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EPB STANDARDS PUBLISHED FOR FORMAL VOTE

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Commission sets up EU's next energy efficiency battle

The European Commission announced increased EU energy efficiency targets on 30 November 2016. But it will face resistance from member states opposed to binding, more ambitious rules, and from the European Parliament, which has demanded much higher goals.

The executive published its 'Winter Package' of new energy legislation aimed at creating an EU Energy Union. The strategy is designed to lessen the bloc's dependence on energy imports and fight climate change.

Among the suite of bills are rules setting EU-wide 2030 climate and energy targets, including energy efficiency. Greater efficiency reduces both emissions and the need for imports because less energy is used. The Commission has repeatedly promised to put "energy efficiency first" in its Energy Union plan.

The executive set a binding EU-level 2030 target of at least a 30% increase in energy efficiency compared to 1990 levels.

Before it can become EU law, an identical goal must be agreed by both the Parliament and Council of Ministers. MEPs have twice backed Parliament resolutions calling for 40% but member states have supported just 27%, suggesting tough negotiations ahead.

This REHVA Journal is providing information on the set of EPB standards. These standards are currently out for Final (Formal) Vote. REHVA member-associations and their members play an important role in supporting this voting on national level. They have good contacts with the national standard bodies. Where necessary it is important the REHVA members support this voting procedure, and see to it that the national standard bodies (NSB's) vote timely, this is before the end of January 2017. As all standards have been accepted during the enquiry stage and all Technical Committees have processed the comments successfully, a positive result of the voting on all EPB standards is expected. However, it is important that all NSB's vote!

Why is it that important that these standards are voted positive and accepted to be published as EN or EN/ISO standards? This modularly structured, transparent, unambiguous, but flexible set of EN and ISO EPB standards is an important instrument to support the proper implementation of the Energy Performance Buildings Directive (EPBD) in the EU- Member States. These standards are also expected to be the basis for the EU voluntary certification scheme for non-residential buildings.

The need for these EPB standards is even more urgent given the COP21 targets, the earlier 20-20-20 targets for EU 2020 and the 2030 and final 2050 targets. (see insert) This EPB set is essential to promote the unambiguity and harmonisation in the energy-efficiency and energy-transition market. In EU-28, about 40% of energy consumption is due to buildings, 2/3 for residential of which 80% heated by gas which the EU imports for 55% (2013). Our first task: reduce building energy use (by measures like insulation, passive solar, system efficiency improvement, etc.). Next: we have to increase the fraction (and production) of renewable energy, locally on the building site or nearby and finally decarbonise the energy grid. All these measures and how to weigh them, are addressed in the overarching standard EN ISO 52000-1 and several other EPB standards.

It is essential that we use these standards at national level and stop using the national procedures as is currently the case in many EU countries. The use of these typical national procedures, only partly taking into account the current EPB standards, is considered a barrier of trade and services for many energy saving technologies and products, due to the diverse assessment procedures. Using EPB standards to assess the Energy Performance of Buildings is essential for our industry. This harmonisation will reward energy saving products, systems and technologies the same way throughout Europe. This will offer great market opportunities for our industry and professionals. Bigger market opportunities mean more possibilities to invest in more energy efficient technologies. This will also have a positive effect on the cost-effectiveness of these technologies and enlarge their market. Europe could in this way be the global frontrunner and our industry could increase their market potential globally.

Widely used EPB standards will give REHVA a unique position to support their Member Associations in developing training schemes, supporting tools, dissemination programs, webinars etc. As partner in the EPB-CENTER initiative REHVA supports setting up an EU-wide program to support EU countries and professionals with their implementation process. Via this EPB-CENTER we will share our experiences and bring the standard developing and using experts together.
Also with the aim to develop tools that can be used EU-wide and deliver feedback to the standardisation field, as improvement is always possible. ■

JAAP HOGELING
Editor-in-Chief

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The set of EPB standards in CEN and ISO: common characteristics

The European Commission asked CEN (mandate M480) to develop standards supporting the application of recast EPBD (Energy Performance of Buildings Directive) in the Member States: the so-called set of Energy Performance of Buildings standards (EPB standards).

This paper summarizes some key aspects that characterize this set of EPB standards.

Keywords: energy performance of buildings, EPB, EPB regulations, system inspection, energy performance rating.

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A comprehensive series of European (CEN) and international (CEN & ISO) standards have been prepared, aiming at international harmonization of the methodology for the assessment of the overall energy performance of buildings, called "set of EPB standards". This work is based on a mandate given to CEN by the European Commission and the European Free Trade Association (Mandate M/480, [2]), to support essential requirements of EU Directive 2010/31/EC on the energy performance of buildings (EPBD) [1]. The main recommendations from the Intelligent Energy Europe CENSE project [5] were adopted in the Mandate.

This article summarizes some key aspects that characterize this set of CEN and ISO standards.

European directive and mandate to CEN

The EPBD

The EPBD promotes the improvement of the energy performance of buildings within the European Union, taking into account all types of energy uses (heating, lighting, cooling, air conditioning, ventilation) and outdoor climatic and local conditions, as well as indoor climate requirements and cost effectiveness (Article 1).

The directive requires Member States to adopt measures and tools to achieve the prudent and rational use of energy resources. In order to achieve those goals, the EPBD requires increasing energy efficiency and the enhanced use of renewable energies in both new and existing buildings. One tool for this is the application by Member States of minimum requirements on the energy performance of new buildings and for existing buildings that are subject to major renovation, as well as for minimum performance requirements for the building envelope if energy-relevant parts are replaced or retrofitted. Other tools are energy certification of buildings, inspection of boilers and air-conditioning systems.

European standards

The use of European standards increases the accessibility, transparency and objectivity of the energy performance assessment in the Member States facilitating the comparison of best practices and supporting the internal market for construction products. The use of EPB-standards for calculating energy performance, as well as for energy performance certification and the inspection of heating systems and boilers, ventilation and air-conditioning systems will reduce costs compared to developing different standards at national level.

History

The first mandate to CEN to develop a set of CEN EPBD standards (M/343, [4]), to support the first edition of the EPBD [3] resulted in the successful publication of all EPBD related CEN standards in 2007-2008. However, although these standards were implemented in many countries, in a practical way, they were not yet fit to be applied as a ready-to-use, compatible and unambiguous set.

The mandate M/480 was issued to review the mandate M/343 as the recast of the EPBD raised the need to revisit the standards and reformulate and add standards so that they become on the one hand unambiguous and compatible, and on the other hand a clear and explicit overview of the choices, boundary conditions and input data that need to be defined at national or regional level. Such national or regional choices remain necessary, due to differences in climate, culture & building tradition, policy and legal frameworks.

Consequently, the set of CEN-EPBD standards published in 2007-2008 had to be improved and expanded on the basis of the recast of the EPBD.

Target groups

The EPB standards are flexible enough to allow for necessary national and regional differentiation and facilitate Member States implementation and the setting of requirements by the Member States.

Further target groups are users of the voluntary common European Union certification scheme for the energy performance of non-residential buildings (EPBD art.11.9) and any other regional (e.g. Pan European) parties wanting to motivate their assumptions by classifying the building energy performance for a dedicated building stock.

The set of EPB standards

What is an "EPB standard"?

An "EPB standard" is a standard that complies with the requirements given in the following three documents: CEN/TS 16628 [6], the basic principles for EPB standards, CEN/TS 16629 [7], the detailed technical rules of EPB standards and EN ISO 52000-1 [8], the overarching EPB standard.

Modular structure

EN ISO 52000-1 [8], the overarching EPB standard, provides a modular structure of the assessment of the overall energy performance of buildings. The structure identifies different modules, see **Table 1** and **Table 2**.

Table 1. Modules main areas, from [6]

Modules	Area
M1	Overarching standards
M2	Building (as such)
M3-M11	Technical Building Systems under EPB
M12-M13	Other systems or appliances (not under EPB)

Table 2. The modular structure of the set of EPB standards.

	Overarching		Building (as such)	
Sub-module	**Descriptions**		**Descriptions**	
sub1		**M1**		**M2**
1	General		General	
2	Common terms and definitions; symbols, units and subscripts		Building Energy Needs	
3	Applications		(Free) Indoor Conditions without Systems	
4	Ways to Express Energy Performance		Ways to Express Energy Performance	
5	Building categories and Building Boundaries		Heat Transfer by Transmission	
6	Building Occupancy and Operating Conditions		Heat Transfer by Infiltration and Ventilation	
7	Aggregation of Energy Services and Energy Carriers		Internal Heat Gains	
8	Building zoning		Solar Heat Gains	
9	Calculated Energy Performance		Building Dynamics (thermal mass)	
10	Measured Energy Performance		Measured Energy Performance	
11	Inspection		Inspection	
12	Ways to Express Indoor Comfort			
13	External Environment Conditions			
14	Economic Calculation			

Technical Building Systems										
	Descriptions	**Heating**	**Cooling**	**Ventilation**	**Humidi-fication**	**Dehumidi-fication**	**Domestic Hot water**	**Lighting**	**Building automation & control**	**PV, wind**
		M3	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**	**M11**
	General									
	Needs									
	Maximum Load and Power									
	Ways to Express Energy Performance									
	Emission & control									
	Distribution & control									
	Storage & control									
	Generation & control									
	Load dispatching and operating conditions									
	Measured Energy Performance									
	Inspection									
	BMS									

The shaded modules are not applicable

Unambiguous, but flexible: the "Annex A/Annex B" approach

The "Annex A/Annex B" approach

All EPB standards follow specific rules to ensure overall consistency, unambiguity and transparency.

At the same time, all EPB standards provide a certain flexibility with regard to the methods, the required input data and references to other EPB standards, by the introduction of a normative template in Annex A and Annex B with informative default choices.

For the correct use of the EPB standards, each EPB standard typically contains a normative template in Annex A to specify these choices. And informative default choices are provided in Annex B.

The main target groups for this document are architects, engineers and regulators.

Use by or for regulators:

In case an EPB standard is used in the context of national or regional legal requirements, mandatory choices may be given at national or regional level for such specific applications. These choices (either the informative default choices from Annex B or choices adapted to national / regional needs, but, in any case, following the template of this Annex A) can be made available as national annex or as separate (e.g. legal) document (national data sheet).

Note that in this case:

- the regulators will **specify the choices**;
- the individual user will apply the standard to assess the energy performance of a building, and thereby use the choices made by the regulators

Topics addressed in a standard can be subject to public regulation. Public regulation on the same topics can override the default values in Annex B of the EPB standard. Public regulation on the same topics can even, for certain applications, override the use of the standard. Legal requirements and choices are in general not published in standards, but in legal documents. In order to avoid double publications and difficult updating of double documents, a **national annex** may refer to the legal texts where national choices have been made by public authorities.

Different national annexes or national data sheets are possible, for different applications.

It is expected, if the default values, choices and references to other EPB standards in Annex B are not followed due to national regulations, policy or traditions, that:

- national or regional authorities prepare data sheets containing the choices and national or regional values, according to the model in Annex A. In this case the national annex (e.g. NA) refers to this text;
- or, by default, the national standards body will consider the possibility to add or include a national annex in agreement with the template of Annex A, in accordance to the legal documents that give national or regional values and choices.

Further target groups are parties wanting to motivate their assumptions by classifying the building energy performance for a dedicated building stock.

More information is provided in the Technical Report accompanying the overarching EPB standard, CEN ISO/TR 52000-2 [6].

Step by step implementation

The modular EPB structure and the "Annex A/Annex B" approach, in particular with the option to (preferably for a limited period) reference to a specific national standard instead of a specific EPB standard, strongly facilitates a step by step implementation of the set of EPB standards by individual countries or regions.

Accompanying technical report

The Detailed Technical Rules for the set of EPB standards [7], responding to the mandate M/480 [2], ask for a clear separation between normative and informative contents:

- to avoid flooding and confusing the actual normative part with informative content
- to reduce the page count of the actual standard
- to facilitate understanding of the package

Therefore, each EPB standard or group of EPB standards is accompanied by an informative Technical Report, containing the informative documentation and justification, including worked examples of the accompanied EPB standard.

Accompanying spreadsheet

Also, according to The Detailed Technical Rules [7], and in agreement with the mandate M/480 [2], for each EPB-standard containing calculation procedures an accompanying spreadsheet has been prepared to test and validate the calculation procedure. The spreadsheet also includes a tabulated overview of all output quantities (with references to the EPB module where it is intended to be used as input), all input quantities (with references to the EPB module or other source from where the data are available) and a fully worked example of the application (the calculation method between the set of input and output quantities) for validation and demonstration.

These spreadsheets have been made publicly available at: https://isolutions.iso.org/ecom/public/nen/Livelink/open/35102456

CEN and ISO

Several EPB standards have been prepared or revised as combined EN ISO standards under the so-called Vienna Agreement between CEN and ISO.

Some other CEN and ISO working groups have decided, for practical reasons, for the time being to work in parallel on separate CEN and ISO EPB standards, aiming to keep these as similar as possible, with the aim to merge these to EN ISO standards when the drafting has reached a more mature stage.

Up until now, 17 of the EPB standards are EN ISO standards: the overarching EPB standard, plus the EPB standards on building and building components (ISO/TC 163 in cooperation with CEN/TC 89). The other 30 EPB standards are up until now only available at European (CEN) level.

The intention is to come (eventually) to a complete and consistent set of ISO (EN ISO) standards on the Energy Performance of Buildings (EPB).

A unique Joint Working Group of ISO/TC 163 and ISO/TC 205, ISO/TC 163/WG 4 [10], [11], [12] co-ordinates since 2009 the development of the set of EPB standards at the global (ISO) level, under the responsibility of the two ISO parent TC's.

The ISO 52000 series: consecutive numbering of all new ISO EPB standards

Upon initiative of the above-mentioned ISO Joint Working Group a series of consecutive ISO numbers has been reserved for the EPB standards, based on the modular numbering of items prepared in ISO 52000-1 [8]. The numbers go from ISO 52000 until ISO 52150, with subseries for the successive modules.

This systematic set of consecutive ISO numbers may significantly boost the awareness on this EPB series. Gradually, all new or significantly revised ISO standards that are part of the set of EPB standards can receive the new number from this series.

The list covers both the standards and the corresponding technical reports. The rule is to always number a standard as an odd part number (part 1, part 3, etc.) and the corresponding Technical Report as an even part number (part 2, part 4, etc.).

For instance, the EPB overarching standard received the number EN ISO 52000-1 and the accompanying technical report is CEN ISO/TR 52000-2.

Collecting errata in Final Drafts of the EPB standards during the final voting

Almost all CEN and EN ISO EPB standards and accompanying technical reports are under Final Vote during the period from (roughly) early November 2016 until (roughly) end of January 2017. The precise dates differ per subset. Inevitably, during the evaluation of the standards to prepare the voting, editorial or technical errors are and will be found. The intention is to collect these errata in the form of a standard comment sheet for each relevant standard, at a publicly accessible location at NEN Isolutions.

This will enable the readers to learn which corrections are already envisaged. In particular: for some of the EPB standards, the editors at the central ISO secretariat applied the internal editing rules so strictly, that for instance references to specific paragraphs or terms in other EPB standards were replaced by references to specific paragraphs or terms in the *earlier published drafts* of these standards for Enquiry, because references are only allowed to published documents. ■

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The authors and CTL of CENTC371 also like to acknowledge the good cooperation with the representatives from the EC member states, and, in particular, the initiatives and efforts by the EPBC-CEN Liaison Committee who successfully translated the wishes and needs from the regulators to the EPB standard writers. The informal communication supported by the CA-II and CA-III EPBD programs[1] where several CEN Task Leaders had the opportunity to exchange ideas how to address these wishes and needs from the EU MS regulators.

[1] The Concerted Action supporting transposition and implementation of Directive 2002/91/EC of the European Parliament and of the Council and its recast (CA EPBD III), henceforth CA, is an activity which aims to foster exchange of information and experience among Member States (MS). It involves the national authorities implementing the Directive, or those bodies appointed and entrusted by the national authorities to do so.

References

[1] Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast), OJ 153, 18.6.2010.

[2] Mandate M/480, Mandate to CEN, CENELEC and ETSI for the elaboration and adoption of standards for a methodology calculating the integrated energy performance of buildings and promoting the energy efficiency of buildings, in accordance with the terms set in the recast of the Directive on the energy performance of buildings (2010/31/EU) of 14th December 2010.

[3] EPBD, Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings.

[4] Mandate M/343 Mandate to CEN, CENELEC and ETSI for the elaboration and adoption of standards for a methodology calculating the integrated energy performance of buildings and estimating the environmental impact, in accordance with the terms set forth in Directive 2002/91/EC; 30 January 2004.

[5] Van Dijk, Dick,: Set of recommendations: Towards a second generation of CEN standards related to the Energy Performance of Buildings Directive (EPBD), CENSE "Arching Document 2", CENSE WP6.1_N05rev02, May 27, 2010.

[6] CEN/TS 16628, Energy Performance of Buildings – Basic principles for the set of EPB standards, July 2014.

[7] CEN/TS 16629, Energy Performance of Buildings – Detailed technical rules for the set of EPB standards, July 2014.

[8] EN ISO 52000-1 Energy performance of Buildings – Overarching EPB assessment – Part 1: General framework and procedures.

[9] CEN ISO TR 52000-2, Energy performance of Buildings – Overarching EPB assessment – Part 2: Explanation and justification of ISO 52000-1, ISO/TC 163/WG 4, Energy Performance of Buildings using the Holistic Approach, a joint working group (JWG) of ISO/TC 163, Thermal performance and energy use in the built environment and ISO/TC 205, Building Environment Design. Co-convenors Dick van Dijk (NL) and Essam Khalil (Eg).

[10] Dick (H.A.L.) van Dijk and Essam E. Khalil, Future cities – Building on energy efficiency, ISO Focus+, The magazine of the international organization for standardization, Vol. 2, No 5, May 2011 (theme: Building energy efficiency with ISO standards - Construire l'efficacité énergétique avec les normes ISO).

[11] ISO News. Boosting energy efficiency of buildings through ISO's holistic approach, by Elizabeth Gasiorowski Denis on 5 August 2015. http://www.iso.org/iso/home/news_index/news_archive/news.htm?Refid=Ref1990.

[12] ISO focus January-February 2016, Boosting energy efficiency of buildings. ISO pushes for zero net energy construction worldwide http://www.iso.org/iso/isofocus_114.pdf.

[13] The REHVA European HVAC Journal, issue: "Focus on EPB standards", Vol. 52, Issue 1, January 2015 (various articles).

[14] The REHVA European HVAC Journal, issue: " EPB standards", Volume 53, Issue 3, May 2016 (various articles).

Overview of EPB standards currently out for formal vote at CEN and ISO level

The European Commission asked CEN (mandate M480) to develop standards supporting the application of recast EPBD.

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This overview is presented to illustrate the list of EPB standards currently out for Formal Vote at CEN and ISO level[1]. For most of the standards this final voting will close before the end of January 2017. Voting takes place through the National Standard Bodies (NSB's). Formal Vote implies that NSB's can only accept or not, editorial issues may be reported but technical changes are not possible. If the standard was earlier accepted in the enquiry stage, a similar positive vote in this Formal Vote stage is expected as well. These final vote versions are based on the draft standards (the prEN's) that have been published for enquiry last year. As all comments received during the enquiry have been processed properly it is expected that the outcome of this final vote will be positive. However, it is imperative that all NSB's really cast their votes in due time!

After the positive voting outcome, the NSB's will have the task, during the first months of 2017, to publish these standards. For the CEN members, this also implies that they have to consider to withdraw the conflicting national standards.

Publishing these standards by the NSB's could just include adding a national coversheet where they have the opportunity to include some national information on the role of this standard in the national regulation. Another most important task is to consider if a National Annex A is needed in case the informative default Annex B values and choices are not expected to be applicable. These national Annexes A could be different for different applications such as new buildings and existing buildings and/or different for different building categories (functions) like residential and non-residential. It is expected that the NSB's will publish these national annexes if needed. Given the situation that it may include various stake holders reaching consensus on these values and choices, also taking into account regulator issues, it is expected to require some time to produce these national Annexes if needed.

[1] In this article and all articles on EPB standards in this REHVA journal we use the indication EN or EN ISO before the standard number and leave out the status indication FprEN FDIS xxxxx or FprENxxxxx for standards at Formal (Final) vote level at CEN and ISO and similar for the Technical Report CEN ISO/TR xxxxx and Fpr CEN/TR we also omitted the publication year, which is when omitted 2006.

The set of EPB Standards

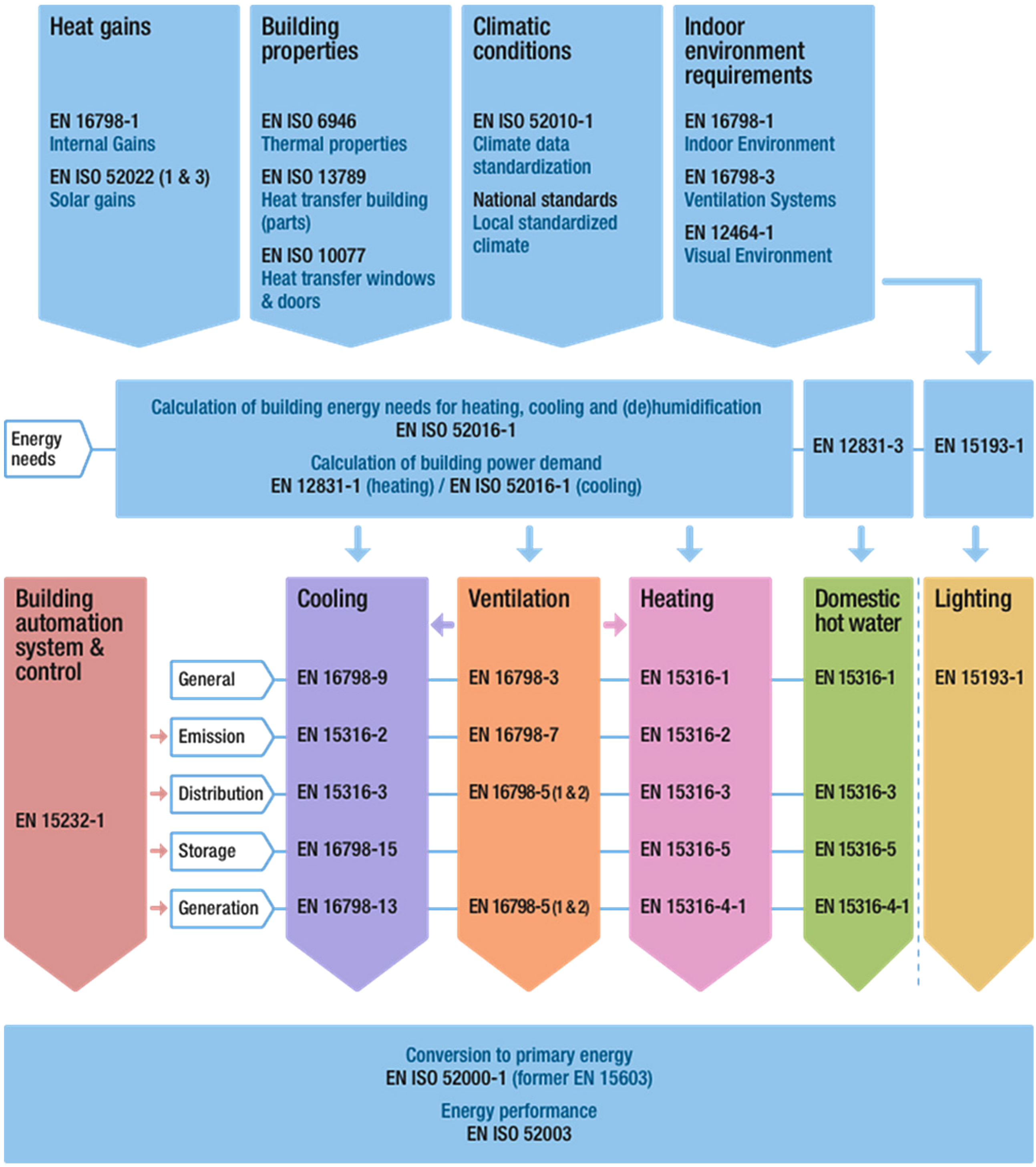
To calculate the energy need and energy use of a building with its installations you need to determine:

- The heat gain: how much free heat by solar and other internal gains (Plug loads, lighting etc.) is entering the building;
- Building properties: The thermal properties of the building envelope and materials of all building elements;
- External climate: the climatic data such as temperatures, humidity, solar data, location/ orientation of the building etc.;
- Indoor environment: the indoor environmental requirements (IEQ) like indoor temperatures, humidity, ventilation rate, lighting and the related assumptions for the user behaviour (schedules for presence and usages).

These input date are the basis for the energy need calculation.

To satisfy the energy needs, the building systems for heating, cooling, humidification, dehumidification, ventilation, domestic hot water and lighting have to provide these IEQ conditions in the most energy efficient way. These calculations are included in the standards related to these systems where the EPB standards related to Building Automation, Controls and Building Management play an important role in reaching the assumed set points.

EPB Standards supporting the implementation of the EU Energy Performance Buildings Directive (EPBD)



The overarching EPB standard

- EN ISO 52000-1 Energy performance of buildings — Overarching EPB assessment — Part 1: General framework and procedures EPB Standards related to Energy Need calculation

EPB Standards related to the Energy Need Calculation

- EN ISO 52022-1 Energy performance of buildings — Thermal, solar and daylight properties of building components and elements — Part 1: Simplified calculation method of the solar and daylight characteristics for solar protection devices combined with glazing
- EN ISO 6946 Building components and building elements — Thermal Resistance and thermal transmittance — Calculation methods
- EN ISO 13789 Thermal performance of buildings — Transmission and ventilation heat transfer coefficients — Calculation method
- EN ISO 10077-1 Thermal performance of windows, doors and shutters — Calculation of thermal transmittance — Part 1: General
- EN 16798-1 (expected 12 -12) Energy performance of buildings — Indoor Environmental Quality — Part 1: Indoor environmental input parameters for the design and assessment of energy performance of buildings.
- EN 16798-3 (expected 12 -12) Ventilation for non-residential buildings — Performance requirements for ventilation, air conditioning and room-conditioning systems
- EN ISO 52016-1 Energy performance of buildings — Energy needs for heating and cooling, internal temperatures and sensible and latent head loads — Part 1: Calculation procedures
- EN 12831-1 Energy performance of buildings — Method for calculation of the design heat load — Part 1: Space heating load, Module M3-3
- EN 12831-3 Energy performance of buildings — Method for calculation of the design heat load — Part 3: Domestic hot water systems heat load and characterisation of needs, Module M8-2, M8-3
- EN 15193-1 Energy performance of buildings – Energy requirements for lighting — Part 1: Specifications, Module M9
- EN ISO 52022-3 Energy performance of buildings — Thermal, solar and daylight properties of building components and elements — Part 3: Detailed calculation method of the solar and daylight characteristics for solar protection devices combined with glazing
- EN ISO 52016-1 Energy performance of buildings — Energy needs for heating and cooling, internal temperatures and sensible and latent head loads — Part 1: Calculation procedures
- EN ISO 52017-1 Energy performance of buildings — Sensible and latent heat loads and internal temperatures — Part 1: Generic calculation procedures
- EN ISO 13786-1 Thermal performance of building components — Dynamic thermal characteristics — Calculation methods
- EN ISO 52010-1 Energy performance of buildings — External climatic conditions — Part 1: Conversion of climatic data for energy calculations

EPB Standards related to Building Automation, Controls and Building Management

- EN 15232-1 Energy Performance of Buildings — Energy performance of buildings — Part 1: Impact of Building Automation, Controls and Building Management — Modules M10-4,5,6,7,8,9,10
- EN 12098-1 Energy Performance of Buildings — Controls for heating systems — Part 1: Control equipment for hot water heating systems — Modules M3-5, 6, 7, 8
- EN 12098-3 Energy Performance of Buildings — Controls for heating systems — Part 3: Control equipment for electrical heating systems — Modules M3-5,6,7,8
- EN 12098-5 Energy Performance of Buildings — Controls for heating systems — Part 5: Start-stop schedulers for heating systems — Modules M3-5,6,7,8
- EN 15500-1 Energy Performance of Buildings — Control for heating, ventilating and air conditioning applications — Part 1: Electronic individual zone control equipment — Modules M3-5, M4-5, M5-5
- EN 16946-1 Energy Performance of Buildings — Inspection of Automation, Controls and Technical Building Management — Part 1: Module M10-11
- EN 16947-1 Energy Performance of Buildings — Building Management System — Part 1: Module M10-12

EPB Standards related to Cooling

- EN 16798-5-1 Energy performance of buildings — Modules M5-6, M5-8, M6-5, M6-8, M7-5, M7-8 — Ventilation for buildings — Calculation methods for energy requirements of ventilation and air conditioning systems — Part 5-1 Distribution and generation — Method 1

- EN 15316-2 Energy performance of buildings — Part 18: Ventilation for buildings — Module M4-11, M5-11, M6-11, M7-11 — Guidelines for inspection of ventilation and air conditioning systems — Technical report — Interpretation of the requirements in EN 16798-17
- EN 15316-3 Energy performance of buildings — Method for calculation of system energy requirements and system efficiencies — Part 3: Space distribution systems (DHW, heating and cooling), Module M3-6, M4-6, M8-6
- EN 16798-15 Energy performance of buildings — Part 15: Module M4-7 — Calculation of cooling systems — Storage
- EN 16798-13 Energy performance of buildings — Part 13: Module M4-8 — Calculation of cooling systems
- EN 15316-4-2 Energy performance of buildings — Method for calculation of system energy requirements and system efficiencies — Part 4-2: Space heating generation systems, heat pump systems, Module M3-8-2, M8-8-2
- EN 15316-4-5 Energy performance of buildings — Method for calculation of system energy requirements and system efficiencies — Part 4-5: District heating and cooling, Module M3-8-5, M4-8-5, M8-8-5, M11-8-5
- EN 16798-17 Energy performance of buildings — Part 17: Ventilation for buildings — Guidelines for inspection of ventilation and air conditioning systems, Module M4-11, M5-11, M6-11, M7-11

EPB Standards related to Ventilation and to Humidification and Dehumidification

- EN 16798-3 (per 2016-12-12) Energy performance of buildings — Part 3: Ventilation for non-residential buildings — Performance requirements for ventilation and room-conditioning systems
- EN 16798-7 Energy performance of buildings — Part 7: Ventilation for buildings — Modules M5-1, M5-5, M5-6, M5-8 — Calculation methods for the determination of air flow rates in buildings including infiltration
- EN 16798-5-1 Energy performance of buildings — Modules M5-6, M5-8, M6-5, M6-8, M7-5, M7-8 — Ventilation for buildings — Calculation methods for energy requirements of ventilation and air conditioning systems — Part 5-1 Distribution and generation — Method 1
- EN 16798-5-2 Energy performance of buildings — Modules M5-6,.2 M5-8 .2— Ventilation for buildings — Calculation methods for energy requirements of ventilation systems — Part 5-2: Distribution and generation (revision of EN 15241) — Method 2
- EN 15500-1 Energy Performance of Buildings — Control for heating, ventilating and air conditioning applications — Part 1: Electronic individual zone control equipment — Modules M3-5, M4-5, M5-5
- EN 16798-17 Energy performance of buildings — Part 17: Ventilation for buildings — Guidelines for inspection of ventilation and air conditioning systems, Module M4-11, M5-11, M6-11, M7-11

EPB Standards related to Heating

- EN 15316-1 Energy performance of buildings — Method for calculation of system energy requirements and system efficiencies — Part 1: General and Energy performance expression, Module M3-1, M3-4, M3-9, M8-1, M8-4
- EN 15316-2 Energy performance of buildings — Method for calculation of system energy requirements and system efficiencies — Part 2: Space emission systems (heating and cooling), Module M3-5, M4-5
- EN 15316-3 Energy performance of buildings — Method for calculation of system energy requirements and system efficiencies — Part 3: Space distribution systems (DHW, heating and cooling), Module M3-6, M4-6, M8-6
- EN 15316-5 Energy performance of buildings — Method for calculation of system energy requirements and system efficiencies — Part 5: Space heating and DHW storage systems (not cooling), M3-7, M8-7
- EN 12098-1 Energy Performance of Buildings — Controls for heating systems — Part 1: Control equipment for hot water heating systems — Modules M3-5, 6, 7, 8
- EN 15316-4-1 Energy performance of buildings — Method for calculation of system energy requirements and system efficiencies — Part 4-1: Space heating and DHW generation systems,
- EN 15316-4-2 Energy performance of buildings — Method for calculation of system energy requirements and system efficiencies — Part 4-2: Space heating generation systems, heat pump systems, Module M3-8-2, M8-8-2
- EN 15316-4-3 Energy performance of buildings — Method for calculation of system energy requirements and system efficiencies — Part 4-3: Heat generation systems, thermal solar and photovoltaic systems, Module M3-8-3, M8-8-3, M11-8-3
- EN 15316-4-4 Heating systems and water based cooling systems in buildings — Method for calculation of system energy requirements and

system efficiencies — Part 4-4: Heat generation systems, building-integrated cogeneration systems

- EN 15316-4-5 Energy performance of buildings — Method for calculation of system energy requirements and system efficiencies — Part 4-5: District heating and cooling, Module M3-8-5, M4-8-5, M8-8-5, M11-8-5
- EN 15316-4-8 Energy performance of buildings — Method for calculation of system energy requirements and system efficiencies — Part 4-8: Space heating generation systems, air heating and overhead radiant heating systems, including stoves (local), Module M3-8-8
- EN 15378-3 Energy performance of buildings — Heating and DHW systems in buildings — Part 3: Measured energy performance, Module M3-10, M8-10
- EN 15378-1 Energy performance of buildings — Heating systems and DHW in buildings — Part 1: Inspection of boilers, heating systems and DHW, Module M3-11, M8-11
- EN ISO 13789 Thermal performance of buildings — Transmission and ventilation heat transfer coefficients — Calculation method
- EN ISO 13370 Thermal performance of buildings — Heat transfer via the ground — Calculation methods
- EN ISO 6946 Building components and building elements — Thermal Resistance and thermal transmittance — Calculation methods
- EN ISO 10211 Thermal bridges in building construction — Heat flows and surface temperatures — Detailed calculations
- EN ISO 14683 Thermal bridges in building construction — Linear thermal transmittance — Simplified methods and default values
- EN ISO 10077-1 Thermal performance of windows, doors and shutters — Calculation of thermal transmittance — Part 1: General
- EN ISO 10077-2 "Thermal performance of windows, doors and shutters — Calculation of thermal transmittance — Part 2: Numerical method for frames"
- EN ISO 12631 Thermal performance of curtain walling — Calculation of thermal transmittance

EPB Standards related to Domestic Hot Water Systems

- EN 15316-1 Energy performance of buildings — Method for calculation of system energy requirements and system efficiencies — Part 1: General and Energy performance expression, Module M3-1, M3-4, M3-9, M8-1, M8-4
- EN 15316-3 Energy performance of buildings — Method for calculation of system energy requirements and system efficiencies — Part 3: Space distribution systems (DHW, heating and cooling), Module M3-6, M4-6, M8-6
- EN 15316-5 Energy performance of buildings — Method for calculation of system energy requirements and system efficiencies — Part 5: Space heating and DHW storage systems (not cooling), M3-7, M8-7
- EN 15316-4-1 Energy performance of buildings — Method for calculation of system energy requirements and system efficiencies — Part 4-1: Space heating and DHW generation systems, combustion systems (boilers, biomass), Module M3-8-1, M8-8-1
- See also the EPB standards on generation systems on Heat Pumps, Solar, Cogen, District Heating and Inspection.
- EN 15378-3 Energy performance of buildings — Heating and DHW systems in buildings — Part 3: Measured energy performance, Module M3-10, M8-10

EPB standard related to Lighting

- EN 15193-1 Energy performance of buildings — Energy requirements for lighting — Part 1: Specifications, Module M9

EPB Standards on expressing the Energy Performance Buildings

- EN ISO 52000-1 Energy performance of buildings — Overarching EPB assessment — Part 1: General framework and procedures
- EN ISO 52003-1 Energy performance of buildings — Indicators, requirements, ratings and certificates — Part 1: General aspects and application to the overall energy performance
- EN ISO 52018-1 Energy performance of buildings — Indicators for partial EPB requirements related to thermal energy balance and fabric features — Part 1: Overview of options
- EN 15459-1 Energy performance of buildings — Heating systems and water based cooling systems in buildings — Part 1: Economic evaluation procedure for energy systems in buildings, Module M1-14
- In Table B.1 from EN ISO TR 52000-2 the standards numbers are all included in the modular structure of the set of EPB standard.

Table B.1. Positions of EPB standards in the EPB modular structure.

Overarching			Building (as such)			Technical Building Systems		
	DESC [b]	ST [c]		DESC [b]	ST [c]		DESC [b]	H
sub1	M1		sub1	M2		sub1		M3
1	General	ISO 520001 ISO/TR 520002	1	General	--	1	General	EN 15316-1
2	Common terms and definitions; symbols, units and subscripts	ISO 520001 ISO/TR 520002	2	Building Energy Needs	ISO 520161, ISO 520171 ISO/TR 520162	2	Needs	
3	Applications	ISO 520001 ISO/TR 520002	3	(Free) Indoor Conditions without Systems	ISO 520161, ISO 520171 ISO/TR 520162	3	Maximum Load and Power	EN 12831-1
4	Ways to Express Energy Performance	ISO 520031 ISO 520032	4	Ways to Express Energy Performance	ISO 520181 ISO/TR 520182	4	Ways to Express Energy Performance	EN 15316-1
5	Building Functions and Building Boundaries	ISO 520001 ISO/TR 520002	5	Heat Transfer by Transmission	ISO 13789 ISO 13370 ISO 6946 ISO 10211 ISO 14683 ISO/TR 520192 ISO 100771 ISO 100772 ISO 12631	5	Emission & control	EN 15316-2 EN 1500 CEN/TR 15500 EN 12098-1 CEN/TR 12098-1 EN 12098-3 CEN/TR 12098-3 EN 12098-5 CEN/TR 12098-5
6	Building Occupancy and Operating Conditions	EN 16798-1 CEN/TR 16798-2 (ISO 177721, ISO/TR 177722)	6	Heat Transfer by Infiltration and Ventilation	ISO 13789	6	Distribution & control	EN 15316-3 EN 12098-1 CEN/TR 12098-1 EN 12098-3 CEN/TR 12098-3 EN 12098-5 CEN/TR 12098-5
7	Aggregation of Energy Services and Energy Carriers	ISO 520001 ISO/TR 520002	7	Internal Heat Gains	See M1-6	7	Storage & control	EN 15316-5 EN 12098-1 CEN/TR 12098-1 EN 12098-3 CEN/TR 12098-3 EN 12098-5 CEN/TR 12098-5
8	Building Zoning	ISO 520001 ISO/TR 520002	8	Solar Heat Gains	ISO 520223 ISO 520221 ISO/TR 520222	8	Generation & control	EN 12098-1 CEN/TR 12098-1 EN 12098-3 CEN/TR 12098-3 EN 12098-5 CEN/TR 12098-5 EN 15316-4-1 EN 15316-4-2 EN 15316-4-3 EN 15316-4-4 EN 15316-4-5 EN 15316-4-6 EN 15316-4-8
9	Calculated Energy Performance	ISO 520001 ISO/TR 520002	9	Building Dynamics (thermal mass)	ISO 13786	9	Load dispatching and operating conditions	
10	Measured Energy Performance	ISO 520001 ISO/TR 520002	10	Measured Energy Performance	- -	10	Measured Energy Performance	EN 15378-3
11	Inspection	- -	11	Inspection	(existing standards on IR inspection, airtightness, ...)	11	Inspection	EN 15378-1
12	Ways to Express Indoor Comfort	EN 16798-1 CEN/TR 16798-2 (ISO 177721, ISO/TR 177722)	12	--		12	BMS	
13	External Environment Conditions	ISO 520101 ISO/TR 520102						
14	Economic Calculation	EN 15459-1						

C	V	HUM	DHUM	DHW	L	BACS	EL
M4	M5	M6	M7	M8	M9	M10	M11
EN 16798-9 CEN/TR 16798-10	EN 16798-3 (EN 13779 rev.) CEN/TR 16798-4	EN 16798-3 (EN 13779 rev.) CEN/TR 16798-4	EN 16798-3 (EN 13779 rev.) CEN/TR 16798-4	EN 15316-1	EN 15193-1	EN 15232 CEN/TR 15232	
				EN 12831-3	EN 15193-1	a	
EN 16798-11 CEN/TR 16798-12				EN 12831-3			
EN 16798-9 CEN/TR 16798-10	EN 16798-3 (EN 13779 rev.) CEN/TR 16798-4	EN 16798-3 (EN 13779 rev.) CEN/TR 16798-4	EN 16798-3 (EN 13779 rev.) CEN/TR 16798-4	EN 15316-1	EN 15193-1 CEN/TR 15193-2	EN 15232 CEN/TR 15232	
EN 15316-2 EN 15500 CEN/TR 15500	EN 16798-7 CEN/TR 16798-8 EN 15500 CEN/TR 15500	EN 16798-5-1; EN 16798-5-2 CEN/TR 16798-6-1 CEN/TR 16798-6-2	EN 16798-5-1; EN 16798-5-2 CEN/TR 16798-6-1 CEN/TR 16798-6-2			EN 15232 CEN/TR 15232	
EN 15316-3	EN 16798-5-1; EN 16798-5-2 CEN/TR 16798-6-1 CEN/TR 16798-6-2			EN 15316-3		EN 15232 CEN/TR 15232	
EN 16798-15 CEN/TR 16798-16				EN 15316-5 EN 15316-4-3		EN 15232 CEN/TR 15232	
EN 16798-13 CEN/TR 16798-14 EN 15316-4-2 EN 15316-4-5	EN 16798-5-1; EN 16798-5-2 CEN/TR 16798-6-1 CEN/TR 16798-6-2	EN 16798-5-1; EN 16798-5-2 CEN/TR 16798-6-1 CEN/TR 16798-6-2	EN 16798-5-1; EN 16798-5-2 CEN/TR 16798-6-1 CEN/TR 16798- 6-22	EN 15316-4-1 EN 15316-4-2 EN 15316-4-3 EN 15316-4-4 EN 15316-4-5 EN 15316-4-6		EN 15232 CEN/TR 15232	EN 15316-4-3 EN 15316-4-4 EN 15316-4-5 EN 15316-4-7
						EN 15232 CEN/TR 15232	
				EN 15378-3	EN 15193-1 CEN/TR 15193-2	EN 15232 CEN/TR 15232	
EN 16798-17 CEN/TR 16798-18	EN 16798-17 CEN/TR 16798-18	EN 16798-17 CEN/TR 16798-18	EN 16798-17 CEN/TR 16798-18	EN 15378-1	EN 15193-1 CEN/TR 15193-2		

[a] The shaded modules are not applicable [b] DESC = Description [c] ST = Standard reference

EN ISO 52010, the overarching EPB standard on external environment conditions

The new standard EN ISO 52010-1 provides the common standard climatic data to be used as input by all EPB standards. It builds on EN ISO 15927 (part 1, 2, and 4) and completes a missing link: the calculation of the distribution of solar irradiation and illuminance on a non-horizontal plane based on measured hourly solar radiation data on a horizontal surface; with or without taking into account solar shading.

Keywords: energy performance of buildings, EPB, EPB standards, EPB regulations, climatic data, solar radiation, daylight, Perez model.

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Standard EN ISO 52010-1 [1], accompanied by the technical report CEN ISO/TR ISO 52010-2 [2], provides the common standard climatic data to be used for all relevant EPB standards. It gives procedures to calculate the hourly distribution of solar irradiation on a non-horizontal plane based on measured hourly solar radiation data on a horizontal surface, obtained from EN ISO 15927 (part 1, 2 and 4) [3]. The calculation procedure described in this standard is based on the widely used "simplified Perez model" [4] proposed in the early 90's.

The procedures include assumptions to assess the impact of surrounding obstacles on the irradiation (shading). A simple method for conversion of hourly solar irradiance to illuminance is provided.

The technical report CEN ISO/TR ISO 52010-2 provides background information, explanation (including examples) and justification (including validation cases).

Main output

The main output from EN ISO 52010-1 is the solar irradiance and illuminance on a surface with arbitrary orientation and tilt, needed as input for energy and daylighting calculations.

Shading by distant objects is (optionally) taken into account through a shading correction coefficient, Shading by fins and overhangs is calculated in EN ISO 52016-1 [5].

The standard contains procedures for the use of (other) output from EN ISO 15927 (part 1, 2, and 4) [3] as input for the EPB assessment, such as:

- air temperature;
- atmospheric humidity;
- wind speed;
- precipitation;
- solar radiation;
- longwave radiation.

The reason for passing these data via this standard is to have one single and consistent source for all EPB standards and to enable any conversion or other treatment if needed for specific application.

Accompanying spreadsheet

In line with the common template for all EPB standards, a spreadsheet has been prepared for demonstration and validation. This spreadsheet shows an overview of all input variables, the (step by step) hourly calculation procedures and an overview of all output variables.

This accompanying calculation spreadsheet (July 2016) provides:

- full year of hourly calculations of solar irradiance (split in components) on a plane with any azimuth and tilt angle;
- validated against BESTEST cases;
- hourly calculations of solar shading by multiple shading objects along the skyline. These calculations also cover the calculation procedures for overhangs from EN ISO 52016 1 [5]; see parallel article Van Dijk on EN ISO 52016 & EN ISO 52017.

Flexibility

Options for national choices provided in "Annex A/ Annex B" of EN ISO 52010-1 comprise:

- Selection of hourly measured climatic data set.
- Different choices of type of measured irradiation, depending on availability.
- Value(s) for ground reflectivity.
- Include or exclude impact of solar shading by external objects. If excluded: the solar shading calculation is done in application standards, such as EN ISO 52016-1, enabling to calculate the impact of all shading objects in a coherent way without duplications. If included: a choice is given between different levels of detail.
- Choice between the given simplified Illuminance calculation method or alternative methods.

Validation

The calculation procedures have been validated by using relevant cases from the so called BESTEST series. The BESTEST cases are well established since decades, widely used worldwide and well described. More background information is given in the technical report, CEN ISO/TR 52010-2. Relevant BESTEST cases are also chosen for the validation of the hourly calculation procedures of EN ISO 52016-1, as presented in the parallel article (see also previous article [6]).

Figures 1-3 show examples of the results of the validation cases. The validation cases concern the hourly calculation of the solar irradiation at vertical planes, using the measured data from a given climate data file.

The results of the comparison show that the method in EN ISO 52010-1 is very fit for purpose. It has to be taken into consideration that not each software program whose results are available for the comparison use nowadays state-of-the-art algorithms (in that sense these are not

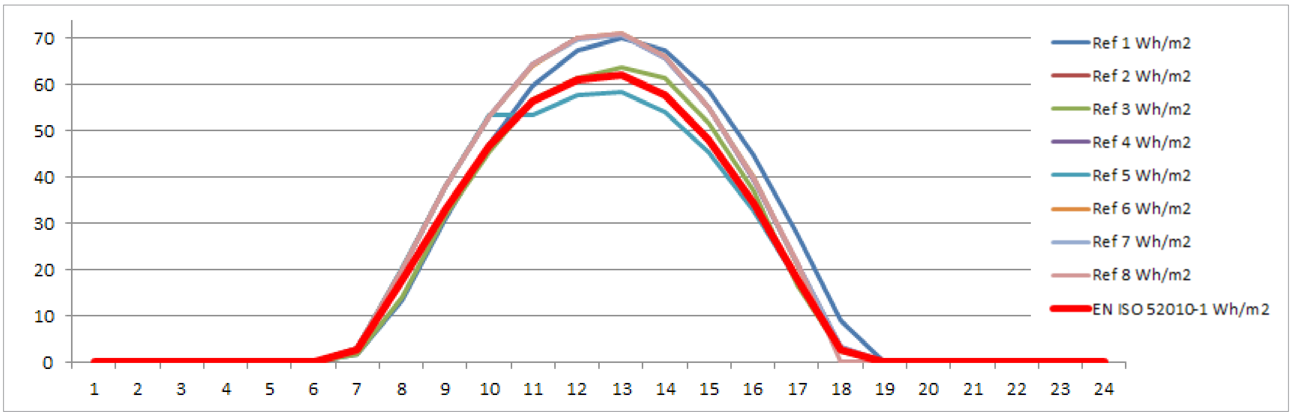

Figure 1. BESTEST validation result: Hourly irradiation on vertical West plane, cloudy day.

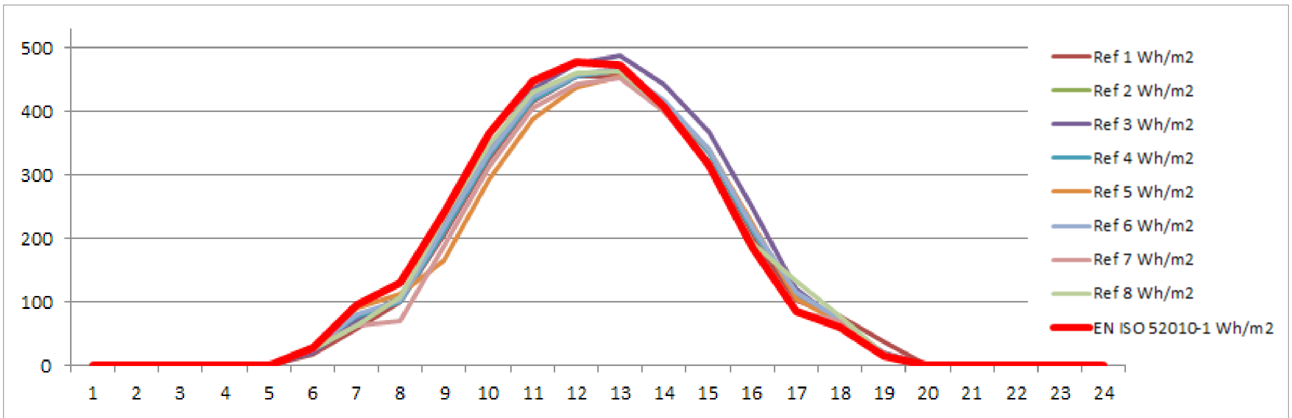

Figure 2. BESTEST validation result: Hourly irradiation on vertical South plane, clear day.

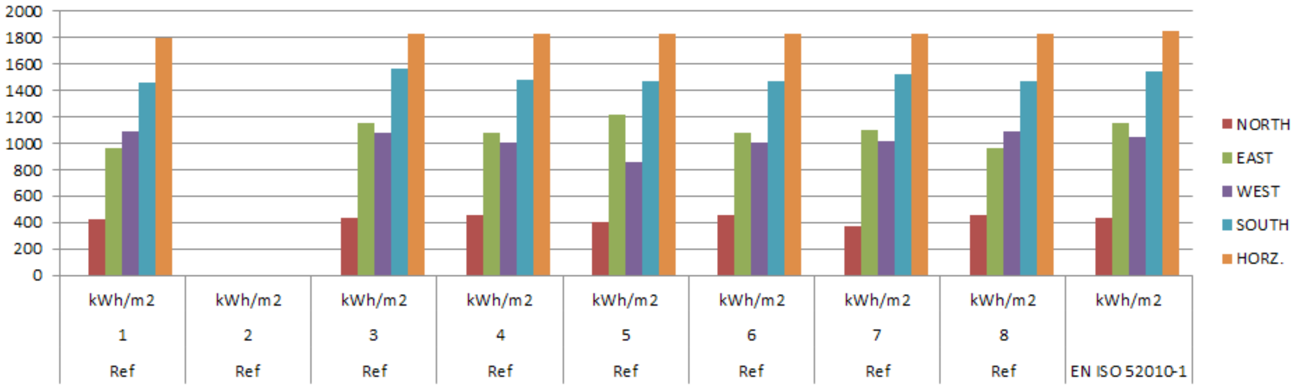

Figure 3. BESTEST validation result: Annual solar radiation on five different planes.

reference results). This is because these base cases of the BESTEST series were created and tested many years ago.

More tests are described in the technical report, CEN ISO/TR 52010-2.

Conclusion

The new EN ISO 52010-1 completes the (until now) missing link in the conversion of climatic data for energy calculations. The procedures have been validated. Choices are possible at national or regional level to accommodate the specific national or regional situation. ■

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EN ISO 52003 and EN ISO 52018: making good use of the EPB assessment outputs

Documents EN ISO 52003-1 & -2 and EN ISO 52018-1 & -2 describe the relation between the indicators to express the various energy performances of buildings (EPB) and the EPB requirements and EPB ratings. These documents provide general insight to private prescribers and public regulators (and all stakeholders involved) on how to make purpose-oriented use of the outputs of the EPB assessment methods.

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These 2 EN ISO standards (i.e. parts 1) [1] [2] and their accompanying technical reports (i.e. parts 2) [3] [4] are of an unusual nature in the set of EPB documents. As a rule, the EPB assessment documents concern inspections/measurements or calculations. The documents at hand concern neither of these aspects, but deal with the productive use of the output (EPB indicators) of the assessment standards for setting requirements, for rating, or for other possible applications. This can be called the "post processing" of the results of the EPB assessment.

The documents EN ISO 52003-1 & -2 deal with the general principles and their application to the overall energy performance. Documents EN ISO 52018-1 & -2 concern their application to various fabric features and to the thermal energy balances for heating, cooling or free floating temperatures (overheating and/or undercooling).

By describing explicitly different aspects related to the development of EPB regulations, all parties involved can gain a better and explicit understanding of the issues at hand, thus facilitating the policy making process. In the case of public regulations, the parties include not only the regulators themselves, but also all stakeholders involved in the policy development, notably diverse organizations representing citizens, designers, supply industry, construction companies, craftsmen, etc.

EN ISO 52003-1 & -2: general principles and overall energy performances

Successively, the following concepts are defined and discussed in the standard and its associated technical report (both replacing EN 15217 and ISO 16343):

- EPB features
- Numerical EPB indicators
- Tailoring for requirements and for ratings
- EPB requirements
- EPB rating
- EPB certificate

Several of these aspects are described in more detail in a previous REHVA article [5] and are not repeated here.

EN ISO 52018-1 & -2: thermal energy balance and fabric features

These documents are new. They list and discuss a variety of possible partial EPB features and indicators for requirements related to the thermal energy balances and to the fabric, notably summer and winter (free floating) thermal comfort, energy needs for heating and cooling, overall envelope thermal insulation, individual element thermal insulation, thermal bridges, window energy performances, envelope air tightness and solar control.

In the standard itself (i.e. in part 1) [2] a very brief possible motivation for each possible requirement is given and different possible EPB indicators are described that can be used for each feature. Annex A provides tables that allow regulators to report in a standardized manner the mix of EPB features and corresponding EPB indicators that have been chosen for the requirements in their jurisdiction. Annex B proposes motivated default requirement mixes for different climates.

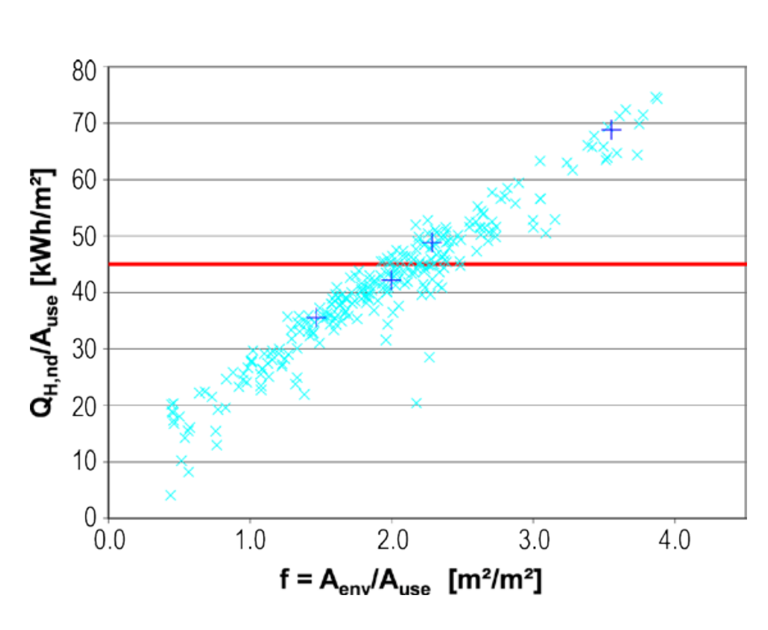

Figure 1. Example of the impact of a fixed (constant value) requirement versus a more appropriate variable value (tailored).

The technical report (i.e. part 2) [4] formulates for each EPB feature background considerations with respect to the following aspects (in as far as applicable): a more detailed discussion of possible motivations, possible indicators, comparable economic strictness of the requirements, practical points of attention, testing, new construction and renovation issues, exceptions and other possible aspects.

Part 2 also illustrates in its annex A a practical manner in which fictitious cooling can be integrated in the overall energy performance by means of a conventional probability weighting factor. In this way, an energy efficient overall design can be stimulated that strikes a good balance between summer and winter thermal comfort.

As explained in EN ISO 52003 ([1], [3] and [5]), for some EPB features/indicators the numeric value that corresponds to the technical and economic optimum often varies strongly from 1 construction project to another, depending on function, size, shape, etc. In order to treat all buildings in the same manner (e.g. reflecting the same technical and economic strictness), it is for these indicators thus of crucial importance to use variable value requirements or references that take into account all relevant project-specific features of each individual building. This is called tailoring.

Figure 1 illustrates on the basis of some 200 real dwelling shapes (each individual cross) how for a given set of technical measures (level of overall thermal insulation, degree of airtightness, energy efficiency of the ventilation system, etc.) the numeric value of the specific heating need (i.e. the heating need per useful floor area) can strongly vary from one project to another. The x-axis is the ratio of the envelope area to the useful floor area. This numeric variability of equal technical-economic strictness obviously explains, in combination with other potentially variable factors, the similar variability of the overall energy performance; see Figure 4 in [5].

If the reference value that is used to set a requirement is a fixed value (in casu: requirement expressed as a constant maximum value in kWh/m² disregarding building shape or size: e.g. red horizontal line), then buildings with a relatively large envelope area[1] (compared to the floor area) would need a large technological-economic effort to meet the requirement, while on the other hand buildings with a relatively small envelope area would need only a small technological- economic effort to meet the same requirement. Such mismatch would correspond to a suboptimal use of investments both

[1] I.e. to the right of the graph. For instance small detached dwellings.

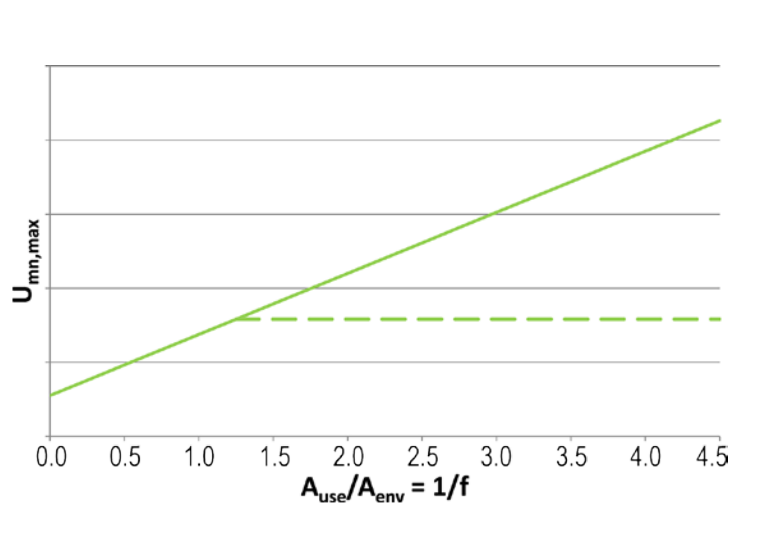

Figure 2. Motivated example of a curve for the maximum mean thermal transmittance as a function of the inverse of the shape factor.

on a societal and on a private level. A more equitable reference for the requirement takes into account this variation and determines project-specific, tailored quantitative requirements.

A more detailed discussion of the graph and further analysis and illustrations of the issue for the specific heating need can be found in annex B of EN ISO 52018-2 [4].

A similar issue arises with a requirement on the mean thermal transmittance of the thermal envelope. It is commonly accepted that the adequate amount of glazing needs to increase with the useful floor area: the broader the building is the more glass is needed for sufficient daylight access and visual outdoor contact. As in practice, the thermal transmittance of transparent elements (windows, etc.) is (due to physical-technical and economic reasons) typically much higher than that of opaque envelope elements, an increasing share of transparent area in the envelope (which reasonably, is thus approximately proportional to the useful floor area) leads to a requirement that increases linearly with the floor to envelope ratio (i.e. the inverse of the shape factor), as illustrated in **Figure 2**. The minimum value of the straight line (for an x-value of 0) corresponds to the (average) thermal transmittance requirement for the opaque elements. The slope of the line depends on the features of the transparent elements: the reasonable fraction as a function of the useful floor area, and their thermal transmittance requirement.

There are however logical limits to the maximal mean thermal transmittance. It should never be larger than value of transparent elements, and in addition, not the entire envelope needs to be glazed: floors are usually opaque, roofs are opaque or only need to be partially transparent, and parts of the facades below the working plane, which do not meaningfully contribute to daylighting anymore, generally do not need transparent elements. In general, the maximum limited is therefore restricted to a constant value above a certain A_{use}/A_{env} value. This is illustrated with the dashed line in **Figure 2**.

Conclusion

Documents EN ISO 52003-1 & -2 and EN ISO 52018-1 & -2 document in a critical manner useful knowledge, distilled from decades-long experiences, that supports politicians/regulators and stakeholders in taking well-informed decisions, optimally tailored to their own jurisdiction. In this manner a well-considered EPB regulation can be developed that matches the sophistication of the EPB assessment methods. ■

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EN ISO 52016 and 52017:

Calculation of the building's energy needs for heating and cooling, internal temperatures and heating and cooling load

EN ISO 52016-1 presents a coherent set of calculation methods at different levels of detail, for the (sensible) energy needs for the space heating and cooling and (latent) energy needs (de-)humidification of a building and/or internal temperatures and heating and/or cooling loads, including the influence from technical buildings systems, control aspects and boundary conditions where relevant for the calculation. EN ISO 52017-1 contains a generic (reference) hourly calculation method. Extensive explanation and justification is given in the accompanying CEN ISO/TR 52016-2.

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Keywords: energy performance of buildings, EPB, EPB regulations, heating need, cooling need, thermal balance, indoor temperature, heating load, cooling load.

EN ISO 52016-1

EN ISO 52016-1 presents a coherent set of calculation methods at different levels of detail, for the (sensible) energy needs for the space heating and cooling and (latent) energy needs (de-)humidification of a building and/or internal temperatures and heating and/or cooling loads.

The effect of specific system properties can also be taken into account, such as the maximum heating or cooling power and the impact of specific system control provisions. This leads to **system-specific energy loads and needs**, in addition to the **basic energy loads and needs**.

EN ISO 52016-1 contains both **hourly** and **monthly** calculation procedures. These are closely linked as explained further on.

Link between EN ISO 52017-1 and EN ISO 52016-1

EN ISO 52017-1 is not needed for the actual calculation of the energy performance of buildings. EN ISO 52017-1 contains a generic (reference) hourly calculation method for (a thermal zone in) a building.

The reference method in EN ISO 52017-1 is based on and replaces EN ISO 13791. EN ISO 52017-1 contains no specific assumptions, boundary conditions, specific simplifications or input data that are not needed to apply the generic calculation method. Compared with EN ISO 13791 the energy needs for heating and cooling are added to increase the application range. This standard does not include validation cases (unlike EN ISO 13791). For validation, specific assumptions and input data would need to be given that only apply to the validation cases. To keep a clear distinction between the generic method and a specific application, verification and validation cases are adopted in EN ISO 52016-1.

EN ISO 52016-1 replaces EN ISO 13790:2008. It contains an hourly calculation method and a monthly calculation method. The hourly calculation method is a specific application of the generic method provided in EN ISO 52017-1.

EN ISO 52016-1 further contains specific boundary conditions, specific simplifications and input data for the application: calculation of energy needs for heating and cooling. Amended simplifications and input data are provided for the application to calculate the design heating and design cooling load and (e.g. summer) internal temperatures.

In this way the generic calculation method (EN ISO 52017-1) is clearly separated from the specific application with all specific assumptions, simplifications and specific input data (EN ISO 52016-1).

The **hourly** method in EN ISO 52016-1 produces as additional output the key parameters needed to generate parameters for the **monthly** calculation method. This means that a number of (nationally) representative cases can be run with the hourly method and from the output, the key monthly parameters for the different cases, the monthly correlation factors can be derived. See flow chart in **Figure 1**.

Input-output relations between EN ISO 52016-1 and other standards of the set of EPB standards

In a previous REHVA Special on the EPB standards [4] the many links of EN ISO 52016-1 with other EPB standards were introduced. Special attention in this respect has been paid to testing the link with the procedures to calculate the thermal transmission through the **ground floor**, taking into account the inertia of the ground. These procedures are given in EN ISO 13370 (see parallel article by Mrs Kosmina) for monthly, but also for hourly calculation methods.

The hourly climatic data are given in EN ISO 52010-1 and the hourly and daily patterns of the conditions of use (operating schedules) are given in the relevant other EPB standards.

More details on the many inputs from and many interactions with many other EPB standards are given in CEN ISO/TR 52016-2.

Hourly versus monthly calculation method

The hourly and the monthly method in EN ISO 52016-1 are closely linked: they use as much as possible the same input data and assumptions. And the hourly method can be used to generate the parameters for the monthly calculation method, as shown above (**Figure 1**).

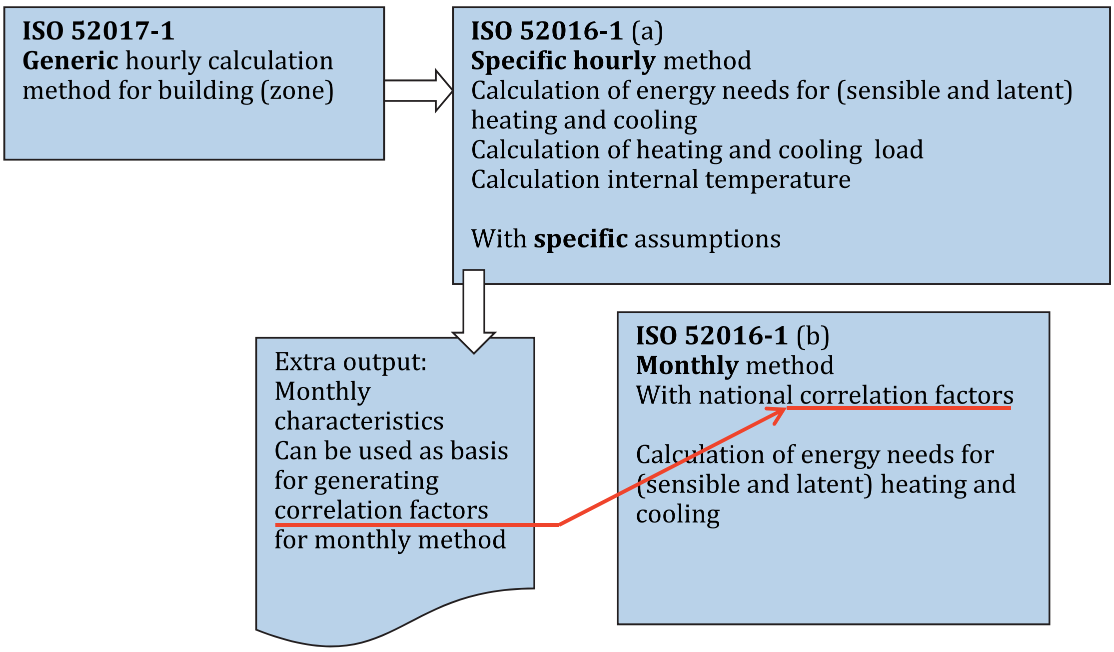

Figure 1. The relation between EN ISO 52016-1 and EN ISO 52017-1.

The hourly method in EN ISO 52016-1 is more advanced than the simplified hourly method given in EN ISO 13790:2008, to make the method more transparent and more widely usable, without asking more input data from the user. This was already explained in a previous article [5].

The main goal of the hourly calculation method compared to the monthly method is to be able to take into account the influence of hourly and daily variations in weather, operation (solar blinds, thermostats, heating and cooling needs, occupation, heat accumulation, etc.) and their dynamic interactions for heating and cooling.

Design heating and cooling load in EN ISO 52016-1

Upon request of CEN/TC 156, the method to calculate the design heating and cooling and latent heat load from prEN 16798-11:2015, prepared by CEN/TC 156, has been integrated in EN ISO 52016-1.

EN ISO 52016-1 includes specification of the method and the boundary conditions for the calculation of the design heating and cooling load, including latent load, as a basis for the dimensioning of equipment on zone level and on central level for cooling and dehumidification. It specifies also the methods and conditions for the calculation of the humidification load.

The method given for the design **heat** load is intended especially for the cases where the **cooling** load calculation needs to be done (for instance when cooling is necessary) and/or an **hourly** calculation is used for the energy needs calculation. The principle idea is that there is only one method needed for load and energy calculations for heating and cooling in case of an hourly calculation interval.

If the design heating load is calculated with another (e.g. simplified) calculation method, such as EN 12831-1, the many input data are for 90% the same as for the energy needs calculation according to EN ISO 52016-1. It is advisable to check if duplication of gathering these input data could be avoided.

Flexibility

Options for national choices provided in "Annex A/ Annex B" of EN ISO 52016-1 comprise:

- References to other EPB or national standards.
- Selection of hourly or monthly method.
- Rules for thermal zoning.
- Simplifications (at various levels).
- Specific details of the hourly calculation method (solution technique, internal modelling of constructions, IR radiation exchange).
- Classification of constructions (e.g. thermal capacity of opaque constructions, solar energy transmittance of solar shading devices).
- (Fixed) values for specific assumed properties.
- Specific solar shading assumptions and simplifications.
- Values for various correlation factors of the monthly calculation method.

Annex C of EN ISO 52016-1 gives a choice in references to other CEN (for CEN area) or ISO (elsewhere) standards that provide thermal, solar or daylight properties of (single or multiple) glazings and/or windows.

Accompanying spreadsheet

An extensive spreadsheet was produced on EN ISO 52016-1, covering both the hourly and the monthly calculation method. Examples of the calculation sheet can be found in CEN ISO/TR 52016-2. The (publicly available) spreadsheet is available since May 2015, based on the draft (prEN ISO/DIS 52016-1). It is intended to update the spreadsheet (symbols, numbering of formulae, minor changes in the calculation method, minor errata) before publication of the standard.

No spreadsheet was produced on EN ISO 52017-1, because this EPB standard (with reference hourly thermal balance calculation procedures) is not directly used for calculations.

Validation and verification

The hourly calculation procedures have been validated by using relevant cases from the so called BESTEST series. The BESTEST cases are well established since decades, widely used worldwide and well described. In the previous article on EN ISO 52016-1 we introduced the validation cases and presented the main results [5].

The technical report CEN ISO/TR ISO 52016-2 provides a detailed description of the verification and validation cases. Relevant BESTEST cases are also chosen for the validation of EN ISO 52010, the overarching EPB standard on external environment conditions, as presented in the parallel article by Mr Plokker on EN ISO 52010.

A full description of the most relevant validation cases and results are given in the standard itself, as a tool to **verify** if an hourly calculation method based on EN ISO 52016-1 is in line with the calculation procedures given in the standard. In case at national level it is decided (following the template of "Annex A" to make use of the specifically allowed deviations from the given calculation procedures, then these verification cases are to be used to **validate** the deviating calculation procedures.

Conclusion

EN ISO 52016-1 presents a coherent set of calculation methods at different levels of detail, for the (sensible) energy needs for the space heating and cooling and (latent) energy needs for (de-)humidification of a building and/or internal temperatures and heating and/or cooling loads. The influence from technical buildings systems, control aspects and boundary conditions can be included where relevant for a "system specific" calculation, in addition to a "basic energy load or need" calculation. Choices are possible at national or regional level to accommodate the specific national or regional situation. The method has been successfully validated using relevant BESTEST cases.

EN ISO 52017-1 is not needed for the actual calculation of the energy performance of buildings. It contains a generic hourly calculation method, intended as reference method, for instance for EN ISO 52016-1.

More information is available in the accompanying technical report, CEN ISO/TR 52016-2 [2]. ■

Acknowledgments

The authors would like to acknowledge the contributions to the preparation of EN ISO 52016: **Dirk Van Orshoven** (DVO, Belgium: contribution to monthly method), **Gerhard Zweifel** (LTH, Luzern: design cooling load, latent heat and links to EPB standards under CEN/TC 156), **Matjaž Zupan** (Planta, Slovenia: calculation examples) and **José L. Molina** (Universidad de Sevilla, Spain) and **Francisco José Sánchez de la Flor** (Universidad de Cádiz, Spain) for the solar shading calculation procedures.

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EPB standards on thermal, solar and daylight properties of windows and facades

This paper introduces the subset of EPB standards dealing with thermal, solar and daylight properties of windows and facades. These EN ISO standards have a long tradition. The changes to make these standards fit into the set of EPB standards were mainly editorial.

Keywords: energy performance of buildings, EPB, EPB standards, EPB regulations, thermal transmission, windows, facades, solar shading, solar transmittance, light transmittance, building components, building elements.

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The EPB standards on thermal, solar and daylight properties of windows and facades concern the following standards mainly under EPB module M2-5 and M2-8 and developed under CEN/TC 89 in collaboration with ISO/TC 163/SC 2: EN ISO 10077-1[2], EN ISO 10077-2[3] and EN ISO 12631[4] as well as EN ISO 52022-1[5] (previously EN 13363-1) and EN ISO 52022-3[6] (previously EN 13363-2), plus the accompanying technical report on this cluster, CEN ISO/TR 52022-2[1].

History of this suite of standards

The first series of standards on thermal, solar and daylight properties of windows and were prepared by CEN/TC 89 in collaboration with ISO/TC 163 in the 1990s, as a result of growing global concern on future fuel shortages and inadequate health and comfort levels in buildings. Furthermore, the standards served for the determination of product characteristics in accordance with the relevant European product standards. During the following decades, these first standards were revised and new standards (on glazing in combination with solar protection devices, on curtain walls) were added, to cope with new developments and additional needs.

Revision of this suite of standards (2013-2016)

The revisions (2013-2016) to make this suite of standards fit into the set of EPB standards are mainly editorial. This includes editorial changes to make the procedures unambiguous and software proof, to rationalize the choices (via the "Annex A/Annex B" approach) and to ensure consistent interconnections, in particular with all the other standards in EPB module M2 subset of EPB standards.

The two standards on glazing in combination with solar protection devices (EN ISO 52022-1 and -3) were upgraded from "CEN only" to "CEN & ISO" level.

EN ISO 100077-2 underwent one technical change, related to the calculation of cavity properties.

Main outputs

The main outputs of these standards are:

- thermal transmittance of windows, doors, curtain walls, shutter boxes and frames;
- solar and daylight characteristics (solar energy transmittance, daylight transmittance) for solar protecting devices combined with glazing.

General description

The standards EN ISO 100771, EN ISO 100772 and EN ISO 12631provide the methodology to obtain the energy losses due to transmission for windows, doors and curtain walls.

The two standards EN ISO 520221 and EN ISO 520223 provide the methodology to obtain the energy gains due to solar radiation for transparent elements in combination with solar protection devices needed for the calculation of a potential cooling demand.

Figure 2 in the parallel article by Mrs Kosmina, on the EPB standards on hygrothermal properties of building components and building elements, illustrates the linkages between the various thermal transmission standards, which includes EN ISO 10077-1, EN ISO 10077-2 and EN ISO 12631.

None of the standards under this cluster contain options for national choices provided in "Annex A/Annex B". One should bear in mind that the output from these standards is also used in the context of product declaration according to the European Construction Products Regulation CPR. This requires European wide uniformity.

EN ISO 10077-1

EN ISO 10077-1 provides a calculation method to obtain the thermal transmittance of windows and pedestrian doors consisting of glazed and/or or opaque panels fitted in a frame, with and without shutters.

In general, the thermal transmittance or *U*-value of the window or door product or assembly is calculated as a function of the thermal transmittance of the components and their geometrical characteristics, plus the thermal interactions between the components.

An alternative to calculation according to EN ISO 10077-1 is testing of the complete window or door according to EN ISO 125671 or, for roof windows, according to EN ISO 125672.

Annex C of the standard gives a choice in references to other CEN (for CEN area) or ISO (elsewhere) standards that provide thermal transmission properties of glazing or additional thermal resistance properties of shutters.

EN ISO 10077-2

EN ISO 10077-2 specifies the method for numerical calculation of the thermal transmittance of frames U_f and roller shutter boxes U_{sb} and the linear thermal transmittance Ψ.

Annex C of the standard gives a choice in references to other CEN (for CEN area) or ISO (elsewhere) standards that provide thermal transmission properties of glazing.

EN ISO 12631

EN ISO 12631 provides a calculation method to obtain the thermal transmittance of curtain walls consisting of glazed and/or or opaque panels fitted in a frame.

In general, the thermal transmittance or *U*-value of the curtain walling is calculated as a function of the thermal transmittance of the components and their geometrical characteristics, plus the thermal interactions between the components.

Two methods of calculating the thermal transmittance of curtain wall systems are specified:

- the single assessment method and
- the component assessment method.

The single assessment method is based on detailed computer calculations of the heat transfer through a complete construction including mullions, transoms, and filling elements (e.g. glazing unit, opaque panel). This method can be used for any curtain walling system (i.e. unitised systems, stick systems, patent glazing, structural sealant glazing, rain screens, structural glazing).

The component assessment method divides the representative element into areas of different thermal properties, e.g. glazing units, opaque panels and frames. This method can be used for curtain walling systems such as unitised systems, stick systems and patent glazing. Structural silicone glazing, rain screens and structural glazing are excluded from the component assessment method.

Both methods result in the same value for the thermal transmittance of a curtain wall.

Annex C of the standard gives a choice in references to other CEN (for CEN area) or ISO (elsewhere) standards that provide thermal, solar or daylight properties of (single or multiple) glazing.

CEN ISO/TR 52022-2 provides calculation examples.

EN ISO 52022-1

EN ISO 52022-1 defines a simplified method for the calculation of

- the total solar energy transmittance,
- the total solar direct transmittance and
- the total light transmittance
  for a glazing in combination with an external or internal or integrated solar protection device

These characteristics are calculated as a function of the "optical" properties of the solar protection device and the glazing, the thermal transmittance of the glazing and the position of the solar protection device.

The formulae given in EN ISO 52022-1 are based on a simple physical model and the values of the notional parameters *G* are mathematically fitted to a more precise reference calculation, following the principles of EN ISO 52022-3.

The results generally tend to lie on the safe side for cooling load estimations. The results are not intended to be used for calculating beneficial solar gains during heating period or thermal comfort criteria.

Annex C of the standard gives a choice in references to other CEN (for CEN area) or ISO (elsewhere) standards that provide thermal transmission or optical properties of glazing.

CEN ISO/TR 52022-2 provides some typical values for the characteristics of glazing and solar protection devices that can be used in the absence of values obtained from measurement or calculation. It also provides calculation examples.

EN ISO 52022-3

EN ISO 52022-3 defines a procedure for a detailed calculation of the solar and daylight characteristics for solar protection devices combined with glazing.

The procedure is based on the spectral transmission and reflection data of the materials, comprising the solar protection devices and the glazing, to determine the total solar energy transmittance and other relevant solar-optical data of the combination. If spectral data are not available, the methodology can be adapted to use integrated data. The use of integrated

In the physical model, the glass panes and blinds are considered as parallel, solid layers. In general, the total solar energy transmittance, the total solar direct transmittance and the total light transmittance is calculated as a function of the thermal resistance and spectral "optical" properties (transmittance, reflectance) of the individual layers.

Two sets of boundary conditions are given for the vertical position of the glazing and the blind.

- **Reference conditions**:
  These boundary conditions are consistent with the general assumptions of EN 410 and ISO 10292 to be used for product comparison and average solar gain calculations during the heating period.
- **Summer conditions**:
  These boundary conditions are representative of more extreme condition and to be used for comfort evaluations and cooling load calculations.

Annex C of the standard gives a choice in references to other CEN (for CEN area) or ISO (elsewhere) standards that provide thermal transmission or optical properties of glazing, solar shading devices and gas spaces.

CEN ISO/TR 52022-2 contains a number of calculation examples on this standard.

Accompanying spreadsheets

In agreement with the rules for all EPB standards containing calculation procedures, spreadsheets were prepared during the preparation of the standards to demonstrate and validate the procedures. Spreadsheets are publicly available on (the draft versions of) EN ISO 10077-1, EN ISO 12631, EN ISO 52022-1.

Calculation examples are presented in the technical report CEN ISO/TR 52022-2.

No accompanying calculation spreadsheets (except spreadsheets with only an overview of input and output quantities) were prepared on:

- EN ISO 10077-2: the standard does not provide a calculation procedure; it provides test cases and performance criteria for calculation procedures.
- EN ISO 52022-3: the standard provides complex calculation procedures that are not easily put in a spreadsheet. Instead of a spreadsheet, Annex H of CEN ISO/TR 52022-2 contains examples of calculation results obtained by computer programs.

Conclusion

The revisions (2013-2016) to make the suite of standards on thermal, solar and daylight properties of windows and facades fit into the set of EPB standards are mainly editorial. This resulted in a subset that is unambiguous and software proof, with rationalized choices (via the "Annex A/Annex B" approach) and with consistent interconnections, in particular with all the other standards in EPB module M2 subset of EPB standards. ■

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[3] EN ISO 10077-2, Thermal performance of windows, doors and shutters – Calculation of thermal transmittance – Numerical method for frames.

[4] EN ISO 12631, Thermal performance of curtain walling – Calculation of thermal transmittance – General.

[5] EN ISO 52022-1, Energy performance of buildings — Thermal, solar and daylight properties of building components and elements — Simplified calculation method of the solar and daylight characteristics for solar protection devices combined with glazing.

[6] EN ISO 52022-3, Energy performance of buildings — Thermal, solar and daylight properties of building components and elements — Detailed calculation method of the solar and daylight characteristics for solar protection devices combined with glazing.

[7] Dick van Dijk, Marleen Spiekman, Dirk Van Orshoven, Wim Plokker, Subset of EPB standards on the energy use and the thermal performance of buildings and building elements, The REHVA European HVAC Journal, issue: "Focus on EPB standards", Vol. 52, Issue 1, January 2015.

EPB standards on hygrothermal performance of building components and building elements

This paper introduces the subset of EPB standards dealing with hygrothermal performance of building components and building elements. These EN ISO standards have a long tradition. The changes to make these standards fit into the set of EPB standards were mainly editorial.

Keywords: energy performance of buildings, EPB, EPB standards, EPB regulations, thermal transmission, building components, building elements.

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The EPB standards on hygrothermal performance of building components and building elements concern the following standards mainly under EPB module M2-5 and developed under ISO/TC 163/SC 2 in collaboration with CEN/TC 89: EN ISO 6946 [2], EN ISO 10211 [3], EN ISO 10456 [4], EN ISO 13370 [5], EN ISO 13786 [6], EN ISO 13789 [7] and EN ISO 14683 [8], plus accompanying technical report, CEN ISO/TR 52019-2 [1].

History of this suite of standards

The first series of standards on thermal and hygrothermal properties of building components and elements were prepared by ISO Technical Committee TC 163 in the 1980s, as a result of growing global concern on future fuel shortages and inadequate health and comfort levels in buildings. During the following decades, these first standards were revised and new standards were added, to cope with new developments and additional needs. From the 1990s on, these standards were developed in close collaboration with CEN/TC 89.

Revision of this suite of standards (2013-2016)

The revisions (2013-2016) to make this suite of standards fit into the set of EPB standards are mainly editorial. This includes editorial changes to make the procedures unambiguous and software proof, to rationalize the choices (via the "Annex A/Annex B" approach) and to ensure consistent interconnections, in particular with all the other standards in EPB module M2 subset of EPB standards.

Main outputs

The main outputs of these standards are:

- thermal transmission properties of building elements (thermal resistance, thermal transmittance or dynamic thermal characteristics of a wall, floor or roof);
- heat transfer coefficient for the whole building (or part of a building).

General description of the standards

Together with EN ISO 10077-1, EN ISO 10077-2 and EN ISO 12631 (see other article, on the windows related standards); these standards provide the methodology to obtain heat transfer coefficients for a building starting from the properties of materials used for its construction and the size and geometry of the building.

The results provide input for calculation of energy needs for heating and cooling by EN ISO 52016-1 when one of the simplified (monthly or hourly) calculation methods is being used in EN ISO 52016-1 (see also [9] and parallel article on EN ISO 52016). In the case of detailed dynamic simulations, the component (or subcomponent) properties are used directly as inputs for the building simulation.

In applications where individual component properties are needed, the standards provide:

- in the case of minimum component requirements, the U-value or R-value of the construction;
- for multi-zone calculations with assumed thermal interaction between the zones, the thermal transmission properties of the separating construction;

Figure 1 illustrates the linkages between the various standards.

EN ISO 6946

EN ISO 6946 provides a calculation method that is valid for most building components (walls, suspended floors and roofs). It is based on calculating the upper limit of thermal resistance of the component (which would apply if the heat flow were unidirectional from warm side to cold side) and the lower limit (in which the plane separating each layer is isothermal). Except for components consisting entirely of homogeneous layers (for which the upper and lower limits are equal), the true thermal resistance of a component is between these two limits. The standard specifies use of the arithmetic mean of the two limits provided that their ratio does not exceed 1,5.

Options for national choices provided in "Annex A/ Annex B" comprise default thermal conductivity or thermal resistance values, criteria to allow specific simplifications and boundary conditions.

CEN ISO/TR 52019-2 provides calculation examples.

EN ISO 10211

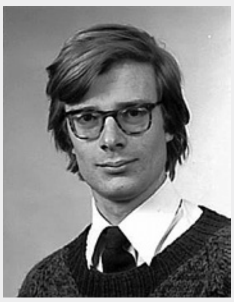
EN ISO 10211 specifies the method for detailed calculation of thermal bridges. It can be applied to a whole building or part of it, and also to the calculation of linear and point thermal transmittances which are used in EN ISO 13789.

Options for national choices provided in "Annex A/ Annex B" comprise default thermal conductivity values, criteria to allow specific simplifications and the required accuracy of the calculations.

EN ISO 13370

EN ISO 13370 is used for calculation of heat transfer via the ground, taking account of its contribution to the total thermal resistance in the case of *U*-value calculations and of its thermal inertia in the case of time-dependent calculations.

Brian Anderson (1948–2016)



It is with great sadness that we have to report that at the end of August 2016 we lost a colleague and friend to many – Brian Anderson.

Brian joined BRE in 1974 where his work was concerned with thermal insulation, thermal performance of buildings and prediction of energy use. He played a leading role in the preparation of European standards for thermal insulation and thermal performance. He was the WG9 convenor in ISO/TC 163/SC2 where he had led the revision of the suite of thermal transmission standards.

As one of the leading experts in the EPBD mandate M/343 (2004-2007), he was the main writer of the EPB "Umbrella document, EN/TR 15615, the basis for the current EN ISO 52000-1 and CEN ISO/TR 52000-2.

Only days after submission of the final drafts of the suite of thermal transmission standards to ISO, he died unexpectedly, just a few months before his retirement from BRE.

EN ISO 13370 specifies thermal properties for three representative types of ground. Particular values can be provided in EN ISO 13370 Annex A. Annex F of EN ISO 13370 contains a procedure for the application to dynamic simulation programs. This procedure is also used in EN ISO 52016-1 (see other article) for the hourly calculation of the energy needs for heating and cooling, internal temperatures and sensible and latent heat loads. In addition, special care has been taken to ensure that the monthly calculated heat transfer through the ground floor can be used as input for the monthly calculation method in the same EN ISO 52016-1. Extensive explanation, including validation and examples can be found in CEN ISO/TR 52019-2.

Options for national choices provided in "Annex A/ Annex B" of the standard comprise default *U*-values for existing buildings, criteria to allow specific simplifications and environment conditions (incl. ground).

EN ISO 13786

EN ISO 13786 defines a method of calculation of the dynamic thermal characteristics of a building component.

Background information, explanation and examples can be found in CEN ISO/TR 52019-2.

Options for national choices provided in "Annex A/Annex B" of the standard are related to

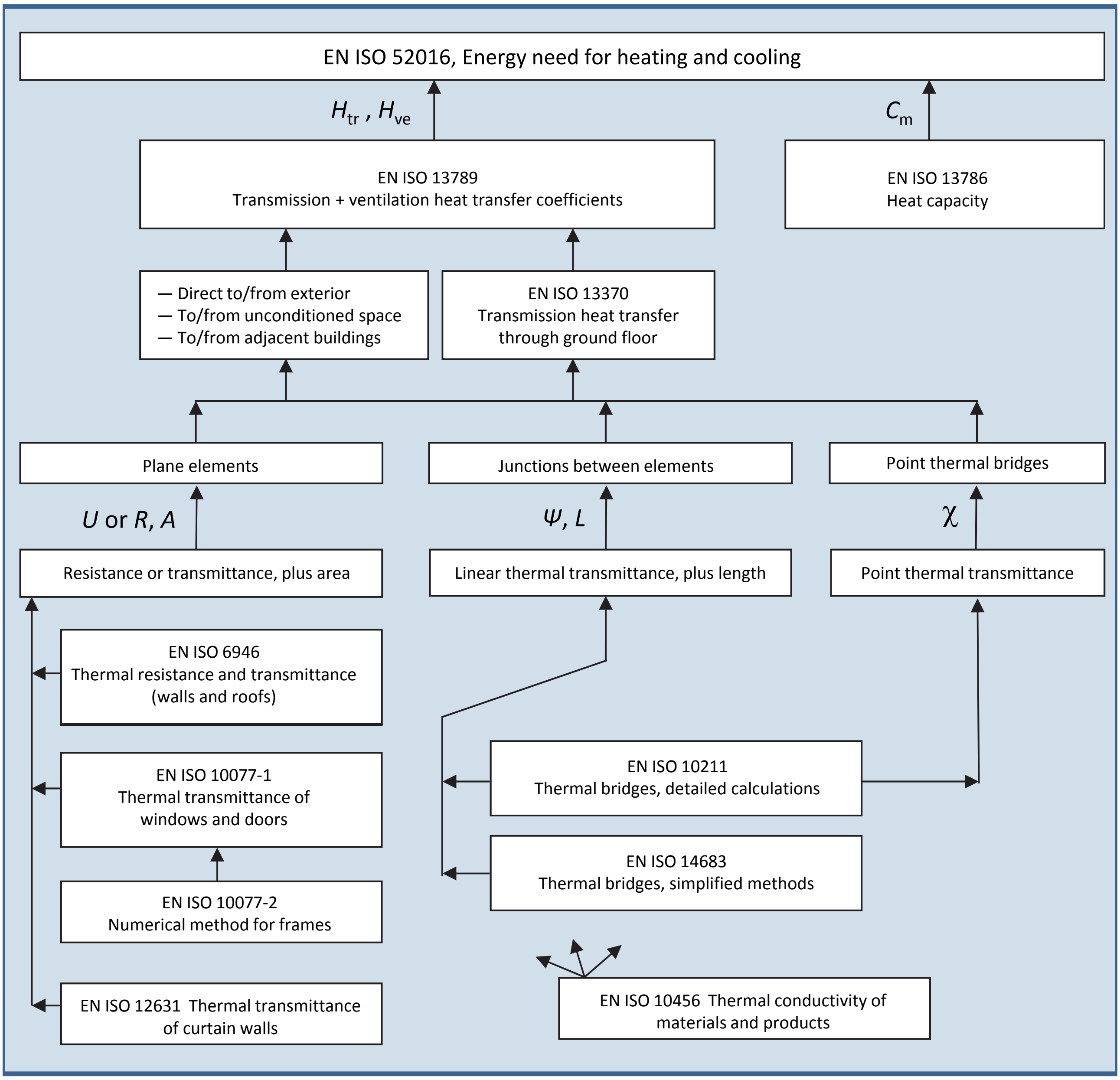


Figure 1. Linkage between the standards.

restrictions on the use of the simplified method given in the standard.

EN ISO 13789

EN ISO 13789 defines the calculation of the transmission heat transfer coefficient of a building, using the heat transmission properties of the building elements and thermal bridge used in its construction. A decision is needed on the system of dimensions to be used – internal, overall internal or external. Annex J of CEN ISO/TR 52019-2 illustrates the three systems and the effect of the systems on the linear thermal transmittance of junctions between elements. This annex is relevant also to EN ISO 10211 and EN ISO 14683.

For the ventilation heat, transfer coefficient the airflow rate through conditioned spaces is needed. Annex K of CEN ISO/TR 52019-2 provides a possible method, with associated data. However, for use within CEN, references are given to the CEN EPB standards under EPB module M5-5 (CEN/TC 156) that have been developed for this purpose.

Options for national choices provided in "Annex A/ Annex B" of the standard are related to the dimensioning system, choice of method for ventilation heat transfer and criteria for specific simplifications.

EN ISO 14683

EN ISO 14683 defines the methodology for determination of linear thermal transmittances and provides default values for when specific information is not available. CEN ISO/TR 52019-2 provides examples of the influence of thermal bridges on the transmission heat loss coefficient.

Options for national choices provided in "Annex A/ Annex B" of the standard are related to optional use of an e.g. national/regional thermal bridge catalogues and optional national/regional manual (simplified) calculation method.

Accompanying spreadsheets

In agreement with the rules for all EPB standards containing calculation procedures, spreadsheets were prepared during the preparation of the standards to demonstrate and validate the procedures. Spreadsheets are publicly available on (the draft versions of) EN ISO 6946, 13370 and 13789. Calculation examples are presented in the technical report CEN ISO/TR 52019-2.

No accompanying calculation spreadsheets were prepared on:

- EN ISO 10211: this standard does not provide a calculation procedure; it provides test cases and performance criteria for calculation procedures.
- EN ISO 13786: this standard provides complex matrix calculation procedures. Instead of a spreadsheet, Annex I of CEN ISO/TR 52019-2 contains examples of calculation results obtained by a computer program.
- EN ISO 14683: this standard does not provide a calculation procedure; it provides choices between procedures provided elsewhere and default tabulated values. Instead of a spreadsheet, Annex L of CEN ISO/TR 52019-2 contains examples of the use of default values.

Conclusion

The revisions (2013-2016) to make the suite of EN ISO standards on hygrothermal performance of building components and building elements fit into the set of EPB standards are mainly editorial. This resulted in a subset that is unambiguous and software proof, with rationalized choices (via the "Annex A/Annex B" approach) and with consistent interconnections, in particular with all the other standards in EPB module M2 subset of EPB standards. ■

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Calculation of the energy performance of ventilation and cooling systems, update of several parts in the EN 16798 family

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This article gives a short summary of the main issues resolved in these new standards currently out for formal vote. More details can also be found the article published in the REHVA Journal May 2016.

EN 16798-5-1

EN 16798-5-1 "Energy performance of buildings — Modules M5-6, M5-8, M6-5, M6-8, M7-5, M7-8 — Ventilation for buildings — Calculation methods for energy requirements of ventilation and air conditioning systems — Part 5-1: Distribution and generation (revision of EN 15241) — method 1" is one of two standards, which is intended to cover a number of modules in the areas of distribution, i.e. the duct system, and "generation", which for the ventilation and air conditioning service, is meant to be the air handling unit (AHU), including humidification and dehumidification. Part 5-1 describes a detailed method for ventilation and air conditioning systems and uses an hourly calculation step. It is a comprehensive calculation of all aspects of AC systems.

The distribution part includes the calculation of duct heat losses and duct leakage, both linked to the zones crossed and/or served by the system.

The "generation" (AHU) includes the ordinary air treatment steps for heating, cooling dehumidification and humidification.

This standard has many options to be chosen, many of them being control options with a link to the building automation (see the CEN/TC 247standards), especially the revised EN 15232-1 , which has been updated to reflect these options:

- Different air flow control types: Depending on the calculation of the required air flow rates on zone level, which is covered in EN 16798-7, the ventilation "emission" standard, the flow rate in the AHU can be controlled to be constant, multi stage or variable.
- Supply air temperature and humidity control types: constant, outdoor air compensated or load compensated.

As in reality, not all combinations are possible: only one of the two (air flow or temperature) can be load dependent.

- Fan control: the fans can be controlled differently to react on the flow control. A direct link is only possible for single zone systems (e.g. serving cinema theaters or auditoria). For multi zone systems, the flow control is usually done on zone level (e.g. by VAV boxes), and the central fan is controlled e.g. pressure dependent. Based on an input from CEN/TC 247, there are several options considering the type of pressure measurement. Experience showed that this has a big impact on the fan energy use and was too optimistic in the preceding standard EN 15241 (which will be withdrawn).
- The fan energy calculation is linked to inputs from product standards (on fans, from WG 17 in TC 156)

The standard covers different types of heat recovery:
- Plate;
- Rotary, with different types of coatings (hygroscopic, non-hygroscopic, absorptive), including humidity recovery.
- Pumped circuit.

For the calculation there is a connection to product standards (EN 308, 13053), and it includes the aspects of
- Control;
- Different ways of frost protection;
- Auxiliary energy consumption.

As the calculation of rotary heat exchangers with the humidity recovery and the auxiliary energy calculation involves a lot of input data, which users may not be familiar with, a part of the calculation was transferred to an informative annex, leaving a generic function to be defined nationally in the normative part. The annex is referred to for the "CEN option" in Annex B.

Further options are
- Recirculation control;
- Humidifier types (adiabatic or steam, involving different energy carriers), with different controls.

The method covers also a couple of special innovative solutions:
- Ground preheating / -cooling, which is described in an informative annex
- Adiabatic cooling by humidification of extract air and heat recovery.

The accompanying TR CEN/TR 16798-6 is a common document for this standard EN 16798-5-1 and the EN 16798-5-2. It gives explanations for the background of different options and choices. It shows also example ways of zoning.

The spreadsheet is fully functional and has a drop down menu structure to choose all the options[1].

EN 16798-5-2

EN 16798-5-2 is part of a series of standards aiming at international harmonization of the methodology for the assessment of the energy performance of buildings, called "set of EPB standards" and is the revision of EN 15241:2007. The revision of EN 15241:2007 includes the division into two parts:
- EN 16798-5-1 (covers complete range of air-conditioning system)
- prEN 16798-5-2 (covers ventilation systems for residential buildings)

EN 16798-5-2 covers energy performance calculation of mechanical ventilation systems with integrated heating/cooling generation, including domestic hot water production, using a monthly or seasonal calculation interval or a bin method. It takes into account the generation (air handling unit) and distribution (duct system) parts. It does not cover the emission part (calculation of the required volume flow rates and/or supply air conditions), which is covered in the M5-5 standard. It does not include humidification and dehumidification. This method is focussed on small, packaged ventilation systems, typically used in residential buildings, although the application is not restricted on the basis of building or space use type.

Other changes compared to EN 15241:2007 are:
- inclusion of ventilation systems for residential buildings (including heating and cooling of air)
- improved calculation of fan energy taking into account new control strategies of TC 247 and product standard regarding fans
- improved calculation of heat recovery plants in consideration of efficiency and auxiliary energy depending on control

More information is provided in the Technical Report accompanying this standard (CEN/TR 16798-6), including examples aiming to check the quality and usability of the standard.

A calculation method for mechanical ventilation and air conditioning systems, including humidification and dehumidification, using an hourly calculation interval or a bin method, is provided in a separate standard EN 1679851.

EN 16798-9

EN 16798-9:2016 "Energy performance of buildings – Part 09: Ventilation for buildings – Module M4-1, M4-4, M4-9 – Calculation methods for energy requirements of cooling systems – General" is the core of the cooling related calculation standards, the "general" part. It is supposed to be the revision of the current EN 15243:2007. However, not much of the content of the latter remained in this new standard. Some parts were moved to other standards (such as the cooling load related issues to EN ISO 52016-1 or the generation related information, as far as normative, to EN 16798-13). A big part of the content was in informative annexes, and some remaining part of this was moved to the accompanying CEN TR 16798-10.

Similar to the EN 15316-1, the general part of the heating and DHW calculation standards, this EN 16798 part 9 connects the calculation pieces of the other standards for emission, distribution, storage and generation to a complete system, considering the flow rate and tempera-

[1] The excel files are publicly available via link: https://isolutions.iso.org/ecom/public/nen/Livelink/open/35102456

ture control of the distribution branches and the load dispatching in case of insufficient energy supplied by the generation system. It follows (as the other parts do) the principle, that a subsequent energy using module reports the required energy supply to the delivering module per calculation interval, and this in turn reports the energy really delivered, based on its operational conditions, back to the using module per calculation interval.

A schematic representation is given in the standard, illustrating the boundaries of the involved modules and the nomenclature used in the detailed calculation method of the standard. The (non-exhaustive) system shown in this scheme, with a generation, a storage and two distribution branches, each serving two thermal zones and one air handling unit, is exactly represented in the spreadsheet going along with the standard. In this spreadsheet, a full annual data set of hourly values is implemented to test the calculation. An hourly calculation interval is needed for this detailed calculation method.

For the water based emission and distribution calculations (modules M4-5 and M4-6) it refers to the TC 228 heating system standards (EN 15316-2 and 3). For the storage calculation it refers to EN 16798-15 and for the generation to EN 16798-13.

In the simplified calculation method, which can also be applied to a monthly calculation interval, the distribution is covered by simply applying factors to the heat extracted from the zones and AHU's. Also, a storage calculation is not applicable. This method also addresses direct expansion (DX) systems, in which case the calculation becomes generally simpler. The emission can be zone based or via air systems. Schematic representations are given in the accompanying CEN/TR 16798-10.

A separate spreadsheet was developed for this simplified calculation method.

The standard also covers module M4-4 with two partial performance indicator proposals for cooling systems.

In the accompanying technical report CEN/TR 16798-10, examples are given for the simplified and detailed calculation methods, where the spreadsheets are provided for. This includes also an example with a whole set of linked spreadsheets for the setup shown in figure 3 of the standard. According to the number of zones, AHUs and distribution branches, there are multiple instances of several of the spreadsheets. With this setup, the functionality of the whole set of calculations in the cooing area can be demonstrated.

An issue of importance repeatedly mentioned by stakeholders is ventilative cooling, i.e. cooling by enhanced natural and/or mechanically assisted ventilation. This cannot be covered by one standard, since it involves the thermal zone calculation as well as flow rate calculations and control issues. Therefore, a description of the necessary procedure, the modules involved and the information flow is given in the accompanying TR.

EN 16798-13:2016

EN 16798-13:2016 “Energy performance of buildings – Part 13: Module M4-8 – Calculation of cooling systems – Generation” is a new standard for the cooling generation calculation, which was until now covered only in an informative annex of EN 15243:2007. It contains 2 Methods:

- Method A for an hourly calculation step;
- Method B for a monthly calculation step.

The technologies covered in both methods are

- Compression and absorption chillers;
- Place holder for “other” type of generator, being used for direct use of boreholes, ground or surface water;
- Multiple generators handling;
- “Free cooling” control option, i.e. direct cooling via heat rejection device
- Different heat rejection types:
  - Air cooled condensers;
  - Dry, wet and hybrid heat recovery devices;
  - Control options for the heat rejection (e.g. switch between dry and wet operation for hybrid heat rejectors);

In method A, there is a connection to product standards for compression chillers: A performance map is used, which is generated on the base of the measurement points from EN 14511 tests, which are used in EN 14825 for the calculation of the SEER. For additional flexibility, the method has been extended to include the case relying only on the nominal EER according to EN 14511, or, if even this is missing, a default nominal EER value. The approach for this case is a constant exergetics efficiency. This was needed because it is not mandatory for the suppliers to provide the EN 14825 based SEER and the related EER values before 2018, and therefore it cannot be expected to get these values in all cases.

An accompanying CEN TR 16798-14 and two separate spreadsheets for the two methods are available for this standard. ■

The set EPB-CEN standards related to the calculation of heating and DHW systems a chance for the heating system professionals to be up taken

The energy performance of buildings is assessed as a whole, taking into account the building envelope and the technical building systems. Therefore, it is essential for the heating professionals to be able to show the positive contribution of the heating and DHW systems to lower the overall building energy consumption. The set of heating and DHW standards related to EPBD provides a consistent, detailed and reliable methodology linking product testing (ErP) and the overall building energy performance (EPBD).

The main challenge is now to bring this set of heating and DHW standards into application.

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Which standards in the CEN EPBD package are related the calculation of heating and DHW systems?

Table 1 provides an overview of the heating and DHW standards. In this tables, only the standards related to the calculation of heating and DHW systems are considered. There are also other standards dealing with inspection and measured energy related to heating systems but these are not considered in this article.

Table 1 shows that there are three families of calculation standards related to:

- Economic evaluation procedure (EN 15459 series);
- Design heat load and characterisation of needs (EN 12831 series);
- Energy performance (EN 15316 series). The energy performance calculation is structured according to emission, distribution, storage and generation following the physical structure of a heating and DHW system.

The calculation standards address three main topics related to the evaluation and design of heating systems:

- the costs;
- the sizing;
- the energy performance.

The Energy performance of Building Directive (EPBD) addresses also these three topics.

Having a consistent set of standards allowing to develop integrated tools where the input data can be used to calculate three different but connected results is a big step towards easy heating product integration (e.g. emitters, boilers, heat pumps) in a common holistic calculation and towards user-friendly and high quality tools for the heating system professionals.

What has been achieved within this second set of heating and DHW standards?

With this set of EPB-standards a consistent methodology with the following advantages has been worked out:

➢ A methodology based on international standards

There are already several methodologies for the sizing and energy performance calculation for heating systems at regional or national level. There are dynamic calculation methods or simplified tabulated tools.

The added value of the CEN EPB package is that it is based on international standards. Standards are recognised worldwide as the "state of art". Standards provide accessibility and transparency and create a level playing field which is the basis for a fair competition between products and technical neutral solutions. CEN Standards are the result of international cooperation, shared knowledge and best practise.

➢ A methodology linking product testing (ErP) and system integration (EPBD)

Assessing Energy Performance of Buildings as required by the EPBD, heating products are contributing to reach an overall yearly energy consumption of a building expressed in primary energy per useful floor area (e.g. 50 kWh/m²). In the Energy related Product

Table 1. Overview of heating and DHW standards related to the EPBD.

EN ISO 52000-1 Modular structure	Standards number	Standard title
		Economic evaluation procedure
M1-14	EN 15459-1	Economic evaluation procedure for energy systems in buildings
		Design heat load and characterisation of needs
M3-3	EN 12831-1	Heating systems in buildings — Method for calculation of the design heat load
M8-2	EN 12831-3	Domestic hot water systems heat load and characterisation of needs
		General and Energy performance expression
M3-1	EN 15316-1	Energy performance of buildings — Modules M3-1, M8-1— Heating and DHW systems in buildings – Part 1: General and Energy performance expression
Space emission systems		
M3-5	EN 15316-2	Energy performance of buildings, modules M3-5, M4-5 – Space emission systems (heating and cooling)
Distribution systems (DHW, heating and cooling)		
M3-6	EN 15316-3	Energy performance of buildings, Modules M3-6, M4-6, M8-6 –Distribution systems (DHW, heating and cooling)
Storage systems for heating and domestic hot water		
M3-7	EN 15316-5	Energy Performance of Buildings – Modules M3-7; M8-7 –: Storage systems for heating and domestic hot water
Heating and DHW generation systems		
M3-8	EN 15316-4-1	Energy performance of buildings, modules M3-8-1, M8-8-1 – Heating and DHW generation systems, combustion systems (boilers, biomass)
	EN 15316-4-2	Energy performance of buildings – Module M3-8:1 - Heating systems – Part 4.2:1: Generation and control – Heat pumps systems
	EN 15316-4-3	Energy performance of buildings, modules 3-8-3, 8-8-3, 11-8-3 – Heat generation systems, thermal solar and photovoltaic systems
	EN 15316-4-4	Energy performance of buildings – Modules M3-8-4, M8-8-4, M11-8-4 – Heat generation systems, building integrated cogenerations systems
	EN 15316-4-5	Energy performance of buildings, Modules M3-8-5; M4-8-5; M8-8-5; M11-8-5 – District heating and cooling
	EN 15316-4-8	Energy performance of buildings – Heating systems and water based cooling systems in buildings - Module M3-8-8 – Space heating generation, air heating and overhead radiant heating systems, stoves (local)

Directive (ErP) the heating products are characterised via a seasonal performance factor (or efficiency) based on product testing (e.g. Lot 1, Lot 2).

In this set of heating and DHW EPB-standards the results of ErP product testing are used as input data to calculate the contribution of the heating systems to the overall energy use of a building. This direct link is also a huge advantage for data collection because common and coherent databases can be set up.

It is likely that the heating systems industrial stakeholders will ask the Member States authorities that these data are to be taken into account in the existing national methodologies for the EPBD calculation. The CEN EPB standards will then be a precious help for the Member States to review their national methodologies or to simply use this set of EPB standards.

➢ A methodology with a modular structure allowing easy integration of new elements

In this set of heating and DHW EPB standards the modular structure has been improved to increase the consistency of the holistic approach. For the heating standards, the cooperation with CEN/TC247 related to controls should be underlined. In the general standard on heating and DHW water systems (EN 15316-1) the control functions and the related input, output data are now well identified as modules (e.g. control module for the space heating distribution, load dispatch module for the heat generators). For example, the distribution control module determines the set point water temperature for the heat distribution according to the type of control (e.g. depending on the outdoor temperature) and the running conditions. This approach provides the possibility for product testing of control units and to differentiate the products.

The definition of input / output of the different modules give flexibility (step by step integration of modules) and allows independent module development. For example, the standard dealing with storage (EN 15316-5) provides the possibility to use it either alone (as Electric Water Storage) or integrated in larger systems (solar systems).

Resume

This set of heating and DHW standards related to the EPBD provides a coherent set of standards dealing with costs, sizing and energy performance as requested by the Directive.

Building energy requirements, e.g. to get the building permit and energy performance certificates are related to the building as a whole. Therefore, it is essential for the heating professionals to show the positive contribution of energy-efficient heating and DHW systems to lower the building energy consumption. There is also a need to calculate the performance of heating systems in a more and more detailed way as the energy need of the building get lower and lower. The interaction between the buildings envelop and the heating systems, multi-generation using renewable energy source should be taken into account. Control becomes more and more important. The results of the calculation must be trustworthy, transparent and technological neutral.

This set of EPB heating standards addresses these aspects by linking the product testing and the holistic approach, by focusing more on the control functions and by developing more detailed calculation. This methodology is the basis for software tools to show the positives contribution of the heating systems in the overall approach of buildings. The main challenge is now to bring this set of heating and DHW EPB standards into application. ■

EN 15316-2: Energy calculation method of emission systems in rooms

The new EN 15316-2, which supersedes the EN 15316-2-1:2007 is currently out for formal vote. Based on the enquiry results of the draft standard prEN 15316-2:2014 the main focus of the work was to create a consistently mathematical approach which is based only on temperature differences.

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The influences of various phenomena are taken into account in the new EN15316-2 by the calculation of the additional energy use due to often called emission (emitter[1]) losses. Although these are sometimes not real losses but additional energy use, it is a convention to speak of "emission losses". These losses are related to physic phenomena like:

- Embedded emission in the building structure (e.g. floor heating);
- Radiation (e.g. meaning air temperature can be lowered due to radiation effects);
- The stratification (higher air temperatures in the near of the ceiling for convective dominated systems);
- Intermittency.

Some other effects, also based on physics are additional influenced by the behavior of the user related to the quality of the building automation and control, the hydraulic balance and the building management systems (BMS). It is observed that if the quality of control is low, the user will compensate by increasing the set point temperature in order to obtain the desired comfort. This is modeled by acting on the set point temperature. The standard proposes to represent all these phenomena by the temperature difference in order to get an unique performance indicator for the classification of the products. The temperature variation based on all influencing factors can be calculated with equation 1. For some cases (e.g. for $\Delta\theta_{roomaut}$) also negative values of the temperature variations are possible.

$$\Delta\theta_{int;inc} = \Delta\theta_{str} + \Delta\theta_{ctr} + \Delta\theta_{emb} + \Delta\theta_{rad} + \Delta\theta_{im} + \Delta\theta_{hydr} + \Delta\theta_{roomaut} \quad (1)$$

The calculation of the thermal input for the cooling/heating emission system can be performed on a monthly or on an hourly basis. In the monthly method, the emission losses are calculated as follows (equation 2).

$$Q_{em;ls} = Q_{em;out} \cdot \left(\frac{\Delta\theta_{int;inc}}{\theta_{int;inc} - \theta_{e;comb}} \right) \quad (2)$$

The first achievement of this new version of this standard is, that now a consistent mathematical approach is available.

The second advantage is, that the calculation method is based on temperature differences which can be easily be measured in practice.

The third advantage is that temperature differences have a strong connection to the assessment of the thermal comfort which allows the user of the standard to indicate information on the comfort levels in the rooms. ■

[1] On overarching EPB level, in EN-ISO 52000-1 the term emission is replaced by the more correct term emitter.

A new technology for airflow and temperature measurement without pressure loss in ventilation systems

With the increased focus on energy saving, ventilation systems with low volume flows have become increasingly common. This has created a need for new measuring instruments that guarantee high accuracy, even with low flows.

UltraLink is a new technology that has the potential to revolutionise the ventilation industry. The technology provides a precise measurement of the entire airflow area in ventilation systems, without ever causing pressure losses. As the technology is based on ultrasound sensors, there are no protruding parts on which dirt can collect. Instead, you get uninterrupted airflow without pressure loss, offering benefits in terms of energy efficiency, simplicity and cleaning. Get in touch or visit lindab.com to learn more about its true potential

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The EN 15316-4-3 Energy performance of buildings

– Method for calculation of system energy requirements and system efficiencies – Part 4-3: Heat generation systems, thermal solar and photovoltaic systems out for Formal Vote

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Purpose

The standard is 1 of the 52 standards in the framework of EPBD standards that work together to determine the energy performance of the building.

Scope

The EN 15316-4-3 covers solar thermal systems and solar photovoltaic systems as energy producing elements in buildings.

Main revisions

- The EN 15316-4-3 replaces the previous EN 15316-4-3:2007 (solar thermal) and EN 15316-4-6:2007 (solar photovoltaic) covering now both solar technologies in one standard.

For each technology three methods are included based on an annual, monthly and hourly time step.

- Method 2, the former monthly method B on solar thermal, in the standard is greatly improved based on comments received during the previous years. Moreover, during the enquiry stage many experts have studied the draft standard and commented on it, improving the quality of the method even more.
- The hourly methods are new and offer an excellent opportunity for accurate assessment of the energy performance with very transparent calculation methods.
- The editorial layout of the methods has been greatly improved in order to facilitate the software designers.
- The connection with the CEN product standards is maintained and broadened with required new standards.
- Annexes have been added to link the standard to the requirements of the European Ecodesign and energy labelling regulations.

Special points for consideration

- By combining the two standards EN 15316-4-3:2007 and EN 15316-5:2007 an hourly simulation model is described covering solar thermal systems, a heat storage system, a backup heater and water and space heating.
- In the framework of the Energy labelling regulation the so called SOLCAL method, based on the EN15316-4-3:2007, is prescribed for solar thermal systems. However, this method is known to have faults. The new EN 15316-4-3 corrects those faults and offers, through the extra annexes meant for harmonization, an alternative and better method. ■

Heating systems – Hot water storage

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EN 15316-5 Energy performance of buildings – Method for calculation of system energy requirements and system efficiencies – Part 5: Space heating and DHW storage systems (not cooling), M37, M87.

Hot Water Storage are broadly used in heating, either alone (as Electric Water Storage) or integrated in larger systems (solar systems). The new standard allows the versatility of use of hot water storage with a multi-node model. Each node can be connected to input, output pipe or heating element.

Heating element could be internal (e.g. electric), external (heat pump) and the heat exchange is either using direct between fluid (input-stored) or through a heat exchanger.

For solar systems, the calculation is presented as iterative has temperature of the storage influences the performance/solar gains of the solar collector.

The energy calculation is proposed to be either hourly or monthly (simplified version) depending of the data available.

As for other EPB standards, there is an Annex A and B. Annex B presents default values to characterise the performance of the storage itself and thermal performance of the connection to the system. The products characteristics are based on the values obtained from the Ecodesign directive or respective product standards able to provide information about thermal losses of the storage component.

Heating systems – Heat pump systems

The EN 1531642 Energy performance of buildings - Method for calculation of system energy requirements and system efficiencies – Part 4.2: Space heating generation – heat pump systems (not cooling), M 382, M882, is published for formal vote.

Heat Pumps for heat production are an energy effective solution for heating and domestic hot water production for domestic or commercial use. This new standard allows to calculate the energy performance for different combination of energy input source (air, ground-water, aquifer,…) and the connection of the heat production to the water heating distribution system. The control system and priorities for the different type of end-use (heating, domestic hot water or storage) are also presented.

As for other EPB standards, there is an Annex A and B. Annex B presents default values to characterise the performance of the heat pump for the different type of combination itself and thermal performance of the connection to the system. The products characteristics are based on the values obtained from the respective products standard used as a basis for the Ecodesign Directive. A set of default tabulated values to be used directly for the different combination of input/output sources are presented in Annex B. An example illustrates the case for air/water heat pump; choice for this type of product have been made as it covers the different possibilities to characterise the heat pump (large variation of the input temperature, different output temperatures, operation with integrated or external back-up system, limit in the operation for high or low temperature).

Cooling systems – Cooling storage systems

The EN 1697815 Energy performance of buildings – Cooling system – Part 15: cooling storage M 37, is published for formal vote.

Impact of r energy efficiency cooling storage is indirect as the consequence of such installation depends on the design and purpose:

- reduce the power of the cooling generation as the peak demand for cooling is insured alone (energy shift) or in supplement of the cooling generation,
- offer operation of the cooling unit with a higher load factor and consequently increase the energy efficiency of the cooling generation,
- increase safety for a define period to avoid oversizing of the cooling generation plant.

The new standard allows to calculate the energy performance for these different modes and is now fully integrated with the modules for cooling generation and cooling distribution. Storage can be used with water/ice and other materials (Phase change materials) offering a various range of properties (latent energy capacity, temperatures for fusion and solidification). Calculation have been simplified and consider the transformation of the material as completed during the time step (for 1 hour to larger time-step).

As for other EPB standards, there is an Annex A and B. Annex B presents default values to characterise the performance of the storage unit and type of materials used for storage. Examples illustrate the case for water/ice and Phase Change Material. ■

The energy retrofit of a multifamily building in Madrid

At 47 Calle de la Canción del Olvido in Madrid, last winter owners have heated their apartments with electric heaters and gas boilers. Since June they can count on a more efficient heating and cooling system based on a smart hydronic unit developed within the FP7 project iNSPiRe.

Keywords: energy retrofit, multifamily house, heat pump, solar thermal, hydronic unit, metering, system management.

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The retrofit of a vast portion of the European building stock is becoming a stringent requirement from the structural, functional and the energy perspectives, following European Commission Directives, deterioration of the buildings and eldering of the population.

EMVS (Empresa Municipal de la Vivienda y Suelo de Madrid) selected the multifamily house located at 47 Calle de la Canción del Olvido in Madrid as a demonstration building to be fully retrofitted in the framework of the FP7 project iNSPiRe.

This building was commissioned in 1960's, and prior to renovation the property showed a number of defects, in particular foundations problems produced by the structure's uneven settlement, which caused significant cracks on the building façade and inner walls (see **Figure 1**). Besides, the building envelope lacked any kind of insulation.

The renovation process has undergone several actions, starting from the structural reinforcement of the building, the thermal insulation of the envelope and

Figure 1. The apartment building before retrofit and cracks assessed during audits.

the installation of a centralised heating and cooling system.

Looking at the structural works, micropiles have been installed under the façade bearing the staircase and the short façades of the building. All micropiles' caps have been interconnected mechanically resulting in a solid foundation. Steel adjustable tension stringers and brackets have been used to embrace the building, and to connect building's concrete walls to the new foundations.

A concrete walls shaft has been raised in front of the existing staircase, with the double objective of incrementing the structural stability and providing the building with a new elevator. To do this, the existing stairwell has been demolished and replaced with a prefabricated one (see **Figure 2**).

This measure has been extremely significant, not only from the technical perspective but also for the owners, mostly retired people, who had started to perceive the missing elevator as a barrier to a comfortable lifestyle.

The high degree of prefabrication allowed the owners to leave in their homes during the entire process.

The existing façades are made from concrete cavity walls without insulation. In order to comply with the national regulations, a new external insulation has been installed with 10 cm thick rock wool panels. A coating with fiberglass mesh and acrylic coloured mortar protects the insulation.

4/10/4 mm double pane, low-emissivity glass, aluminium frame windows have been flux mounted onto the new insulation outside the existing ones, which have been left in place. The existing roller shutters have also been conserved minimising the discomfort for the inhabitants.

An empty gap with a height of about 1.4 m separates ground floor apartments from grade. Polyurethane foam with a thickness of about 5 cm has been sprayed onto the lower surface, to insulate and to partially cut thermal bridges.

The exiting roof cover has been dismantled and the remaining structure has been reinforced with an added concrete structure to avoid any future structural failures. A geotextile polyester foil covered with 60 mm XPS insulation and a 1.2 mm PVC-P coating reinforced with fiberglass guarantees waterproof insulation.

Centralised space heating, cooling and DHW preparation system

A technical room was not present before building renovation since single dwelling electric heaters and gas boilers where used for both space heating and DHW preparation. Due to the narrow gap, available underneath the building, it has not been possible to place the technical room at ground level.

To this purpose, the elevator shaft has demonstrated to be most useful: the structural reinforcement provided has permitted to install on the roof a new, relatively heavy, centralised heating and cooling system.

Figure 2. Lift shaft during installation and at the end of the retrofit.

The plant installed is based on a reversible 20 kWth air-to-water double circuit heat pump: one circuit is always turned in heating mode and connected to a 500 litres thermal storage for domestic hot water preparation; the other is turned in heating mode in winter and in cooling mode in summer. In summer the heat pump can produce contemporarily cooling and heating: the rejected heat from cooling is recycled to produce DHW if needed, instead of being rejected in the environment.

The heat pump is located externally on the roof, next to the east wall of the technical room in order to be shaded during hottest hours of summer days (see **Figure 3**).

22 m² solar thermal collectors mounted vertically on the south-oriented façade also contribute to the DHW preparation. An 800 litres storage with internal heat exchanger has been set up to harvest the solar energy. The latter storage is connected in series to the 500 litres fed by the heat pump, due to the lack of space in the technical room for the installation of a unique 1300 litres tank.

Due to space and aesthetic constraints (the collectors are aligned with to windows on the same façade), 8 solar collectors have been installed on the parapet of the building, while other 2 collectors have been installed on the wall of the technical room. In order to allow maintenance directly from the roof, the solar collectors have been installed with a gap of 200 mm one from another and with a distance of 200 mm between bottom connections and roof surface. An anchoring structure made with "c-shape" profiles has been used to bear collectors' weight and wind loads.

The distribution system is a four pipes one: two pipes are used for space heating or cooling, and two for DHW delivery. Polypropylene (PPR) pipes have been used, allowing for a cheaper and faster installation.

Figure 3. Heat pump and solar thermal field installation on the south facing parapet.

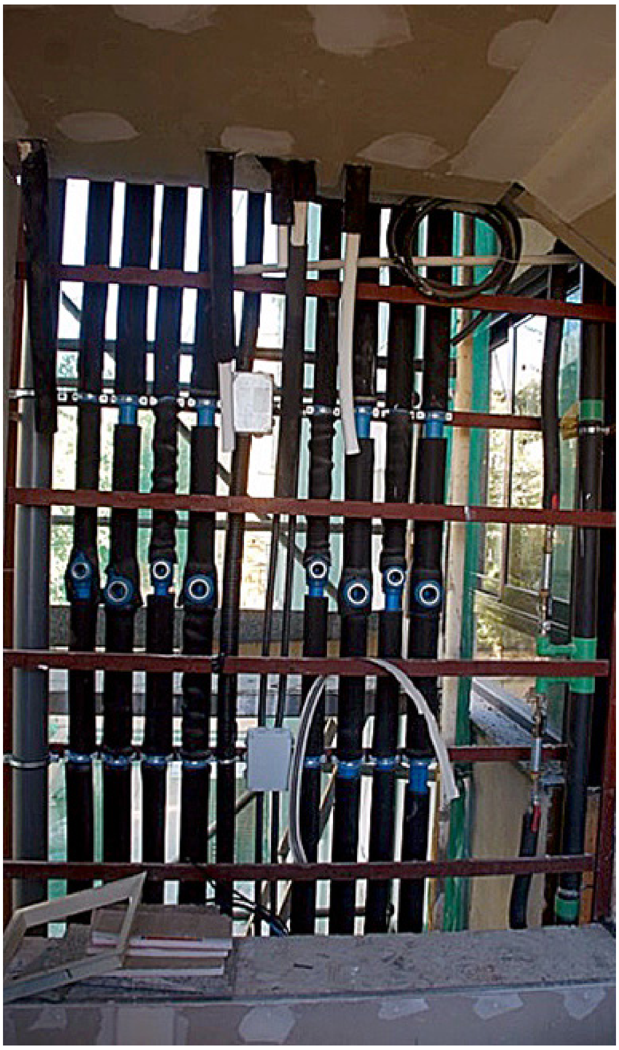
Once again, the newly raised shaft has been used to set up the vertical mains connecting the technical room to the single dwellings. As shown in **Figure 4**, they have been arranged into two groups, each feeding one column of apartments on the two sides of the staircase.

Lastly, space heating and cooling are delivered to dwellings through radiant ceiling panels set up during retrofit.

The design of such a system is challenging to many small energy-consulting offices, and the installation is not expected to be a competence of the plumbers, due to the strong integration needed among all the units set up (heat pump, solar collectors, storages), where optimal renewable energy harvest and minimum thermal energy losses are required.

For this purpose, the project partners have collaborated to develop a modular technology facilitating the installation of this complex heating and cooling systems in small- and medium-sized residential buildings. The solution is based on a plug-and-play hydronic unit (Energy Hub - EH) including the needed pumps and valves, designed to connect hydraulically to the components of a heating and cooling system, and electronically to a central controller (Energy Manager - EM).

Compared to most of the modules available on the market that enable hydronic integration of the system components and metering of the energy uses, the EHs are smart elements allowing also continuous monitoring and management of the plant. To this end, the EHs are all connected via Modbus to the EM.



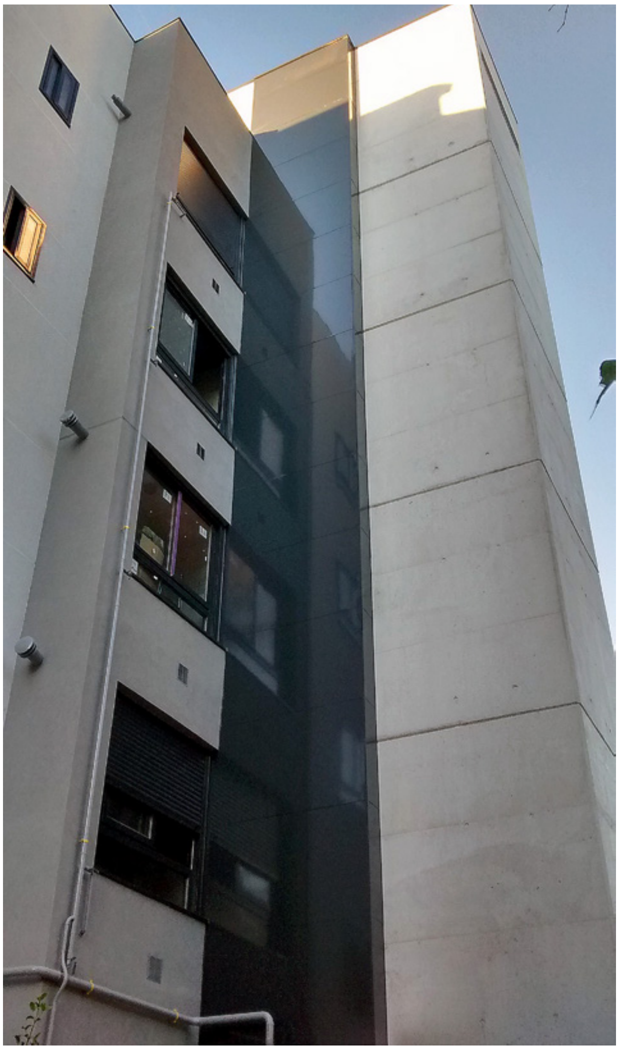


Figure 4. Vertical pipelines construction.

The latter is used to manage the EHs in the network and provides to the users and to the system manager supervision, control and monitoring functions, via a graphical human-to-machine interface. This feature supports a continuous commission of the systems through its lifetime preventing long-lasting malfunctioning and allowing to optimise its operation during the first months after setup.

Figure 5 shows the EHs in the technical room, used to connect heat pump and solar collectors to the storage tanks and to distribute water into the building; the 4 EHs that are installed on each floor to provide DHW, and space heating and cooling to the dwellings.

Figure 5. Energy Hubs in the technical room (top) and on each floor (bottom).

Lessons Learned

The level of disruption introduced during retrofit has been acceptable to the residents. Thanks to prefabrication, setting up the pipelines, technical room and Energy Hubs has been unproblematic, although the design phase has been longer compared to traditional processes and required well-structured coordination among all the actors involved.

Despite the use of prefabricated solutions, the electric/electronic integration and commissioning of the Energy Hubs has still resulted complex to the installer. This shows that training of the professionals must always follow the introduction on the market of new enabling technologies.

Finally, a deep rehabilitation process does not only involve the implementation of energy efficiency measures. It usually accounts for structural reinforcement of the building and update to the latest regulations, for instance eliminating architectural barriers, updating electric wiring and water pipelines, etc.

Consequently, after renovation, the property has not only higher energy efficiency but also higher value and longer lifetime. This is not accounted for when evaluating the payback based on the energy savings achieved: a specific property value estimation – before and after renovation – should be carried out, as a value proposition of the retrofit undertaken, showing the overall financial picture to owners and public/private investors. ■

Optimization of HVAC system operation based on a dynamic simulation tool

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Energy efficiency measures in existing buildings include improvements in heating, ventilation and air conditioning systems through systems renovation and components upgrade. These measures target building energy consumption through improving the overall system efficiency, with the thermal comfort of occupants being observed through only one or two parameters. Improvements in the existing system operation can lead to better energy efficiency as well, but with a possibility of maintaining the occupant thermal comfort in the desired range. This paper implements the parallel particle swarm optimization to determine the operation parameters of an existing HVAC system that corresponds to the minimal primary energy use while maintaining the desired occupant thermal comfort. The existing HVAC system is modeled in the simulation software EnergyPlus. The moving horizon approach in near-real time was adopted. The focus in this paper is shifted from the minimal energy consumption to the minimal energy consumption for a desired thermal comfort level, without any renovation or upgrade of the system.

Keywords: building energy simulation; primary energy; thermal comfort; operation optimization; EnergyPlus.

Energy consumption in buildings is one of the top priorities in official energy policies of many countries. The main reason behind this lies in the significant increase in energy consumption in the building sector. According to Perez-Lombard [1], buildings accounted for more than 37% of the final energy consumption in EU during 2004, with a similar situation present in the USA where in 2010 buildings participated with more than 40% of primary energy consumption [2]. Gruber [3] points out that 50% of the energy consumed in buildings in industrialized countries is used for heating, ventilation and air-conditioning. The situation is almost identical in Serbia, where the building sector participates with more than 50% of the consumed energy [4].

Energy consumption in buildings can be reduced by a number of energy efficiency measures, with the most frequent being: improving the building envelope thermal characteristics, using energy efficient HVAC equipment, and employing renewable energy sources. What is common for all these measures is that they are implemented during the refurbishment of existing buildings or the construction of new buildings, and that in the majority of cases it is legally regulated [5]. Recently, strong research efforts have been put in to improve building energy performance without major renovations of buildings/systems, but just by improving the existing systems and incorporating new automatic regulation concepts [6–8]. This primarily relates to the minimization of energy consumption/energy cost/GHG emissions in buildings while maintaining the thermal comfort of occupants within the desired range. The basis for this kind of research are the mathematicsl models of buildings and related systems. Modeling and prediction of performance focus on three categories [9]: long-term load forecasts for system selection and planning; medium-term forecasts for system maintenance and fault detection and diagnosis; and short-term forecasts for daily operation, scheduling and load-shifting plans.

Models of buildings and their accompanying systems for short-term forecasts are as follows: white-box models, black-box models, and gray-box models. White-box models include physical characteristics and relations of buildings and their systems, and are incorporated in the best-known building dynamic simulation programs such as: EnergyPlus [10], TRNSYS [11] etc., and are of special interest for this research.

The optimization process can be repeated time after time, resulting in the moving horizon optimization implemented in numerous studies on the topic of model predictive control [12–16].

This paper presents the possibility to minimize building energy consumption by optimizing the existing HVAC system operation modeled in EnergyPlus, while maintaining the occupant thermal comfort at the same time. The planning horizon is set to one day assuming a perfect weather forecast, and the optimization process is repeated day-by-day in the observed period.

Optimization process

The optimization process is based on the combination of detailed hourly simulations of the building performed in EnergyPlus and the operation optimization of selected HVAC systems developed in the C# programming language.

The optimization process follows a relatively simple iterative procedure described in [9].

The optimization problem is solved by using the parallel particle swarm optimization (PSO) [17].

The program starts by loading the building model and weather file. The building energy model created in EnergyPlus contains all the information on the analyzed building, and it is, basically, a text file with the values in particular lines which the optimization algorithm will replace with the values of selected decision variables. At the beginning of each iteration, the program randomly generates a population of decision vectors and creates as many text files as there are vectors. The program initiates the simulation of all files related to a current PSO iteration, and all simulations are carried out simultaneously. After all the simulations have finished, the program reads the resulting output files and extracts the values required to calculate the objective function value(s). The objective function can be easily defined according to a particular interest. The process is then repeated in a new iteration, with a new population of decision variable vectors randomly generated around an optimal vector of the last completed iteration. This process repeats until the exit criteria is fulfilled.

When the exit criteria is satisfied, the optimization process is repeated for the next optimization period (part of day, one day, several days, etc.).

Case study

Building description

The case studied in this paper is the office part of the Feniks BB Company building in Niš, Serbia (**Figure 1**). The building is a combination of the office and manufacturing type.

The building is located on the outskirts of Niš, the largest city in Southeast of Serbia. The useful floor area of the building is 1630 m². One part of the building, approximately a half, represents a manufacturing hall, while the other part is divided into two stories. The lower storey houses manufacturing premises and warehouses, while the upper storey is where offices and manufacturing of electronic components are located.

The building is mainly heated by radiators and air heaters (the manufacturing hall), while the office part of the building can also be heated by a ducted fan-coil unit with 100% of fresh air which at the same time presents the basic cooling system in the said space. The AHU consists of the following sections: air-to-air plate heat exchanger for heat recovery, coil section (cooling or heating as necessary), fan sections, and sound attenuators. The air conditioning system is designed in the classical manner to ensure the indoor temperature for a summer design day. The operation of all secondary systems is controlled by PLCs.

Gas-fired condensing boilers and air-to-water heat pump are used as the primary energy sources.

The simulation program EnergyPlus was used to create the building model and the mentioned HVAC systems. The building geometry was created using the *Open Studio Plug-in* for *Google SketchUp*. All rooms in the building were treated as separate thermal zones.

To simulate the building, an appropriate weather file containing all boundary conditions was also needed. A custom weather file in was formed from the data provided by the hydrometeorological station Niš.

The offices were assumed to be occupied during weekdays from 08:00 to 17:00 (the last occupied hour is from 16:01 to 17:00), with a number of occupants occupying them as defined in **Table 1**. The aim is to maintain thermal comfort within the prescribed range by optimizing the HVAC system operation day by day. As the indicator for thermal comfort the predicted mean vote (PMV) was used, and this value could be generated as the output from the simulations on an hourly basis for every modeled zone. Even though the outputs for PMV are expressed on a discrete scale from –3 to +3, the EnergyPlus algorithms carry out the calculations on a continuous scale which is not an error [18], and the value of PMV obtained through simulation can be treated as the one which meet or does not meet the desired value (e.g. PMV can have the value of 0.23784, so if the desired comfort value is 0.5, this means that the comfort is satisfied in the given hour).

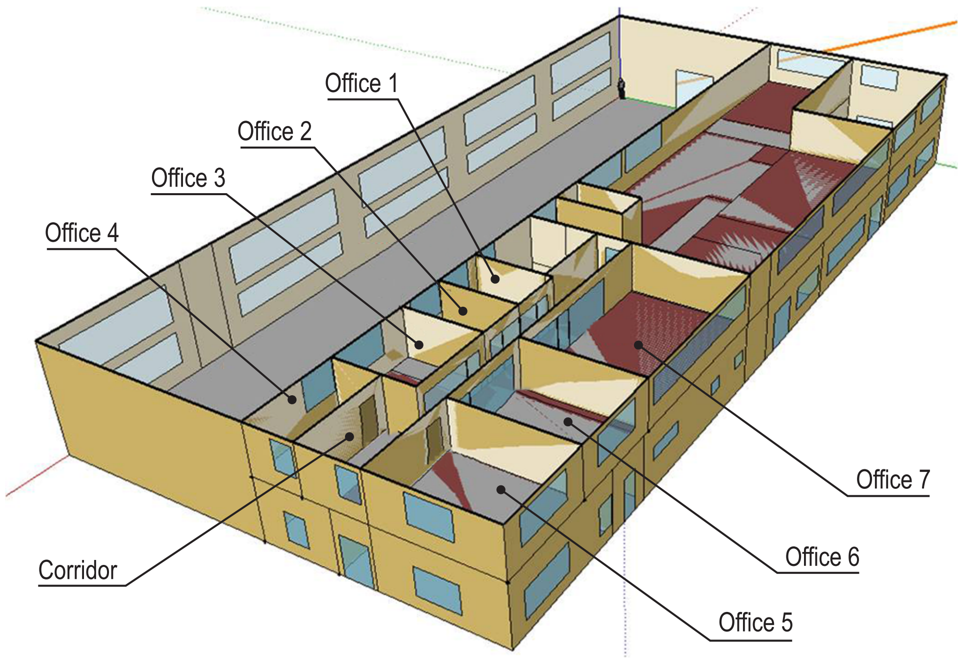

Figure 1. Office part of the building.

Table 1. Typical number of occupants in offices during weekdays.

Thermal Zone	Number of occupants
Office 1	2
Office 2	2
Office 3	2
Office 4	2
Office 5	1
Office 6	4
Office 7	4
Corridor/lobby	2

Application of the Optimization process

The period starting on January 27th 2014 and ending on February 6th 2014 was selected to meet the needs of this paper and check the methodology. A weather file in the appropriate format was created on the basis of the data provided by the Republic Hydrometeorological Service of Serbia – the hydrometeorological station Niš. The optimization period of one day was adopted, and the optimization process itself was performed for each day of the stated period including weekends, which were treated as a single optimization period.

Decision variables

To perform the optimization task and calculate the objective function, decision variables should be defined first. Since the optimization goal is to achieve the minimum primary energy consumption while maintaining the thermal comfort for one day, having the simulation tool limitations in mind, variables were classified into two groups: the ones which can be modified hourly/daily and the others which can be modified once per simulation. Certain variables were further subdivided into three periods of day for each day in the observed period: unoccupied before occupants arrive (from midnight to 08:00); occupied period (from 08:00 to 17:00); unoccupied after occupants leave (from 17:00 to midnight). To reduce the total number of decision variables, only one decision variable for each of the unoccupied periods was allowed. Furthermore, some decision variables were constrained by the fact that the system was already installed and there were limitations especially in terms of capacity and maximum flow rates.

For the observed winter operation, the following variables were adopted:

- Hot water supply temperature (hourly with distinction between occupied and unoccupied periods) - 13 variables within range 40–70°C;
- Heating set-point for offices served by baseboard heaters (hourly with distinction between occupied and unoccupied periods) - 13 variables within range 18–24°C;
- System air flow rate (once per simulation) - 1 variable within range 0.5–1.2 m³/s ;
- Minimum outside air fraction (hourly) - 24 variables within range 0.6–1;
- Baseboard heaters runtime (daily) - 1 variable;
- Baseboard heaters finish time (daily) - 1 variable;
- Heat Recovery runtime (daily) - 1 variable;
- Heat Recovery finish time (daily) - 1 variable;
- Heating Coil runtime (daily) - 1 variable;
- Heating Coil finish time (daily) - 1 variable;
- Heat Recovery bypass minimum limit temperature (once per simulation) - 1 variable.

Since two different HVAC systems (radiator heating and air-conditioning system) were served by the same heat source, using a built-in energy management system of EnergyPlus, a syntax was created according to which the heat source (boiler) was available whenever either of the two systems was required. A similar syntax was created for the AHU supply and exhaust fans, depending on whether the heating coil and/or heat recovery were needed.

Objective function

The objective function of the optimization problem is given in the form:

$$min\, E[kWh] = E_B \times 1.1 + (E_{SF} + E_{RF}) \times 2.5 \qquad (1)$$

subject to:

$$-0.5 < TCF < 0.5 \qquad (2)$$

where E represents the primary energy consumption from the systems; E_B [kWh] is the boiler energy consumption; E_{SF} [kWh] is the supply fan electricity consumption; E_{RF} [kWh] is the return fan electricity consumption; 1.1 is the primary energy conversion factor for natural gas; 2.5 is the primary energy conversion factor for electricity; 0.5 is the boundary value of PMV, and TCF is the thermal comfort related function in the form:

$$TCF = \sum_{i=1}^{i=8} (min\, PMV_i) \times \frac{N_i}{N_{tot}} \qquad (3)$$

In equation 3, *i represents the zone identifier;* minPMV_i is the minimal value of PMV in the *i*-th zone; N_i is the number of occupants in the *i*-th zone; N_{tot} is the total number of occupants.

The values of E_B, E_{SF}, E_{RF} and PMV are the outputs from EnergyPlus simulations.

For the PSO algorithm, the population size was set to 1000, while the number of generations was set to 50. The exit criteria were not defined, meaning that all 50,000 simulations were performed.

Results and discussion

The simulations were run on a 24-core Intel Xeon working station with 32GB of RAM memory. The optimization process was run for every weekday of the observed period and also for the weekend but with less strict criteria for TCF. The optimization lasted between 22 and 24 hours, meaning that there was enough time left to implement the optimal decision variables vector into the existing automatic regulation system, assuming that the weather forecast for that particular day was perfect.

To compare the results obtained in the optimization, a baseline case was adopted. This case represented the usual operation of the existing HVAC systems. The main differences between the baseline and the optimal model were:

- in the baseline case, the given thermostat values for all zones were predefined with constant value setpoints (18/20/22°C during the occupied period depending on the part of the building), while in the initial models, the thermostat values in the office part of the building were varied (in the remaining zones of the model the values are the same as in the baseline model),
- the systems were turned on in a predefined manner - 1 hour before the occupants arrive (AHU was turned on during the occupied period only), and remained on for the entire occupied period of day, while in the initial models these could be turned on any time if necessary,
- in the baseline case the heating supply temperature was dependent on the outdoor temperature, while there was no such dependency in the initial models,
- during the weekend there were no occupants, thus the systems remained turned off in the baseline model, while in the optimized model the systems might be run in order to provide good initial values for the first day following the weekend.

In the baseline case, the primary energy consumption had the value of 3451.2 kWh for the analyzed period, out of which 3232.6 kWh was for space heating (baseboards, unit ventilators and heating coil), and 218.6 kWh was for electricity for running the AHU fans. The PMV values in the offices are shown in **Figure 2.** As it can be seen, the PMV value in every zone was not even near the threshold value of –0.5. For the optimized case (the optimal

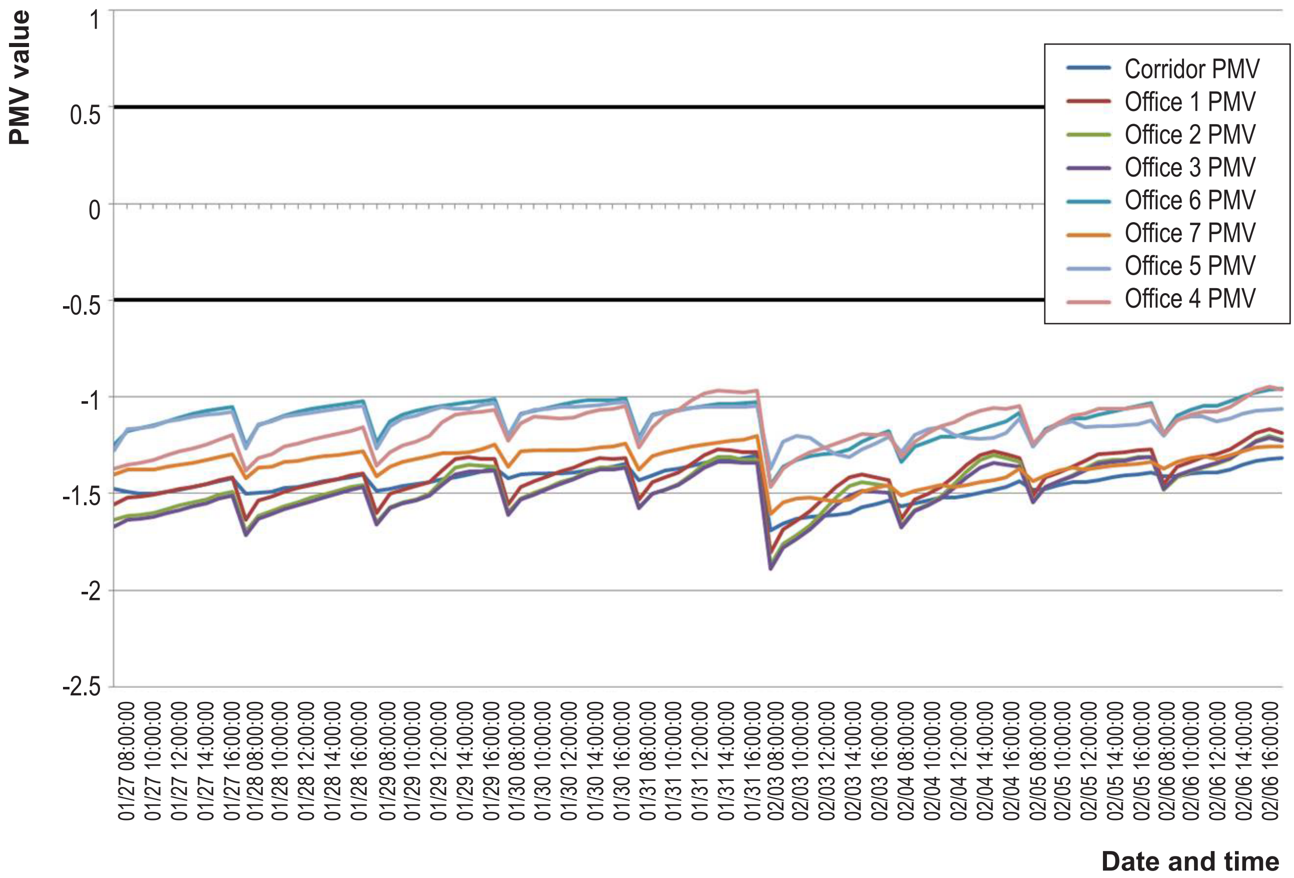

Figure 2. PMV variation in offices - baseline case.

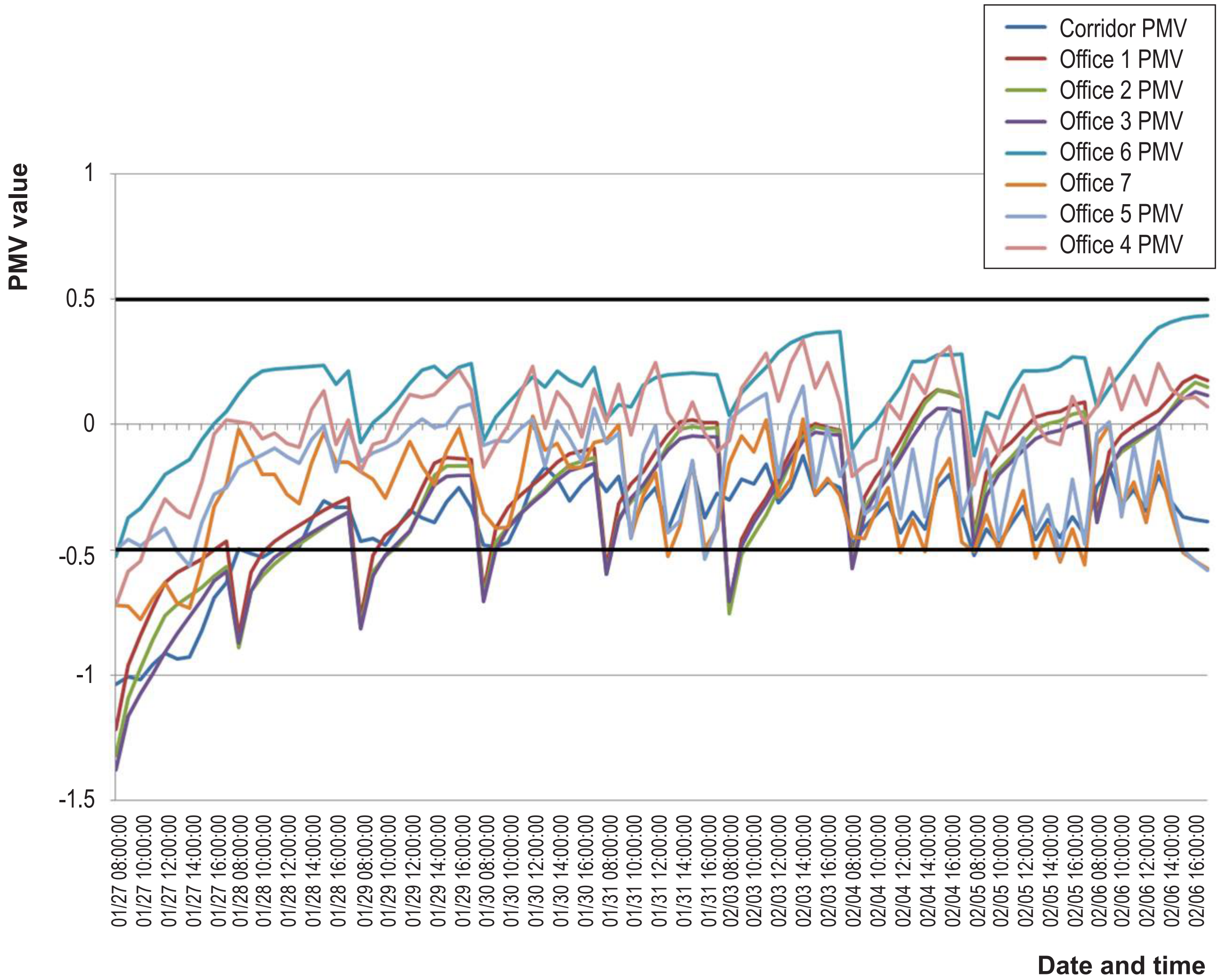

Figure 3. PMV variation in offices - optimized operation.

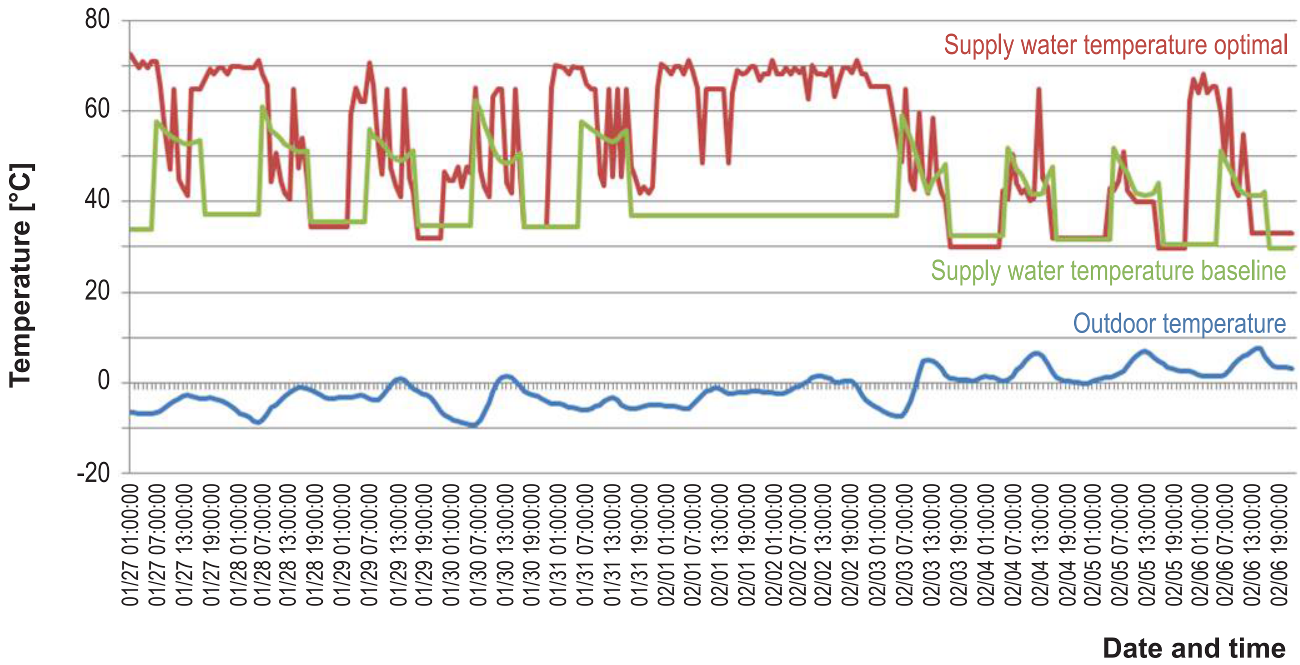

Figure 4. Heating supply temperature variation.

values from each day joined into a single simulation), the primary energy consumption had the value of 4024.9 kWh, and was used only for space heating, meaning that there was no need to turn on the AHU. The increased energy consumption was due to the weekend operation of the systems and resulted in 618.2 kWh of primary energy consumption. Thus increased energy consumption resulted in a much better occupant thermal comfort in all zones as shown in **Figure 3**.

It is interesting to note that for the optimal case no correlation could be made between the heating supply temperature and the outdoor temperature (**Figure 4**), which can potentially represent the material for future research with the aim of finding the heating curves with which system operators are familiar.

Conclusion

This paper presents the possibility to minimize primary energy consumption in offices by implementing the optimized operation of the existing HVAC systems, while simultaneously maintaining the thermal comfort of occupants within the desired range. The main goal of the paper was to show that with the existing HVAC system designed in the traditional manner, users or system operators can define in advance the thermal comfort level which the system will try to meet with minimal energy consumption. The main advantage of this methodology is that it can be applied with relatively small modifications of the existing HVAC system. Future research will be dedicated to the moving horizon approach and the implementation of the obtained optimal values into a real system, as well as their experimental verification. In addition, decision variables and objective function need to be checked in order to generalize the application of the presented process. ■

Acknowledgements

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Ordem dos Engenheiros – 16th Climatization days – 20 October, 2016

The 16th Climatization Days of *Ordem dos Engenheiros* (OdE, Portuguese Association of Engineers) was held in Lisbon on 20 October 2016. Two major themes were discussed: "The importance of water in air conditioning systems" and "Hydrogeology and Geothermal Energy". REHVA was invited to present the Guidebook Nr 20 on GEOTABS that was translated by OdE this year into Portuguese.

The event was opened and chaired by Serafin Graña, the Coordinator of the Climatization Chapter of Ode. The interdisciplinary session on "Hydrogeology and Geothermal Energy" was subject of a high interest among the participants. This great involvement of the attendees was due to the complexity of the topic and the need of interdisciplinary knowledge for the proper application in the heating and cooling systems of buildings.

Elsa Ramalho, a geological engineer, presented an interesting and valuable contribution of hydrogeological knowledge to the development of geothermal energy in Portugal, which will certainly be used as a "roadmap" for projects dealing with this area.

Luis Coelho, a mechanical engineer, presented the "European H2020 TESSe2b Project" which consists in thermal energy storage utilization using PCMs in conjunction with solar energy and geothermal energy. The Polytechnic Institute of Setubal is leading this project in partnership with other ten organizations from eight European countries (universities, companies and associations).

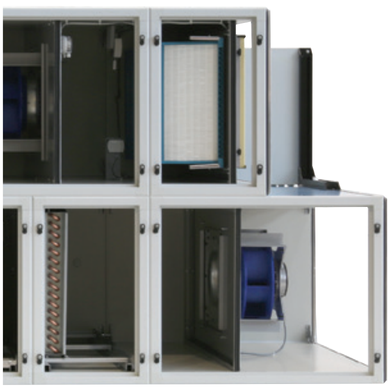
Two case studies from Portugal and Italy were presented, providing details and lessons learned from the experiences. Geologist, Pedro Madureira, presented methodologies, advantages and difficulties encountered during the ongoing work for the implementation of a geothermal energy project in a resort in Algarve (Portugal). The second case study on the Cubo Rosso building was presented by Domenico Mazzetti, a mechanical engineer from CALEFFI Hydronic Solutions. Cubo Rosso integrates solar thermal, photovoltaic and geothermal solutions. The case study session ended with a broad and lively debate among the panel of speakers and participants.

Anita Derjanecz thanked OdE for promoting the knowledge exchange by continuously translating REHVA Guidebooks. She presented new strategic activities of REHVA and the Guidebook No 20 on "Advanced system design and operation of GEOTABS buildings". This Guidebook was translated to Portuguese and offered to all registered attendees of the event.

The 16th Climatization days was attended by approximately 150 participants. OdE President, Carlos Mineiro Aires and Serafin Graña closed the successful event. ■

ADV Next Air

The air treatment evolution



A new comfort level

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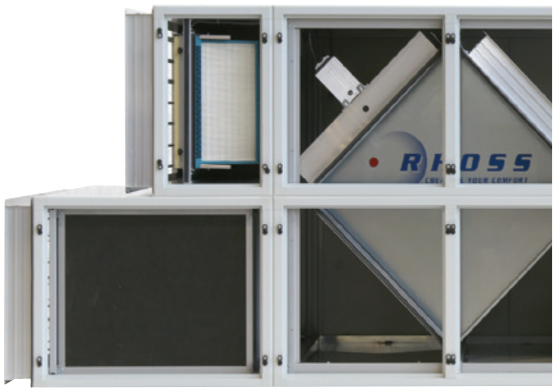
No Waste

Best efficiency in minimum space

Built-in intelligence



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REHVA – EUROVENT seminar discussed the reviews of directives, inclusion of indoor climate and situation with national nZEB as main topics

This year REHVA organized the "October Supporters Seminar" on EU regulation towards energy efficient and healthy buildings on 29 September 2016 during EUROVENT Summit in Krakow. As a joint event with EUROVENT the seminar had more audience than usually, around 100 participants, as well as three speakers representing European Commission.

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Claudia Canevari, from European Commission DG Energy, provided an overview of the reviews of EED and EPBD. These reviews included results of many evaluations and impact assessments.

The 2030 Energy Efficiency Target Level is still not fixed. The European Council set in 2014 an indicative 2030 target at EU level of at least 27%, to be reviewed by 2020, having in mind an earlier agreed EU level of 30%. The European Parliament asked in 2014 and 2015 for a binding 2030 target of 40%.

The baseline will be a scenario with GHG 40%, RES 27% and EE 27% in 2030, but the analysis of four additional EE target levels of 30%, 33%, 35%, 40% have been conducted. These analyses have shown many benefits, therefore, there are strong arguments for more ambitious target than 27%.

Regarding minimum indoor environment quality levels, which are not explicitly required in the current EPBD, the main findings from EC evaluation indicate

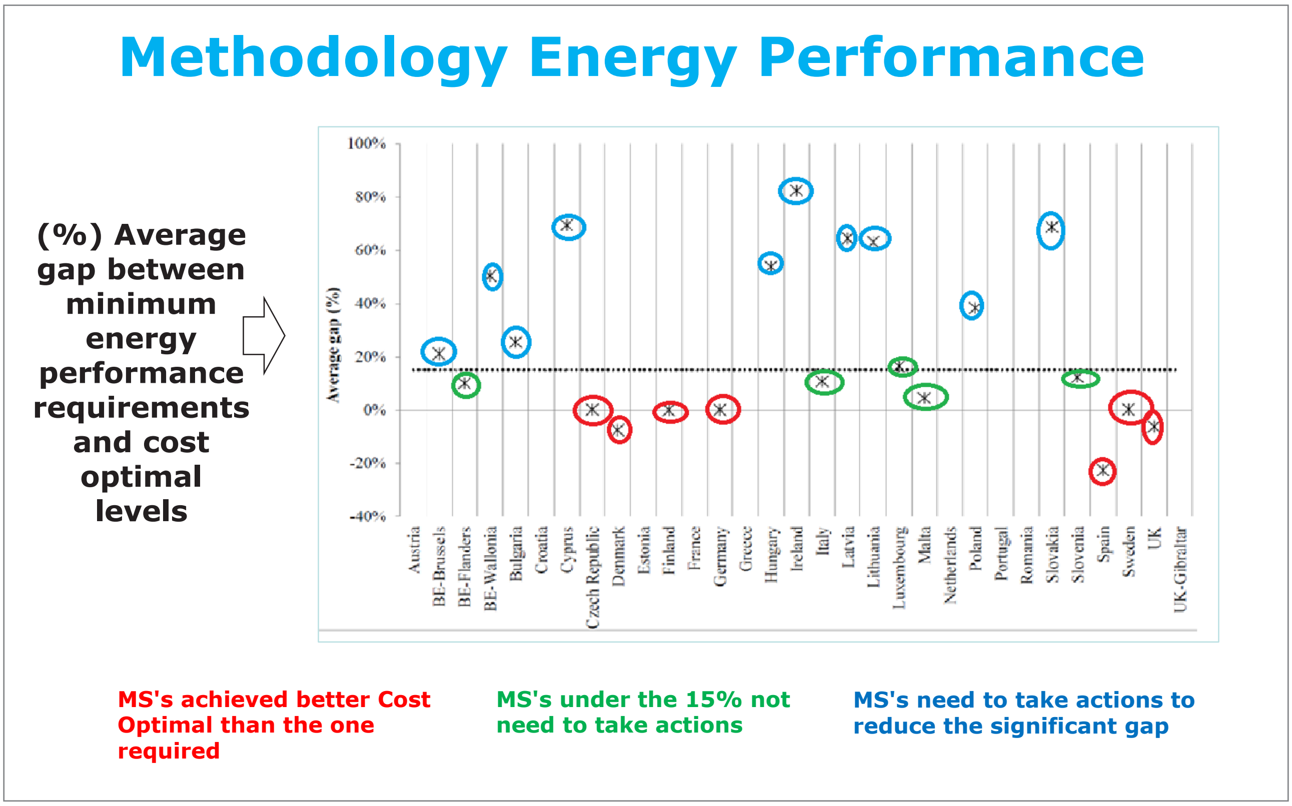

Figure 1. EC evaluations shows that MS marked with blue color need to take actions towards stringent energy performance requirements.

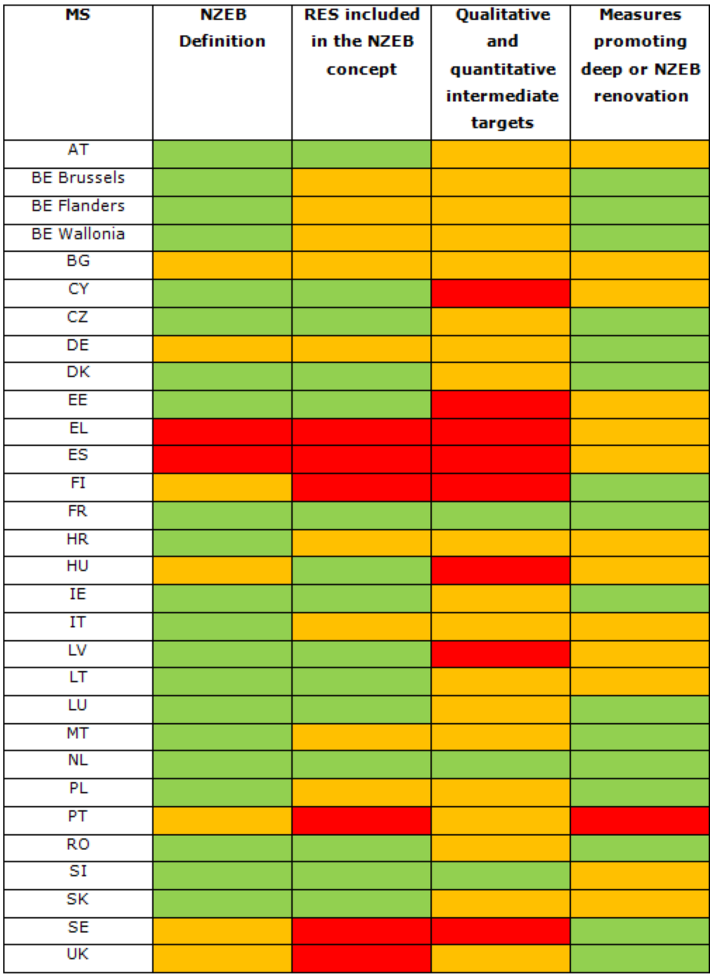

Figure 2. nZEB development evaluation in MS, available definitions, renewable energy included in definitions/system boundary, availability of intermediate targets and promotion measures. Green: satisfactory development; Orange: partial development; Red: not defined/unclear.

NZEB level of energy performance	Mediterranean Zone 1: Catania (others: Athens, Larnaca, Luga, Seville, Palermo)	Oceanic Zone 4: Paris (others: Amsterdam, Berlin, Brussels, Copenhagen, Dublin, London, Macon, Nancy, Prague, Warszawa)	Continental Zone 3: Budapest (others: Bratislava, Ljubljana, Milan, Vienna)	Nordic Zone 5: Stockholm (Helsinki, Riga, Stockholm, Gdansk, Tovarene)
	Offices kWh/(m2/y)			
net primary energy	20-30	40-55	40-55	55-70
primary energy use	80-90	85-100	85-100	85-100
on-site RES sources	60	45	45	30
	New single family house kWh/(m2/y)			
net primary energy	0-15	15-30	20-40	40-65
primary energy use	50-65	50-65	50-70	65-90
on-site RES sources	50	35	30	25

Figure 3. Numeric benchmarks for nZEB primary energy use set by EC recommendations EU 2016/1318. **Net primary energy** means the primary energy from that on-site renewable energy is reduced. Default values of on-site renewable are also provided.

the need to set such minimum requirements, summarized by Claudia Canevari as follows:

- EPBD and Indoor Environment Quality are not in contradiction.
- Gaps exist in the national regulatory framework.
- For existing buildings, mandatory minimum Indoor Environment Quality requirements can hardly be found in national/regional building codes.

EC has also completed the evaluation of national energy performance minimum requirements which should be on cost optimal level. Results in **Figure 1** show that in many countries minimum requirements are less strict than the cost optimal levels (marked with blue color).

Delia D'Agostino, from European Commission Joint Research Centre, spoke about the evaluation of national nZEB definitions. The number of MS with nZEB definition with a numerical target of primary energy use has increased, but still the definition is not approved in 9 countries as shown in **Figure 2**.

European Commission has published official recommendations EU 2016/1318 in order to ensure that it is possible to reach the nZEB by 2020. Main recommendations reflect EC concern about low ambition of national nZEB targets as well as the challenge with time schedule to deliver nZEB by the end of 2020. Some highlights of the recommendations:

- Set national definitions of *NZEB at a high level of ambition* – not below the cost-optimal level of minimum requirements.
- Use *renewables in an integrated design concept* to cover the low energy requirements.
- Assure proper indoor environment to avoid deterioration of *IAQ, comfort and health.*

Recommendation of nZEB ambition level states that the nZEB level for new buildings has to be determined *by the best technology that is available and well introduced on the market at that time, financial aspects and legal and political considerations at national level.* In order to make the ambition transparent, EC has set *numeric benchmarks for nZEB* primary energy use in the four climate zones, see **Figure 3**.

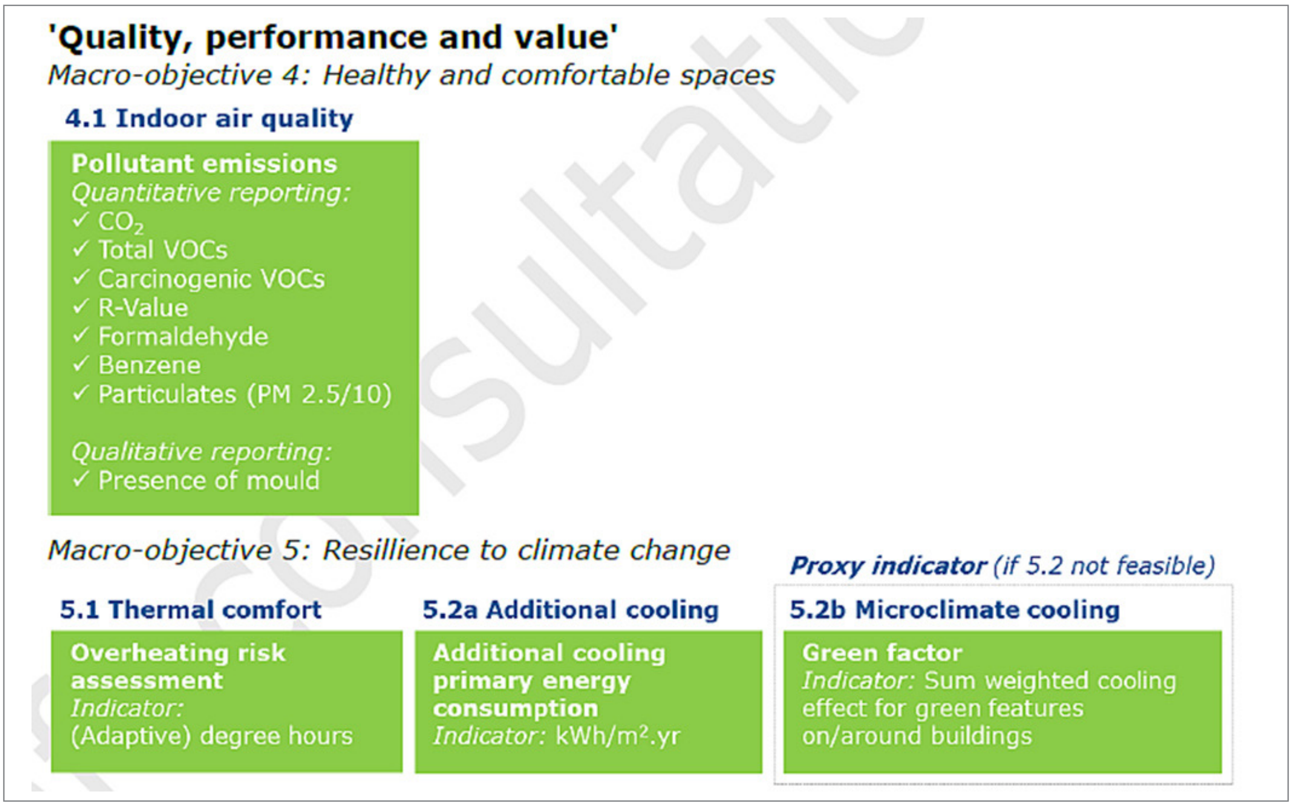

Figure 4. Indoor air quality and thermal comfort are among core performance indicators in the environmental performance assessment of buildings according to JRC **Life Cycle Environmental Performance** report.

If compared with EC benchmarks, many countries are facing the problem of too low ambition of nZEB, that applies for instance for Austria, Cyprus, Finland, Latvia, Malta, Romania and Slovenia, and is more difficult to assess in MS representing targets as relative percentage of current requirements.

Josefina Lindblom, from European Commission DG Environment, made considerations regarding core indicators development for buildings environmental performance assessment. JRC has prepared a *Life Cycle Environmental Performance* report that was on the public consultation. This report has identified in total 7 macro objectives from which two are dealing with indoor environment: Healthy and comfortable spaces (e.g. indoor air quality) and Resilience to climate change (thermal comfort/overheating risk), **Figure 4**. This JRC and DG Environment proposal aims to voluntary framework, no legislative action is foreseen, and it is expected that in the case of well-defined and transparent criteria, environmental performance will be more considered in decision making in building sector.

The rest of the presentations were conducted by the REHVA president **Stefano Corgnati**, EUROVENT **Quentin Liebens**, REHVA Vice presidents **Jarek Kurnitski** and **Atze Boerstra**. Those presentations dealt with various indoor climate and other challenges to be solved to reach a successful transformation to nZEB. **Quentin Liebens** introduced the new concept of hygienic AHU released by Eurovent Certita Certification. Jarek Kurnitski introduced the results of DG ENER – JRC project which assessed the implementation status of the EPBD by the EU MS in terms of ventilation and indoor air quality criteria and requirements. This JRC project, to which REHVA provided a solid contribution, concluded that current EPBD statement "to avoid possible negative effects such as inadequate ventilation" has revealed to be too soft formulation without expected effect. To ensure adequate IEQ, the EU-MS's shall define minimum indoor environment levels including minimum ventilation requirements. Currently, minimum ventilation requirements are set only for about half of the countries, which may lead to the situation where energy calculation may be done with ventilation, but building designed without ventilation. ■

SODEX will bring together the HVAC-R Industry in Ankara

SODEX ANKARA (May 10th – 13th, 2017 – ANKARA)

Hosting the most important meetings of the HVAC-R industry, SODEX Exhibitions are preparing to bring together the industry with the **SODEX Ankara** (May 10th – 13th, 2016 – ANKARA) exhibition following the ISK-SODEX Istanbul show which achieved significant success with 1,293 exhibitors and 83,764 visitors. Set to be organized by Hannover Messe Sodeks Fuarcılık, the event will bring together various product groups such as Natural Gas, Heating, Cooling, Air-Conditioning, Pump, Valve, Plumbing, Water Treatment, Geothermal and Solar Power Systems under a single roof and allow visitors to discover the innovations in the industry. Exhibitors will be able to reach their existing and potential customers directly.

SODEX Ankara:
Keep your finger on the pulse of the industry in the capital city

SODEX Ankara will take place in ATO International Congress and Exhibition Center on May 10th – 13th, 2017. Held for the first time in 2011 and achieving a successful 40 percent growth in 2013, SODEX ANKARA allows its exhibitors and visitors to keep their finger on the pulse of the industry in the capital city. Intensely visited by the public authorities who are an important part of the industry, the event steps forward as the most important event where the industry meets public institutions and organizations. The most important HVAC-R meeting of Ankara allows visitors to have direct access to the newest products and services.

Online thermal comfort compliance tool included in new ASHRAE user's manual

ATLANTA – A new User's Manual for ASHRAE's thermal comfort standard provides an overview for new users while also including more detailed information for those more familiar with its requirements.

The User's Manual, based on ANSI/ASHRAE Standard 55-2013, *Thermal Environmental Conditions for Human Occupancy*, provides detailed information on the requirements of the standard. It includes tables, illustrations and examples to aid users in the design, commissioning, and measuring and rating of thermal comfort in buildings.

The manual includes a free online thermal comfort tool that can be used as the official tool for showing compliance with Standard 55-2013 along with all of the published addenda. This online tool is available only to those who purchase the User's Manual and can be accessed from any internet connected device. The web-based CBE/ASHRAE Thermal Comfort Tool was developed by the Center for the Built Environment at the University of California Berkeley.

"For a new user of Standard 55, the manual provides a great overview of what it takes to make a space thermally comfortable for the occupants," Abhijeet Pande, chair of the Standard 55 committee, said. "This includes descriptions of how to account for the environmental, occupant and local factors that impact comfort. For an experienced user of Standard 55, the manual provides insights into requirements that are sometimes hard to understand in the standard. The User's Manual provides examples of calculations that will help even the most experienced user who may struggle with figuring out where and how to get an input needed for thermal comfort calculations."

ACREX India 2017

– An International Show which is truly National!

ISHRAE as a team has consciously decided to implement long term goals while simultaneously fulfilling short terms goals required for the success of the yearly events and to incorporate benefits for individual participants. The long term goal which we have set for ourselves is to make ACREX India an event where every one finds value. Be it Major Players of the industry or MSME companies, be it visitors to the show or delegates of the workshop or seminar, there will be something for everyone at ACREX India 2017, South Asia's largest exhibition on Refrigeration, Air-Conditioning, Ventilation & Intelligent Buildings.

It has been an endeavour of ISHRAE to bring HVAC&R Industry into the forefront and make ACREX India the most coveted event for the built environment. Therefore, ISHRAE has formulated a "Build Fair Alliance" this year, with five independent shows catering to the various segments of the building construction industry. The Alliance comprises following events and will be conducted at the same venue as ACREX India:

- **ACREX India** - covering HVAC, Refrigeration and Building Automation Systems
- **ISH India powered by IPA** – International trade fair showcasing plumbing, sanitation, bathroom & kitchen, renewable energy and home automation systems in India
- **Fire & Security India Expo (FSIE)** - previewing Fire safety & security solutions
- **FENSTERBAU FRONTALE INDIA** focusing on Façade & Fenestration products
- **glasspro INDIA** encompassing solutions and innovations for the glass industry

India is the fastest growing economy in the world today – an impressive position it has held since the year 2015. Our theme for this year at ACREX India 2017, **Rising India: Enterprising and Cool**, is directly linked to the growing economy of India, laying emphasis on how welcoming a country can be.

Over and above, we would like to reiterate the other highlights for this year's grand event:

- A new venue, India Exposition Mart, Greater Noida, with world class facilities and a bigger exhibition space
- Encouraging the MSME companies to take part in ACREX, offering them a platform to share the stage with the who's who of the industry, we have introduced an SME package, with huge benefits and advantages for the MSME companies participating for the first time.
- One of the biggest highlights this year will be, for the first time we have a Guest Country at our show, Turkey, represented by ISIB, to improve relations between India and Turkey
- A democratic event, with emphasis laid on the stakeholders that make the event for us – An event by the industry and for the industry – We are organising various Industry Think Tank Meetings, which are attended by the captains of the industry to share their suggestions and feedback to make the event even bigger
- ACREX India 2017 Roadshows were held at 5 locations across the country to promote the event ACREX Hall of Fame, an initiative of ISHRAE powered by DANFOSS, is organising various Roadshows across the country to recognise more iconic buildings and rewarding them.
- A few more initiatives by ACREX India 2017 this year include sector specific meetings on Refrigeration and Cold Chain, Building Management Systems, Government Advisory Meetings etc.
- Interactive Workshops and Seminars with emphasis on Indian Standards during the course of the event
- aQuest, A Student Competition, that is held every year, to recognise the talent of the future
- Celebrating India Day at International forums

With our sincere efforts this year, it will be heartening to see the International interest the show is generating, with participation of companies from more than 25 countries. Besides participation of International Global Players the show will also see International support from organizations like ASHRAE, REHVA, ISKID, CAR, ANPRAC, Eurammon, KNVIK, ISIB, CIBSE, etc.

Organizer

ISHRAE (Indian Society of Heating, Refrigerating and Air Conditioning Engineers), was founded in 1981 at New Delhi by a small band of die-hard HVAC&R Engineers. Today, ISHRAE has over twelve thousand Members and, over three thousand Student Members organized in thirty-nine chapters all across India. ISHRAE organizes Exhibitions and Catalog Shows, conducts Seminars, Workshops, Training Programs, Certification Programs and Product Presentations throughout the country to achieve its primary objective of Advancement of the Sciences of Heating, Ventilation, Air Conditioning, Refrigeration Engineering & Related Services. ISHRAE Publications strive to help readers keep up to date with the happenings, learn new techniques, improve old designs and use new devices to improve Energy Efficiency and enhance Indoor Air Quality in the Built Environment.

Event Producer

NürnbergMesse is one of the 15 largest exhibition companies in the world. The portfolio covers some 120 national and international exhibitions and congresses and approx. 40 sponsored pavilions at the Nuremberg location and worldwide. Every year, around 30,000 exhibitors (international share: 41%) and up to 1.4 million visitors (international share of trade visitors: 24%) participate in the own, partner and guest events of the NürnbergMesse Group, which is present with subsidiaries in China, North America, Brazil, Italy and India. The group also has a network of about 50 representatives operating in over 100 countries. ■

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World Sustainable Energy Days:
the energy efficiency community meets in March

As one of Europe's largest annual conferences on energy efficiency and renewable energy, the **WORLD SUSTAINABLE ENERGY DAYS** (WSED) have grown over the past 20 years into the global meeting place for the sustainable buildings community. Each year, the unique combination of events attracts experts from all over the world to Wels. The next edition will be held from 1–3 March 2017 in Wels/Austria.

8 specialised conferences offer the opportunity to learn about current trends in sustainable energy world and interactive events provide valuable networking possibilities. In 2016, over 700 energy experts from 57 countries took part in the World Sustainable Energy Days.

A FOCUS ON ENERGY EFFICIENCY AND BUILDINGS

The **European Energy Efficiency Conference** covers policies, markets, business models, research & innovation, technologies, financing and best practice solution with a strong focus on high energy efficiency buildings.

The **European Research Conference: Buildings** delivers new research results on energy-efficient and sustainable buildings. Topics include novel materials, energy storage, building energy systems, smart and high performance buildings, deep renovation, renewable energy and indoor air quality.

The **Young Researchers Conference: Energy Efficiency** presents the work and achievements of young researchers in the field of energy efficiency in buildings.

The **European Nearly Zero Energy Buildings Conference** is dedicated to very high efficiency buildings supplied to a large extent by renewable energy. Experts from all over the world come together at the European NZEB Conference to discuss innovative concepts and present solutions for efficient building technologies and renewable energy. The conference provides information on technologies and strategies, focuses on costs and innovative financing and operational models and presents flagship projects in the areas of new construction and retrofitting.

Mark your calendars for 1–3 March 2017 and join experts in Wels/Upper Austria at the **World Sustainable Energy Days**. For more information, visit the conference website **www.wsed.at**.

8 SPECIALISED CONFERENCES

- European Energy Efficiency Conference
- European Pellet Conference
- European Research Conference: Buildings
- European Nearly Zero Energy Buildings Conference
- Young Researchers Conference: Biomass + Energy Efficiency
- Energy Efficiency Services and Business Conference
- E-Mobility & Smart Buildings Conference
- European Energy Efficiency Watch Conference

3 HANDS-ON EVENTS

- Major energy tradeshow
- Cooperation platform
- Technical site visits

REGISTRATION & INFORMATION

Conference-website **www.wsed.at** and OÖ Energiesparverband, Landstrasse 45, 4020 Linz, T: +43-732-7720-14386, office@esv.or.at, **www.esv.or.at**

ISH The world's leading trade fair The Bathroom Experience, Building, Energy, Air-conditioning Technology Renewable Energies

Interview with **Ms Iris Jeglitza-Moshage,** Senior Vice President, Messe Frankfurt

1) What distinguishes ISH 2017?

As in the past, the coming ISH will be the number one for the sector and, even at this early stage, can already underscore its significance as the world's leading trade fair for visitors and exhibitors with some impressive statistics. Thus, over 2,400 exhibitors, including all market and technology leaders from home and abroad, will once again launch their new products onto the world market at ISH in Frankfurt am Main from 14 to 18 March 2017. ISH itself plays a leading role because it is THE meeting place for the international sector with 61 percent of exhibitors and 39 percent of visitors coming from outside Germany in 2015.

2) Which themes will ISH 2017 focus on?

The motto of ISH 2017 is 'Water. Energy. Life.', which clearly shows where the focus of the world's biggest trade fair for the combination of water and energy lies and, in particular, where its keystones are located. With a broad spectrum of future-oriented building-services technology, the biennial trade fair offers solutions for current political and economic themes.

The ISH Energy and Aircontec sections are devoted to energy efficiency and comfort in buildings. The decisive trends are to be found in the field of efficient, future-oriented technologies and intelligent building-services technology. In a nutshell, it is necessary to take account of the ever-closer relationship between heat and renewable energy. Also, digital heating and the associated integration of IT in innovative heating technologies will be an important subject – all concentrated together under the heading, 'The energy revolution with a bright future – we have the solutions'.

In the Aircontec segment, the focal points will include modern home-ventilation systems, which embraces the subjects of energy efficiency and comfort in the home, as well as central and decentral solutions for new buildings and modernisation projects. Additionally, attention will also be paid to the technological challenges facing the sustainable air-conditioning and ventilation sector.

3) Why should engineers visit ISH?

At ISH, planners and engineers can see the entire spectrum of innovative and energy-efficient building-system technology together with concepts and solutions not only for modernising existing buildings but also for new buildings in the residential and non-residential sectors. In this connection, we offer free guided tours of the fair especially for planners and engineers, which give them a good opportunity to orientate themselves and to make contact with colleagues. All this is rounded off by our complementary programme of events, which includes the ISH Technology and Energy Forum, the Air-conditioning Forum and the Building and Real Estate Forum.

Additionally, there will be a special REHVA Day on 15 March 2017, the main part of which will be a guided tour to the REHVA Supporters' booths and the reHVAClub reception for REHVA Members and Supporters. On the following day, REHVA will hold a seminar consisting of lectures and a concluding discussion on the subject of 'Controlled Residential Ventilation'. In this connection, I can report that, in the Aircontec segment, there has been an increase in interest and greater demand from new home-ventilation companies. For the Seminar participants, ISH offers the associated range of products and, therefore, represents the perfect conclusion to the seminar. Accordingly, we are delighted with the productive collaboration and looking forward to intensifying our working relationship with REHVA. ■

BELIMO

New Generation of Butterfly Valves and Actuators from Belimo

First butterfly valve actuator designed specially for the HVAC market

The heating, ventilation and air-conditioning industry has very specific requirements with respect to butterfly valves – ones that could not previously be fulfilled in their entirety. The new butterfly valves and PR actuators from Belimo are now closing this gap and meeting through their technology 100% of these high HVAC market requirements.

Thanks to its considerably reduced installation height and its greatly reduced weight, the new PR actuator from Belimo can be mounted without difficulty on the butterfly valve. The actuator can be readily commissioned, parameterised and provided with maintenance through the integrated Near Field Communication (NFC). With this new product generation, Belimo has also succeeded in reducing the torque requirement of the butterfly valves and the power consumption of the actuator. To be more precise, in some applications, these innovative butterfly valve-actuator combinations can be used to achieve energy savings of up to 80%.

Two additional highlights of the new butterfly valve-actuator combination are the flexible position indicator, that shows the position of the butterfly valve even from distance, and the smart heating used to prevent condensation inside the actuator. Thanks to an integrated temperature and humidity sensor, this smart heating does not switch on until it is actually required by the application.

The latest technology for butterfly valves and PR actuators from Belimo is thus the most intelligent, energy-efficient and reliable high flow solution in the HVAC market. The central advantages of this product series are thereby obvious: simplicity of installation, the flexibility of application and durability. Belimo is setting new standards with the new butterfly valve-actuator combination.

More information: **www.belimo.eu**

Trane now offers Airfinity Solar as a renewable energy source for commercial buildings

New Airfinity Solar integrated solar rooftop system reduces peak time electricity consumption, operating costs and carbon footprint without compromising comfort.

Brussels, Nov. 22, 2016 –Trane, a leading global provider of indoor comfort solutions and services and a brand of Ingersoll Rand, introduces Airfinity™ Solar, a scalable and pre-packaged solution of photovoltaic (PV) solar panels compatible with the Trane Airfinity range of heating, ventilation and air-conditioning (HVAC) rooftop units.

The new solar rooftop system offers a new way for building owners across Europe to implement a sustainable energy solution and reduce operational costs, while also being compliant. The new system complies with the Building Research Establishment Environmental Assessment Method (BREEAM), Leadership in Energy and Environmental Design (LEED) certifications and regulations such as the Renewable Energy Directive 2009/28/EC, which encourages the use of energy from renewable sources and commits to achieving a 20 percent share of renewable energy in the European Union's gross final energy consumption by 2020.

"HVAC systems consume valuable power during peak times when solar energy is most available. By installing the solar panels to power the HVAC equipment, the building reduces carbon emissions and peak time electricity consumption," said Dominique Silva, unitary product manager at Trane in Europe. "The new Airfinity Solar offers customers a pre-packaged kit that is adaptive to their needs and budget. It combines the latest Trane compact and light Airfinity rooftop units with proven silicon PV technology with best-in-class inverters."

The Trane Airfinity Solar system is composed by:

- Airfinity rooftop unit(s): High-efficiency direct-expansion air-conditioning units designed to provide air-conditioning and ventilation to an indoor space.
- Silicon photovoltaic panels: to convert solar energy into DC electrical power.
- Mounting membranes: to support the PV panels on the roof and also serve as a wind deflector.
- High Efficiency Inverter: Converts DC power supply provided by the PV panel(s) into AC power input which can be absorbed the rooftop HVAC unit and building utility grid
- Cables and connectors: Double isolation and UV resistant cables suitable for rooftop applications and IP65 crimped connectors
- Easy system integration: Plug-and-play solutions

Already installed and operating Trane Airfinity rooftop units can be easily upgraded to an Airfinity Solar system.

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StrengThin™ 100 Factsheet

1. Victaulic background

Since 1919, Victaulic has been the world's leading producer of grooved mechanical couplings and pipe-joining systems. Used in the most demanding markets, Victaulic's innovative piping technologies and services put people to work faster while increasing safety, ensuring reliability and maximizing efficiency. The company has 15 major manufacturing facilities, 28 branches worldwide and over 3,600 employees who speak 43 languages across the globe. With more than 1,900 active global patents, Victaulic's solutions are at work in 115 countries across diverse business lines including plumbing, heating, ventilation, oil and gas, chemical, mining, power generation, water and wastewater treatment, military and marine, as well as commercial building and fire protection.

2. Thin wall piping – the challenge

The popularity of thin wall stainless steel piping has grown significantly in recent years. Today, it occupies a central position in the European construction market and is particularly popular for chilled and potable water, cooling and oil free air systems. The many benefits which thin wall stainless steel pipes can bring to the construction industry include substantially increasing the efficiency of onsite material handling while simultaneously cutting down installation costs.

However, thin wall stainless steel pipes are not without their drawbacks, and welding, the traditional method used for joining them, involves a range of various challenges and complexities. Notably, welding often leaves the pipes susceptible to overheating and requires the use of chemical treatment on pipes to restore their corrosion resistance. Noxious fumes and fire hazards are all among the very real challenges associated with the welding process for thin wall stainless steel pipes.

Other challenges are that thin wall stainless steel pipe welding can typically only be carried out by specially certified welders, requires optimal weather conditions and necessitates the procurement of firewatch permits by construction firms. These obstacles, as well as the additional inspection costs, which come with welding thin wall stainless steel pipes, are a significant hindrance in the thin wall stainless steel pipe joining process.

3. Thin wall piping – the solution

To address these industry challenges, Victaulic has launched its StrengThin™ 100 product range. The Victaulic StrengThin™ 100 System for Thin Wall Type 304/316 Stainless Steel Pipe includes couplings, fittings and valves, and is the industry's first grooved mechanical piping system specifically designed to perform up to 16 bar on thin wall 304/316 pipes. StrengThin™ 100's new grooved mechanical piping system uses the company's propriety Installation-Ready™ Technology, which provides fast, easy pipe connections, eliminating the need to disassemble the coupling with no loose parts to lose or drop. The StrengThin™ 100 system also features an innovative groove profile which creates coupling engagement while eliminating the risk of pipe flare.

 Find the full report at http://bpie.eu/publication/renovation-passports/

Building Renovation Passports

Customised roadmaps towards deep renovation and better homes

The European Union is facing a double challenge: increasing building renovation rates while aiming at achieving "deep renovations"[1]. Increasing the current EU renovation rate from 1.2% per annum to 2-3% is essential to meet both the EU 2020 targets and the commitment undertaken in Paris in December 2015[2]. About 75% of the EU's 210 million buildings are not energy efficient, and 75% to 85% of them will still be in use in 2050. Ensuring a highly-efficient and fully decarbonised building stock by 2050 is a major challenge. The quality of the energy renovation of our building stock is, therefore, of paramount importance. Despite the proven economic and technical feasibility of building renovation, and despite the societal and environmental benefits it could bring, renovation rates are still low and considerably below the expected level.

Building owners and potential investors face multiple barriers to improve the energy performance of their buildings. Together with difficulty to access finance, one of the most often quoted barriers is the lack of knowledge about what to do, where to start, and which measures to implement in which order.

Energy Performance Certificates (EPCs) were introduced by the first Energy Performance of Buildings Directive in 2002 (2002/91/EC)[3] with the aim to make the energy performance of individual buildings more transparent. The EPBD recast in 2010 (2010/31/EU) reconfirmed and strengthened the instrument in a number of ways: independent quality control of EPCs, penalties for non-compliance, display of the energy label in advertisements, a mandatory requirement to hand out a copy of the EPC in sale and rent transactions and improvement of renovation recommendations (cost-effective and cost-optimal measures).

EU Member States have implemented national EPC schemes, although different approaches about the comprehensiveness and quality assurance provide a very diverse picture of its implementation[4]. To date, the implementation of EPCs varies significantly across Member States in terms of scope and information available, with limited market penetration or acceptance by the users due to low reliability and lack of user-friendliness. The required recommendations for measures improving energy performance are mostly scarce, too general or non-existent in most national EPC versions. Additionally, EPC-related services such as energy consultancy and audits for residential buildings differ significantly between Member States and programmes.

As a result, the relevance of EPCs for owners and their stimulating effect for the renovation of buildings is limited[5].

Among the most important benefits of renovation are increased thermal comfort and air quality, better daylight entry and improved health of occupants. Those benefits, even if they are the main drivers for renovation, are not covered by the current EPC formats.

EPCs could be the appropriate tool to provide the information in a meaningful and comprehensible way to the individuals who are making decisions about renting, buying or investing into a property. To become more relevant, EPCs could contain useful, tailor-made and understandable information directly related to the decision-making criteria of potential investors and building owners.

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1 There currently isn't a common definition of "deep renovation". An overview of the main definitions of deep renovation used in the EU is available in Annex 1.

2 Keeping the long-term increase in global average temperature well below 2°C above pre-industrial levels, with the aim to limit the increase to 1.5°C

3 Directive 2002/91/EC and recast: Directive 2010/31/EU, https://ec.europa.eu/energy/en/topics/energy-efficiency/ buildings.

4 BPIE (2014): Energy Performance Certificates across the EU [1].

5 According to the ZEBRA2020 survey: the real-estate market does not see a link between the improvement of the energy performance of buildings and EPCs. [10]

Thus, two main issues should be solved for EPCs to have a higher impact on energy performance of buildings and renovation: the concerns about reliability and compliance, and their relevance in the decision-making process of building owners.

While an amendment of the EPBD in favour of enforcing stricter compliance and triggering a further evolution of EPCs would certainly be very welcome, some initiatives have started to develop in the past few years, with the aim to establish a more comprehensive and user-friendly instrument to support building owners with personalised instructions on their renovation options. At the core of these initiatives is the idea that renovation plans are very often limited by factors such as financial constraints, the need to reduce the time of renovation, discomfort during the works and the lack of knowledge regarding the best solutions available[6].

The aim of this report is to provide an overview of initiatives currently developed: three of them were selected, in Flanders, France and Germany, all revolving around the concept of "building renovation roadmap or passport"[7]. These initiatives were chosen for their advanced phase of development (they will soon enter the implementation phase), as they provide a good overview of the process supporting the creation of a Building Renovation Passport and as they cover the main issues that need to be addressed for its development and implementation. In the three cases, public authorities have shown interest for this concept (France) and have supported or driven (Flanders and Germany) its development.

WHAT IS A BUILDING RENOVATION PASSPORT?

There is no common definition of what a Building Renovation Passport (BRP) stands for. Each of the examples taken into account differs in some elements and the terminology used. The definitions below are based on the main findings of the cases analysed and could be used to initiate and structure a debate on BRP at the European level.

Figure 1 presents an overview of the main components of the BRP to provide a common understanding of the terminology and the different elements covered by the three examples analysed. In section 2, the terminology and definitions adopted in each country will be explained.

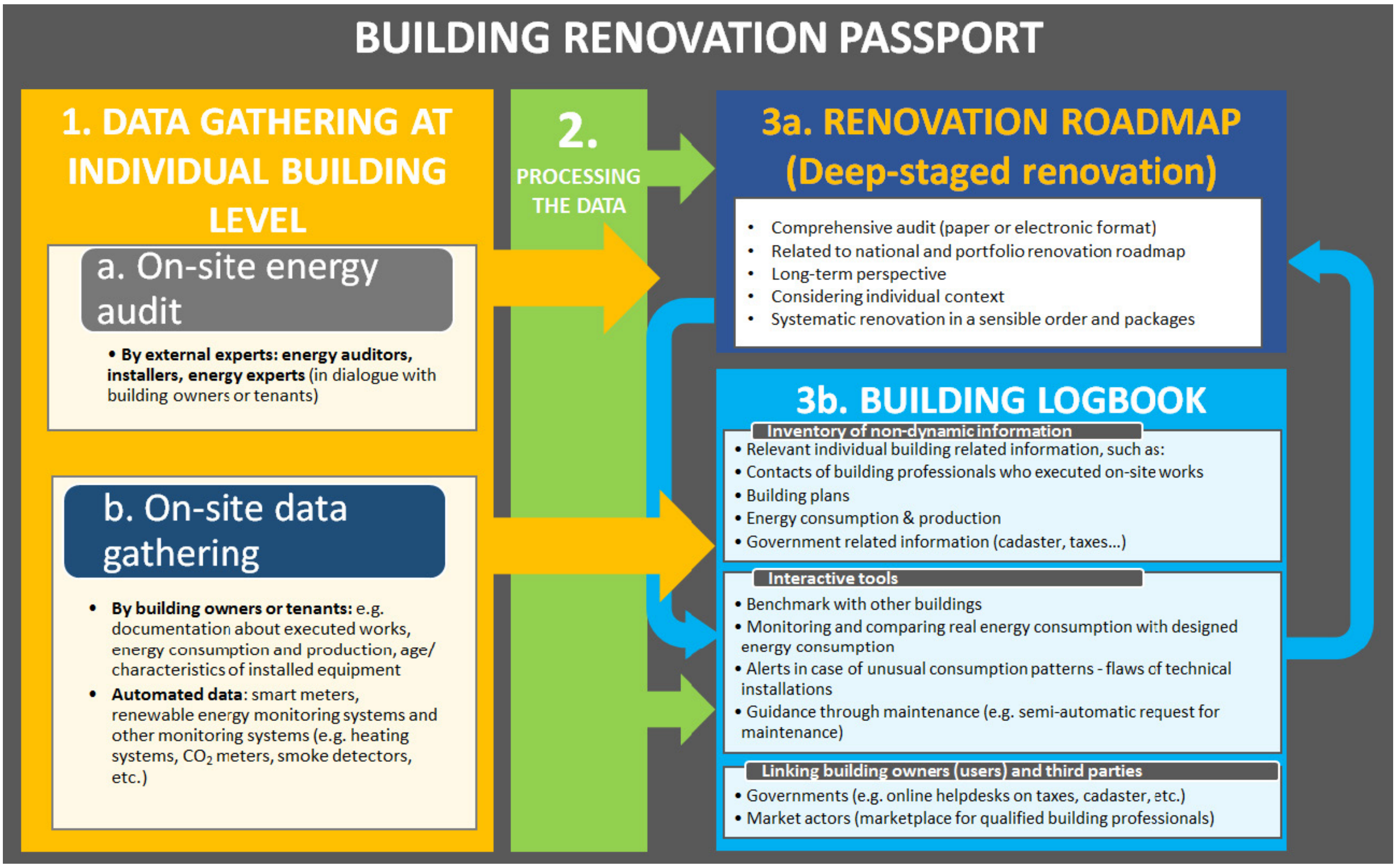

Figure 1. Building Renovation Passport – Overview of its component. (Source: BPIE)

[6] BPIE (2013): Boosting building renovation: an overview of good practices. [12]

[7] In this article, the expression "Building Renovation Passport" is used.

A **Building Renovation Passport** is defined as a document – in electronic or paper format – outlining a long-term (up to 15 or 20 years) *step-by-step renovation roadmap* for a specific building, resulting from an *on-site energy audit* fulfilling specific quality criteria and indicators[8] established during the design phase and in dialogue with building owners. The expected benefits in terms of reduced heating bills, comfort improvement and CO_2 reduction are a constitutive part of the BRP and are explained in a user-friendly communication. The renovation roadmap can be combined with a repository of building-related information (logbook) on aspects such the energy consumption and production, executed maintenance and building plans.

On-site data gathering is the first step towards the creation of a BRP. The data processing can change according to each model (e.g. by using a dedicated software or by adapting the existing energy audit software). The outcome of step 1 and 2 is a comprehensive step-by-step renovation roadmap, with tailored solutions aiming at achieving deep-staged renovation.

Step-by-step renovation roadmap (or staged renovation)

A renovation plan with a horizon of up to 15-20 years that, by looking at the building as a whole, suggests the installation of selected measures in a certain order to avoid that at any stage of renovation the installation of additional measures is precluded.

Depth of renovation

There is no common definition for "deep renovation", "staged renovation" and "deep-staged renovation". As described in section 2, each of the examples analysed uses a different definition of what a deep renovation[9] is.

There are, however, common features among all initiatives, like the will to raise the level of ambition for achieved energy performance, to ensure consistency between short and long term measures and to align the target for the performance of individual buildings with the long-term target for the entire building stock.

By supporting staged renovations, adapted to the preferences of individual building owners, BRPs give them the opportunity to have an overview of the full range of renovation options and to easily identify each renovation step from beginning to the end. As a result, staged renovation strategies facilitate the owner's decision to invest in a deeper renovation process, in particular if specific elements that need to be taken into account for later renovations are also highlighted. For example, if a roof is insulated, roof overhangs, downspout connections, adjustment of the boiler and piping penetrations for future solar systems, etc. are also included. The final product is a Renovation Roadmap outlining each renovation step and the links between all measure implemented, presenting the renovation as a home-improvement plan (not just a technical intervention) and helping to avoid lock-in effects10 (see point 3a in **Figure 1**).

It is essential for owners to take possession of the project: for individual building owners, the uncertainty regarding future renovation options typically leads to retention with respect to renovation decisions or to limited renovations (installation of easy measures). From this perspective, any instrument that triggers a long-term perspective and allows building owners and potential investors to clearly outline robust long-term renovation plans, including short-term measures and measures that need a more adaptive and flexible approach (e.g. sequencing of measures' installation over time) could increase their confidence and enhance the rate of renovation.

BRPs provide a comprehensive set of relevant indicators (e.g. energy consumption, CO2 emissions, thermal and acoustic comfort, indoor air quality and daylight) and include a dynamic dimension by delivering information about recommended improvement strategies in a detailed way and, by doing so, stimulate deep or staged deep renovations.

Logbook

In addition to the renovation roadmap, the building renovation passport can also include a separate element, a storage space where the building's features and information (e.g. stability, durability, water, installations, humidity, maintenance requirement, etc.) can be collected and regulatory updated, becoming a proper repository of information and data related to a specific building. The logbook could also include other sets of information related to each individual building, such as the financing options available in the area for renova-

[8] E.g. energy consumption, daylighting, indoor air quality, health conditions, thermal comfort, acoustic comfort, cost.

[9] An overview of the definitions of "deep renovation", "staged renovation" and "staged deep renovation" commonly used among building experts is available in Annex 1.

[10] The energy savings which are not going to be realised due to un-ambitious and insufficiently stringent energy requirement targets for buildings, building element and equipment (IEA Glossary). [2]

tion projects (e.g. green loans, incentives, tax credits) as well as energy bills, equipment maintenance recommendations as well as insurance and property obligations. All this information could be inventoried in a digital register, available to property owners.

Figure 2. Data/information modules that can be included in the building renovation passport. (Source: VEA)

Logbook user

The main user of the logbook is the building owner. Depending on the type of logbook or its intended use, owners could grant access to some information to public authorities (e.g. municipality, property tax office), building professionals and craftsmen, and make some information publicly available, while keeping other data private or restricted (semi-public upon authorisation to third-parties).

In Flanders, building owners will have access to the logbook, with the opportunity to authorise access to public authorities too.

In its most sophisticated form, the logbook could also be used as an interactive tool to monitor (both at individual building level and building stock level) and compare real energy consumption with designed energy consumption, send alerts in case of unusual consumption patterns or flaws in technical installations. It could also be linked to market actors (such as building professionals, craftsmen or financial institutions) to provide information regarding (certified) contractors and installers, facilitate invoicing and simplify the process for subsidies or loans repayment (see **Figure 1**, 3b).

All the models described in this paper are still under development and only the Flemish example plans to include a Building Renovation Passport and logbook as described above.

Targeted building typology

The three examples in this paper target residential buildings, with a focus on single-family houses, and provide a tailor-made renovation plan and customised recommendations presented to building owners in an attractive and motivating form. In principle, BRPs could also be adapted to multi-family buildings, but the three cases examined do not include this building typology.

http://bpie.eu/publication/renovation-passports/

CONCLUSIONS AND RECOMMENDATIONS FOR THE DEVELOPMENT OF A BUILDING RENOVATION PASSPORT IN THE EU

CONCLUSIONS

Based on the three cases examined in this BPIE study, five common guiding principles can be identified as the basis of the building renovation passport:

- **Long-term perspective**: the integration of a long-term thinking is essential for the success of building renovation passports, since they aim at helping the owner to carefully plan for renovation in a consistent manner, achieve a high-level of energy performance over time and better control the total cost of renovating.
- **Timing and sequencing of actions**: building renovation passports include both short-term and long-term measures and clearly indicate the correct order in which to install them (e.g. sequencing of the measures' installation over time) to avoid lock-ins, increase building owners' confidence and enhance the rate of deep renovation. Passports therefore address uncertainty regarding future renovation steps, which typically lead to retention with respect to renovation decisions or to limited renovations (installation of short-term measures).
- **Customer engagement and consideration of the individual renovation context**: The wishes, needs - in particular expectations regarding comfort - and the financial situation of the occupants must be considered. These include, for example, financial opportunities, living space changes and family planning (e.g. having a baby, or children moving out). In all the study cases, the fact that the owners take ownership of the project is seen as a key success factor.
- **Attractiveness and motivation**: BRPs should be very attractive and user-friendly. Building owners have to be guided throughout the process and receive clear indications so that they can confidently take action without being discouraged by the complexity of the renovations. The visual graphics of the BRPs must therefore be carefully designed and easy -to-understand.
- **Automation:** experts should be able to perform the audit and deliver the results as easily as possible. The instrument offered to the auditors (e.g. software) to input data during the audit should be structured in modular blocks, indicate default values and highlight errors in case of wrong inputs, etc. Once the audit is concluded, an automated information sheet (including text and figures) can be filled with specific property parameters. This facilitates the energy auditors' work while delivering personalised advice at the same time.

RECOMMENDATIONS

In recent years, the concept of building renovation passport has been gaining attention as a way to achieve higher (and deeper) renovation rates. The upcoming review of the Energy Performance of Buildings Directive creates the opportunity to introduce this concept, to strengthen the use of EPC and to evolve the tool with the aim to make it an effective instrument for consumer and investor guidance. In their current application, EPCs are mostly not considered a suitable instrument to increase renovation rates. As such, it is either not taken into account (like in Germany), or just used as a reference (e.g. P2E) for BRPs. BPIE therefore suggests steps to initiate a dialogue about the opportunity to successfully promote the notion of building renovation passports across the EU:

- **Adopt a long-term perspective**

BRPs can help to make the concept of "renovating the building stock" a reality for building owners. To do so, BRPs should be linked to long-term renovation targets (e.g. building-stock renovation by 2050) consistent with a common EU vision and ambition, and include an implementation roadmap. This is particularly relevant if BRPs are promoted as a voluntary tool. Setting a clear long-term goal could stimulate the development of BRPs, which could be included in future national renovation strategies.

- **Clearly define the concept and components of the BRPs**

This is important to define the key elements to be included in the passport, based on a modular approach (mandatory components + additional modules, mixed in different manners based on specific situations and needs) that can be built overtime. BRPs should also identify their target audience and include monitoring and evaluation tools to track renovation actions over time.

- **Establish a target (building typology and users)**

Identifying the BRPs' target users and building typology from the start allows flexibility in design and future implementation.

- **Be clear on ambition and definitions**

Since BRPs promote a step-by-step approach (staged-renovation), a common definition across Europe of deep renovation and deep-staged renovation would be welcome.

- **Adopt the appropriate regulatory framework and link Building Renovation Passports to EPCs**

To avoid uneven implementation across Member States, a common regulatory framework, linking EPCs to deep or staged-deep renovation across the EU is necessary. The ongoing review of the Energy Performance of Buildings Directive (EPBD) would be an excellent opportunity to strengthen the provisions around EPCs and link them to the notion of BRPs. Integrating EPCs in the process, promoting them as the starting point to develop BRPs (as VEA is doing) has a threefold advantage:

a) it provides mandatory requirements for Member States to implement BRPs;
b) avoids competition between these two instruments and
c) creates an opportunity to encourage deep renovation.

- **Adopt common tools**

Adopting common tools or, at least, clear methodological guidelines for measurement, statistics and analysis of each module will facilitate monitoring and implementation across countries.

- **Engage stakeholders beyond the building sector**

Stakeholders, covering a large range of competences and know-hows, going beyond the building and construction sectors, must be involved from the start. In particular, behavioural experts, data analysts, experts in data acquisition/sharing and protection, market researchers and communication strategists should be consulted.

- **Develop a user-friendly tool (for the auditors and the users)**

The BRPs should be easy-to-use for both the auditors and the final users. The audit process should be systemised as much as possible (modular structure, pre-defined text, graphs, etc.). This is imperative that the savings and non-energy benefits aspects are visible and understandable to owners. Equally important is that energy auditors and craftsmen are aware of the tool and feel confident about its use and effectiveness.

- **Include technical and communication training**

Some of the main barriers to the market uptake of BRPs is the diversity and large numbers of SMEs that characterise the construction market, and the anticipated "resistance to change", of the craftsmen, energy auditors and, potentially, building owners. For this reason, it is vital to provide craftsmen and energy auditors with the necessary knowledge to understand the benefits of BRPs and how to use them, so they can become "ambassadors" of the BRPs towards building owners.

- **Find the balance between technical features and the ability to communicate**

The ability of auditors and craftsmen to create a dialogue with building owners is a key element for the success of BRPs and their market uptake. Building owners are usually interested in knowing how their comfort experience will change after renovation, but are less involved in the technical aspects of the process.

- **Reduce the administrative hurdles**

Making the BRP as simple as possible for the user is essential to its success. This is important to adapt building permit requirements to avoid extra administrative hurdles for building owners opting for deep-staged renovation. Having a single permit valid over time, rather than requiring a new permit every few years, may facilitate the market uptake of BRPs.

- **Consider comfort as driver for renovation**

BRPs should express in a clear manner how the various improvements of a building will positively impact the comfort and well-being of its occupants. Therefore, climatic conditions, including the designed indoor climate regarding temperature, indoor air quality, acoustics and lighting should be among the main indicators featured in a BRP.

This will facilitate that, alongside the evaluation of the energy performance of the building, BRPs address comfort. While the notion of comfort varies in each country based on cultural and historical differences, home well-being and energy savings drive renovation across Europe today. Most home-owners consider their comfort and well-being (e.g. comfortable indoor temperatures, satisfactory levels of daylight, appropriate levels of humidity and fresh air supply allowing a better living environment and improved sleeping conditions) key characteristics of a healthy and desirable home and one of the main reasons for renovation. ■

Send information of your event to Ms Chiara Girardi cg@rehva.eu

Events in 2016 - 2017

Conferences and seminars 2017

Jan 28 - Feb 1	ASHRAE Winter Conference	Las Vegas, NV, USA	http://ashraem.confex.com/ashraem/w17/cfp.cgi
Feb 7-10	Aquatherm Moscow	Crocus Expo, Moscow, Pavilion 3, Halls 13-15	https://goo.gl/DzmN9r
Feb 14-17	Aquatherm Novosibirsk	Novosibirsk Expo Centre	https://goo.gl/1pgR8h
Mar 1-3	World Sustainable Energy Days 2017	Wels, Austria	http://www.wsed.at/en/world-sustainable-energy-days/
Mar 14-15	Is ventilation the answer to indoor air quality control in buildings? Do we need performance-based approaches?	Brussels, Belgium	https://goo.gl/94J3wX
Apr 19-22	Teskon+Sodexis	Izmir, Turkey	http://www.teskonsodex.com/
Apr 19-21	Aquatherm St. Petersburg	EXPOFORUM, Pavilion G, St. Petersburg, Russia	https://goo.gl/9CuVsh
May 10-11	50th International Congress "Beyond NZEB retrofit of existing buildings"	Matera, Italy	
May 10-12	1st Buildings India 2017 Exhibition and Conference	New Delhi, India	http://www.smartcitiesindia.com/
May 10-13	Sodex Ankara	Ankara, Turkey	http://www.sodexankara.com/
May 12-13	Climamed 2017 Conference "Historical buildings retrofit in the Mediterranean area"	Matera, Italy	
May 18 - 20	ISH China & CIHE 2017	New China International Exhibition Center, Beijing, China	www.ishc-cihe.hk.messefrankfurt.com
Aug 7-9	Building Simulation 2017	San Francisco, California, USA	www.buildingsimulation2017.org
Aug 23 - 25	43rd International Symposium of CIB W062 Water Supply and Drainage for Buildings 2017	Haarlem, The Netherlands	http://www.tvvl.nl/cib-w062-2017
Sep 5 - 7	ISH Shanghai & CIHE 2017	Shanghai New International Expo Centre, Shanghai, China	www.ishs-cihe.hk.messefrankfurt.com
Sep 28 - 29	7th International Conference on Solar Air-Conditioning - PV Driven/Solar Thermal	Tarragona, Spain	http://www.solaircon.com/

Exhibitions 2017

Feb 15-17	HVAC R EXPO Saudi	Jeddah, Saudi Arabia	https://www.hvacrexposaudi.com/
Jan 30 - Feb 1	2017 AHR Expo	Las Vegas, NV, USA	www.ahrexpo.com
Feb 23-25	ACREX 2017	Delhi, India	www.acrex.in
Mar14-18	ISH	Frankfurt am Main, Germany	http://www.ish2017.com/

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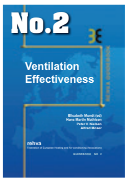
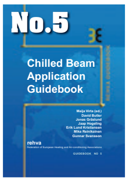
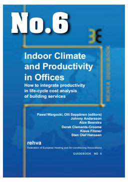


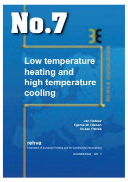
Ventilation Effectiveness. Improving the ventilation effectiveness allows the indoor air quality to be significantly enhanced without the need for higher air changes in the building, thereby avoiding the higher costs and energy consumption associated with increasing the ventilation rates. This Guidebook provides easy-to-understand descriptions of the indices used to measure the performance of a ventilation system and which indices to use in different cases.



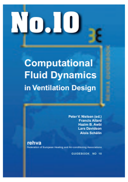
Chilled Beam Cooling. Chilled beam systems are primarily used for cooling and ventilation in spaces, which appreciate good indoor environmental quality and individual space control. Active chilled beams are connected to the ventilation ductwork, high temperature cold water, and when desired, low temperature hot water system. Primary air supply induces room air to be recirculated through the heat exchanger of the chilled beam. In order to cool or heat the room either cold or warm water is cycled through the heat exchanger.



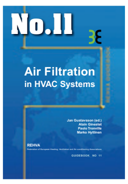
Indoor Climate and Productivity in Offices. This Guidebook shows how to quantify the effects of indoor environment on office work and also how to include these effects in the calculation of building costs. Such calculations have not been performed previously, because very little data has been available. The quantitative relationships presented in this Guidebook can be used to calculate the costs and benefits of running and operating the building.



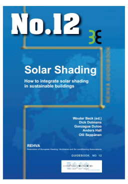
Low Temperature Heating And High Temperature Cooling. This Guidebook describes the systems that use water as heat-carrier and when the heat exchange within the conditioned space is more than 50% radiant. Embedded systems insulated from the main building structure (floor, wall and ceiling) are used in all types of buildings and work with heat carriers at low temperatures for heating and relatively high temperature for cooling.



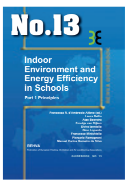
Computational Fluid Dynamics in Ventilation Design. CFD-calculations have been rapidly developed to a powerful tool for the analysis of air pollution distribution in various spaces. However, the user of CFD-calculation should be aware of the basic principles of calculations and specifically the boundary conditions. Computational Fluid Dynamics (CFD) – in Ventilation Design models is written by a working group of highly qualified international experts representing research, consulting and design.



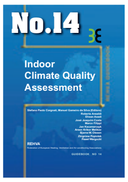
Air Filtration in HVAC Systems. This Guidebook will help the designer and user to understand the background and criteria for air filtration, how to select air filters and avoid problems associated with hygienic and other conditions at operation of air filters. The selection of air filters is based on external conditions such as levels of existing pollutants, indoor air quality and energy efficiency requirements.



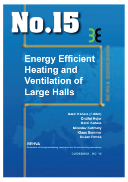
Solar Shading – ***How to integrate solar shading in sustainable buildings.*** Solar Shading Guidebook gives a solid background on the physics of solar radiation and its behaviour in window with solar shading systems. Major focus of the Guidebook is on the effect of solar shading in the use of energy for cooling, heating and lighting. The book gives also practical guidance for selection, installation and operation of solar shading as well as future trends in integration of HVAC-systems with solar control.



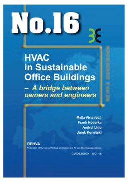
Indoor Environment and Energy Efficiency in Schools – ***Part 1 Principles.*** School buildings represent a significant part of the building stock and also a noteworthy part of the total energy use. Indoor and Energy Efficiency in Schools Guidebook describes the optimal design and operation of schools with respect to low energy cost and performance of the students. It focuses particularly on energy efficient systems for a healthy indoor environment.



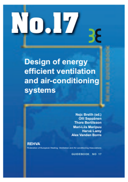
Indoor Climate Quality Assessment. This Guidebook gives building professionals a useful support in the practical measurements and monitoring of the indoor climate in buildings. Wireless technologies for measurement and monitoring have allowed enlarging significantly number of possible applications, especially in existing buildings. The Guidebook illustrates with several cases the instrumentation.



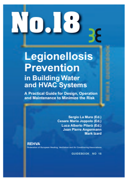
Energy Efficient Heating and Ventilation of Large Halls. This Guidebook is focused on modern methods for design, control and operation of energy efficient heating systems in large spaces and industrial halls. The book deals with thermal comfort, light and dark gas radiant heaters, panel radiant heating, floor heating and industrial air heating systems. Various heating systems are illustrated with case studies. Design principles, methods and modelling tools are presented for various systems.



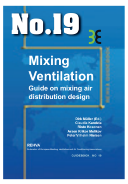
HVAC in Sustainable Office Buildings – ***A bridge between owners and engineers.*** This Guidebook discusses the interaction of sustainability and heating, ventilation and air–conditioning. HVAC technologies used in sustainable buildings are described. This book also provides a list of questions to be asked in various phrases of building's life time. Different case studies of sustainable office buildings are presented.



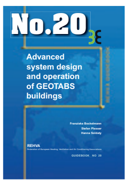
Design of energy efficient ventilation and air-conditioning systems. This Guidebook covers numerous system components of ventilation and air-conditioning systems and shows how they can be improved by applying the latest technology products. Special attention is paid to details, which are often overlooked in the daily design practice, resulting in poor performance of high quality products once they are installed in the building system.



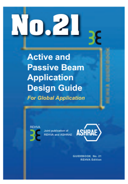
Legionellosis Prevention in Building Water and HVAC Systems. This Guidebook is a practical guide for design, operation and maintenance to minimize the risk of legionellosis in building water and HVAC systems. It is divided into several themes such as: Air conditioning of the air (by water – humidification), Production of hot water for washing (fundamentally but not only hot water for washing) and Evaporative cooling tower.



Mixing Ventilation. In this Guidebook most of the known and used in practice methods for achieving mixing air distribution are discussed. Mixing ventilation has been applied to many different spaces providing fresh air and thermal comfort to the occupants. Today, a design engineer can choose from large selection of air diffusers and exhaust openings.



Advanced system design and operation of GEOTABS buildings. This Guidebook provides comprehensive information on GEOTABS systems. It is intended to support building owners, architects and engineers in an early design stage showing how GEOTABS can be integrated into their building concepts. It also gives many helpful advices from experienced engineers that have designed, built and run GEOTABS systems.



Active and Passive Beam Application Design Guide is the result of collaboration by worldwide experts. It provides energy-efficient methods of cooling, heating, and ventilating indoor areas, especially spaces that require individual zone control and where internal moisture loads are moderate. The systems are simple to operate and maintain. This new guide provides up-to-date tools and advice for designing, commissioning, and operating chilled-beam systems to achieve a determined indoor climate and includes examples of active and passive beam calculations and selections.

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