Ventilative Cooling Potential

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Extended Abstract

Europe's building stocks faces a growth of energy demand for cooling, which contradicts the targets of climate protection. Main drivers of this development are growing comfort expectations, changes in architectural design and already effects from climate change and urban heat islands.

Ventilative Cooling subsumes strategies and technologies that retract heat from buildings or increase the perception of summer comfort by deliberate air change or air movement but without use of energy consuming chillers. Typical startegies of Ventilative Cooling are night flush ventilation and comfort ventilation.

Both strategies are widespread elements of traditional architecture, but today facing numerous practical obstacles: Recent demands for air tightness, for protection from outdoor noise and pollutants, for protection from risk of burglary and from storms and driving rain make the easy coice of Ventilative Cooling in fact a challenging one.

Overcoming these modern obstacles of Ventilative Cooling and developing improved strategies and technologies for implementation of Ventilative Cooling into Net Zero Energy Buildings is the aim of the ongoing Annex 62 Ventilative Cooling within IEA Task Energy Conservation in Buildings and Community Systems EBC, running from 2014 to 2017. The author of the paper in hand takes part in this international research effort, leading Subtask B - Solutions.

Within this international research program, the authors have conducted strategic analyses of the potential, obstacles and chances of ventilative Cooling, especially focussed on its implementation in Nearly Zero Energy Buildings. The anlysis is structured in a four-step-approach:

a) Climatic Potential Analysis of Ventilative Cooling
b) Venilative Cooling Building Database
c) Reality Checks
d) Structured Experts' Interviews

The paper in hand describes this research and presents the outcomes in the form of a SWOT Analysis and a R&D Roadmap Ventilative Cooling. Both results form the basis of systematic R&D Activities during the remaining period of IEA Annex 62. The R&D roadmap for the ongoing Task is, in short, formulated like this:

1. Improvement of automation systems, including sensors, actuators and controllers, aiming at better compatibility and at intuitive operability
2. Investigation of strategies towards optimization of thermal mass activation
3. Improvement of wind driven Ventilaiev Cooling strategies.
4. Development of hybrid ventilation and hybrid cooling stretgies.
5. Development of basic design guidelines
6. Development of design tools

Recipients of this paper, namely from ventilation and building construction industry, are warmly invited contacting the authors and considering using the gathered knowledge for own developments.

Keywords: Ventilative Cooling, Indoor Environmental Quality, Summer Comfort, Natural Ventilation

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1. Introduction

Europe's building stocks faces a growth of energy demand for cooling, which contradicts the targets of climate protection. Main drivers are growing comfort expectations, changes in architectural design and effects from climate change and urban heat islands. Last not least Nearly Zero Energy Buildings, with their diminished potential for night cooling via transmission losses, call for increased ventilative night cooling.

Ventilative Cooling subsumes strategies that retract heat from buildings or increase the perception of summer comfort by air change or air movement but without use of energy consuming chillers. Ventilative Cooling offers significant potential over a wide range of building types and climate zones. Typical startegies of Ventilative Cooling are night flush ventilation and comfort ventilation.

Both strategies are widespread elements of traditional architecture, still offering significant potential of reducing the cooling load and increasing summer comfort, but today facing numerous practical obstacles: air tightness, protection from outdoor noise and pollutants, protection from risk of burglary and from storms and driving rain make the easy coice of Ventilative Cooling in fact a challening one.

Overcoming these obstacles of Ventilative Cooling and developing improved strategies and technologies for implementation of Ventilative Cooling into Net Zero Energy Buildings, is the aim of the ongoing Annex 62 Ventilative Cooling witin IEA Tasc Energy Conservation in Buildings and Community Systems EBC, running from 2014 to 2017. [1]

The Annex is led by Prof. Per Heiselberg from Aalborg University, DK. Research teams from European and Overseas contries analyse the challenges and potentials of Ventilative Cooling in todays building context and drive developments towards its forced implementation. The author of the paper in hand takes part in this international joint effort, leading Subtask B - Solutions.

Within the first half of the international research program, the authors have conducted strategic analyses of the potential, obstacles and chances of ventilative Cooling, especially focussed on its implementation in Nearly Zero Energy Buildings, leading to a R&D roadmap of further developments needed. The paper in hand describes this research and presents the outcomes in the form of a SWOT Analysis and a R&D Roadmap Ventilative Cooling. Both results form the basis of ongoing R&D Activities during the remaining period of IEA Annex 62.

Recipients of this paper, namely from ventilation and building construction industry, are warmly invited contacting the authors and considering using the gathered knowledge for own developments.

2. Methodology

The strategic analyses of the potential, distribution, obstacles and chances of ventilative Cooling, especially focussed on its implementation in Nearly Zero Energy Buildings have been substructured in

a) Climatic Potential Analysis of Ventilative Cooling
b) Venilative Cooling Building Database
c) Reality Checks
d) Structured Experts' Interviews

In the following chapters, this four-step-approach is presented in chapters 3 to 6, including both the methodology and the results of the specific approach. Finally, a summarization of results, leading to a R&D roadmap Ventilative Cooling is presented in capter 7.

3. Climatic Potential Analysis of Ventilative Cooling

The theoretical Ventilative Cooling potential has been investigated by means of VCP-Tool, an Excel tool by EURAC, Bolzano, IT, specifically designed for the purpose of Ventiative Cooling potential analysis and having been validated against sophisticated dynamic building enegy modelling [2]. The work has been embedded in the Bachelor Thesis of Mr. Martin E. Ecker under the supervision of the author [3].

Investigations have been carried out for test cases representing all combinations of

a) Usage patterns of both residential and office
b) Nine different locations within Austria, formed by Austria's nine regional capitals.
c) Building physics patterns of NZEBs, Low Energy Buildings and "old" buildings.

The calculations on an hourly basis compare the inside heating and cooling setpoint temperature against the outside temperature increased by the temperature rise which is expected from internal and solar gains. Within this comparison, four different cooling cases are differentiated:

Case 0: Outside temperature T_o is lower than heating balance point temperature $T_{o\text{-}hbp}$. Heating is necessary.

Case 1: Outside temperature T_o is higher than but low enough that ventilative cooling at minimum (hygienical necessary) rate extracts excessive heat.

Case 2: Outside temperature reaches a level where ventilative cooling at extended ventilation rate is both necessary and possible.

Case 3: Outside temperature rises to only 2 degrees lower than inside cooling setpoint temperatur $T_{i\text{-}csp}$, which terminates the chance for Ventilative Cooling.

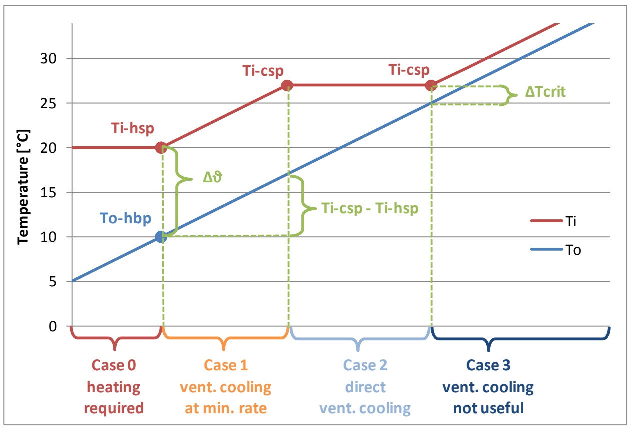


Figure 1: Ventilative cooling cases (with exemplary values on temperature scale)

The heating set point temperature was decided to 20°C, the cooling set point temperature to 27°C operative temperature. Furthermore the benchmark of a maximum acceptable absolute humidity of 13 g/kg, equalling a dewpoint temperature of 17°C, was defined. The calculation results are presented by the following key-figures:

Cooling Case distribution: Relative periods of the full year, when one of the four specific cooling cases occurs. Given in nondimensional proportions of time.

CCP: Climate Cooling Potential per Night. Degree hours between inside cooling setpoint temperarure and outside temperature during one night following a day where Case 3 (Ventilative Cooling not useful) occurs at least for one hour. Counted only if $T_o<T_{i\text{-}csp}$ and if outside humidity is lower than the indoor humidity setpoint.CCP may be averaged for one month or for the full year. Given in the unit of Kh/night.

NCP: Night Time Cooling Potential per night. Specific internal load during one night in exactly the same cases as CCP. NCP may be averaged for one month or for the full year. Given in the unit of $W/(m^2_{floor\ area}.ACH)$

DCP: Direct Cooling Potential per month. Proportion of hours of Cooling Cases 1+2 devided by the hours of a month multiplied by the inner load. Given in the unit of $W/m^2_{floor\ area}$.

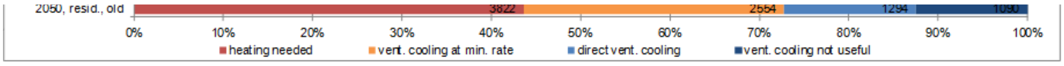
CDH: Cooling Degree Hours per day. Degree hours between inside temperarure and outside temperature within case 1+2. CDH may be averaged for one month or for the full year. Given in the unit of Kh/day.

ODH: Overheating Degree Hours. Degree hours between inside temperature and inside overheating setpoint temperature, which usually is equal to inside cooling setpoint temperature. Summed up over one month or one year. Given in the units of Kh/month or Kh/year.

Active Cooling Avoided: period of cooling case 2 relatively to period of cooling case 2+3. Given in a nondimensional proportion of time.

The parameter study of nine different locations, two different usage patterns (residential and office) plus three different efficiency-standards (old, low-energy-building, nearly-zero-energy-building) clearly shows :

1. There's a substantial Ventilative Cooling potential in Austria, both for office + residential.
2. Climate change will increase the pressure towards active cooling, but will sustain the potential of ventilative cooling.



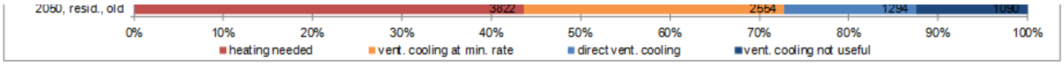


Figure 3 presenting the Cooling Case distributions for the town of Innsbruck.
The light blue beams indicate the number of hours within one year with ventilative cooling applicable and sufficient. The dark blue beams indicate the number of hours with active cooling necessary.

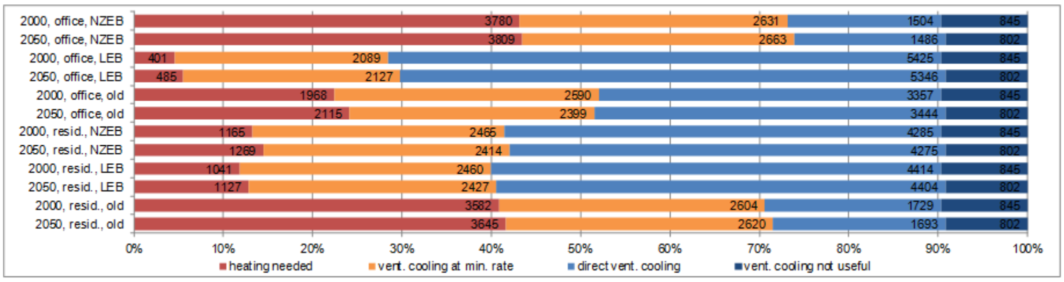


Figure 2: Cooling Case distributions for the town of Vienna

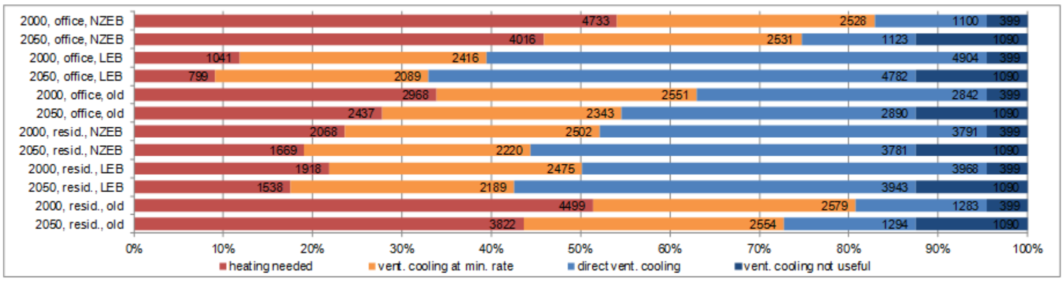


Figure 3: Cooling Case distributions for the town of Innsbruck

The tool does not include effects from thermal mass activation, which practically increase the potential of Ventilative Cooling beyond the results of this parameter study. Thus, the outputs may be regarded as careful benchmarks.

4. Building Database

A building database, has been set up, systematically documenting buildings that deliberately make use of Ventilative Cooling. The database is part of concerted action witin Subtask B of the international programme of Annex 62, supervised by the author [4].

The database contains the following information:

- Statistical building data (dominant use, year of construction, special qualities)
- Political, geographic and climate concerning data (location, climate)
- Ventilative cooling in site design (sun protection, wind guidance, etc.)
- Ventilative cooling in the architectural design (shape, morphology, envelope, etc.)
- Ventilative Cooling technical components and control strategies
  (airflow guiding components, passive cooling components, actuators, sensors etc.)

The database is transposed both as a set of loose-leaf booklet, meant for dissemination, and an Excel spreadsheet, prepared for later statistical correlation analysis.

So far a number of in total 91 buildings from Denmark, Ireland, Austria, Italy and Switzerland are implemented, with the process of filling this database still ongoing. An exemplary piece of the loose-leaf booklet is presented in Figure 4 below.

DK_ Amager_Københavns Universitet (KUA1)

Image 01: East façade	**Image 02:** External solar shading	**Image 03:** Three parts of KUA construction process
		

1. Building Specifications	
Address	Karen Blixens Vej 4, 2300 Copenhagen S, Denmark
Building Category	Educational building
Year of Construction	Construction started in 2000 (3 different steps)
Special Qualities	New concepts and strategies for control of natural and hybrid ventilation. User-friendly control
Location	56° northern latitude, 13° eastern longitude, located in urban area. The building complex is surrounded by other same size buildings to the east, west and south and free land to the north. There is a water channel located along the west side of the building complex
Climate	Cfb (warm temperate climate, moist with adequate precipitation in all months and no dry season, warm summer with the warmest month below 22°C)

2. Vent. Cooling Site Design Elements (Solar Site Design and Wind Exposure Design, Evaporative Effects from Plants or Water)
Evaporative cooling effect of the water channel to the west facilitates the natural cooling effect. The building is sheltered from wind by neighboring buildings
3. Vent. Cooling Architectural Design Elements (Form, Morphology, Envelope, Construction & Material)
Form: Consists of several long, stretched, rectangular 6 storey buildings placed along north/south direction Morphology: The building is divided in 6 floors, where the first two are intend for teaching, while the 4 last floors are used for offices and research. An atrium, which connects all the different floors, is placed in the middle of each building Envelope: Large windows sections facing east of west, as well as skylights above the atriums on the roof are designed with natural ventilation in mind Construction: Heavy mass building
4. Vent. Cooling Technical Components (Airflow Guiding Components, Airflow Enhancing Components, Passive Cooling Components)
Natural ventilation is used in rooms for up till 36 persons (offices, group rooms). Mechanical ventilation is used in rooms, which are designed for more than 36 persons (auditoriums, meeting rooms) and in rooms where is required to have mechanical ventilation according to legislation. Around 65% of the floor area is naturally ventilated. Both the inlet and outlet is placed close to the ceiling, and the air is extracted through the chimneys. A mechanical ventilator is located in the top of the chimneys to assist the natural ventilation, when it isn't efficient enough. The group rooms can also be ventilated by manually opening the windows. The offices are ventilated by single sided or cross ventilation principle depending on their location in the building. Night ventilation is done by automated window control making use of the stack-effect. Comfort ventilation is ensured by automatic window ventilation system. Automated awnings are installed on the on the east and west façade windows to provide solar shading.
5. Actuators, Sensors and Control Strategies
Room sensors for CO_2 and temperature to control the automatic ventilation Users always have the option to overwrite the automatic control. Simple on/off buttons together with an instruction are added to each room The automatically controlled openings and sensors are connected to a CTS-system
6. Building Energy Systems (Heating, Ventilation, Cooling, Electricity)
District heating, radiators Hybrid ventilation with both mechanical ventilation and automatic natural window ventilation Heating surfaces are added to secure a satisfactory air temperature Information about electricity was not available
7. Building Ownership and Building Facility Management Structures
Bygningsstyrrelsen is the owner of the building, and Københavns Universitet is the user
8. Aknowledgements
The buildings are a part of a larger project (3 parts, KUA1, KUA2 and KUA3 – only KUA1 and KUA2 are done). Building description is based on information materials provided by COWI

Figure 4: Exemplary building data sheet of the International Ventilative Cooling building database

It's too early for substantial statistical correlation analysis. More buildings especially from warm climates have to be added. Preliminary results out of the 91 buildings are:

- 60% of the buildings have been found within urban surroundings
- 58% of the buildings use elements of ventilative cooling site design, dominantly wind exposure.
- 79% of the buildings use elements of ventilative cooling architectural design, dominantly envelope and construction+material
- Amongst the airflow guiding ventilation components, which are found in every building, by far dominating are windows, doors and rooflights, followed by dampers, flaps and louvres.

– Amongst the airflow enhancing ventilation components the dominating technology is atria, which is applied in 66% of the buildings. Far behind follow chimneys in 16% and venturi or powerless rotating exhaust ventilators in only 11% of the buildings.
– Additional passive cooling components, such as convective or evaporative or phase change cooling components are applied only in a minority of 30% of the buildings.

5. Reality checks

Reality checks were carried out on two specific buildings, analysing the design process, visiting the buildins, doing spontaneous measurements, talking to the designers and users, learning about their practical observations, learnings and attitudes.

The first building, named “zu haus” which in german means “added building” as well as “home”, is a small, newly built, distinctively simple single family house, being added to an old farm house in a rural surrounding. It is equipped with automated windows, controlled by CO_2, temperature and humidity or – alternatively – manually. Solid brick walls and concrete floor slab serve as buffer mass. Exterior sun shading effectively reduces the heat gains during summer. The design allows bouancy driven airflow over three floors. See [5] for the impressum of the architect.

The house shows very high user satisfaction with the implemented system of Ventilative Cooling. An ongoing monitoring proves the effectiveness of the concept. The insect problem has been solved by mosquito nets, which had to be changed once after the clients’s dog overlooked and damaged one. A noise problem doesn’t occur from outside noise, but has been reported regarding the noise of the window actuators, when operating in the early mornig hours. The burglary risk is addressed by burglary proof fixed louvres in the ground floor and is simply accepted regarding the automated skylights.

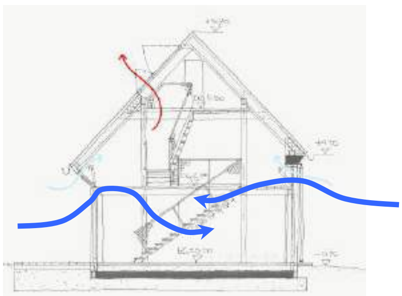



Figure 5: Reality ceck bulding No.1, “zu haus”, Auersthal, Lower Austria

The second building is a newly built office building, again in a rural area, being the headquarters of a wind-turbine operating company. It is a net zero energy building, highly insulated, with cross flow mechanical ventilation with heat recovery and with optimized passive soar gains. The south facing, east-west-sterched atrium serves as an airflow enhancing component for night time ventilation, activating the thermal mass from concrete slabs and walls. Air inlets are constructed as a row of bottom hung façade windows, the outlet vents are powerless rotating tornado vents. Additionally to night ventilation a chiller for humidity control and peak load cooling and a concrete core slab activation via chiller or alternatively via freecooling have been installed. A fully automated centralized DDC-system controls all functions. See [6] for the impressum of the architect.

After its first year of operation the house performs well, offering learnings and options for improvement. Especially the multiple technologies challenge the control system, which subsequently has been optimized from parallel operation to alternative operation of mechanical and natural ventilation system.

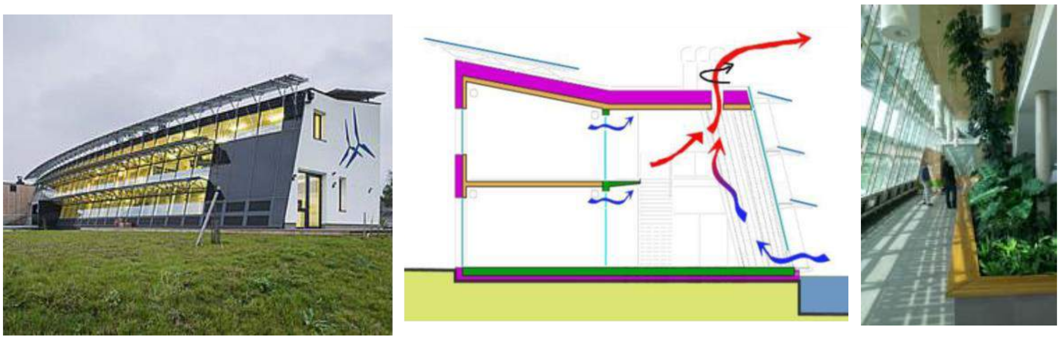


Figure 6: Reality check bulding No.2, "Headquater Windkraft Simonsfeld", Ernstbrunn, Lower Austria

6. Structured Experts' Interviews

Additional to the Reality Checks, structured interviews with relevant experts from the fields of architecture, HVAC-design and building-industry have been carried out. Three core questions formed the backbone of these interviews: Do you have personal experience with design and/or opearation of Ventilative Cooling? If yes, which kind of? How do you assess, within or beyond personal experience, the strenths and weaknesses of ventilative cooling? How do you assess the demand for further development in the field of ventilative cooling, to establich ventilative cooling as an competitive alternative to mechanical cooling and air conditioning?

In total eleven interviews have been carried out. The answers showed quite a consistant picture and confirmed the assumptions and observations which had been the drivers for establishing Annex 62 within the R&D network of International Energy Agency. The evaluation of the expert consultations was summarazed in a SWOT analysis, shown in Figure 7 below.

simple low maintainance needs highly economic reliable and robust not compromising the microclimate no or low need of auxiliary energy CO2 and humidity control	user-dependent limited effectiveness influencing architectural design sensitive against burglary, insects and pollution sensitive agaist noise and driving rain raising indoor humidity
STRENGTHS	**WEAKNESSES**
OPTIONS	**THREATS**
Improvement of automation optimization of thermal mass activation harmonizing stand alone components improving wind driven strategies application towards humidity control	deficiencies in the design process miscalculation of effectiveness climate change and urban heat islands refusal by clients and users lack of available components

development of basic design guidelines knowledge deficits
development of design tools

Figure 7: SWOT analysis of ventilative cooling

7. Results: The R&D Roadmap Ventilative Cooling

As an overall result of both the theoretical and practical analyses of Ventilative Cooling potential and challenges the R&D roadmap for the ongoing Task is formulated.

1. Improvement of automation systems, including sensors, actuators and controllers, aiming at better compatibility and at intuitive operability
2. Investigation of strategies towards optimization of thermal mass activation
3. Improvement of wind driven Ventilaiev Cooling strategies.
4. Development of hybrid ventilation and hybrid cooling stretgies.
5. Development of basic design guidelines
6. Development of design tools

Manuacturers are warmly invited to make use of these results and the knowledge gathered and join the Annex 62 with teheir specific product developments.

8. Acknowledgements

The research presented in this paper has been financially supported by the Austrian Ministry for Transport, Innovation and Technologyministries within the Interational Energy Agency's programme. It was carried out together with the Austrian partner in this prramme, e7 Energie Markt Analyse GmbH, Vienna. The Institute of Building Research & Innovation ZT-GmbH particularly wants to express its appreciation to all organisations and persons involved.

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[4] Single family house "zu haus" by Architect Martin Rührnschopf, Vienna
[5] Office building Windkraft Simonsfeld by Architect Wolfgang Reinberg, Vienna