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Energy in Buildings and Communities Programme

IEA EBC ANNEX 62

# VENTILATIVE COOLING

## -POTENTIAL, LIMITATIONS AND DESIGN CONSIDERATIONS

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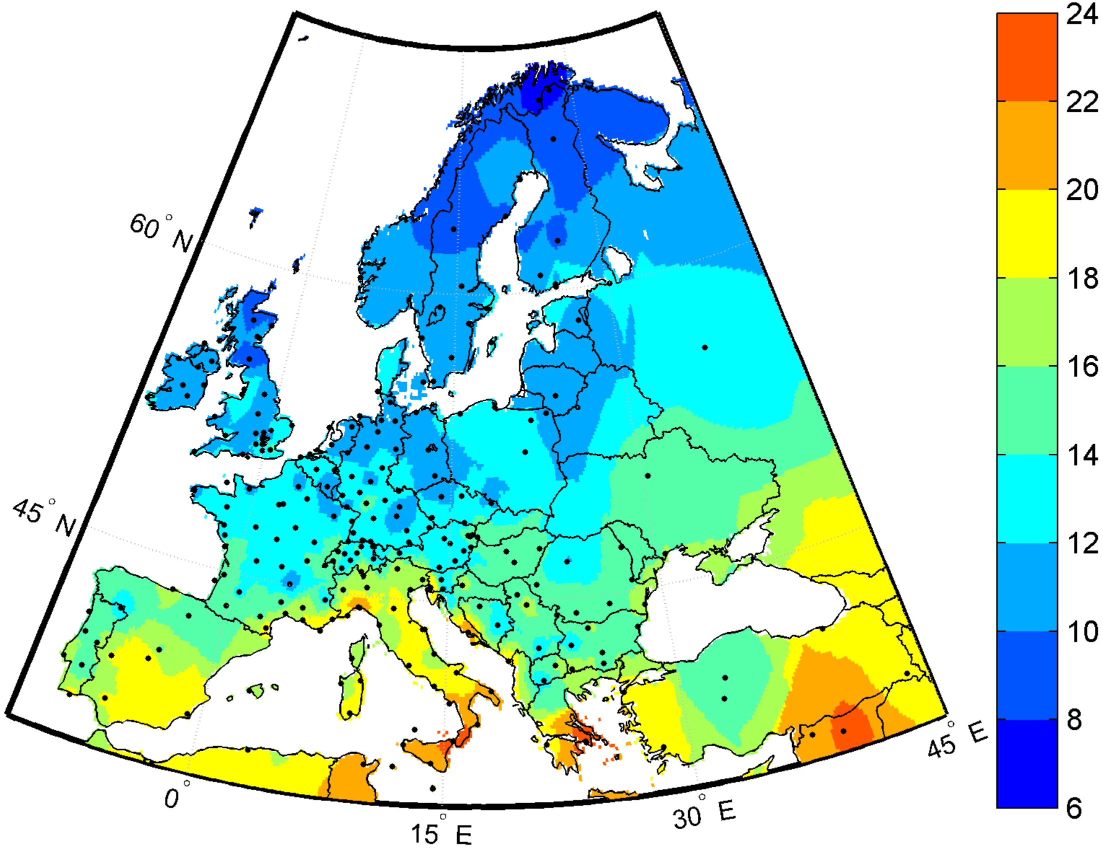
DENMARK

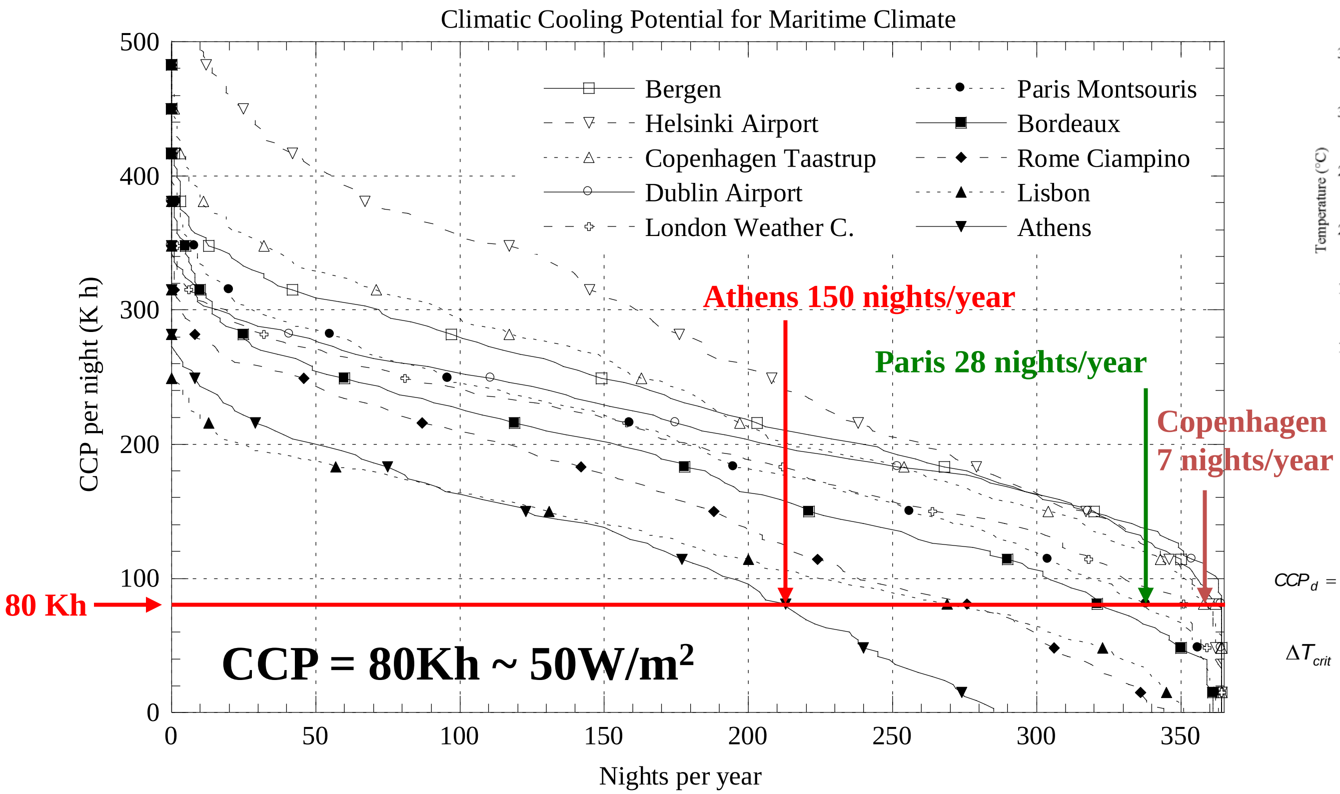
# Cooling Potential

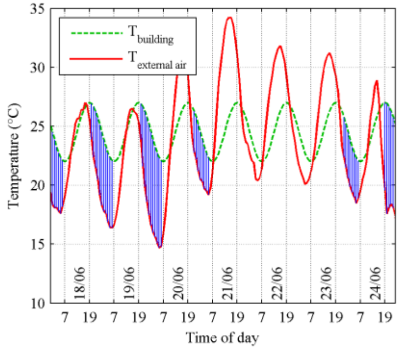
# DAILY MINIMUM TEMPERATURE JULY




Meteonorm Data

# CUMULATIVE FREQUENCY DISTRIBUTION OF CCP




$$CCP_d = \sum_{t=t_i}^{t_f} m_{d,t} \left(T_{b(d,t)} - T_{e(d,t)}\right) \quad \begin{cases} m = 1\,\text{h} & \text{if } T_b - T_e \geq \Delta T_{crit} \\ m = 0 & \text{if } T_b - T_e < \Delta T_{crit} \end{cases}$$

$$\Delta T_{crit} = 3K$$

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Artmann, N., Manz, H., Heiselberg, P.
*Applied Energy, Vol. 84, 2007, pp 187-201*

# VENTILATIVE COOLING POTENTIAL

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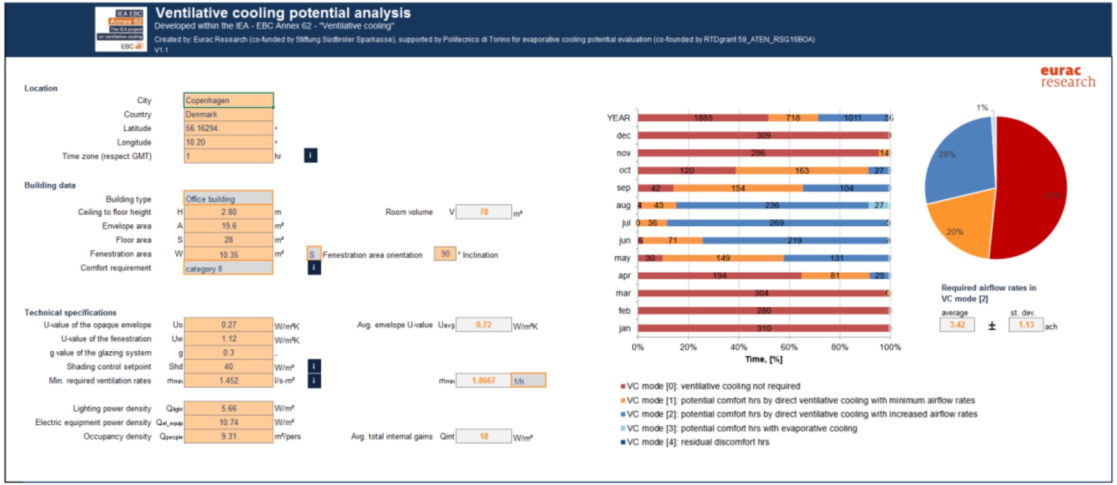
## CHARACTERISTICS

- Can estimate climate potential
- Take into account building characteristics and loads
- Suggest potential relevant strategies
- Estimate necessary air flow rates




■ VC mode [0]: ventilative cooling not required

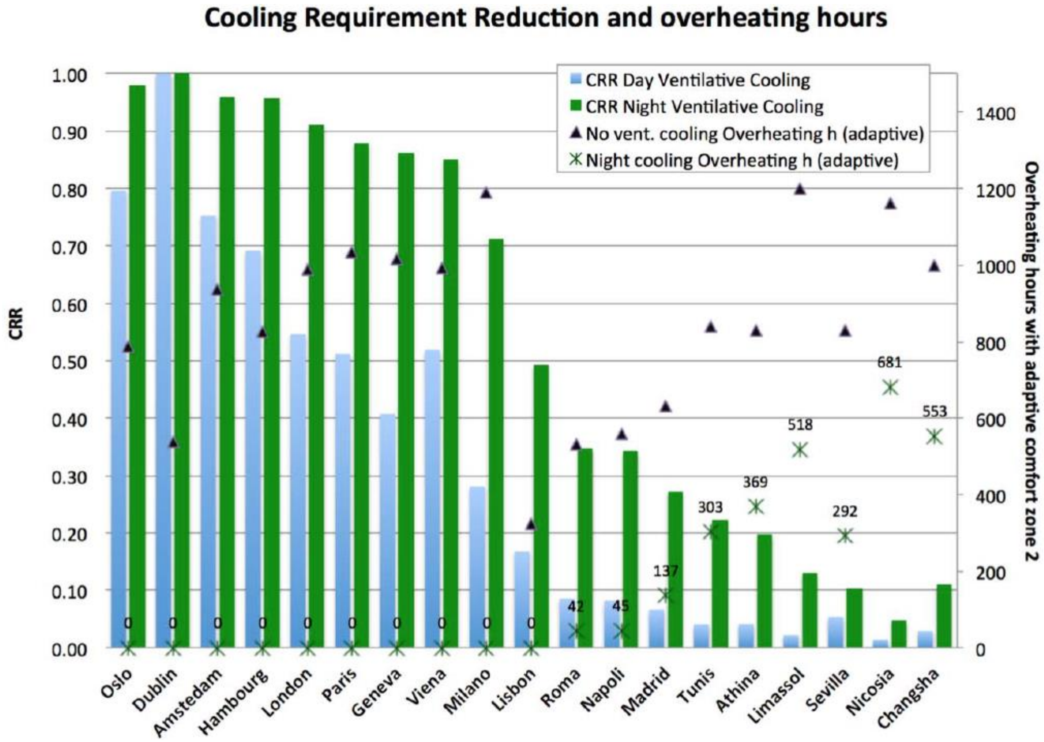
■ VC mode [1]: potential comfort hrs by direct ventilative cooling with minimum airflow rates

■ VC mode [2]: potential comfort hrs by direct ventilative cooling with increased airflow rates

■ VC mode [3]: potential comfort hrs with evaporative cooling

■ VC mode [4]: residual discomfort hrs

# COOLING REQUIREMENTS REDUCTION (CRR)




$$CRR = \frac{Q_{t,c}^{ref} - Q_{t,c}^{scen}}{Q_{t.c}^{ref}}$$

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# Limitations

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# LIMITATIONS

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- Climate
  - Peak summer conditions and periods with high humidity reduce the applicability
  - Temperature increase due to climate change might reduce potential
- Urban location
  - Might reduce the cooling potential (heat island)
  - Reduced driving forces for natural systems (higher temperature and lower wind speed).
  - Elevated noise and pollutions levels might also be present
- Other
  - High energy use for air transport limit the potential for use of mechanical systems
  - Building design, fire regulations, security are issues that might decrease the potential use of natural systems

# Design Considerations

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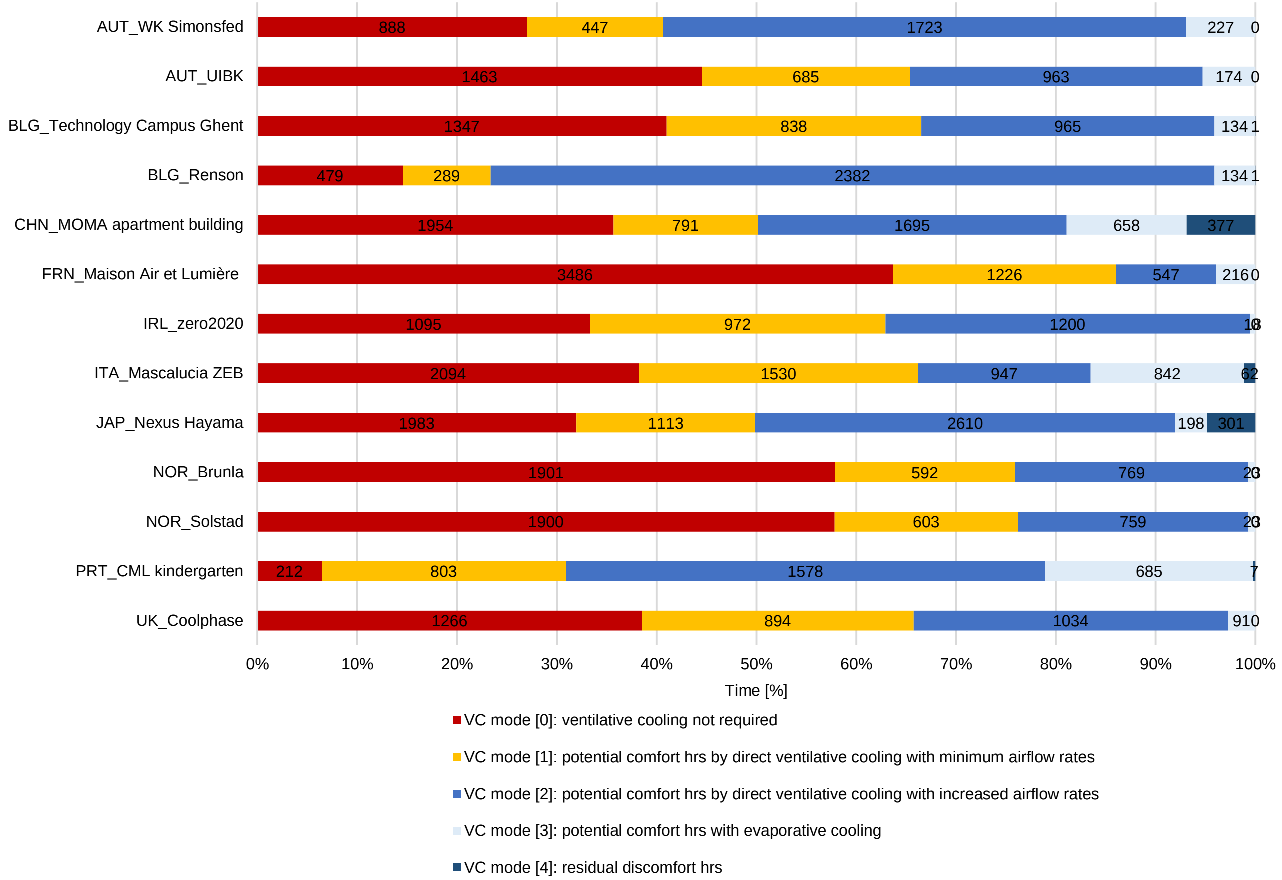
# DESIGN INFLUENCES

| | Country | Building | Surroundings | Lower Initial costs | Lower Maintenance Costs | Lower Energy Costs | Reducing Solar Loads | Reducing Internal Loads | Reducing External Noise | High Internal noise | Elevated Air Pollution | Avoiding Rain Ingress | Insect Prevention | Burglary Prevention | Reduced Privacy |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01 | IE | Zero2020 | R | H | M | H | H | L | L | L | L | M | L | H | M |
| 02 | NO.1 | Brunla School | R | H | H | H | L | M | L | L | H | M | L | L | L |
| 03 | NO.2 | Solstad Kindergarten | R | L | L | H | L | L | L | M | H | L | L | L | L |
| 04 | CN | Wanguo MOMA* | U | H | M | H | H | L | L | L | L | M | L | M | L |
| 05 | AT.1 | UNI Innsbruck | U | H | H | H | M | L | M | L | L | M | L | L | L |
| 06 | AT.2 | wkSimonsfeld | R | H | H | H | M | L | L | L | L | L | L | L | L |
| 07 | BE.1 | Renson | R | L | L | M | H | H | H | H | M | H | H | L | L |
| 08 | BE.2 | KU Leuven, Ghent | U | H | L | H | H | H | L | L | L | M | L | L | L |
| 09 | FR | Maison Air et Lumiere* | U | M | M | L | H | M | L | L | H | L | L | M | L |
| 10 | IT | Mascalucia ZEB* | R | H | M | H | H | L | L | L | L | L | L | M | L |
| 11 | JP.1 | Nexus Hayama | R | M | M | H | H | L | L | L | L | M | H | H | M |
| 12 | PT | CML Kindergarten | U | H | L | L | M | M | L | L | L | M | M | M | M |
| 13 | JP.2 | GFO | U | H | M | L | L | L | L | L | L | L | L | L | L |
| 14 | UK | Bristol University | R | H | H | H | L | H | L | M | L | M | M | H | L |
| 15 | NO.3 | Living Lab* | U | L | L | H | H | M | L | M | L | H | L | L | L |

# VENTILATIVE COOLING STRATEGIES



| Ventilative Cooling Principle | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Case Study No.** | | **Type and location** | **Day time air supply** | **Night time air supply** | **Natural ventilation combined with mechanical exhaust** | **Mechanical ventilation in winter, natural ventilation in summer** | **Mechanical ventilation with natural night time ventilation** | **Mechanical ventilation with increased flow rate** |
| 01 | IE | Zero2020 | x | x | | | | |
| 02 | NO.1 | Brunla school | | | x | | | |
| 03 | NO.2 | Solstad Kindergarten | | | | x | | |
| 04 | CN | Wanguo MOMA | | | | | | x |
| 05 | AT.1 | UNI Innsbruck | x | x | | | | |
| 06 | AT.2 | wkSimonsfeld | | | x | | | |
| 07 | BE.1 | Renson | x | x | | | | |
| 08 | BE.2 | KU Leuven, Ghent | | | | | x | |
| 09 | FR | Maison air et lumiere | | | | x | | |
| 10 | IT | Mascalucia ZEB | | | | x | | |
| 11 | JP.1 | Nexus Hayama | x | x | | | | |
| 12 | JP.2 | GFO | x | x | x | | | |
| 13 | PT | CML Kindergarten | x | x | | | | |
| 14 | UK | Bristol University | | | | | | x |
| 15 | NO.3 | Living Lab | x | | x | | | x |

| Ventilative Cooling Components and Technologies | | | Air Flow Guiding components | | | | | Air Flow Enhancing Components | | | | Supplementary Cooling Technologies | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Case Study No.** | | **Type and location** | Windows | Insulated louvre | Overflow vents between rooms | Air pipes and air supply devices | Roof vents | Chimney | Fan | Ground cooling | Evaporative cooling | Ground Source heat pump | Earth to air Heat Exchanger | Radiant solar heat and cooling | PCM storage |
| 01 | IE | Zero2020 | | x | | | | | | | | | | | |
| 02 | NO.1 | Brunla school | x | | | | | | x | | | | | | |
| 03 | NO.2 | Solstad Kindergarten | x | | | x | | | x | | | | | | |
| 04 | CN | Wanguo MOMA | | | | x | | | x | | | x | | | |
| 05 | AT.1 | UNI Innsbruck | x | | x | | | | | x | | | | | |
| 06 | AT.2 | wkSimonsfeld | x | | | | x | | | x | | | | | |
| 07 | BE.1 | Renson | x | | | | | x | | | | | | | |
| 08 | BE.2 | KU Leuven, Ghent | x | | | | | | | | x | | | | |
| 09 | FR | Maison air et lumiere | x | | | x | | | x | | | | | | |
| 10 | IT | Mascalucia ZEB | x | | | | | | x | | | | x | | |
| 11 | JP.1 | Nexus Hayama | x | | | | x | | | | | | | x | |
| 12 | JP.2 | GFO | | x | | x | | | x | | | | | | |
| 13 | PT | CML Kindergarten | x | x | | | | x | | | | | | | |
| 14 | UK | Bristol University | | | | x | | | x | | | | | | x |
| 15 | NO.3 | Living Lab | x | | | | | | | | | | | | |

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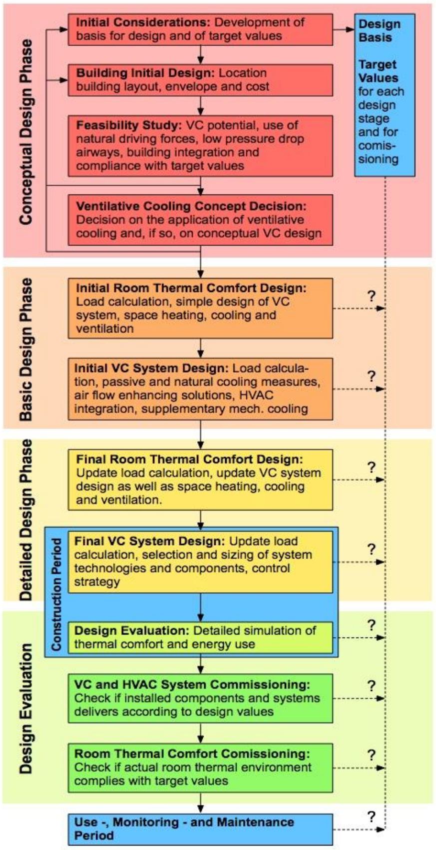
# DESIGN CONSIDERATIONS




## Look for when searching for solutions

- ✓ Possibility to use outdoor air without filtering
- ✓ Possibility to use direct airflow from/to outside without a noise problem, a control problem, a burglary, insect and/or rain problem
- ✓ Use exposed thermal mass in the building structure
- ✓ Use heat recovery in cold climates and in buildings with relatively low heat loads
- ✓ Use a large height difference between ventilation intake and exhaust to maximize stack effect and vertical temperature differences
- ✓ Use overflow between rooms either for supply- or extract side of ventilation
- ✓ Minimize need for ducting of ventilation air
- ✓ Minimize airflow rate by air distribution design that can provide low supply air temperatures with risk of draught

## Avoid when searching for solutions

- Direct solar exposure of occupants
- Solar heating of intake air
- Negative effects from wind on buoyancy driven air flow
- Building design with little thermal mass exposed in intake air flow paths and in rooms
- Noise transfer from outside and from other rooms of building
- Inefficient room air distribution
- Air flow paths which do not allow easy inspection and cleaning

| Ventilative cooling System: Need for supplementary cooling? | | | | | | |
|---|---|---|---|---|---|---|
| **Outdoor environment** | | **N** | | **M** | | **Y** |
| Cold (> 10ºC from comfort zone) | | | | | | |
| Temperate (2-10ºC from comfort zone) | | | | | | |
| Hot and dry (-2ºC …. +2ºC from comfort zone) | | | | | | |
| Hot and humid | | | | | | |
| Dense urban area with low wind speeds (low natural driving force) | | | | | | |
| Dense urban area with high night temperatures (heat island) | | | | | | |
| High pollution level in the area | | | | | | |
| Noisy surroundings | | | | | | |
| **Building heat load level:** | | **N** | | **M** | | **Y** |
| Low heat loads < 20 W/m² during occupation | Cold (> 10ºC from comfort zone) (heat recovery needed) | | | | | |
| | Temperate (2-10ºC from comfort zone) | | | | | |
| | Hot and dry (-2ºC …. +2ºC from comfort zone) | | | | | |
| | Hot and humid | | | | | |
| Medium heat loads 20 -30 W/m² during occupation | Cold (> 10ºC from comfort zone) (heat recovery needed) | | | | | |
| | Temperate (2-10ºC from comfort zone) | | | | | |
| | Hot and dry (-2ºC …. +2ºC from comfort zone) | | | | | |
| | Hot and humid | | | | | |
| High heat loads > 30 W/m² during occuation | Cold (> 10ºC from comfort zone) (heat recovery needed) | | | | | |
| | Temperate (2-10ºC from comfort zone) | | | | | |
| | Hot and dry (-2ºC …. +2ºC from comfort zone) | | | | | |
| | Hot and humid | | | | | |
| **Thermal comfort:** | | **N** | | **M** | | **Y** |
| High requirements for 95% of occupancy hours | | | | | | |
| Normal requirements for 95% of occupancy hours | | | | | | |
| Normal requirements for 80% of occupancy hours | | | | | | |
| Requirements adaptive to outdoor conditions | | | | | | |
| **Building and system:** | | **N** | | **M** | | **Y** |
| Low level of exposed building thermal mass | | | | | | |
| Moderate level of exposed building thermal mass | | | | | | |
| High level of exposed building thermal mass | | | | | | |
| High space- and use-flexibility | | | | | | |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# Thanks for your attention

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