IEA Annex 62
Ventilative Cooling

Design guidelines

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Ventilative cooling in buildings: now & in the future
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Introduction

- Ventilative cooling can be an attractive and energy efficient natural cooling solution **to reduce cooling loads and to avoid overheating** in buildings.
- Ventilation is already present in most buildings through mechanical and/or natural systems and by adapting them for cooling purposes, cooling **can be provided in a cost-effective way** (the prospect of lower investment and operation costs).
- Ventilative cooling can both remove excess heat gains as well as increase air velocities and thereby **widen the thermal comfort range**.

Ventilative Cooling Principles

		Ventilative Cooling	Supplementary Solutions
Daytime mean outdoor temperature	Cold (> 10°C from comfort zone)[1]	Minimize air flow rate - draught free air supply	-
	Temperate (2-10°C)	Increasing air flow rate from minimum to maximum	Strategies for enhancement of natural driving forces to increase flow rates Natural cooling strategies like evaporative cooling, earth to air heat exchange to reduce air intake temperature during daytime
	Hot and dry (-2°C …. +2°C)	Minimum air flow rate during daytime Maximum air flow rate during night time	Natural cooling strategies like evaporative cooling, earth to air heat exchange, thermal mass and PCM storage to reduce air intake temperature during daytime. Mechanical cooling strategies like ground source heat pump, mech. cooling
	Hot and humid	Natural ventilation should provide minimum outdoor air supply	Mechanical cooling/ dehumidification

[1]*Temperature difference between indoor and outdoor air temperature.*

Design process

Conceptual design phase
- Targets
- Ventilative cooling potential
- Ventilative cooling principle
- Supplementary passive or natural cooling

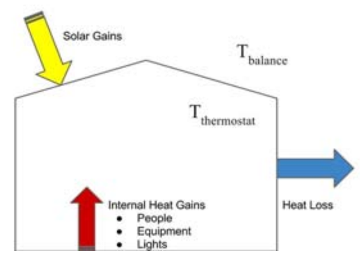
Basic design phase
- Integration of building and ventilative cooling system
- Load calculation

Detailed design phase
- Type and location of ventilative cooling components
- Control strategy
- Design validation

How to evaluate the ventilative cooling potential at early design stages?

How to assess ventilative cooling performance?

Ventilative cooling potential



To assess the potential of ventilative cooling by taking into account also:
- building envelope thermal properties
- internal gains
- ventilation needs

Ventilative Cooling mode [0]: no ventilative cooling required;
Ventilative Cooling mode [1]: potential comfort hours by direct ventilative cooling with minimum airflow rates;
Ventilative Cooling mode [2]: potential comfort hours by direct ventilative cooling with increased airflow rates;
Ventilative Cooling mode [3]: potential comfort hours with evaporative cooling;
Ventilative Cooling mode [4]: residual discomfort hours.

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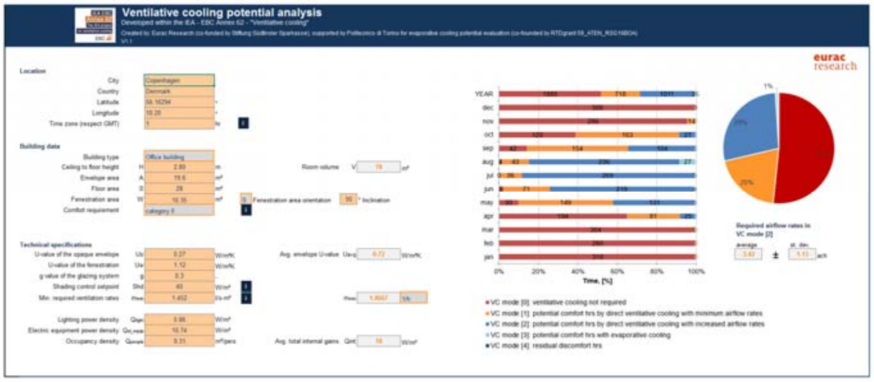
Ventilative cooling potential



http://venticool.eu/wp-content/uploads/2017/05/V1.0_Ventilative-cooling-potential-analysis-tool.xlsm

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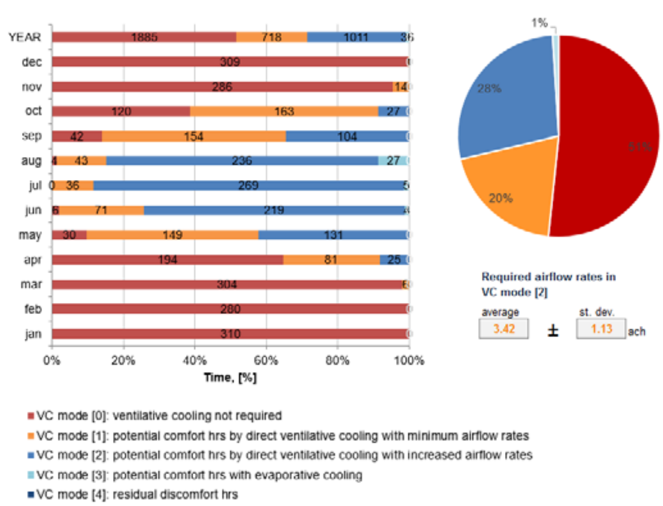
Ventilative cooling potential



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Key performance evaluation

- to evaluate and compare in a fairly way both new and old, innovative and standard, passive and active technologies;
- to value the performance of ventilative cooling both in energy and thermal comfort terms;
- to include KPIs for ventilative cooling and push towards their application in standards, design protocols and guidelines, monitoring protocols, dynamic simulation tools, energy labels;
- to assess designs in a standardized way.

Design for thermal comfort

Thermal comfort indicators should take into account the following aspects:

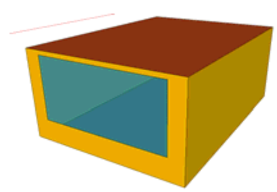
- represent discomfort situation due to both overheating and overcooling;
- different thermal comfort models (Fanger, adaptive);
- overheating severity

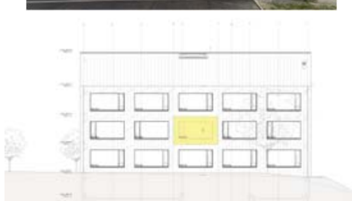
Design for energy saving

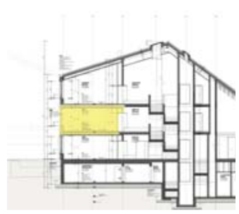
Energy indicators should be able to take into account the following aspects:

- cooling need and/or energy savings related to ventilative cooling;
- ventilation need and/or savings related to ventilative cooling only;
- possible drawbacks on energy behavior during heating season, i.e. increase of heating need due to cold draughts or higher infiltrations etc..;
- ventilative cooling effectiveness: match of cooling need and ventilative cooling “generation”

Reference office

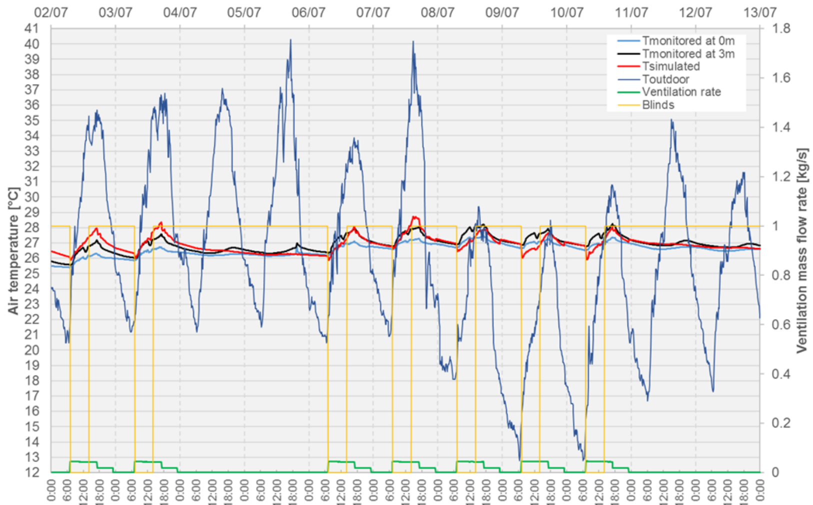




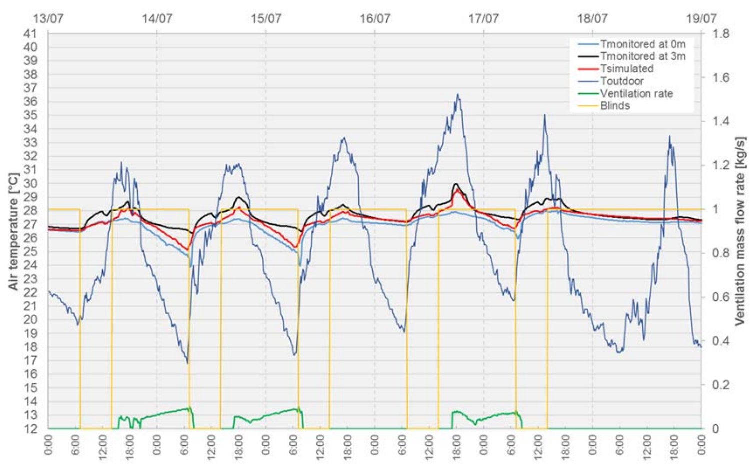


Location: Sion (CH)

Model validation: mechanical ventilation



Model validation: natural ventilation



Ventilation strategy

1. Balanced mechanical ventilation

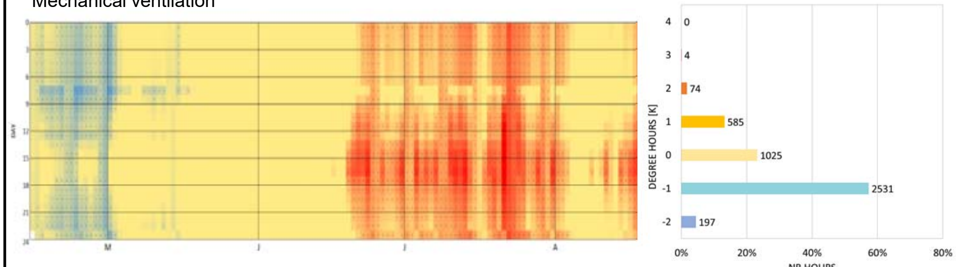
2. Direct natural ventilation with window control based on indoor-outdoor temperatures: Tzone > Tout AND Tzone > 23°C

3. Direct natural ventilation with window control based on thermal adaptive comfort: Tzone > Tcomfort

4. Passive night ventilation: Tzone > Tout AND Tzone > 23°C

Degree hours criteria

Mechanical ventilation



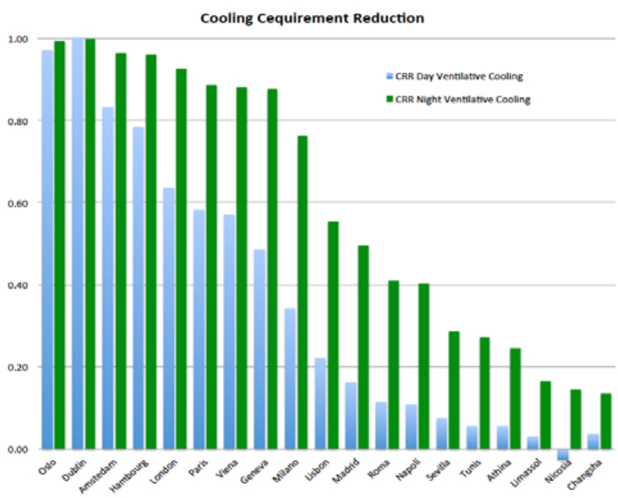
Natural ventilation (strategy 3)

Thermal comfort

Index	Description	Mechanical ventilation	Daytime natural ventilation	Adaptive daytime natural ventilation	Daytime and night-time natural ventilation
POR	Percentage outside the range	48%	17%	20%	2%
DhC (warm)	Degree hours Criterion (warm period)	478	176	148	5
DhC (cold)	Degree hours Criterion (cold period)	66	0	16	0

Index	Description	Metric	Mechanical ventilation	Daytime natural ventilation	Adaptive daytime natural ventilation	Daytime and night-time natural ventilation
Q_t	Annual heating and cooling energy demand	[kWh]	54	44	44	16
$Q_{H/C,sys}$	Total system energy use for space heating and cooling and for ventilation systems	[MJ]	48	6	6	1
$Q_{el, vent}$	Electricity consumption for ventilation	[kWh]	103	0	0	0
$Q_{pe, HVAC}$	Primary energy for heating, cooling and ventilation	[kWh_pe]	346	45	40	10
CRR	Cooling Reduction Requirement	%	-	0.4	0.5	0.9

Cooling Requirement Reduction (CRR)



Source: Flourentzou et al., 2017

Conclusion

- In general, ventilative cooling is particularly suitable to temperate and hot and dry climates
- Ventilative cooling potential depend not only on outdoor temperature, but more on solar radiation and internal heat gains
- The Percentage Outside the Range (POR) and the Degree Hours Criteria (DhC) enable to identify overheating time and severity as well as overcooling situations
- The Cooling Requirement Reduction (CRR) expresses the reduction of the energy need for cooling due to ventilative cooling

Thank you for your attention

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Annex

Thermal comfort indicators:

- Percentage Outside the Range (POR)
- Degree hours Criteria (DhC)

Energy indicators:

- Primary energy consumption
- Cooling Requirement Reduction (CRR)
- Seasonal Energy Efficiency Ratio (SEERvc)
- Ventilative Cooling Advantage (ADVvc)

Thermal comfort indicators

The **Percentage Outside the Range** index calculates the percentage of occupied hours when the PMV or the operative temperature is outside a specified range.

$$POR = \frac{\sum_{i=1}^{Oh}(wf_i \cdot h_i)}{\sum_{i=1}^{Oh} h_i}$$

Degree hours criterion: the time during which the actual operative temperature exceeds the specified range during the occupied hours weighted by a factor which is a function depending on how many degrees the range has been exceeded.

$$DhC = \sum_{i=1}^{Oh}(wf_i \cdot h_i)$$

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Energy indicators

annual primary energy consumption for ventilative cooling

$$Q_{pe,vc} = Q_{pe,v} + Q_{pe,h} + Q_{pe,c} - Q_{pe,v\_hyg}$$

where
$Q_{pe,v}$ = annual primary energy consumption of the fan,
$Q_{pe,h}$ = annual primary energy consumption for space heating
$Q_{pe,c}$ = annual primary energy consumption for space cooling
Q_{pe,v_hyg} = annual primary energy consumption of the fan when operating for hygienic ventilation.

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Energy indicators

Cooling Requirements Reduction (CRR), is meant to express the percentage of cooling requirements saved of a scenario with respect to the ones of the reference scenario. where $Qt,cref$ is the cooling need of the reference scenario and $Qt,cscen$ is the cooling requirement of the ventilative cooling scenario.

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

where

$Qt,cref$ = cooling need of the reference scenario
$Qt,cscen$ = cooling requirement of the ventilative cooling scenario.

Energy indicators

The Seasonal Energy Efficiency Ratio of the ventilative cooling system, which expresses the energy efficiency of the whole system.

$$SEER_{VC} = \frac{Q_{t,c}^{ref} - Q_{t,c}^{scen}}{Q_{el,v}}$$

where

$Qt,cref$ = cooling need of the reference scenario
$Qt,cscen$ = cooling requirement of the ventilative cooling scenario
$Q_{el,v}$ = electrical consumption of the ventilation system

Energy indicators

The ventilative cooling advantage (ADV_{VC}) indicator defines the benefit of the ventilative cooling in case ventilation rates are provided mechanically, i.e. the cooling energy difference divided by the energy for ventilation.

$$ADV_{VC} = \frac{Q_{el,c}^{ref} - Q_{el,c}^{scen}}{Q_{el,v}}$$

where

$Q_{el,c}^{ref}$ = electrical consumption of the cooling system in the reference case
$Q_{el,c}^{scen}$ = electrical consumption of the cooling system in the ventilative cooling scenario
$Q_{el,v}$ = electrical consumption of the ventilation system