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International Energy Agency

Status and recommendations for better implementation of ventilative cooling in standards, legislation and compliance tools

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September 2018

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Preface

The International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme. A basic aim of the IEA is to foster international co-operation among the 29 IEA participating countries and to increase energy security through energy research, development and demonstration in the fields of technologies for energy efficiency and renewable energy sources.

The IEA Energy in Buildings and Communities Programme

The IEA co-ordinates international energy research and development (R&D) activities through a comprehensive portfolio of Technology Collaboration Programmes. The mission of the Energy in Buildings and Communities (EBC) Programme is to develop and facilitate the integration of technologies and processes for energy efficiency and conservation into healthy, low emission, and sustainable buildings and communities, through innovation and research. (Until March 2013, the IEA-EBC Programme was known as the Energy in Buildings and Community Systems Programme, ECBCS.)

The research and development strategies of the IEA-EBC Programme are derived from research drivers, national programmes within IEA countries, and the IEA Future Buildings Forum Think Tank Workshops. The research and development (R&D) strategies of IEA-EBC aim to exploit technological opportunities to save energy in the buildings sector, and to remove technical obstacles to market penetration of new energy efficient technologies. The R&D strategies apply to residential, commercial, office buildings and community systems, and will impact the building industry in five focus areas for R&D activities:

– Integrated planning and building design
– Building energy systems
– Building envelope
– Community scale methods
– Real building energy use

The Executive Committee

Overall control of the IEA-EBC Programme is maintained by an Executive Committee, which not only monitors existing projects, but also identifies new strategic areas in which collaborative efforts may be beneficial. As the Programme is based on a contract with the IEA, the projects are legally established as Annexes to the IEA-EBC Implementing Agreement. At the present time, the following projects have been initiated by the IEA-EBC Executive Committee, with completed projects identified by (*):

Annex 1: Load Energy Determination of Buildings (*)
Annex 2: Ekistics and Advanced Community Energy Systems (*)
Annex 3: Energy Conservation in Residential Buildings (*)
Annex 4: Glasgow Commercial Building Monitoring (*)
Annex 5: Air Infiltration and Ventilation Centre
Annex 6: Energy Systems and Design of Communities (*)
Annex 7: Local Government Energy Planning (*)
Annex 8: Inhabitants Behaviour with Regard to Ventilation (*)
Annex 9: Minimum Ventilation Rates (*)
Annex 10: Building HVAC System Simulation (*)
Annex 11: Energy Auditing (*)
Annex 12: Windows and Fenestration (*)
Annex 13: Energy Management in Hospitals (*)
Annex 14: Condensation and Energy (*)
Annex 15: Energy Efficiency in Schools (*)
Annex 16: BEMS 1- User Interfaces and System Integration (*)
Annex 17: BEMS 2- Evaluation and Emulation Techniques (*)
Annex 18: Demand Controlled Ventilation Systems (*)
Annex 19: Low Slope Roof Systems (*)
Annex 20: Air Flow Patterns within Buildings (*)
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Annex 35: Design of Energy Efficient Hybrid Ventilation (HYBVENT) (*)
Annex 36: Retrofitting of Educational Buildings (*)
Annex 37: Low Exergy Systems for Heating and Cooling of Buildings (LowEx) (*)
Annex 38: Solar Sustainable Housing (*)
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Annex 47: Cost-Effective Commissioning for Existing and Low Energy Buildings (*)
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Annex 49: Low Exergy Systems for High Performance Buildings and Communities (*)
Annex 50: Prefabricated Systems for Low Energy Renovation of Residential Buildings (*)
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Annex 52: Towards Net Zero Energy Solar Buildings (*)
Annex 53: Total Energy Use in Buildings: Analysis & Evaluation Methods (*)
Annex 54: Integration of Micro-Generation & Related Energy Technologies in Buildings (*)
Annex 55: Reliability of Energy Efficient Building Retrofitting - Probability Assessment of Performance & Cost (RAP-RETRO) (*)
Annex 56: Cost Effective Energy & CO2 Emissions Optimization in Building Renovation
Annex 57: Evaluation of Embodied Energy & CO2 Equivalent Emissions for Building Construction
Annex 58: Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurements (*)
Annex 59: High Temperature Cooling & Low Temperature Heating in Buildings
Annex 60: New Generation Computational Tools for Building & Community Energy Systems
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Working Group - Energy Efficiency in Educational Buildings (*)
Working Group - Indicators of Energy Efficiency in Cold Climate Buildings (*)
Working Group - Annex 36 Extension: The Energy Concept Adviser (*)
Working Group - Survey on HVAC Energy Calculation Methodologies for Non-residential Buildings

Executive Summary

Introduction

Overheating in buildings is an emerging challenge at the design stage and during operation. This is due to a number of reasons including high performance standards to reduce heating demand by high insulation levels, and restriction of infiltration in heating dominated climatic regions; the occurrence of higher external temperatures during the cooling season due to changing climate and urban climate is not usually considered at the design stage, and changes in internal heat gains during operation are not factored in the design. Such factors have resulted in significant deviations in energy use during operation which is usually termed 'performance gap'. In most energy performance comparative studies energy use is higher than predictions, and in most post-occupancy studies overheating is a frequently reported problem.

A major challenge is the increased need for cooling arising in the highly insulated and airtight buildings. The cooling demand depends less on the outdoor temperature, and more on solar radiation and internal heat gains. This normally provides more opportunities for the use of ventilative cooling technologies, because the cooling need is not only during the summer time, but actually all year round.

What is ventilative cooling?

Ventilative cooling is a way to cool indoor spaces through the use of natural ventilation (i.e. natural ventilative cooling), mechanical ventilation strategies (i.e. mechanical ventilative cooling) or a combination (i.e. hybrid ventilative cooling). Ventilative cooling uses outside air to cool indoor spaces, mitigating overheating in both existing and new buildings. Ventilative cooling can save cooling energy and give more flexibility and design options for buildings, enabling a broader range of design solutions to fulfil building energy legislations. But for ventilative cooling to become a more widely used solution, it needs to be well integrated into standards, legislation and compliance tools. This summary report will evaluate if this is the case or not.

Objectives and contents of the summary recommendation report

The overall objective of this summary report is to describe the current status and future recommendations for better implementation of ventilative cooling in standards, legislation and compliance tools. The basis for this summary report is the current implementation of ventilative cooling in EN standards, ISO standards and national standards, as well as national legislation and national compliance tools. This information is obtained through questionnaires answered by experts in 11 countries, all of which participate in IEA EBC Annex 62 (see Table 1). Also, another objective is to evaluate if new Technical documents on ventilative cooling (e.g. European standards (EN), Technical specifications (TS) or Technical reports (TR)) should be considered at European level (in CEN).

Detailed information on the evaluation of missing parameters in standards, legislation and compliance tools as regards ventilative cooling is available in the completed questionnaires of Annex A to Annex C of the Venticool background report [1].

Scope and target group for the recommendation report

The introduced status and recommendations for better implementation of ventilative cooling in standards, legislation and compliance tools address residential and non-residential buildings as well as natural, mechanical and hybrid ventilative cooling systems.

The summary report on recommendations is intended for building designers, builders and experts working with building energy performance standards, legislations and compliance tools. It aims at helping these target groups with concrete recommendations for a better future implementation of ventilative cooling.

The first part of the summary report presents the status of ventilative cooling, followed by overall recommendations.

Main results

The summary report on recommendations deals with the status and recommendations for better implementation of ventilative cooling in standards, legislation and compliance tools. The report reveals that ventilative cooling is not well-integrated in standards, legislation and compliance tools. However, it also reveals that there is a broad field of evaluation methods for ventilative cooling, ranging from very simple to detailed, which can support a better integration of ventilative cooling in the near future.

Even though the benefits of ventilative cooling are widely acknowledged, its use by e.g. designers or architects strongly depends on a few intertwined challenges:

- The adequate modeling of natural ventilation and especially of air flows
- The share of the energy for cooling for summer comfort and to avoid overheating risks, which is close to becoming equivalent to the energy consumption for heating in winter, depending on the climate
- The adequate prediction of the expected "thermal comfort and cooling requirements", as well as the "energy performance" when using ventilative cooling in buildings (this could e.g. be based on Static models (e.g. Fanger PMV model) or Adaptive models (e.g. adaptive comfort model))

Although the first point can be handled by the use of adequate air flow models, the second point requires national ambitions and targets to be set up in building regulations and standards. Finally, the third point requires that both static and adaptive comfort models are supported in standards, building legislation and compliance tools.

The split of roles and responsibilities between legislation, standards and compliance tools differ from country to country. The collective task is to set up targets for certain parameters and methods to evaluate if these targets have been met. The targets are assumed to be defined in the legislation, and the methods to evaluate if the targets are met are defined in standards and/or national compliance tools.

The main results for standards, legislation and compliance tools are summarized below, some with specific examples in different countries, showing what evaluation methods are used for ventilative cooling. Each section presents several important parameters which should be taken into account, to ensure a more fair and better implementation of ventilative cooling in future standards, legislation and compliance tools.

Main recommendations for standards and other technical documents

Regarding national standards, the conclusion drawn was that overall ventilative cooling is not integrated in the standards of most of the evaluated countries e.g. in the United Kingdom, Italy and China. For instance, in Italy, standard user behaviours are assumed in reference ventilation; ventilation is principally considered for IAQ purposes and hence the suggested minimal air change rates of 0.5 h^{-1} for residential (point D5.1 UNI EN 12831:2006) and for industrial/artisan buildings are not sufficient for pursuing cooling through the use of ventilative cooling strategies.

As regards European Standards and other Technical Documents, there are European Technical reports in CEN (TR's) which cover to some extent some of the "system design" aspects of natural ventilative cooling in a building by mentioning natural ventilation systems (not ventilative cooling) namely CEN/TR 16798-4:2017 (TR to EN 16798-3:2017) and CEN/TR 14788:2006. However, European EN standards as well as ISO standards covering this sufficiently, are missing. The aforementioned standards CEN/TR 14788:2006, EN 16798-3:2017 and CEN/TR 16798-4:2017 are all under revision.

To allow for ventilative cooling to be treated better in standards both at the design stage, where initial calculations of e.g. the natural forces are made, as well as at more detailed stages where more detailed calculations are needed, it is important that several parameters are taken into account, such as:

- Assessment of overheating, e.g.:
    - Utilizing thermal comfort indicators, including adaptive temperature sensation
    - Utilizing energy performance indicators
- Assessment of natural and mechanical ventilative cooling
- Assessment of night cooling
- Calculation methods that fairly treat natural ventilative cooling for determination of air flow rates including e.g. the dynamics of varying ventilation and the effects of location, area and control of openings

When revising standards with respect to calculation and design of ventilative cooling systems, specific technologies shouldn't be favoured and emerging technologies such as hybrid systems should be considered. Among other things, the determination of air flow rates in buildings is important to consider for ventilative cooling. Calculation methods can be found in e.g. calculation standard; EN 16798-7:2017 for both mechanical and natural ventilation, enabling the designer to choose the level of detail needed for the given purpose and stage of the construction [2].

It is recommended that the full effects of ventilative cooling are evaluated reflecting the real conditions for the building, control, use and climate. This should include in particular the actual building physics and geometry, supporting a fair evaluation of natural ventilation (e.g. stack effects, cross ventilation), mechanical ventilation, control system, night/day ventilation and summer/winter ventilation.

Lastly it is recommended to use the Key Performance Indicators for "thermal comfort" and "energy performance" used in the IEA EBC Annex 62 "Ventilative cooling design guide” [3], for:

- "Thermal comfort" indicator: supports either the static Fanger model (PMV evaluation) or the Adaptive comfort model, using the Percentage outside the range (POR). POR evaluates the percentage of occupied hours when PMV/Operative temperature is outside the range, and the Degree-hours criterion (DhC) which evaluates the time the operative temperature is above the range during occupied hours.
- "Energy performance" indicator: using the Cooling Reduction Requirement (CRR), and the Ventilative Cooling Seasonal Energy Efficiency Ratio (SEER) defined as the cooling requirement saving divided by the electrical consumption of the ventilation system.

Main recommendations in legislation

The research conducted has revealed that the control of ventilation (air flow rate) for ventilative cooling and its effect on thermal comfort and on cooling demand reduction is not clear [2] - generally being too simplified or even missing in legislation and compliance tools. In many national building codes and energy performance regulations, ventilative cooling is not explicitly referred to as a cooling option for meeting requirements of energy performance and thermal comfort.

Generally, the calculation of air flow rates in buildings and their control is not sufficiently reflecting the real conditions such as the actual building design, physics, geometry and operation, thereby underestimating the potential of ventilative cooling. A better integration of ventilative cooling is possible in Switzerland, Norway and Austria where legislation supports hourly time step calculations for thermal comfort, which better support the adaptive comfort model and the prediction of need for cooling in the building and hereby also the overheating, instead of less precise, monthly calculations. In this sense, these countries could be seen as pioneers.

To allow for ventilative cooling to be treated better in building performance evaluations in legislation, several parameters are necessary to consider in the building regulation, such as:

- Assessment of overheating e.g.:
    - Requirements to thermal comfort, including adaptive temperature sensation
    - Requirements to energy performance including cooling
- Acknowledgement of natural and mechanical ventilative cooling
- Support to evaluation methods considering the dynamics of varying ventilation
- Support to evaluation methods considering the effects of location, area and control of openings

Overheating is highly dynamic and so are the effects of ventilative cooling and overheating prevention measures such as solar shading. Luckily, calculation methods and tools are available to deal with these dynamics. To assess the resulting performance with respect to both thermal comfort and energy use for cooling, it is clearly recommended for legislation to require overheating effects to be assessed by means of detailed assessment methods. These be detailed add-on modules accompanying existing simplified tools (as in e.g. Denmark) or (preferred) added features in a more detailed tool, capable of taking dynamics into account (as in e.g. Switzerland).

Main recommendations in Compliance Tools

Several building simulation tools are available today around the world, which allow architects or engineers to assess buildings with a high accuracy on energy performance or indoor climate. Some of them are already implementing modules to consider natural ventilation or natural ventilative cooling through windows and its effect on thermal summer comfort.

In particular, natural ventilative cooling is difficult to assess in most existing compliance tools, reflecting what's stated in the national legislation. Since compliance tools are the only evaluation tools used in many cases, it is recommended to secure the implementation of ventilative cooling in compliance tools, allowing the evaluation of overheating issues at the earliest stage of the design process when decisions on e.g. windows location or orientation can still be taken.

The recommendations from the report show that, even though simulation tools today are available on the market, the critical channel to spread the rational assessment of over-heating and the use of ventilative cooling remains in compliance tools on which building legislation is based.

Therefore, depending on the national context and the progress made on these compliance tools, it is recommended to aim at solutions considering ventilative cooling in a realistic and efficient way. For example, an effort should be made to implement hourly calculation time steps for both thermal comfort and energy performance evaluations in more compliance tools (currently available in just a few countries), instead of less precise monthly calculations, to better support the adaptive comfort model and consider the dynamic nature of ventilative cooling. Advanced calculation methods like e.g. dynamic simulations based on hourly time-steps are usually closer to reality and lead to more realistic air change rates. Moreover, hourly calculations have the capability to predict the cooling loads in the building and hereby assess the overheating more precisely compared to monthly calculations; this is crucial for today's buildings.

The main recommendations from the IEA EBC Annex 62 are summarised below, covering all investigated compliance tools.

To allow for ventilative cooling to be better considered in compliance tools' evaluations, several parameters should be considered, such as:

1. Assessment of overheating, e.g.:
    a. Thermal comfort indicators, should be implemented in compliance tools, considering air flow rates when evaluating internal temperature and adaptive temperature sensation
    b. Energy performance indicators, are either an alternative or a complementary solution to be used for evaluating the benefits of ventilative cooling (by acknowledging the reduction of cooling needs)

2. Assessment of increased air flows when efficient ventilative cooling systems are used:
    a. Differentiation should be made i.e. between cross- or stack ventilation vs. single-sided ventilation, automated systems vs. manual control, large vs. small opening areas
    b. Associated airflows should preferably be based on building physics e.g. dynamic tools (using pressure equations) or – as a simpler solution - "coefficients" which increase air flows based on the chosen system
3. Implementation of different levels of approaches to the evaluation of ventilative cooling, depending on the level of detail needed for the given purpose and stage of the construction.
    a. **Simplified approach:**
       Using national compliance tools based on monthly calculations with specific assumptions on input air flows for natural ventilation and ventilative cooling (like e.g. in Belgium, Flanders).
       The main benefit of this method is its direct applicability towards most existing compliance tools.
       It allows modelling of ventilative cooling via the use of constant air flows over a given period and can, like in Belgium, promote the gradual use of openable windows, stack effect, cross-ventilation and even control systems.
       Its simplicity will of course lower the air flows and tends to reduce the impact of ventilative cooling on thermal summer comfort.
    b. **Intermediary approach** (combining simplified and detailed approach):

       Using national compliance tools based on monthly calculations + using an add-on tool or plugin to address thermal summer comfort and ventilative cooling in a more accurate way (like e.g. in Denmark for residential buildings).

       The main benefit of this approach is to keep the existing compliance tool, but could be less accurate (and then less beneficial to ventilative cooling) due to the reduced number of parameters that can be used by the add-on tool (in several cases, this tool will usually be using the same input parameters as the main compliance tool)

    c. **Detailed approach**:
        i. Using national compliance tools based on full dynamic calculations (e.g. like in Switzerland, where several simulation tools from the market are allowed)
        ii. Using national compliance tool based on simplified hourly calculations (like e.g. in France or in The Netherlands)

       These tools can support the modelling of natural ventilation and do not require the integration of environmental parameters (outdoor temperature, wind speed, wind direction, solar radiation…) over a given period (e.g. no pre-calculation should be performed to evaluate an average outdoor night temperature over the summer period).

These tools can therefore fully use the evaluation method given in EN 16798-7:2017 (modelling of air flows through windows via discharge coefficients (Cd)) and also allow the use of control strategies like e.g. sensor-based systems.

References

[1] Status and recommendations for better implementation of ventilative cooling in standards, legislation and compliance tools. A publication in the context of IEA EBC Annex 62 ventilative cooling, September 2018. INIVE eeig. Retrieved from http://venticool.eu/venticool-publications/reports/

[2] State-of-the-art-review, IEA Annex 62, 2015, accessible on http://venticool.eu/wp-content/uploads/2013/09/SOTAR-Annex-62-FINAL.pdf

[3] IEA EBC Annex 62 deliverable "Ventilative cooling design guide", http://venticool.eu/wp-content/uploads/2016/11/VC-Design-Guide-EBC-Annex-62-March-2018.pdf

Table of content

Abbreviations

Abbreviations	Meaning
BPIE	Buildings Performance Institute Europe
CEN	European committee for standardization
CH	Switzerland
DK	Denmark
EN	European Norm
EPBD	Energy Performance of Buildings Directive
IEA-EBC	Energy in Buildings and Communities Programme of the International Energy Agency
ISO	International organization for standardization
NP	New Proposal
NV	Natural ventilation
NWI	New work item
NZEB	Nearly zero energy building or nearly zero emissions building
SOTAR	State of the are review
TC	Technical committee
TS	Technical specification
WG	Working group

Definitions

Air change rate (ach)

The volumetric rate at which air enters (or leaves) a building or zone expressed in units of building or zone volume [4].

Air flow rate (kg or m³/time units)

The mass or volume of air moved per unit of time through a flow opening or duct [4].

Air velocity (m/s)

The rate relative to the surroundings and direction of air movement (air speed). Air velocity is measured with an anemometer, usually as part of a common weather station [4].

Aperture effective openable area (m^2)

The effective openable area of an aperture results in from the multiplication of the geometric openable area and the performance indicator of aerodynamic permeablitity, discharge coefficient (C_d; [2]).

Automated window opening

Window configuration that activated based on an integrated automation and defined control strategies. It may be part of the building management system [2].

Building envelope

The total area of the boundary surfaces of a building through which heat light, air and moisture are transferred between the internal spaces and the outside environment [4].

Cooling (kWh)

The transfer of energy from a body of solid liquid or gas by the existence of a temperature gradient from that body to its surroundings which are at a lower temperature, and may also be solid, liquid or gas. Heat extraction from a space for improving thermal comfort. This process is the opposite of heating [2, 4].

Cooling season

Part of the year during which passive or active cooling systems are needed to keep the indoor temperatures at specific levels [1].

Cross ventilation

Air enters on one side of a room and leaves on a different side of the same room. Airflow between the entry and exit provides ventilation. Also used for flow between rooms, where the inlet is in one room and the outlet is in another [4].

Discharge coefficient (C_d)

Discharge coefficient is a dimensionless coefficient relating the mean flow rate through an opening to an area and the corresponding pressure difference across the opening. It is characterizing the aerodynamic quality of an aperture. Discharge coefficient is a basic coefficient in many aerodynamic algorithms. In case of architectural apertures, the discharge coefficient lays within the narrow band of 0.6-0.7 [2, 4].

Draft or Draught

Excessive air movement (i.e. cold air) in an occupied enclosure causing discomfort [4].

Hybrid ventilation

Ventilation, relying of both natural and mechanical ventilation in the same part of a building, but using different features of these systems at different times of the day or season of the year, and are subject to control selecting the ventilation mode appropriate for the given situation [2].

Indoor air quality

The air quality within buildings, related to conditions around buildings and structures, and its relationship to the health and comfort of building occupants [3].

Indoor operative temperature (°C)

The uniform temperature of an imaginary black enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual non-uniform environment [1].

Infiltration (ach)

The uncontrolled inward leakage of outdoor air through cracks, interstices, and other unintentional openings of a building, caused by the pressure effects of the wind and/or the stack effect (airtightness; [4]).

Internal pressure (Pa)

The pressure inside a building envelope or space. Usually expressed with respect to outside or atmospheric pressure [4].

Manually operated opening

Ventilation systems operated by the occupants [2].

Mechanical ventilation

Ventilation, where the air is supplied or extracted from the building or both by a fan and using supply and exhaust air terminal devices, ducts and roof/wall inlets and outlets [2].

Natural ventilation

Ventilation, where the air is moved by natural driving forces into the building through intentionally provided openings in the envelope and leaves the building through intentionally provided openings in the envelope, cowls or roof outlets, including vertical ducts used for extraction [2].

Night cooling (kWh)

Utilization of differences between indoor and outdoor temperatures for airborne cooling by means of ventilation at night during warm periods, with the purpose of removing accumulated heat from the building stock and thereby achieving a lower indoor temperature in the morning [2].

Night ventilation

Ventilation of a space, room or building during the night time. The night time cooling potential is higher compared with the day potential [2].

Outdoor air temperature (°C)

Air taken from the external surroundings and therefore not previously circulated through the system [4].

Overheating

The result of the external and internal heat build up indoors (risk, severity, likelihood; [2]).

Passive cooling (kWh)

Covers processes and techniques to provide protection and/or prevention of external and internal heat gains in buildings as well as processes and techniques for heat modulation that allow the building to absorb and store heat for dissipation at a later stage [2].

Running mean outdoor temperature (°C)

Exponentially weighted running mean of the daily mean external air temperature [1].

Single side ventilation

Airing with openings located on only one side of the ventilated zone [2].

Stack effect

The pressure differential across a building caused by the differences in the density of the air due to an indoor-outdoor temperature difference [4].

Temperature (°C)

A property of an object which determines the direction of heat flow. When the object is placed in thermal contact with another object, heat flows from the higher temperature object to the lower temperature one [4].

Thermal comfort

The state of mind that expresses satisfaction with the surrounding thermal environment [2].

Thermal mass

A property of the mass of a building which enables it to store heat, providing "inertia" against temperature fluctuations [3].

Ventilation

The process of supplying or removing air, by natural or mechanical means to and from a space [4].

Ventilation strategy

A plan by which ventilation air is purposefully provided to a space. When such a strategy is employed, it is normal to take action to minimise background leakage [4].

Ventilation system

A combination of appliances or building components designed to supply indoor spaces with outdoor air and/or to extract polluted indoor air [1].

Ventilative cooling

Utilization of differences between indoor and outdoor temperatures for airborne cooling by means of ventilation to reduce or even eliminate the cooling loads and/or the energy use by mechanical cooling in buildings, while resulting in a comfortable thermal environment [2].

References

[1] European Committee for Standardization. EN 15251:2007. Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics. Brussels: ECS; 2007.

[2] Kolokotroni M, Heiselberg P. Ventilative cooling. State of the art review. 2015; Available at: http://venticool.eu/wp-content/uploads/2013/09/SOTAR-Annex-62-FINAL.pdf/, 2017.

[3] www.wikipedia.com (30/10/2017)

[4] Limb M. Air infiltration and ventilation glossary. Coventry: AIVC; 1992.

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1. Introduction

1.1. General context

IEA EBC Annex 62 on Ventilative Cooling was an international research project running from 2014 to 2018 [1]. The research focus of the annex was on the development of design methods and compliance tools related to predicting, evaluating and eliminating the cooling need and the risk of overheating in buildings as well as on the development of new attractive energy efficient ventilative cooling solutions.

The main goal was to make ventilative cooling an attractive and energy efficient cooling solution to avoid overheating of both new and renovated buildings. To fulfil its main goal, the Annex had the following targets for the research and development work:

- To develop and evaluate suitable design methods and tools for the prediction of cooling needs, ventilative cooling performance and risk of overheating in buildings;
- To develop guidelines for an energy-efficient reduction of the overheating risk using ventilative cooling solutions and for the design and operation of ventilative cooling in both residential and commercial buildings
- To develop guidelines for the integration of ventilative cooling in energy performance calculation methods and regulations including specification and verification of key performance indicators;
- To develop instructions for improvement of the ventilative cooling capacity of existing systems and for the development of new ventilative cooling solutions including their control strategies;
- To demonstrate the performance of ventilative cooling solutions through the analysis and evaluation of well-documented case studies.

IEA EBC Annex 62 included the participation of approximately 15 countries from Europe, Japan, China and the US, from universities, research centres and manufacturers and suppliers of ventilation equipment.

The research results are published in the following publications:

- Overview and state-of-the-art of ventilative cooling
- Status and recommendations for better implementation of ventilative cooling in standards, legislation and compliance tools
- Ventilative cooling source book
- Ventilative cooling case studies
- Ventilative cooling design guide

All publications can be found on www.iea-ebc.org [1].

1.2. Why ventilative cooling

Ventilative cooling is a way to cool indoor spaces using outside air, in this way mitigating overheating in both existing and new buildings - being both a sustainable and energy efficient solution. By using ventilative cooling, cooling energy can be saved and thereby the flexibility and design options for buildings is increased, enabling a broader range of design solutions to fulfill building energy legislations. Ventilative cooling may be split up into natural, mechanical and hybrid ventilative cooling, where natural ventilative cooling is e.g. the opening of windows, which is a very direct and fast method of influencing the thermal environment. An open window will cause increased air motion, and if the outdoor temperature is lower than indoors the temperature will fall. Even when the outdoor air temperature is slightly higher than the indoor, the elevated air speed due to increased airflow will increase the cooling of the body and reduce the thermal sensation.

1.3. Main Goals of IEA-EBC Annex 62 Ventilative Cooling

The main goal is to make ventilative cooling an attractive and energy efficient cooling solution to avoid overheating of both new and renovated buildings. Ventilation is already present in buildings through mechanical and/or natural systems and it can remove excess heat gains as well as increase air velocities and thereby also widen the thermal comfort range.

1.4. Purpose of the report

The overall purpose was to make a summary report that describes the current status and provides recommendations for better implementation of ventilative cooling in standards, legislation and compliance tools. In order to present the status of how well ventilative cooling is implemented, experts in 11 countries, participating in IEA EBC Annex 62 (see Table 1), were asked to fill-in a questionnaire looking into which parameters influencing ventilative cooling are included in standards, legislation and compliance tools. The filled in questionnaires were used as background for the summmarized answers found in the “standards”, “legislation” and “compliance tools” sections of this report. For more detailed evaluation of missing parameters in standards, legislation and compliance tools for ventilative cooling, see the filled in questionnaires in Annex A to Annex C of the Venticool background report) [2].

Based on the initial findings, another objective was to evaluate if new Technical documents on ventilative cooling (e.g. EN standards, technical specifications or technical reports) should be proposed in Europe, by evaluating if there was a critical lack of content in existing standards regarding ventilative cooling.

This report focuses on the status and recommendations specifically given for EN, ISO and national standards, national legislation and national compliance tools. IEA EBC Annex 62 sums up specific overall recommendations, given per topic as overall changes in standards, legislation and compliance tools to be used directly by the target group of this report (i.e. building designers, builders and experts working with building energy performance standards, legislations and compliance tools) for future revisions of these documents.

The sub-purpose is to ensure communication of the missing aspects found in EN standards, ISO standards, national standards, national legislations and national compliance tools regarding ventilative cooling.

To fulfil the main goal of the Annex, the following are the targets for the research and development work:

- To evaluate the status of how well ventilative cooling is integrated in EN standards and ISO standards (for more detailed evaluation of missing parameters in EN and ISO standards for ventilative cooling, see the filled in questionnaires in Annex A to Annex C of the Venticool background report) [2]
- To evaluate the status of how well ventilative cooling is integrated in national standards, national legislation and national compliance tools (for more detailed evaluation of missing parameters in EN and ISO standards for ventilative cooling, see the filled in questionnaires in Annex A to Annex C of the Venticool background report) [2]
- To evaluate if new standards on ventilative cooling should be proposed in Europe (in CEN), based on the initial findings, by evaluating if there was a sufficient lack of content in existing standards regarding ventilative cooling
- To give recommendations for better implementation of ventilative cooling in EN standards and ISO standards
- To give recommendations for better implementation of ventilative cooling in national standards, national legislation and national compliance tools (for more detailed evaluation of missing parameters in standards, legislation and compliance tools for ventilative cooling, see the filled in questionnaires in Annex A to Annex C of the Venticool background report) [2]
- To give overall recommendations to be proposed as overall changes in future standards, legislation and compliance tools

1.5. References

[1] www.iea-ebc.org

[2] Status and recommendations for better implementation of ventilative cooling in standards, legislation and compliance tools – background report. A publication in the context of IEA EBC Annex 62 ventilative cooling, September 2018. INIVE eeig. Retrieved from http://venticool.eu/venticool-publications/reports/

2. Foreword

This summary report presents insights on recommendations into how ventilative cooling is integrated in EN standards, ISO standards, national standards, national legislation and national compliance tools. The information presented derives from feedback by IEA EBC Annex 62 experts of 11 countries (see Table 1) who have completed a questionnaire. This gives a high level of insight into the current status, and thereby the recommendations to be given on the basis of this knowledge. The Venticool background report on recommendations is the background for this IEA EBC Annex 62 summary report and should be seen as supplementary material for the State-of-the-Art Review (SOTAR).

Natural ventilative cooling, is difficult to assess in most existing compliance tools. Several building simulation tools are available today, allowing architects or engineers to assess buildings with a high accuracy on energy performance or indoor climate. Some of them are already implementing modules to consider natural ventilation through windows and its effect on thermal summer comfort. Nevertheless, even though some of these tools have reached an elevated level of user-friendliness, they are only occasionally used for building design as the compliance of a project with building regulation also requires the use of calculation tools. Therefore, these so-called “compliance tools” are usually preferred in the design process of a building to secure the performance of buildings and their compatibility with national regulations.

The summary report on recommendations is oriented to building designers, builders and experts working with building energy performance standards, legislations and compliance tools. It aims to support them when making future revisions of these documents or tools dealing with passive cooling, where e.g. ventilative cooling is a sustainable choice when aiming to achieve energy neutral buildings (e.g. NZEB), alongside buildings with a good thermal comfort and reduced overheating issues.

A list of editors, authors and reviewers to this report are listed in Table 1, together with their affiliation (research institutes, universities to companies). The final report was edited by the Subtask A IEA EBC Annex 62 participant, Christoffer Plesner, with the help from Flourentzos Flourentzou, Guoqiang Zhang, Hilde Breesch, Per Heiselberg, Michał Pomianowski, Peter Holzer, Maria Kolokotroni and Annamaria Belleri.

Research participants worked together collaboratively under the umbrella of the IEA EBC framework to provide the information included in this summary report.

Table 1 - Research particpants helping with input to this report

Name	Institute-Affiliation	Role in report
Christoffer Plesner	VELUX A/S, Denmark	Auhtor and editor
Flourentzos Flourentzou	ESTIA SA, Switzerland	Author and reviewer
Guoqiang Zhang	Centre for Sustainable Built Environment, Hunan university, China	Author and reviewer
Hilde Breesch	KU Leuven, Belgium	Author and reviewer
Per Heiselberg	Aalborg University, Denmark	Author and reviewer
Michał Pomianowski	Aalborg University, Denmark	Author and reviewer
Peter Holzer	Institute of Building Research and Innovation (IBRI), Austria	Author and reviewer
Maria Kolokotroni	Brunel University, United Kingdom	Author and reviewer
Annamaria Belleri	Eurac Research, Italy	Author and reviewer
Giacomo Chiesa	Politecnico di Torino, Italy	Author
Guilherme Carrilho da Graça	University of Lisbon, Portugal	Author
Hans Martin Mathisen	Norwegian University of Science and Technology (NTNU), Norway	Author
Paul D. O' Sullivan	Cork Institute of Technology (CIT), Ireland	Author
Toshihiro Nonaka	Lixil Corporation, Japan	Author

3. Status of ventilative cooling

This section evaluates how ventilative cooling is treated in EN, ISO and national standards, as well as other technical documents e.g. Technical reports. Furthermore, national legislation and national compliance tools are evaluated by seeing to which extent certain ventilative cooling parameters are integrated (e.g. cross ventilation or which calculation time step is used). One of the areas of interest are e.g. how to predict the expected "thermal comfort and cooling requirements", as well as the "energy performance" when using ventilative cooling in buildings. These may be predicted by using the so called “indicators”, which may be based on either Static models (e.g. Fanger PMV model) or Adaptive models (e.g. adaptive comfort model).

For more detailed evaluation of missing parameters in standards, legislation and compliance tools for ventilative cooling, see the filled in questionnaires in Annex A to Annex C of the Venticool background report [1].

3.1. Status in standards and other technical documents

There are many types of standards (EN standards, ISO and national standards) in relation to ventilative cooling. Furthermore, other technical documents exist such as Technical reports, which are often more descriptive than typical standards (often describing the content of a standard or a topic). Technical reports are chosen to be part of this investigation as for example in the EPB package where there is one Technical report per standard, e.g. CEN/TR 16798-4:2017 (Technical Report) to EN 16798-3:2017 (EN Standard). Some examples of relevant EN and ISO standards are given below. Actually, a Technical Report has a lower status than EN standard (actually two steps lower). Some examples of relevant standards follow and could be split into different types, namely "system design” and “performance standards”. System design standards deal with how to design the ventilation system in regard to ventilative cooling, and performance standards have to do with either the calculations or the requirements. In this report, this division of "system design" vs. "performance" is only used for EN standards to easier distinguish EN standards’ main contents from one another - this division would e.g. not make sense for the status in national legislation.

Figure 1 provides an overview of the new EPBD standards relevant to ventilative cooling [2], and their significant differences in terms of content for example, prEN 16798-1:2017 (though not yet accepted in formal vote) deals with building occupancy and operating conditions e.g. including the adaptive comfort model used by natural ventilation (in buildings without mechanical cooling).

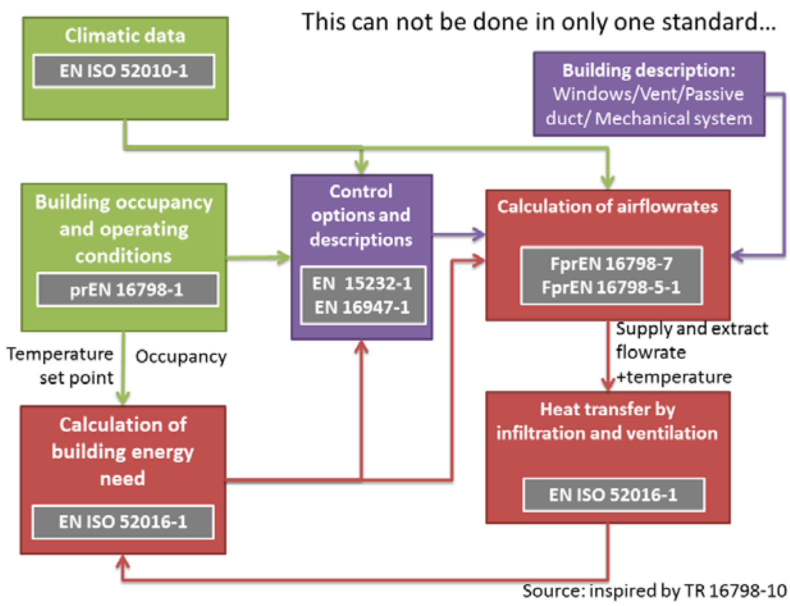

Figure 1 – Overview of new EPBD standards relevant to Ventilative cooling, inspired by CEN/TR 16798-10 (PE draft, 2015)

Within existing CEN standards, relevant to ventilative cooling, and used in energy performance legislations (EN 15242:2007, EN 15241, EN 15251:2007 and EN 13779:2007), there remain some critical limitations for these technologies. For example, how to properly reflect the effective cooling potential of outdoor air which varies within a single day, in seasonal or monthly methods.

The CENSE project includes a very useful site with summations of Energy Performance of Buildings Directive (EPBD) related EN standards [3].

3.1.1. European standards (EN) and other technical documents (status)

In this section, the status of relevant EN standards concerning ventilative cooling is evaluated.

In the previous years, many EN standards relating to the 2010 recast of the Energy Performance of Buildings Directive (EPBD) have been revised. In this summary report, some of the important standards for ventilative cooling have been chosen for further elaboration; both new and old versions of the standards have been investigated in order to better understand the changes in the new revised versions. Some of the identified European standards are:

- EN 13779:2007 (EN 16798-3:2017)
- EN 15251:2007 (prEN 16798-1:2017), though not yet accepted in formal vote
- EN 15242:2007 (EN 16798-7:2017)

As briefly explained in the introduction, standards could be split into different types, namely “system design” and “performance” standards. In this report, only EN Standards use this division; “system design” standards deal with how to design the ventilation system, whereas “performance” standards concern calculations and/or requirements e.g. by looking at EPBD standards, among others. As mentioned in the beginning of this section, only EN standards use the division of "system design" vs. "performance" to easier distinguish the main contents from one another. Below is a short overview and examples of the different types.

System design (how to design ventilation systems and what to consider when designing):

- System design standards e.g. CEN/TR 14788:2006 (upcoming revision in 2018), EN 16798-3:2017 (under revision) and CEN/TR 16798-4:2017 (under revision))

Performance (performance aspects, e.g. calculation and requirement standards):

- Performance calculation (e.g. air flow rate calculations, e.g. EN 16798-7:2017 and CEN/TR 16798-10)
- Performance requirements (e.g. thermal comfort requirements, e.g. prEN 16798-1:2017 (in voting)) and EN 15665:2009 (upcoming revision in 2018)

In respect to European standards, there is a Technical Report called CEN/TR 14788:2006 which covers some of the aspects of natural ventilative cooling by mentioning stack effect and cross ventilation. This Technical Report informs readers on what to be aware of when designing a natural ventilation system. Unfortunately, CEN/TR 14788:2006 is not an EN standard, but “only” a Technical report, which is two steps below an EN standard in status. Actually CEN/TR 14788:2006 together with EN 15665:2009 is under upcoming revision in 2018, so the above information explains only the current content.

Overall there are European Technical reports (TR’s) which to some extend cover some of the “system design” aspects of natural ventilative cooling in a building, such as CEN/TR 16798-4:2017 (TR to EN 16798-3:2017) and CEN/TR 14788:2006, but European EN standards covering this sufficiently are missing. As previously mentioned, standards CEN/TR 14788:2006, EN 16798-3:2017 and CEN/TR 16798-4:2017 are under revision.

With the revisions of EN 15251:2007 (now prEN 16798-1:2017) and EN 15242:2007 (now EN 16798-7:2017) some aspects of natural ventilative cooling are covered. However, other aspects are still missing or lacking in content in different areas (e.g. as identified by venticool [2]). Some of these missing parameters in the existing standards are:

- Control of systems
- Internal partition of buildings
- Guidance on parameters that shall be defined by user or taken by default

For more detailed evaluation of missing parameters in EN standards for ventilative cooling, see the filled in questionnaires in Annex A to Annex C of the Venticool background report [1].

3.1.2. ISO standards (status)

There are many ISO standards which take into account ventilation, but few ISO standards evaluate the effect of natural ventilation on reducing cooling energy consumption or improving indoor thermal comfort.

ISO 13153:2012 shows a framework of a design process for energy-saving in single-family residential buildings and small commercial buildings. The “Energy consumption ratio” is determined in the standard by the location of the building and the method(s) for taking cross ventilation into account. ISO 7730:2005 also describes the effect of air velocity which is relevant to indoor thermal comfort, but this standard is intended for steady-state rooms. Standards ISO 16890 series, specific use of room (ISO 7547, ISO 8304, ISO 8861, ISO 8862, ISO 8864, ISO 9099, ISO 9785, ISO 9943, ISO 11105 for ship and marine technology), the age of air (ISO 16000-8) and thermal insulation (ISO 8144-1, ISO 8144-2), are not directly relevant to ventilative cooling in buildings (although they do include mechanical ventilation). Nonetheless, they support the importance of ventilative cooling in other areas aside from buildings.

For more detailed evaluation of missing parameters in ISO standards for ventilative cooling, see the filled in questionnaires in Annex A to Annex C of the Venticool background report [1].

3.1.3. National standards (status)

In this section, the status of relevant national standards concerning ventilative cooling is summarised and shortly described for selected countries, in this case for Japan and Australia. The information presented is based on the filled in questionnaires found in Annex A to Annex C of the Venticool background report [1], covering different climates with information for e.g. Denmark, Switzerland and Australia, providing a broad overview of how ventilative cooling is implemented in national standards.

The Japanese national standard, “Energy saving standard for residential buildings, 2015” takes into account the effect of cross ventilation as a method for reducing the cooling energy consumption. The level of air-change rate (“none”, “5 ACH and more”, and “20 ACH and more”) is determined by the location of the building and the position arrangement of openings (windows and internal doors). The effect of natural ventilation has not yet been evaluated in the energy saving standard for non-residential buildings.

Australian Standards 1668.2 and 1668.4 namely: “The use of ventilation and air-conditioning in buildings. Part 2: Mechanical ventilation in buildings and Part 4: Natural ventilation of building” cover the requirements for mechanical and natural ventilation in occupied spaces. The objective of these two standards is to define the minimum ventilation rates per person or minimum window openings required for natural ventilation. They do not specifically address the design of ventilative cooling systems, nor the effect of using ventilation for cooling purposes. Only 1668.2 suggests that when a mechanical HVAC system is in place an economizer damper should be installed.

For more detailed evaluation of other national standards, see the missing parameters of ventilative cooling in Annex A to Annex C of the Venticool background report [1].

3.2. Status in legislation

This section looks at the overall status and overview of legislation concerning ventilative cooling. Legislations could be divided into national and regional legislations. The type of legislation differs from country to country, as not all countries have regional legislations. Furthermore, the way ventilative cooling is treated in legislation is evaluated by looking into what extent certain ventilative cooling parameters are integrated nationally (e.g. cross ventilation or which calculation time step is used).

The status of relevant national legislation concerning ventilative cooling follows, based on results from previously published reports (e.g. looking at the national building codes through questionnaires).

Regarding legislation, a broad field of methods for ventilative cooling seem to be integrated, ranging from very simple to detailed. For quite a few countries, among the reviewed ones, there is a lack of ventilative cooling integration in legislation and compliance tools e.g. in the United Kingdom, Italy and Japan. Generally, the calculation of air flow rates in buildings is not sufficiently reflecting the real conditions, being either the actual building design, physics or geometry, and thus undermining the full potential of ventilative cooling.

For example, in Japan there is no legislation integrating ventilative cooling, but there will be an obligation to take an "energy saving standard" for residential buildings into account by year 2020. The "Energy saving standard for residential buildings, 2015" takes the effect of cross ventilation into account. On a more positive note, Swiss legislation provides a sufficient framework to consider ventilative cooling by referring to SIA 180 for thermal protection and by taking into account the resulting air conditioning energy consumption for the energy label.

To understand the content given by the detailed evaluations from the Venticool background report it was chosen to include the Austrian reply (included below), which will give insight into how Ventilative cooling is integrated in Austrian legislation.

3.2.1. Austrian reply for Ventilative cooling Implementation in national legislation (an excerpt from the Venticool background report):

Since when is the current national building legislation enforced?

- March 2015

When is the next revision of your national building legislation?

- Presumably 2019

How is the air flow rate determined for ventilative cooling in your national building legislation/guideline?

- Fixed ACH without any sensitivity to building design in case of cooling demand compliance tool
- More detailed calculation incl. window position, size and temperature in case of IEQ compliance tool for free running rooms

Which standards/guidelines are referred to in your national building legislation/guideline (if relevant incl. short scope)?

- For energy demand compliance, the calculation method is defined within ÖNORM B 8110-5, -6, ÖNORM H 5055, 5056, 5057, 5058 and 5059. All together they are Austria's answer to the EPBD requirements and Austria's Interpretation of EN ISO 13790. Within these standards, it is ÖNORM B 8110-5 which defines the outdoor climate and the usage input parameters.
- For summer comfort of rooms without cooling demand (obligatory for residential) buildings, compliance calculation is defined in ÖNORM B 8110-3. Its algorithms are closely linked to ISO 13791 and ISO 13792.

Are the effects of actual window position and geometry of the building included in your national building legislation/guideline? (e.g. orientation and height difference between windows in building?)

- Within the compliance tool for summer comfort, the ACH is calculated with a simplified formula from window area, window height and temperature difference. Windows in two different levels are accounted for. No option is given to take into account cross ventilation. No wind effect may be taken into account.
- The formula is:

$$\dot{V} = 0{,}7 \cdot C_{ref} \cdot A \cdot \sqrt{H} \cdot \sqrt{\Delta T}$$

with C_{ref} Austauschkoeffizient; $C_{ref} = 100\ m^{0{,}5}/(h \cdot K^{0{,}5})$

C_{ref} = exchange coefficient (in English)

If windows in two heights are applied, the surface calculation is altered to

$$A_{eff} = \sqrt{\frac{1}{\frac{1}{A^2_{oben}} + \frac{1}{A^2_{unten}}}}$$

State the name of your national legislation/guideline and furthermore, indicate which parameters regarding ventilative cooling are included, below:

Table 2 – Ventilative cooling parameters in your national legislation and or/guideline for residential buildings

Parameters	**National standard ON B 8110-3 being obligatory referred to in national building code OIB RL 6 forming the compliance for summer comfort in buildings without cooling demand**	**National standard family ON B 8110-3, -6 and ON H 5055, 5056, 5057, 5058, 5059 being obligatory referred to in national building code OIB RL 6 forming the compliance for energy demand for heating, cooling and lighting in buildings**
Single-sided ventilation	Yes	No, fixed ACH
Cross ventilation	No	No, fixed ACH
Stack ventilation	Yes	No, fixed ACH
Night cooling	Yes	Yes, at fixed ACH of 1,5 h^{-1}
Free cooling	Not applicable, since only meant for buildings without cooling demand	Now cooling demand in residential buildings is allowed. Result of cooling demand calculation has to be zero
Hybrid systems	Not applicable, see above	See above
Position of windows in building	Yes, partly: Only regarding relative vertical distance of windows, not orientation	Not applicable, since ACH is fixed

Is wind included in your calculation?	No	Only by influencing the infiltration rate
Effect of having manual or automatic window operation	No	No
Steady-state or dynamic calculation?	Dynamic, on basis of a repeated design-day	Steady state, with some performance indicators having been derived from preliminary dynamic simulation
Time-step (monthly or hourly)?	Hourly	Monthly
Indicate important issue not included in this table		

For more detailed evaluation of missing parameters in legislation for ventilative cooling, see the filled in questionnaires in Annex A to Annex C of the Venticool background report [1].

3.3. Status in compliance tools

This section looks into the overall status and overview of compliance tools concerning ventilative cooling. The degree of complexity among national compliance tools can vary a lot and it's sometimes difficult to distinguish between national regulation and national compliance tools. The way ventilative cooling is considered in compliance tools is assessed by checking to what extent certain ventilative cooling parameters are integrated nationally (e.g. cross ventilation or which calculation time step is used).

As regards compliance tools, a broad field of methods for ventilative cooling appears to be integrated, ranging from very simple to detailed. Actually, for quite a few countries there was a lack of ventilative cooling integration e.g. in the United Kingdom, Italy and Japan. For example, in Italy, upper limits on indoor temperature (i.e. according to the adaptive thermal comfort model) and thermal comfort/overheating indicators are not included in the energy performance evaluation; this could be improved. Switzerland's, Norway's and Austria's legislation appear to better integrate ventilative cooling through hourly time step calculations which better support the adaptive comfort model, instead of the less precise, monthly calculations.

Another example is Denmark, which have started to improve the possibility of using ventilative cooling by making a selection between single-sided and cross ventilation strategy is not possible directly through the software interface, but recommended air flow rates take into account these strategies recommending higher air flows for cross ventilation than for single-sided ventilation. Also, simple relations between air flow and openable window area are included in the help file of the tool (not in the interface). This is on the right track, even though air flow rates should reflect the real conditions to a higher degree, based on actual building physics and geometry and allowing for more flexibility e.g. higher air change rates allowed in unoccupied rooms during night and lower if the rooms are occupied.

For more detailed evaluation of missing parameters in compliance tools for ventilative cooling, see the filled in questionnaires in Annex A to Annex C of the Venticool background report [1].

3.4. References

[1] Status and recommendations for better implementation of ventilative cooling in standards, legislation and compliance tools. A publication in the context of IEA EBC Annex 62 ventilative cooling, September 2018. INIVE eeig. Retrieved from http://venticool.eu/venticool-publications/reports/

[2] Overview of advances and remaining challenges to implement ventilative cooling with the new EPBD standards", presented at Clima 2016, François Rémi Carrié, Valérie Leprince, Maria Kapsalaki. Accessible on www.venticool.eu

[3] http://www.iee-cense.eu/Events-and-publications/Publications

4. Recommendations for standards, legislation and compliance tools - for better implementation of ventilative cooling

This section provides recommendations per country for standards, legislation and compliance tools for better implementation of ventilative cooling, based on the findings from the “status” section. In regard to legislation it is not always easy to align recommendations, due to the different ways ventilative cooling is included (or not) nationally and the differences in the use of calculation methods. Furthermore, this section discusses if new technical documents on ventilative cooling are needed, based on the findings from the filled-in questionnaires in Annex A to Annex C of the Venticool background report [1].

All the recommendations that follow are important and may be used as input to regulators on how to improve the implementation of ventilative cooling in future standards, legislation and compliance tools.

Overall the summary report has provided a lot of recommendations for both standards, legislation and compliance tools which vary depending on the type of document and country. To conclude on all these recommendations, it was chosen to make specific overall recommendations given per topic as proposed changes in standards, legislation and compliance tools, to be used directly by the target groups of this summary report (building designers, builders and experts working with building energy performance standards, legislations and compliance tools) for future revisions of these documents.

This section summarises the "overall recommendations across all standards, legislation and compliance tools". For more specific details on recommendations on national level please see the recommendation sections on "national legislation" and "national compliance tools" in the Venticool background report [1].

4.1. General

The split-up of roles and responsibilities between legislation, standards and compliance tools differ from country to country. The collective task is to set up targets for certain parameters and methods to evaluate if these targets have been met. In the following paragraphs, the targets are assumed to be defined in the legislation and the methods to evaluate if the targets are met are defined in standards and/or national compliance tools.

4.2. Overall recommendations in standards and other technical documents

The recommendations for EN standards are given below, based on the findings from the filled in questionnaires, to be used directly by the target group of this report for future revisions of these documents.

Below recommendations first for EN standards and other technical documents are given, following by ISO standards. Finally, the main recommendations from the IEA EBC Annex 62 on "Ventilative cooling" are given across all standards. The recommendations are listed as proposed changes in standards and other technical documents to be used directly by the target group of this report (building designers, builders and experts working with building energy performance standards, legislations and compliance tools) for future revisions of these documents.

4.2.1. European standards (EN) and other technical documents (recommendations)

Evaluation of possible new technical documents on ventilative cooling in CEN

While working on the IEA EBC Annex 62 recommendation report to evaluate the status of ventilative cooling in existing standards, conclusions were drawn throughout the process, to act for better implementation.

One of the goals of the report was to evaluate if new Technical documents (e.g. EN standards, Technical specifications or Technical reports) on ventilative cooling should be proposed in Europe (in CEN), based on the initial findings, by evaluating if there was a sufficient lack of content in existing standards regarding ventilative cooling.

To sum up, there was an overall lack of ventilative cooling integration, in existing and revised European standards regarding “system design” and “performance” aspects of ventilative cooling, and therefore new work items (NWI's) relevant to ventilative cooling applications were proposed to the European Committee for Standardization (CEN). These new work items were approved and have now started up under CEN/TC 156 in various working groups (already launched at the time of writing of this report).

These new projects have the scope of making technical documents focusing on the design aspects of ventilative cooling and natural and hybrid ventilation systems in residential and non-residential buildings. There is good development in these recently launched projects, with a plan to coordinate to eliminate overlaps.

The following 3 projects relevant to ventilative cooling applications have begun:

- Ventilative cooling systems
  - Main focus: Thermal comfort (reduce cooling loads and prevent overheating)
  - Document type: A CEN Technical specification
  - Work started up in WG/21 in CEN/TC 156
- Natural and Hybrid ventilation systems in non-residential buildings
  - Main focus: Indoor air quality

- Document type: A CEN Technical specification
  - Work started up in WG/20 in CEN/TC 156
- Design process of natural ventilation for reducing cooling demand in energy-efficient non-residential buildings
  - Main focus: Thermal comfort (design process to reduce cooling demands and/or overheating)
  - Document type: ISO standard
  - Work started up in WG/2 in ISO/TC 205

And, one project is upcoming:

- Expansion of Natural and Hybrid ventilation in residential buildings in upcoming "Revision of EN 15665:2009 and CEN/TR 14788:2006"
  - Main focus: Indoor air quality
  - Document type: Goal is to merge both documents into one document (e.g. EN standard)
  - Work started up in WG/2 in CEN/TC 156

The initiated projects are foreseen to be released as European Technical Specifications (normative documents of lower status than EN Standards) and as an EN standard under CEN/TC 156. The technical documents are a good opportunity to define the design aspects of ventilative cooling and natural and hybrid ventilation systems on the European and International scene e.g. by applying findings from the venticool platform [2] and the final deliverables of the IEA EBC Annex 62 reports [3].

Some more concrete recommendations to the future implementation of ventilative cooling in EN standards follow:

- The new projects in CEN could contain separate sections on thermal summer comfort which is very relevant to ventilative cooling, explaining how ventilative cooling may reduce overheating (as in e.g. Japanese design guideline for ventilative cooling [4], CIBSE AM 10:2005 (first part of the guide (design) or in section "control of summer overheating") [5] and/or DS 447:2013 [6])
- The new projects in CEN could give guidance on how to design and dimension ventilative cooling and natural and hybrid ventilation systems in buildings
- In future standards "performance" aspects areas such as control of systems, internal partition of buildings and guidance on parameters that shall be defined by users, should be better integrated
- In future standards it should be considered that windows are not the only mean to provide ventilative cooling but there are other components already available on the market (i.e. louvre, operable opaque envelope parts, thermal chimneys, wind catchers, etc..) that can effectively contribute to overheating reduction
- Building designers, builders and experts need more information on how to design and calculate on ventilative cooling systems, instead of only being given requirements to follow or general information on natural forces
- Design of natural ventilative cooling systems should consider the effect of:
  - Height difference between windows or other opening types

- Placement of windows or other opening types in regard to noise, outdoor air pollution and security
- Placement of windows or other opening types (opposite sides of building/room) in regard to maximum cross ventilation (advantage using this)
- Control strategies
- Window operation management according to outdoor climate and pollution conditions
- Simple calculation methods for ventilative cooling

The recommendations for ISO standards are given below, based on the findings from the filled in questionnaires, to be used directly by the target groups of this report for future revisions of these documents.

4.2.2. ISO standards (recommendations)

This section describes recommendations for better implementation of ventilative cooling in ISO standards.

As in CEN, New work items relevant to ventilative cooling applications have recently been proposed to the International Organization for Standardization (ISO) aiming at making a descriptive technical document focusing on the design process or aspects of natural ventilation systems.

One project has already started up:

- "Design process of natural ventilation for reducing cooling demand in energy-efficient non-residential buildings" (ISO/TC 205), NP 22511

The effect of cross ventilation on reducing cooling demand is described in ISO 13153:2012, but single-sided ventilation is excluded and buoyancy driven ventilation is not taken into account. This standard should be expanded to allowing to consider natural ventilation. This standard describes only the design process and thus the control strategy or methods for windows and cooling devices will be needed in other standards. No ISO standards for design methods of (large) non-residential buildings are available; hence, the new ISO standard NP 22511 (in progress) is being developed under ISO/TC 205.

4.2.3. National standards (recommendations)

The recommendation is to base national standards on the same methods as in EN and/or ISO standards.

See text below for further recommendations across all standards.

4.2.4. Overall recommendations (across all standards)

The main recommendations across all investigated standards, summing up specific overall recommendations per topic are presented below. To allow for ventilative cooling to be treated better in standards both at the design stage, where initial calculations of e.g. the natural forces are made as well as, at more detailed stages where more detailed calculations are needed, it is important that several parameters are taken into account, such as:

- Assessment of overheating, e.g.:
    - Utilizing thermal comfort indicators, including adaptive temperature sensation
    - Utilizing energy performance indicators
- Assessment of natural and mechanical ventilative cooling
- Assessment of night cooling
- Calculation methods that fairly treat natural ventilative cooling for determination of air flow rates including e.g. the dynamics of varying ventilation and the effects of location, area and control of openings

When revising standards with respect to calculation and design of ventilative cooling systems ensure that the standards don't favour specific technologies and allow for emerging technologies such as hybrid systems and for components alternative to windows (i.e. louvers, thermal chimneys, wind catchers..). Among other things, the determination of air flow rates in buildings for e.g. natural ventilative cooling is important to consider, where both simplified and detailed calculation methods can be found in e.g. calculation standard; EN 16798-7:2017, enabling the designer to choose which level of detail is needed for the given purpose and stage of the construction.

It is recommended that the full effects of ventilative cooling are evaluated reflecting the real conditions for the building, control, use and climate. This should include in particular the actual building physics and geometry, supporting a fair evaluation of e.g. stack effects, cross ventilation, mechanical ventilation, control system, night/day ventilation and summer/winter ventilation.

Inspiration for recommendations in standards can be found in the recently published IEA EBC Annex 62 "Ventilative cooling design guide" [7], which gives information on how to design ventilative cooling systems by e.g. using Key performance indicators for "thermal comfort" and "energy performance" aspects. These key performance indicators are addressed in this section.

Air flow rate

Recommendation: <u>Use main calculation standard, EN 16798-7:2017 for the calculation of air flow rates in buildings:</u>

- We recommend using the standard, EN 16798-7:2017 for the calculation of air flow rates in buildings for ventilative cooling. The standard contains both simple direct methods and a detailed iterative method covering different needs and complexities. E.g. for quicker calculations, simple direct methods of calculation using wind velocity and temperature difference as input, can be used for single-sided and cross-ventilation, whereas for more detailed calculations, the detailed iterative mass-balance method calculation using internal reference pressure as input can be used.

Recommendation: <u>Consider infiltration, natural and mechanical ventilation:</u>

- A clear distinction between infiltration related air flow rates and natural ventilation airflow rates should be made. It must be clearly stated that infiltration airflow rate is the uncontrolled air flow while natural ventilation related air flow rate is controlled and may depend on several factors, such as, opening position, opening types, opening effective area, automation possibility, etc. If infiltration and natural ventilation airflow rates are not considered separately then high ventilation heat losses in the cold season would be observed since natural ventilation has no possibility for heat recovery and air flows should be significantly higher than for infiltration.

Recommendation: <u>Flexibility allowing calculation of air flow rates based on real conditions:</u>

- When revising standards with respect to calculation and design of ventilative cooling systems ensure that both day and night ventilation are taken into account, for various scenarios, including window openings. Generally, we recommend that standards reflect the real conditions based on actual building physics and geometry. This increases flexibility to reach the relevant air flows depending on room type and thermal loads.
- Air flow rates shall be adjustable depending on the ventilation need for: indoor air quality, overheating prevention, day/night and depending on season

Thermal comfort indicators (e.g. criteria for overheating)

- When revising standards with respect to the prediction of the expected thermal comfort and cooling requirements by using ventilative cooling, it is recommended to use a method that is based on the static Fanger model (PMV evaluation) (using mechanical ventilative cooling) or the Adaptive comfort model (using natural ventilative cooling)
- It is recommended to use Key Performance Indicators for "thermal comfort" that are used in the IEA EBC Annex 62 "Ventilative cooling design guide" (p. 33-34) [7]. A set of two indicators enable to properly evaluate of thermal comfort; the Percentage outside the range (POR) (see method A, in prCEN/TR 16798-2:2017) evaluating the percentage of occupied hours when PMV/Operative temperature is outside the range and; according to the Degree hours criterion (DhC) (see method B, in prCEN/TR 16798-2:2017), the time during which the actual operative temperature exceeds the specified range during the occupied hours is weighted by a factor which is a function depending on how many degrees the range has been exceeded.

Energy performance indicator (e.g. criteria for energy performance)

- It is recommended to use Key Performance Indicators for "energy performance" that are used in the IEA EBC Annex 62 "Ventilative cooling design guide" (see pages 34-36): the Cooling Reduction Requirement (CRR) evaluating the percentage of reduction of the cooling demand of a scenario, compared to a reference scenario and; the Ventilative Cooling Seasonal Energy Efficiency Ratio (SEER), which is defined as the cooling requirement saving divided by the electrical consumption of the ventilation system [7]
- Alternatively, give a "penalty" associated to the energy performance of the building if cooling is needed - like the method used in the Danish compliance tool. This penalty raises awareness for the necessity of cooling and encourages the implementation of an efficient ventilative cooling

system. In southern Europe cooling need will occur anyway during summer period, so a penalty could be given if the building has a cooling need in the shoulder seasons.

Flexibility towards new/alternative technologies

- When revising standards with respect to calculation and design of ventilative cooling systems ensure that new and alternative technologies are allowed. It is recommended that technologies such as hybrid ventilation are supported where the full effect of natural ventilative cooling used during periods of overheating is evaluated reflecting on the real conditions based on actual building physics and geometry.

4.3. Overall recommendations in legislation

The main recommendations from the IEA EBC Annex 62 are given below together with specific overall recommendations per topic covering all investigated legislations. To allow for ventilative cooling to be treated in building performance evaluations, several parameters are necessary to take into account, such as:

- Assessment of overheating, e.g.:
    - Requirements to thermal comfort, including adaptive temperature sensation
    - Requirements to energy performance including cooling
- Acknowledgement of natural and mechanical ventilative cooling
- Support to evaluation methods considering the dynamics of varying ventilation and ventilation modes
- Support to evaluation methods considering the effects of location, area and control of openings

When revising legislation with respect to calculation and design of ventilative cooling systems, ensure that the legislation is technology neutral thereby not favouring specific technologies and allowing emerging technologies such as hybrid systems. It is recommended that the full effects of ventilative cooling are evaluated reflecting the real conditions for the building, control, use and climate. This should include in particular the actual building physics and geometry. Legislation should include or refer to guidelines, standards or compliance tools on how to calculate the cooling effect, resulting temperatures and the energy performance.

4.3.1. Overall recommendations (across all legislations)

Below are specific overall recommendations given per topic as proposed changes across all legislations.

Thermal comfort indicator (e.g. criteria for overheating/overcooling)

- Methods for a long-term evaluation of thermal comfort conditions should be taken into consideration and used actively as a requirement in the national legislation as supported by prEN 16798-1:2017 and the associated Technical report, prCEN/TR 16798-2:2017. prCEN/TR 16798-2:2017 proposes different long-term evaluation methods e.g. the “Percentage Outside the Range Index” (method A) and the “Degree-hours Criterion” (method B) enabling the evaluation of both frequency and severity of overheating occurrences. The reference comfort temperature and the evaluation of overheating and overcooling can be derived from the Fanger model or the adaptive comfort model.

Available opening area for natural ventilative cooling

- Since natural ventilative cooling is highly dynamic, the legislation should support evaluation methods based on the actual building geometry, climatic conditions and actual use and control of the building. Necessary opening areas should be based on calculations where discharge coefficients of openings have been included.

Criteria for draught risk

- The legislation should require the use of draught rate calculation according to ISO 7730 by using one of the three categories (A, B or C) for the evaluation. Draught due to air inlets will be related to their position in the room and distance from the occupied area. A description should be given for the occupied zone which should fulfil the requirements. A deviation from the requirements could be suggested if the air velocity is under personal control e.g. by using openable windows, table- or ceiling fans. It should be noted, that under thermal summer comfort conditions with indoor operative temperatures above 25ºC, increased air velocity can be used to compensate for increased air temperatures if the increased air velocity is under personal control. The correction value depends on the air speed range of the appliance. Draught rate should include temperature, air velocity and turbulence intensity, meaning e.g. that with higher temperatures, higher air speed is accepted.
- In order to avoid other types of discomfort (e.g. flying papers, ingress of leaves, slamming doors etc.) in the occupied zone, one may set upper limits for air velocities different from the pure thermal draught assessment.

All day ventilation

- Legislation should require that ventilative cooling can be applied during both occupied and unoccupied periods, meaning all day if needed. For openings used for ventilation, legislation should require considerations on the need for burglary, noise, pollution, rain and mosquito proofing.

4.4. Overall recommendations in compliance tools

The main recommendations across all investigated compliance tools, summing up specific overall recommendations per topic are presented below. It is essential that national compliance tools can interpret the legislation in a fair and correct manner in order for the increased use of ventilative cooling to become fully relevant in different countries.

4.4.1. Overall recommendations (across all compliance tools)

Several building simulation tools are today available around the world that allow architects or engineers to assess buildings with a high accuracy on energy performance or indoor climate. Some of them are already implementing modules to consider natural ventilation or natural ventilative cooling through windows and its effect on thermal summer comfort.

Especially natural ventilative cooling is difficult to assess in most existing compliance tools, which should reflect what is stated in the national legislation. Since compliance tools are the only evaluation tools used in many cases, it is recommended to secure the implementation of ventilative cooling in compliance tools, allowing the evaluation of over-heating issues at the earliest stage of design process when decisions on e.g. windows location or orientation can still be taken.

Despite the fact that some of these tools have reached an elevated level of user-friendliness, they are only occasionally used for building design as the compliance of a project with building regulation also requires the use of calculation tools. Therefore, these so-called “compliance tools” are usually preferred in the design process of a building to secure the performance of buildings and their compatibility with national regulations.

This background observation highlights the necessity of implementing ventilative cooling in compliance tools to promote its use, but also to secure that it is considered at the earliest stage of design process when decisions on e.g. windows location or orientation can still be taken.

The main recommendations from the IEA EBC Annex 62 across all investigated compliance tools follow. To allow for ventilative cooling to be treated in building performance evaluations, several parameters should be considered, such as:

- Assessment of overheating, e.g.:
    - Thermal comfort indicators, including adaptive temperature sensation
    - Energy performance indicators like e.g. virtual cooling needs, cooling consumptions etc.
- Assessment of increased air flows when efficient ventilative cooling systems are used:
    - Differentiation should be made i.e. for cross- or stack ventilation vs. single-sided ventilation, automated systems vs. manually controlled, large vs. small opening areas
    - Associated airflows should preferably be based on building physics for e.g. dynamic tools (using pressure equations) or - as a simpler solution - on “coefficients” which increase air flows based on the chosen system
- Implementation of different levels of approaches to the evaluation of ventilative cooling, depending on the level of detail needed for the given purpose and stage of construction:
    - **Simplified approach:**
      Using national compliance tools based on monthly calculations with specific assumptions on input air flows for natural ventilation and ventilative cooling (like e.g. in Belgium, Flanders).
      The main benefit of this method is its direct applicability towards most existing compliance tools.

It allows modelling of ventilative cooling via the use of constant air flows over a given period, and can, like in Belgium, promote the gradual use of openable windows, stack effect, cross-ventilation and even control systems.
Its simplicity will of course lower the air flows and tends to reduce the impact of ventilative cooling on thermal summer comfort.

- **Intermediary approach** (combining simplified and detailed approach):
  Using national compliance tools based on monthly calculations + using an add-on tool or plugin to address thermal summer comfort and ventilative cooling in a more accurate way (like e.g. in Denmark).
  The main benefit of this approach is to keep the existing compliance tool, but could be less accurate (and then less beneficial to ventilative cooling) due to the reduced number of parameters (in several cases, this tool will usually be using the same input parameters as the main compliance tool)
- **Detailed approach**:
  - Using national compliance tools based on full dynamic calculations (e.g. like in Switzerland, where several simulation tools from the market are allowed).
  - Using national compliance tools based on simplified hourly calculations (like e.g. in France or in The Netherlands).

Examples on different national evaluation approaches for ventilative cooling in compliance tools:

In most cases, simplified approaches underestimate the impact of ventilative cooling. Advanced calculation methods like e.g. dynamic simulations based on hourly time-steps are usually closer to reality and lead to more realistic air change rates. Examples of different "levels" of approaches to the evaluation of ventilative cooling in national legislation ranging from simplified to detailed, as explained in the above three bullet points, follow.

The three examples that follow show interesting national approaches used for compliance tools. These methods are using different ways to evaluate air flows and thermal summer comfort, by making use of the technical possibilities of each tool (e.g. static tool, hourly tool, dynamic hourly tool…).

Belgium: Simplified approach (To provide monthly inputs)

Since January 2018, the Belgian region Flanders, has introduced a new evaluation method for ventilative cooling in residential buildings to be used in the EPB compliance tool. It consists of a simple chart flow for designers, which identifies the potential for ventilative cooling (ranked from “No potential” to “Maximum potential”) [8].

This approach is simple and promotes the use of ventilative cooling, by ranking solutions based on their efficiency potential (e.g. accessible from the outside, protected from the outside, possible adjustment of opening area, automatic control). The impact of ventilative cooling is then assessed according to its effect on the thermal comfort indicator but could also be implemented to energy cooling needs.

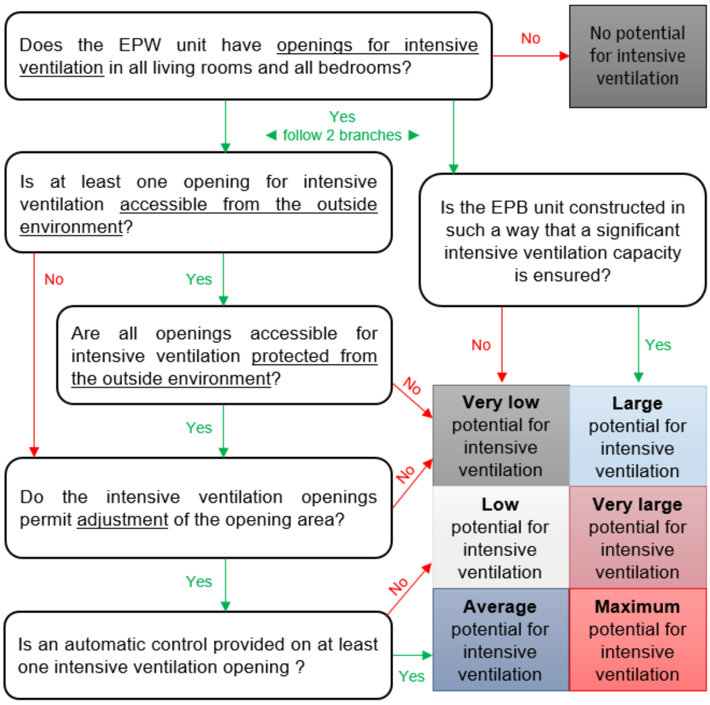

Figure 2 - Ventilative cooling potential (assessment flowchart)

Denmark: Intermediary approach (Add-on tool to improve the evaluation of thermal summer comfort)

Since 2015, the Danish Building Institute – SBi, has implemented an additional feature to the official compliance tool to evaluate thermal comfort. This module is called “Summer comfort” and is used to document the thermal comfort in summer in residential buildings through hourly calculations (described as total number of hours above 27°C and 28°C). Due to the limited number of parameters available in the main compliance tool, only some features of ventilative cooling can be considered in the add-on module, but it still allows the promotion of cross-ventilation, number of openable windows and geometrical free area of windows.

Even though these compliance tools are limited for the modeling of ventilative cooling, the Danish approach shows that more advanced simulation tools can be developed and connected to the existing compliance tool, without jeopardizing well-known approaches.

Switzerland: Detailed approach (Dynamic simulation software allowed)

The Swiss regulation MuKEn shows a specific approach for the energy calculation, and allows the use of several simulation tools available on the market.

This approach brings more flexibility regarding the use of ventilative cooling as most software are dynamic (hourly) simulation tools, which is the most accurate way of evaluating air flows (simplified methods usually tend to lower the impact of ventilative cooling in order to be conservative). Allowing several simulation tools could also lead to some disadvantages due to potential differences in input data if not standardized. Therefore, projects results might not be comparable with the results of other softwares. The use of software like e.g. DIAL+ promotes a realistic effect of ventilative cooling and considers influent parameters like e.g. window dimensions, stack effect, cross-ventilation or automatic control.

The main recommendations from the IEA EBC Annex 62 are given below together with specific overall recommendations per topic covering all investigated compliance tools; these are listed as proposed changes in compliance tools.

Air flow rate

Recommendation: Air flow rates to be used for ventilative cooling should be either assessed or at least provided as input value:

- When technically possible, air flow or air flow rates should be evaluated based on building features and climatic conditions
- When incompatible with national compliance tool(s), simplified approaches should be provided to building designers by e.g. providing fixed average air flow rates to be used for “cooling” purposes.
- When provided as input value, air flow rates should be divided into several levels to account for various systems efficiency (cross- or stack ventilation vs. of single-sided ventilation, automated systems vs. of manual control, large vs. of small opening areas)
- When air flow rates are accounted for via fixed values in compliance tools, the user must be able to specify different input values depending on the considered season (e.g. one value for winter, one value for summer). This is the only way to avoid a negative interaction between the heating and the cooling season, and to avoid that air flow rates associated with ventilative cooling are used all year long.
- Air flow rates shall be adjustable depending on the ventilation need and on occupied/not occupied time for indoor air quality or overheating prevention

Recommendation: Consider infiltration, Natural and Mechanical ventilation:

- Clear distinction between infiltration related air flow rates and natural ventilation airflow rates should be made. It must be clearly stated that infiltration airflow rate is the uncontrolled air flow while natural ventilation related air flow rate is controlled and may depend on several factors, such as, opening position, opening effective area, automation possibility, outdoor conditions etc. If infiltration and natural ventilation airflow rates are not considered separately then high ventilation heat losses in the cold season would be observed since natural ventilation has no possibility for heat recovery and air flows should be in general significantly higher than for infiltration.

Available opening area

- The compliance tool should - as an additional feature - be able to estimate air flow rates from a given list of predefined openings (inlets and outlets), for example “window top hinged”, “window side hinged” and “louvre” when they are fully opened, allowing for the possibility to overwrite this feature. In addition, it should introduce some interpolation of some intermediate openings. Discharge coefficients should be included in the predefined units. Based on this, the tool should confirm if the designed opening areas provide sufficient air flow rates.

Criteria for draught risk

- In modern airtight buildings, draught due to infiltration is almost non-existing in cold climates and reduced in warmer climates. Then draught is therefore mostly related to deliberately made inlets. Simple compliance tools are hardly designed or suitable for draught calculations and separate tools for evaluations are often necessary.

Flexibility towards new/alternative technologies

- Compliance tools should be updated regularly with respect to calculation of the new ventilative cooling technologies, such as diffuse ceiling ventilation for natural and mechanical ventilation, ventilation units accounting for heat/cold storage and utilization of phase change materials (PCMs), hybrid ventilation systems and others. Moreover, more effort should be made to integrate components promoting ventilative cooling in compliance tools, like wind chimneys, air vents, trickle vents, and many others. At present, these components are poorly or even not at all included in compliance calculation tools.

4.5. References

[1] Status and recommendations for better implementation of ventilative cooling in standards, legislation and compliance tools. A publication in the context of IEA EBC Annex 62 ventilative cooling, September 2018. INIVE eeig. Retrieved from http://venticool.eu/venticool-publications/reports/

[2] www.venticool.eu

[3] IEA EBC Annex 62 on "Ventilative cooling" – official deliverables, http://venticool.eu/annex-62-publications/deliverables/

[4] Design guideline of window for outdoor air cooling, Northern regional building research institute, Japan, 2010

[5] CIBSE AM 10:2005 (Application manual, UK), "Natural Ventilation in Non Domestic Buildings", 2005 (under revision)

[6] DS 447:2013 (Danish standard), "Ventilation for buildings – Mechanical, natural and hybrid ventilation systems", 22013

[7] IEA EBC Annex 62 deliverable "Ventilative cooling design guide", http://venticool.eu/wp-content/uploads/2016/11/VC-Design-Guide-EBC-Annex-62-March-2018.pdf

[8] Belgian EPB order (Annex V) "Method of determining the level of primary energy consumption for residential units", p.40-41

5. Conclusion

The overall purpose of the summary report was to describe the current status and make recommendations for better implementation of ventilative cooling in standards, legislation and compliance tools.

In order to present the status of how well ventilative cooling is implemented, experts in 11 countries participating in IEA EBC Annex 62 (see Table 1) were asked to fill-in a questionnaire looking into which parameters influencing ventilative cooling are included in standards, legislation and compliance tools. The filled in questionnaires were used as backgrounds for the summmarized answers found in the “standards”, “legislation” and “compliance tools” sections of this report. For more detailed evaluation of missing parameters in standards, legislation and compliance tools for ventilative cooling, see the filled in questionnaires in Annex A to Annex C of the Venticool background report.

The report reveals that ventilative cooling is in most cases not sufficiently integrated in standards, legislation and compliance tools. However, it also reveals that there is a broad field of evaluation methods for ventilative cooling, ranging from very simple to detailed that can support a stronger integration of ventilative cooling in the near future.

Even though the benefits of ventilative are widely acknowledged, its use by e.g. designers or architects strongly depends on a few intertwined challenges:

- The adequate modelling of natural ventilation and especially of air flows
- The share of the energy used for cooling to provide summer comfort and avoid the overheating risk tends to become equivalent to the energy consumption for heating in winter, depending on the climate
- The adequate prediction of the expected "thermal comfort and cooling requirements", as well as the "energy performance" when using ventilative cooling in buildings (this could e.g. be based on Static models (e.g. Fanger PMV model) using mechanical ventilative cooling or on Adaptive models (e.g. adaptive comfort model)) using natural ventilative cooling

For an easier overview, the conclusions are split up into standards, legislation and compliance tools as seen below:

Standards and other technical documents:

There was generally a lack of ventilative cooling integration, in most of the evaluated countries e.g. United Kingdom, Belgium and China. In Japan, there is no legislation concerning ventilative cooling, but there will be an obligation to consider an "energy saving standard" for residential buildings by the year 2020. The “Energy saving standard for residential buildings, 2015” considers the effect of cross ventilation.

Calculation of air flow rates in buildings should reflect the real conditions based on actual building physics and geometry. This allows for flexibility e.g. higher air change rates allowed in unoccupied rooms during night and lower when occupied. In conclusion, there was generally a lack of ventilative cooling integration, in existing and revised European standards regarding “system design” and “performance” aspects of ventilative cooling, and therefore new work items (NWI's) relevant to ventilative cooling applications were proposed in the European Committee for Standardization (CEN). These new work items were approved and have now started up under CEN/TC 156 in various working groups (already launched at the time of writing of this report).

To allow for ventilative cooling to be treated better in standards both at the design stage, where initial calculations of e.g. the natural forces are made as well as, at more detailed stages where more detailed calculations are needed, it is important that at least the following point is considered:

- The support of calculation methods that fairly treat natural ventilative cooling for the determination of air flow rates including e.g. the dynamics of varying ventilation and the effects of location, area and control of openings

Lastly it is also recommended to use the Key Performance Indicators used in the IEA EBC Annex 62 "Ventilative cooling design guide" for "Thermal comfort" (Percentage outsider range and the Degree hours criterion) and "Energy performance" (Cooling reduction requirement and the Ventilative cooling seasonal efficiency ratio.

Legislation:

Several countries have taken significant steps to better implement ventilative cooling, especially countries like Switzerland, Norway and Austria which allow hourly time steps for thermal comfort evaluations. This important decision generally allows for better inclusion of highly dynamic measures such as ventilative cooling. Also, e.g. Denmark has implemented an add-on module which supports the hourly approach for over-heating evaluation. This happens in a simplified module outside the monthly energy performance evaluation tool used in Denmark. This approach could potentially allow for a reasonable evaluation of the over-heating risk but is more difficult to be used in the energy performance evaluation.

Furthermore, in Switzerland, legislation provides a sufficient framework to consider ventilative cooling by referring to norm; SIA 180 for thermal protection which considers the resulting air conditioning energy consumption for the energy label.

To allow for ventilative cooling to be treated better in building performance evaluations in legislation, several parameters are necessary to be considered in the building regulation; it is thus important that at least the following point is considered:

- Assessment of overheating, e.g.:
  - Requirements to thermal comfort, including adaptive temperature sensation
  - Requirements to energy performance including cooling

Compliance tools:

Because of the dynamic nature of ventilative cooling, the recommendation is to implement hourly calculation time steps, instead of less precise monthly calculations, in more compliance tools for both thermal comfort and energy performance evaluations for a better support of adaptive comfort. The hourly calculations have the capability to predict the cooling loads in the building and hereby assess the overheating more precisely than the monthly calculations, which is crucial in many of the buildings nowadays.

To allow for ventilative cooling to be treated better in compliance tools evaluations, it is important that at least the following points are considered:

1. Assessment of increased air flows when efficient ventilative cooling systems are used:
   a. Differentiation should be made i.e. for cross- or stack ventilation vs. single-sided ventilation, automated systems vs. manual control, large vs. small opening areas
   b. Associated airflows should preferably be based on building physics for e.g. dynamic tools (using pressure equations) or - as a simpler solution - on “coefficients” which increase air flows based on the chosen system

Lastly it is important to evaluate if the current methodology for the evaluation of ventilative cooling in compliance tools is sufficient to assess overheating. In contrast to most European countries’- where compliance tools using the monthly average models for energy calculations can underestimate the cooling potential of Ventilative cooling - Denmark has been moving forward with the implementation of an additional feature to the official compliance tool to evaluate thermal comfort. The official compliance tool is based on monthly calculations, whereas the integrated module called "summer comfort" in the official compliance tool performs hourly calculations for thermal comfort in summer in residential buildings only. This method could be seen as an "intermediary" approach, in between the simplified monthly average models and the more dynamic hourly-based models. Although the "add-on" module method is a step forward, it is equally important that the calculated or allowed air change rates are high enough to actually achieve the needed cooling effect. Improvements in the "Danish" method are still needed - e.g. by ensuring the associated airflows are preferably based on building physics for e.g. dynamic tools (using pressure equations).

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