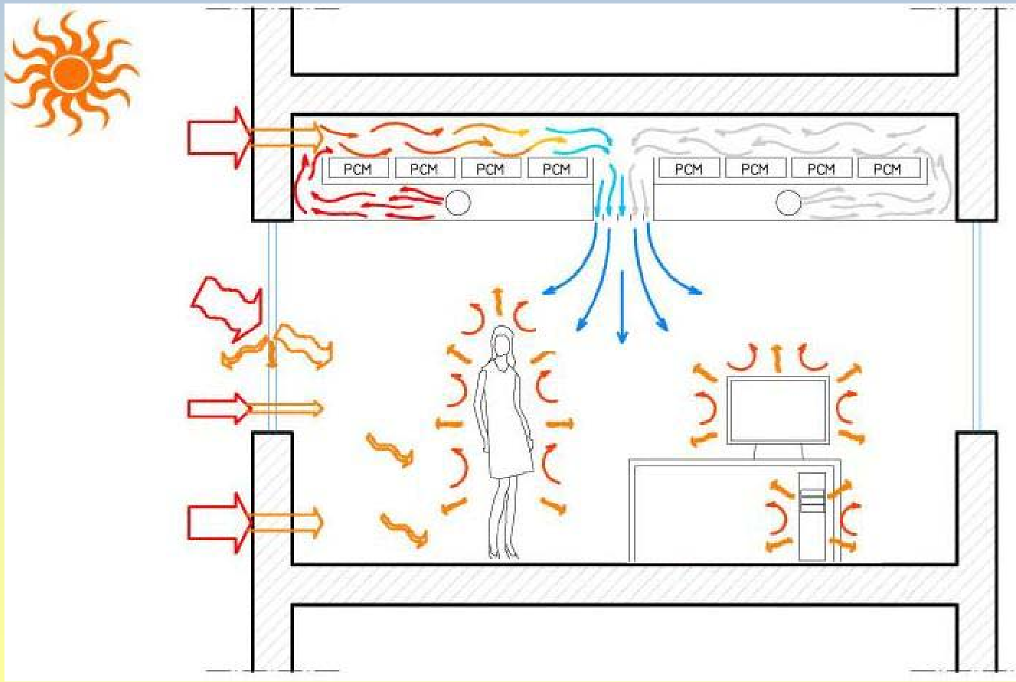
PCM Ventilation system

External air, before entering the room, is introduced in the PCM box

Night → Not Occupation Period

Ventilation roll:

- ➢ Freezing the PCM
- ➢ Indoor thermal loads removing



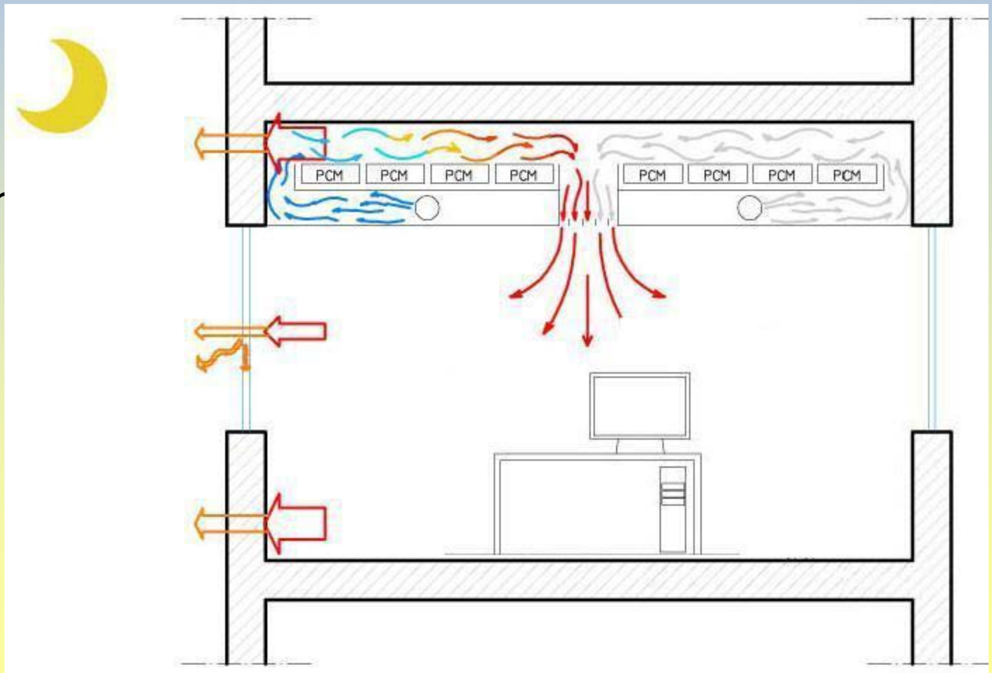
PCM Ventilation system

External air, before entering the room, is introduced in the PCM box

Day → Occupation Period

PCM role: ventilation loads removir

Ventilation role: IAQ



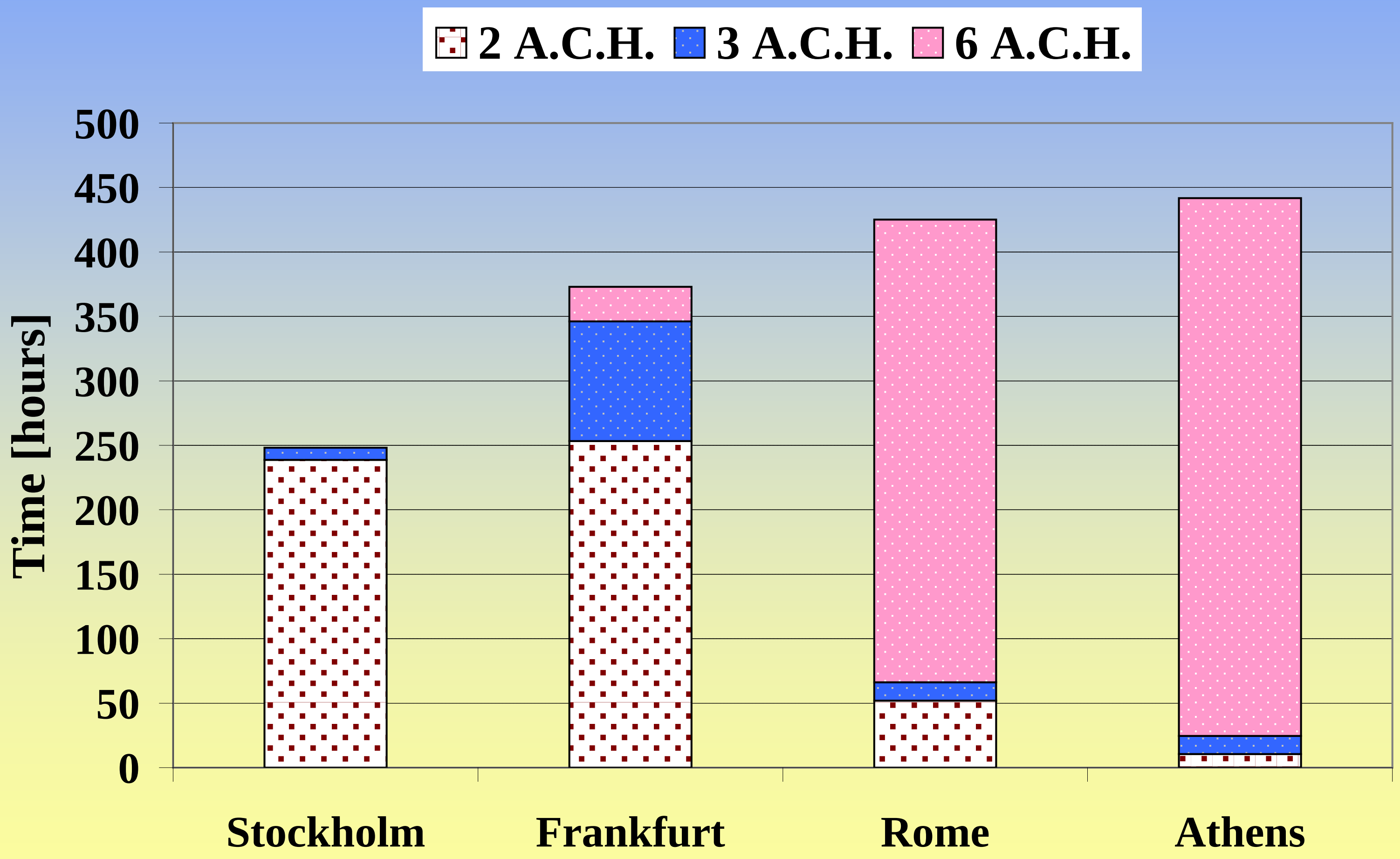
TABS: airborne TMA

Thermal analysis of an office building in European climate for the comparison of a traditional ventilation system with a thermal mass activation system.

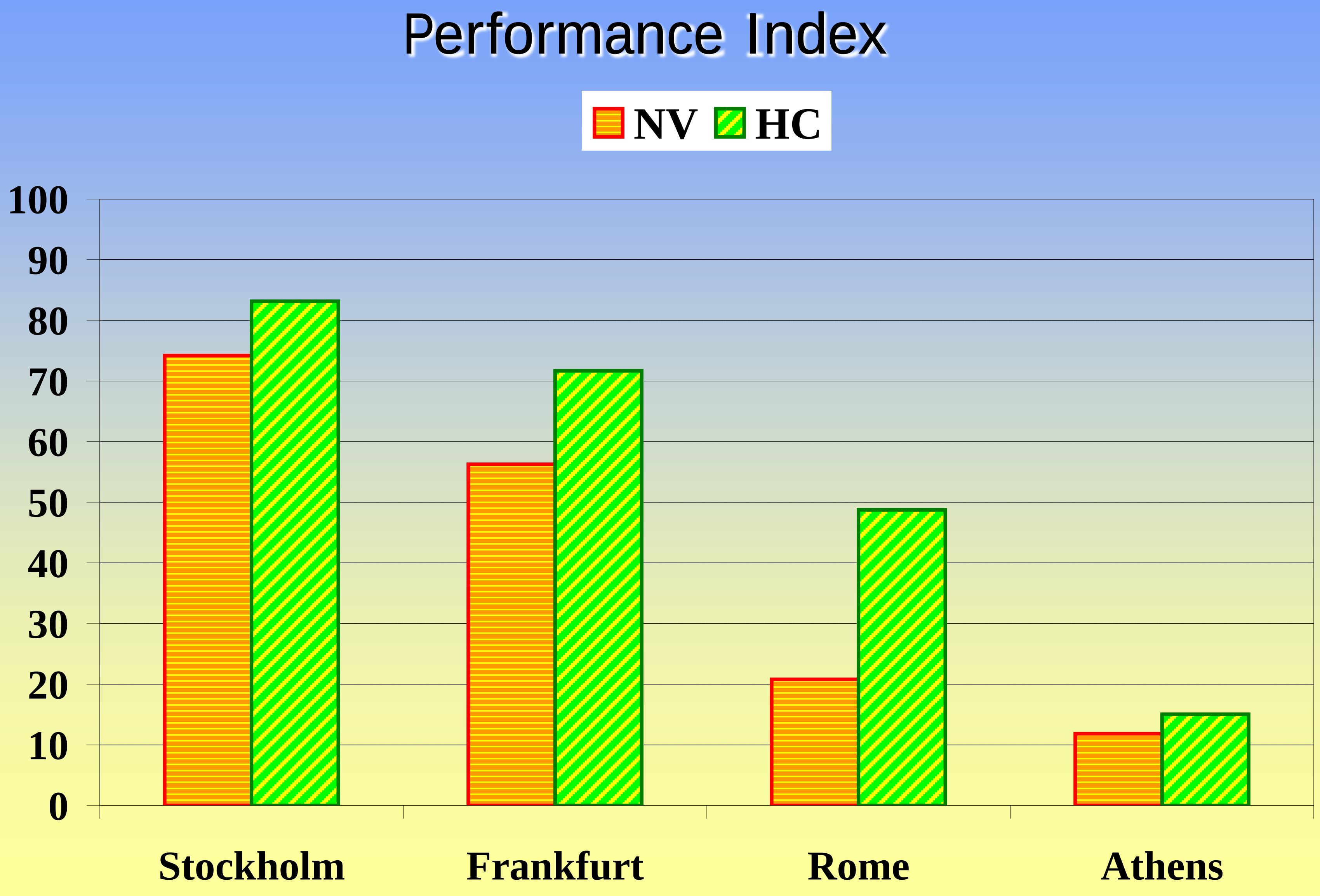
- Cities: Stockholm, Frankfurt, Rome, Athens
- Ventilation systems:
  - **NV**: generic mixing ventilation system
  - **HC**: thermal mass activation system
- Strategies:
  - ✓2 A.C.H. in occupied periods
  - ✓2, 4, 6 in nighttime
- Thermal Discomfort Analysis
  - ✓Performance Index
  - ✓Weighted Discomfort Index

TABS: Results

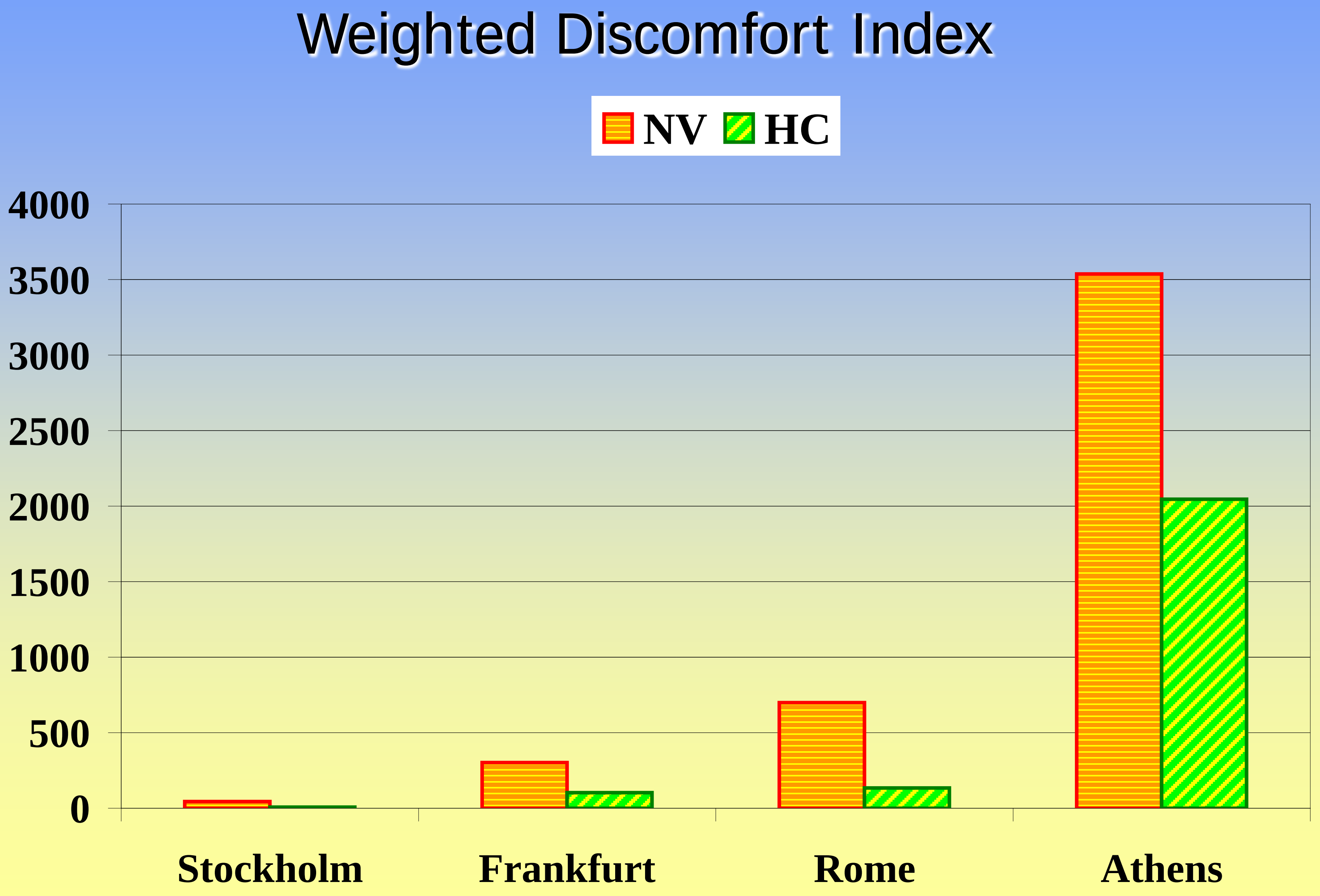
Hours and distribution of night ventilation



TABS: Discomfort Analysis

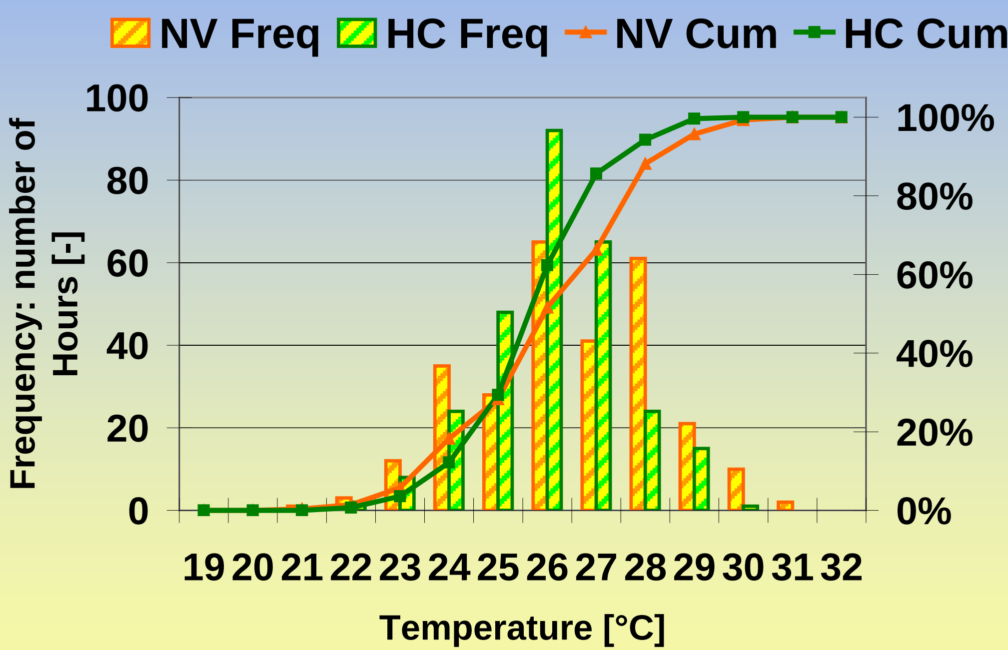


TABS: Discomfort Analysis

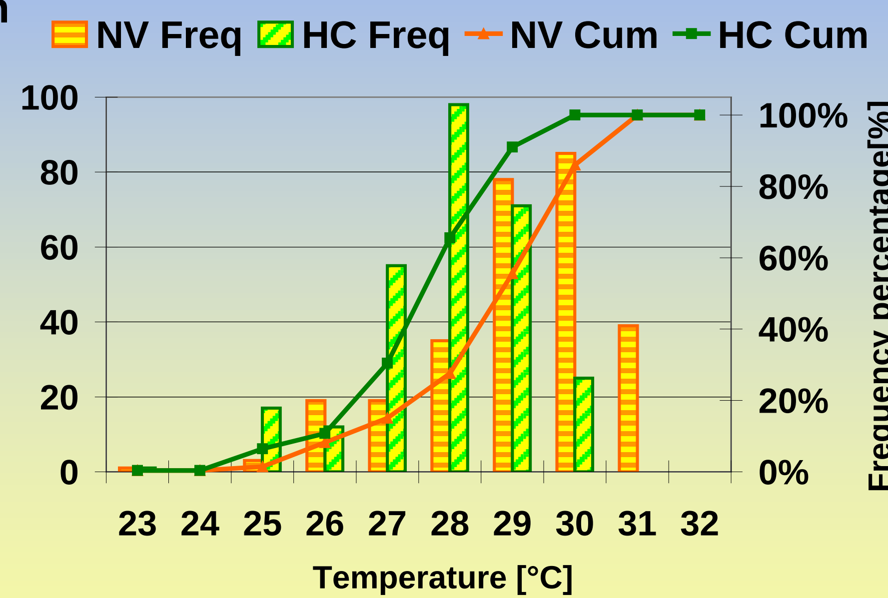


TABS: Frequency Distribution

Frequency Distribution of indoor air temperatures in occupation period

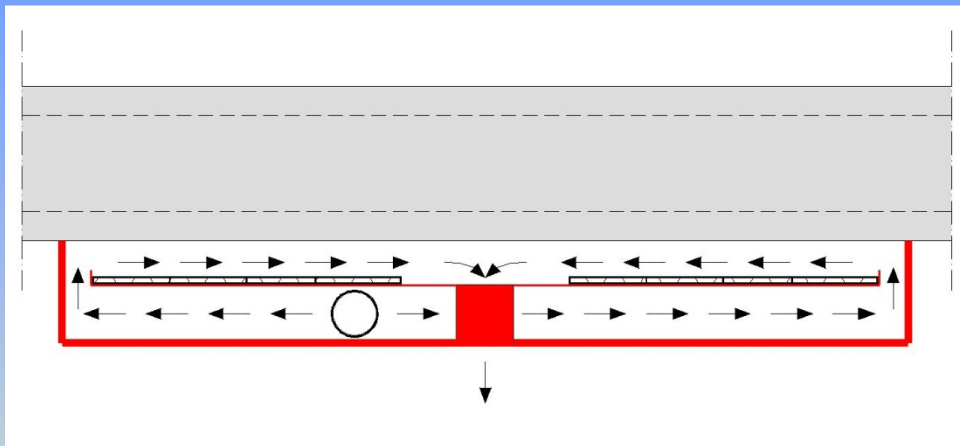


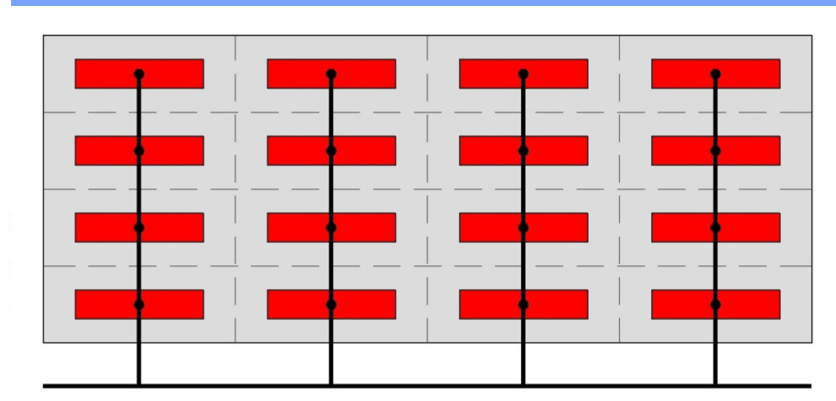
Frankfurt



Rome

Activated PCM: ventilation system





Two ventilation systems are compared:

PCM NVS: Phase Change Materials Night ventilation System

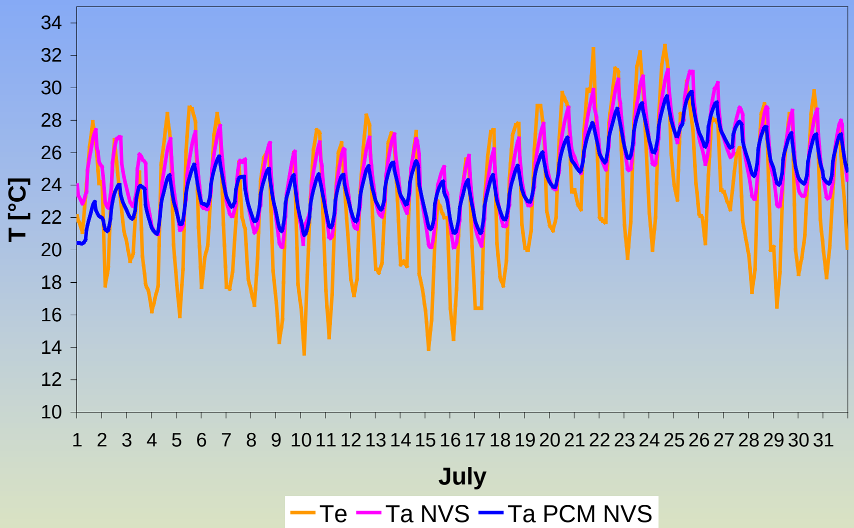
NVS: Night Ventilation System

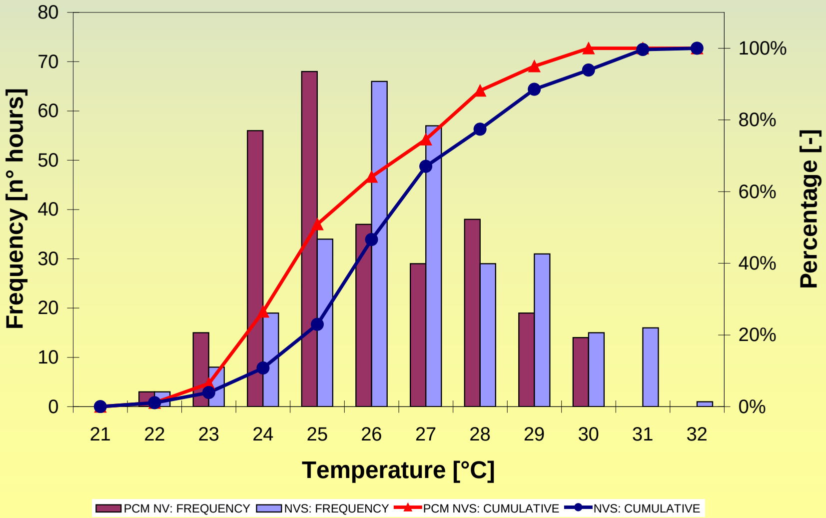
- 16 PCM Boxes
- Each Box with 8 PCM pouches
- Ventilation Strategies:

2 h^{-1} in Occupation Periods

10 h^{-1} in Not Occupation periods

Activated PCM: ventilation system





Milan	NVS	PCM NVS
T_{indoor} [°C]	26,4	25,4
DTP [%]	22	11
DI [$°C^2$]	149	33

Conclusions

The main aspects of originality of the research consist of:

- Actuality of the topic of thermal mass activation
- Comparison analysis of the diverse possible storage technologies
- Detailed modelling of the storage elements
- Detailed modelling of the coupling of the storages and building + HVAC system
- Study of the energy & environmental effects and of the comfort of thermal mass activation systems in buildings