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Ventilative cooling potential & operational strategies

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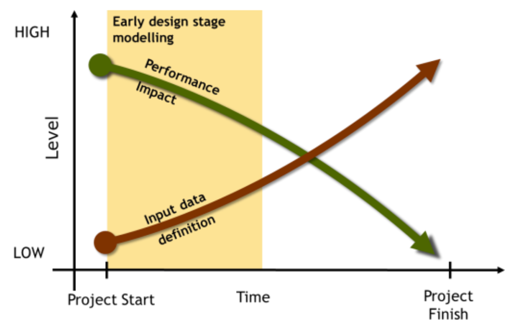
Outline

- Ventilative cooling potential tool
- How to use the tool within the design process
- Outlook and further tool developments ongoing

Why do we care?

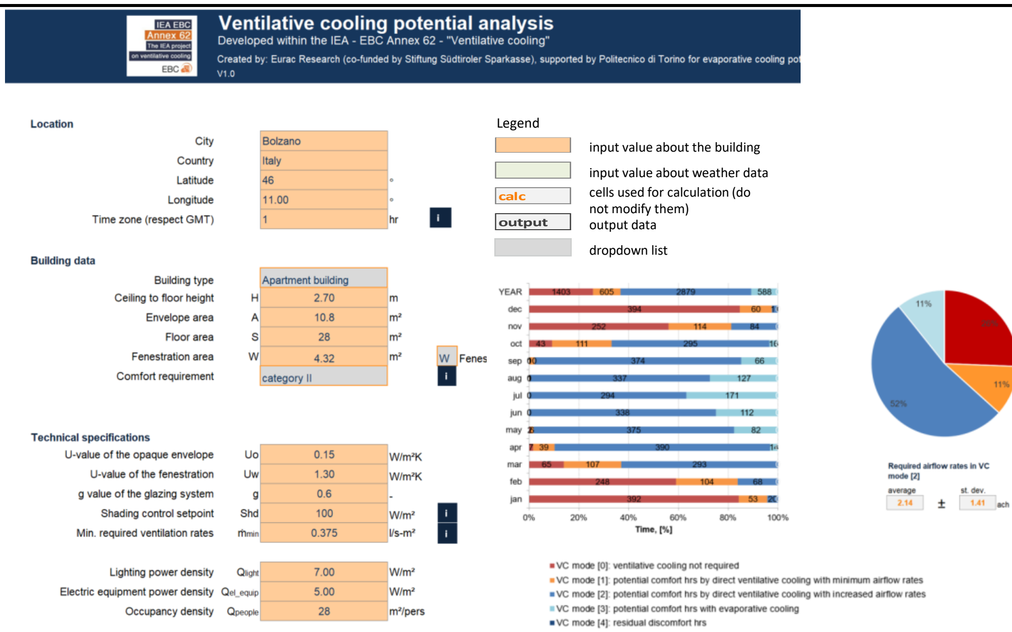
Being able to assess ventilative cooling potential **during the conceptual design phase**, when decisions about ventilative cooling application are made

Provide design airflow rates for ventilative cooling



Introduction

- Ventilative cooling is dependent on the **availability of suitable external conditions** to provide cooling
- As buildings with different use patterns, envelope characteristics and internal loads level (i.e. due to occupants, equipment and lighting) react differently to the external climate condition, the **ventilative cooling potential analysis cannot abstract from building characteristics and use**

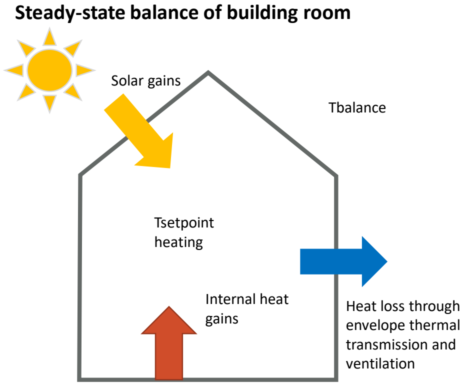


http://venticool.eu/wp-content/uploads/2017/05/V1.0_Ventilative-cooling-potential-analysis-tool.xlsm

Ventilative cooling potential evaluation

Background

Steady-state balance of building room



The **heating balance point temperature** is the outdoor temperature at which heat gains are equal to heat losses.

When outdoor temperature falls below heating balance point temperature, heating must be provided to maintain indoor air temperatures at a defined internal heating set point temperature.

This relies on the assumption that the accumulation term of the energy balance is negligible. It is a reasonable assumption if either the thermal mass of the zone is negligibly small, or the indoor temperature is regulated to be relatively constant.

For each hour of the annual climatic record (user-input) of the given location, the algorithm splits the total number of hours when the building is occupied into the following groups:

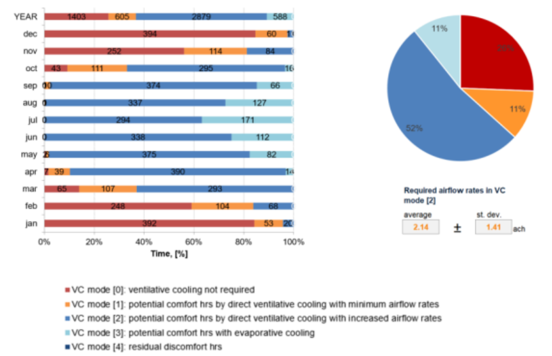
Ventilative cooling not required: when the outdoor temperature is below the heating balance point temperature no ventilative cooling can be used since heating is needed;

Potential thermal comfort by health-based ventilation: when the outdoor temperature exceeds the balance point temperature, yet falls below the lower temperature limit of the comfort zone, direct ventilation with airflow rate maintained at the minimum required for indoor air quality can provide comfort;

Potential thermal comfort by ventilative cooling: when the outdoor temperature is within the range of comfort zone temperatures, direct ventilation with increased airflow rate can provide thermal comfort

Potential thermal comfort by evaporative cooling: when the outdoor humidity is low enough to cool the air through water evaporation.

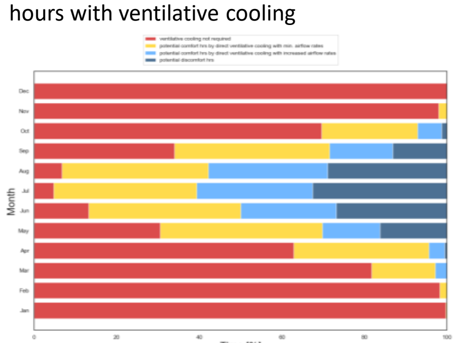
Remaining potential thermal discomfort hours: when the outdoor temperature exceeds the upper temperature limit of the comfort zone and furthermore this limit is also overtaken from the expected DEC outlet temperature.



Annamaria Belleri, Marta Avantaggiato, Theofanis Psomas & Per Heiselberg (2018) Evaluation tool of climate potential for ventilative cooling, International Journal of Ventilation, 17:3, 196-208, DOI: 10.1080/14733315.2017.1388627

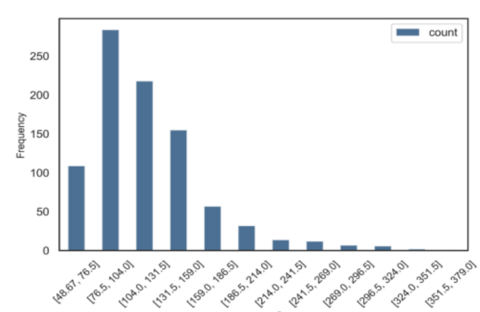
How to use the tool within the design process

1 Estimate the number of potential comfort hours with ventilative cooling



Light blue bars represent the percentage of time when ventilative cooling can potentially provide comfort.

2 Identify the design airflow rate



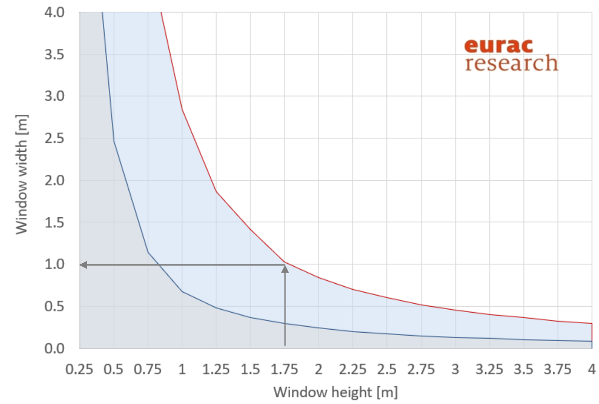
Frequency of the required airflow rates to keep building temperature within the comfort range.

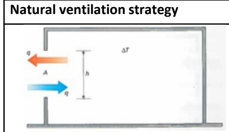
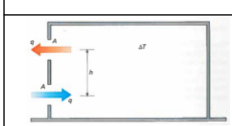
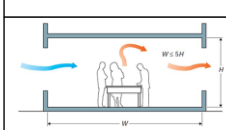
How to use the tool within the design process

3 Size window openings to provide the design airflow rate at pre-defined conditions

Window design

Max required airflow rate for ventilative cooling	ṁmax	360	m³/hr	
Required airflow rate for IAQ	ṁmin	103	m³/hr	
Room height	H	2.7	m	
Room depth	D	6	m	2H < D < 5H
Ventilation strategy		Single-sided: buoyancy only		
Select window opening type		side hung		
Window maximum opening angle	α	45	°	
Window opening discharge coefficient	cd	0.6		
Indoor temperature	Ti	25	°C	
Indoor-outdoor temperature difference	ΔT	3	K	
Wind speed	vref	0	m/s	
Insect screen?		N	Y/N	
Stack height - vertical distance between 2 openings	h	1	m	
Wind pressure coefficient - window 1	Cp1	0.2		
Wind pressure coefficient - window 2	Cp2	0.1		



Natural ventilation strategy		Equation	
	Single-sided ventilation – buoyancy driven	$A_{geo} = \frac{3q}{c_d\sqrt{\frac{g(T_i - T_e)H}{T_i}}}$	q = total air flow rate through the opening [m³/s]; A_{geo} = geometrical opening area [m²]; c_d = discharge coefficient for the opening. For windows typically 0,6-0,7 [-]; H = opening height [m]; g = gravitational acceleration [m/s²]; T_e = external temperature [K]; T_i = internal temperature [K]
	Single-sided ventilation – buoyancy and wind driven	$A_{geo} = \frac{2q}{c_d\sqrt{0.001v_{ref}^2 + 0.035 * H * (T_i - T_e) + 0.01}}$	v_{ref} = wind speed at a reference height (building height) [m/s]; H = opening height [m]; T_e = external temperature [K]; T_i = internal temperature [K]
	Stack ventilation	$A_{geo} = \frac{q\sqrt{2}}{c_d\sqrt{\frac{2gh(T_i - T_e)}{T_e}}}$	q = total air flow rate through the opening [m³/s]; c_D = discharge coefficient h = height difference between midpoint height of the two openings [-]; T_e = external temperature [K]; T_i = internal temperature [K]
	Cross ventilation	$A_{geo} = \frac{q}{c_d\sqrt{\frac{\lvert c_{p1}\rho_u v_{ref}^2 - 2P_i\rvert}{\rho_u}}}$	A = effective opening area of the two windows ($A_1 = A_2$) [m²]; c_d = discharge coefficient [-]; C_{p1} = wind pressure coefficient of opening 1 [-]; C_{p2} = wind pressure coefficient of opening 2 [-]; ρ_u = outdoor air density [kg/m³]; v_{ref} = wind speed in the reference height (normally building height) [m/s]; P_i = internal pressure [Pa].

Source: IEA Annex 62 - ventilative cooling design guide

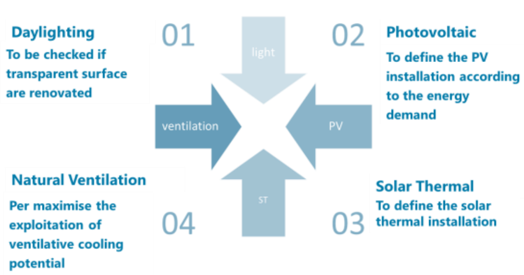
Outlook and further tool developments ongoing

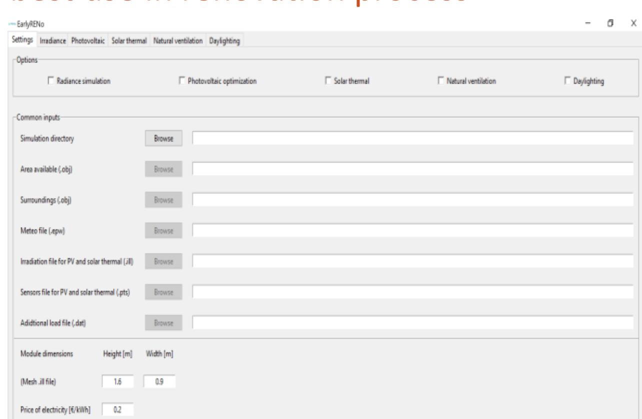
After release of version 1.0 (excel-based) as outcome of IEA EBC Annex 62, we have been working on:

- Integrating new window design features
- Ensuring compliance with new standard EN 16798-1: 2019 requirements
- User interface (simplified input data, data visualizations..)
- Python version including solar gains calculation through Radiance
- Investigating the use of a lumped capacitance model to consider building thermal mass
- Adapting the calculation methodology to EN ISO 52016-1 on building energy performance calculation and potential integration in the new standard on ventilative cooling systems (CEN/TC 156/WG21)

Early RENo tool

Early design methodology for RES best use in renovation process





https://4rineu.eu/2019/03/25/early-reno-graphical-user-interface/

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Conclusion

- The tool is particularly suitable for **concept design phases**, as it requires only basic information about the building features and use
- The tool also provides building designers with useful information about the level of **ventilation rates needed to offset given internal heat gains rate**
- The tool is under continuous improvement and its methodology is being adapted to existing standard on energy performance calculation

Thank you for your attention

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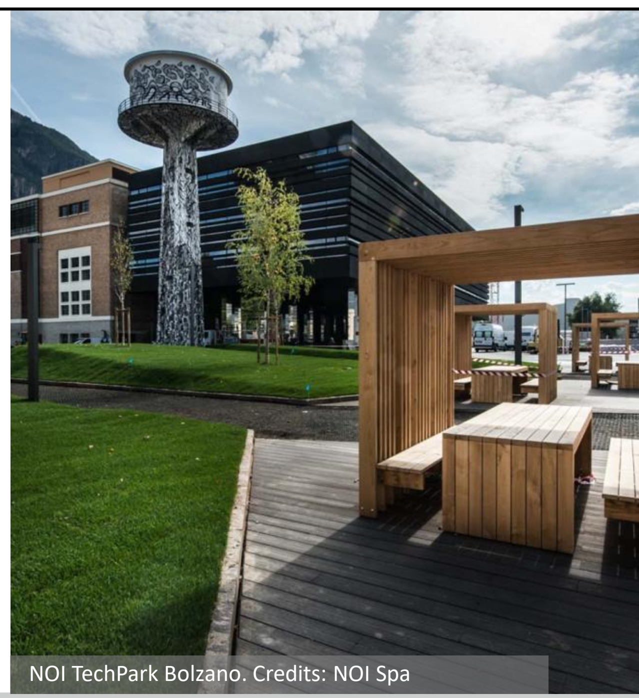

NOI TechPark Bolzano. Credits: NOI Spa