ISSN 1307-3729

REHVA

Federation of European Heating, Ventilation and Air Conditioning Associations

The REHVA European HVAC Journal

Volume: 56 Issue: 5 October 2019 www.rehva.eu

Use of EPB Standards

Ventilation standards supporting innovation

Demand controlled filtration for cleanrooms

Design of displacement ventilation

The REHVA European HVAC Journal

www.rehva.eu

Volume: 56 Issue: 5 October 2019

SUBSCRIPTIONS and CHANGES OF ADDRESSES

REHVA OFFICE:
Washington Street 40
1050 Brussels, Belgium
Tel: +32-2-5141171
info@rehva.eu, www.rehva.eu

PUBLISHER

TEKNİK SEKTÖR YAYINCILIĞI A.Ş.
Barbaros Mahallesi, Uğur Sk. No: 2/2
Üsküdar/İstanbul, Turkey

Contents

Download the articles from **www.rehva.eu** -> REHVA Journal

Advertisers

Next issue of REHVA Journal

Instructions for authors are available at **www.rehva.eu** (> Publications & Resources > Journal Information). Send the manuscripts of articles for the journal to Jaap Hogeling **jh@rehva.eu**.

Global warming some facts, what can the HVAC and Building sector do?

The last months strong messages reached us regarding the not substantial decrease of CO_2 emission and the increasing global warming. The Paris agreement targets of 2 °C or preferably the 1,5 °C seem unachievable given the current energy policy from many countries around the globe. Europe formulated targets that MS's agreed to achieve.

JAAP HOGELING
Editor-in-Chief
REHVA Journal

Amended EU Directive 2012/27/EU on Energy Efficiency, endorses the mainstreaming of more efficient technologies in heating and cooling. It sets a general indicative target of 32,5% reduction in energy use by 2030. In the longer term, the Union is committed to decarbonise the energy sector and transition to a net-zero greenhouse gas emission economy by 2050 [1]. Efficient H&C in buildings and industry are a key component in this transition, making use of energy need reduction, energy use reduction by improved system efficiency and the use of renewable energy. Half of the energy in EU is used for H&C and 80% of this is consumed in buildings. This means that the transition would be impossible without an intelligently engaging H&C sector.

At the same time, we listen to the strong messages voiced by our children. On September 23, 2019, at the climate summit in New York immediately after Secretary General António Guterres, Greta Thunberg called on the United Nations General Assembly in a sharp tone to account for their negligence on decisive action against the climate crisis. Not many of us will have missed this message. But what state leaders, we voted for, do is repeating that this have to be cost effective. It is cost effective if we include all environmental costs in our equations. But this is still not happening. Even the simplest way, to tax the CO_2 emission is not enforced because we wait for international agreement on this.

Some facts: Yes, we are with many people on this planet. 15% of the people ever lived on earth are currently running around. Half of the worldwide CO_2 emission since 1750 dates from the years after the Kyoto Protocol (1997), we didn't achieve much! Those who believe that nuclear energy will save us have to bear in mind that the carbon footprint of nuclear produced electricity is on average 65 CO_2-eq gr/kWh [2]. Which is comparable with fossil fuel produced electricity with CCS technology. Compare this with the CO_2-eq footprint of wind turbines which is around 15 gr/kWh.

What can we do as building HVAC sector to convince our clients that reducing the energy needed by investing in better designed buildings and at the same time reducing their remaining energy use by smart and energy efficient HVAC and domestic hot water systems and on top of that we have to add sustainable energy producing and using systems. We all know how to do this, how to reach the zero carbon emission buildings. We can do it tomorrow. But the way we calculate the costs, not including the total environmental impact (LCA), prevents us doing this. Pricing the carbon emission and other environmental impacts in a honest and transparent way will help. This is why CEN, the European Standards organisation, developed the set of EPB standards [3] to at least assess the Energy Performance of our buildings and systems in a transparent and reliable way. Most EU MS's still struggle accepting these EP assessment procedures (see articles on pages 6 – 38). These standards are there to support and increase transparency regarding the declared Energy Performance of buildings we built, buy or rent out. The recently published prEN 17423 (see page 54 of REHVA Journal 4/2019) on Primary Energy Factors and CO_2 emission factors is an important step to increase the transparency of the energy performance declarations. For the time being the MS's politicians have the privilege to declare and justify the underlying policy factors, this standard will help them to do this in a transparent way. ■

[1] A Clean Planet for all. A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy, COM(2018) 733, 28.11.2018.

[2] Life Cycle Greenhouse Gas Emissions of Nuclear Electricity Generation Systematic Review and Harmonization. Ethan S. Warner, Garvin A. Heath.

[3] See www.epb.center.

Ongoing EPBD implementation and the use of the set of EPB standards in various EU countries

JAAP HOGELING
Editor-in-Chief
REHVA Journal

REHVA Journal asked several persons informed about the developments in their country on the use of the EPB standards, about their personal observation regarding the status of the implementation of the EPBD (Energy Performance Buildings Directive) and in connection to this the use of the set of EPB standards.

The EPBD doesn't require EU Member States to use the EPB standards. The national EPB assessment procedures have to meet the requirements included in the Directive. The set of EPB standards developed under Mandate 480 given to CEN meets the requirements of the EPBD. If MS's use these standards it is quite easy to demonstrate that they follow the EPBD requirements.

As published in earlier articles in this journal, the way the EPB standards are developed and set up offers the MS's the required flexibility needed to apply these EPB standards throughout Europe. All EPB standards include an Annex B with default values and choices. MS regulators can use these default values of Annex B or adapt them to their national wishes according annex A of these standards.

Transposition measures and recommendations[1]

In accordance with EPBD Annex I, 'Member States must describe their national/regional calculation methodologies following the national annexes to the overarching standards'. Member States will have to meet this requirement at the latest by the transposition deadline, i.e. 10 March 2020. Member States have several options for notifying compliance with this obligation. One straightforward option is to include the filled-in annexes to the overarching standards when officially notifying the Commission of national measures trans-

[1] See: COMMISSION RECOMMENDATION (EU) 2019/786 of 8 May 2019 on building renovation (notified under document C(2019) 3352) clause 3.2.3. Transposition measures and recommendations.

posing the EPBD. In order to facilitate transparency and improve comparability, it is recommended that Member States make the description of their calculation methodologies publicly available, e.g. by uploading the filled-in templates to a website or annexing them to their building codes, etc. In such cases, they may notify the Commission of the publicly available source to prove that they have fulfilled the obligation.

Making the calculation methodology publicly available will also help Member States fulfil the requirement to ensure that 'the methodology applied for the determination of the energy performance of a building shall be transparent…' in Annex I (Point 1, second paragraph) to the EPBD. Where a Member State adopts an EPB standard in full in national law (i.e. it uses the standard (as is) as part of its building regulations implementing the EPBD), it can choose:

(a) to ask its national standardisation body to develop a national annex based on the Annex A template — in that case, it could be considered to have fulfilled the obligation in Annex I to the EPBD in respect of that standard by publishing the national annex together with the national regulations requiring use of the standard in question; or

(b) to publish the filled-in Annex A as a national data sheet:

(i) as a separate document referred to by the building regulations; or

(ii) as an integral part of the building regulation implementing the EPBD.

The national annex or data sheet is then used to meet the requirements of the EPBD and facilitate the use of the standard at national level. When EPB standards are not adopted in full by a Member State, then the Annex A of the standard should be used as a template to describe the national calculation methodology and national choices, ensuring compliance with the EPBD.

The various personal observations on what is happening in their countries illustrate the hard work that is going on in the different EU countries to have the revised national EP assessment methods timely in place. ■


FRITERM®
Dry Coolers
EUROVENT CERTIFIED PERFORMANCE
CERTIFY ALL DRY COOLERS
www.eurovent-certification.com
Certified
Vertical Type
Dry Cooler with
Axial Fan
V Type
Dry Cooler
Horizontal Type
Dry Cooler with
Axial Fan
Reliable Solution Partner

Status of implementation of EN-EPB standards in Italy

LAURENT SOCAL
Consultant
E-mail: socal@iol.it

Keywords: EPBD – CEN - standards

Energy performance calculation in Italy

Energy performance calculation has been required well before requirements by the EPB directive, like in several other European countries. Regulation 10/91 of 1991 and its application decree DPR 412/93 of 1993 first asked for an energy performance calculation and demonstration of minimum energy performance levels to get a building permit. At that time calculation and requirements were limited to heating service in new buildings. Later, requirements for new buildings were extended to other services (domestic hot water, cooling, ventilation, lighting, etc.) and partial energy performance requirements (e.g. maximum U-values and minimum system efficiencies) were introduced when renovating existing buildings.

Energy performance calculation for legal purpose (e.g. to get a building permit and to issue an EPC) shall be done according to the calculation method specified by the regulation. The national regulation always referred to UNI-CTI standards, that is UNI standards developed by CTI (Comitato Termotecnico Italiano, www.cti2000.it), which is the association in charge of standardisation in the HVAC sector.

Italian standards were developed by experts which at the same time were also participating into CEN working groups, so there has always been a strong connection between CEN standards and the corresponding Italian standards. Several EN standards are already referenced since a long time, like the former EN 832, then EN-ISO 13790 and now EN-ISO 52016 with all the supporting standards. The current general part about weighting is a subset of ISO 52000-1 because it was developed at the same time by experts participating in CEN work.

The main steps in the development of the Italian calculation method were:

- 1993 First set of standards, monthly calculation covering only heating with basic generators (boilers)
- 2003 Extension of scope to domestic hot water
- 2008 Complete revision of the procedure, the package is named UNI-TS 11300 with several parts (see **table** next page).
- 2010 Extension to cooling and ventilation
- 2012 Extension to the full set of heating generators (heat pumps, thermal solar, cogeneration, etc.) and renewable sources
- 2016 New general part for weighting (primary energy calculation), addition of people transport.

Step by step revision is needed to allow software manufacturers to prepare, update and submit for approval by CTI the calculation tools to be used for legal purpose.

The current set of energy performance calculation standards in Italy is described in the **table** below.

Why to change now?

In Italy there is consensus on the fact that the current set of energy performance calculation standards needs a major revision. The monthly calculation is well tested and provides representative results only when dealing with heating and domestic hot water, both for building envelope and technical systems. An experienced designer may support an energy audit about heating and domestic hot water using the UNI-TS 11300 calculation model. Experience and know how allow to tailor the input data to get results in close accordance with actual energy use.

The same cannot be said for the parts of UNI-TS 11300 concerning cooling, ventilation and air conditioning. There are two main technical issues:

- the monthly time step makes it difficult to calculate cooling needs and to consider complex usage patterns (intermittent occupation) of non-residential buildings;
- the calculation methodology for cooling systems and air conditioning (UNI-TS 11300-3) is very basic and cannot consider the variety of systems used for these services. This standard cannot be used as the calculation model for an energy audit on cooling, ventilation and air conditioning systems.

Standard number	Scope	Notes
UNI-TS 11300-1:2014	Building needs, including heating, cooling, ventilation and humidification	The first version was published in 2008. It mostly refers to ISO-EN 13790:2008 and supporting standards.
UNI-TS 11300-2:2019	Basic heating and domestic hot water systems.	The first version was published in 2008. Several parts are identical to EN 15316:2007 (example: boiler calculation is the same as EN 15316-4-1:2007) or use the same concepts. The revision published in 2019 is a minor review with some errata corrige and the addition of heat recovery on domestic hot water sewage.
UNI-TS 11300-3:2010	Cooling and air conditioning systems	This standard should cover cooling and air conditioning. It is very basic and doesn't cover the huge variety of possible HVAC systems.
UNI-TS 11300-4:2016	Heating and domestic hot water systems using renewables	The first version was published in 2012. Thermal solar part is identical to EN 15316-4-3:2007. Heat pumps are calculated with monthly bins.
UNI-TS 11300-5:2016	General part and delivered energy weighting	This standard deals with the global energy balance for electricity, weighting according to primary energy and calculation of RER. It is a subset of ISO 52000-1 (identical equations). Conforming to national regulation, exported energy is not considered into the building energy balance.
UNI-TS 11300-6:2016	People transport	It is a simple standard about elevators and travelators that is based on tabulated values
UNI 10349:2016	Climatic data	The first version was published in 1994. The new revision includes monthly and hourly data for more than 100 reference locations

New buildings are more and more insulated (legal requirements on new buildings envelopes is quite tough) and therefore most of the energy is used for cooling, ventilation, lighting and domestic hot water, not for heating. Dealing with these services, an hourly method makes it easier to capture the cooling needs, which are often a matter of some hours a day and also makes it simple to describe complex time schedules of non-residential buildings where there may be several categories of spaces in one single building.

Since the last major review of the energy calculation method in Italy dates back about 10 years ago and buildings are more and more performing, it's time for a complete review.

Why EN standards

Let's forget for one minute that in EU countries there should be no other standards than EN on topics covered EN standards: most large countries have indeed their own methods in force for energy performance calculation.

The first CEN-EPB package had coordination issues and could not be adopted as a whole. However, UNI-TS 11300 referred to well accepted and tested standards (like EN 13790) and incorporated methods from several other EN standards, indeed.

Now the second CEN-EPB package, developed thanks to the second mandate to CEN, is available, and:

- EN 52016 specifies a fully detailed hourly method to calculate heating and cooling needs, which relies on the same data input as the monthly method;
- EN 16798 about cooling and ventilation covers a wide range of systems;
- there is a wide possibility to customize calculation modules and to specify national application data via the Annex A/B system.
- several modules were tested, and demonstration spreadsheets are available
- the modular structure of the package allows to connect national modules to the general frame, if needed.

Adopting this package in the Italian context would solve several issues, such as:

- switching to an hourly method while keeping traceability and transparency of the method. A parallel calculation with XLS spreadsheet is possible, at least for simple cases. The alternative is switching to tools based on Energy plus, Transys and similar but modules are often black boxes and not suitable to routine energy performance calculation purpose.
- Switching to an hourly method while keeping nearly the same description of the building. This minimizes the impact on professionals (learning new input methods) and on software manufacturers (develop new interfaces)

The remaining issue is being sure that the overall package will work. Since switching from monthly to hourly time step is a big change, the risk of wrong calculation connections and of hidden issues must be controlled.

What's going on

National annexes have already been prepared for most EN-EPB standards.

A few **alternative national calculation modules** are being prepared. These are the transposition into the CEN-EPB modular structure of current national calculation modules. This is being done for a few EN modules where there are uncertainties and/or issues and keeping the current national procedure is the preferred option. These national modules will be later proposed to the relevant CEN TCs.

A general overarching document is being prepared to provide all the links and "details" that are not obvious (or hidden) until you really try to transfer the method into software. A simple example is that adopting an hourly method and using weekly profiles that differentiate between weekdays and weekend, you must decide which day is Monday. Another subtle issue is the definition of operating time schedule for intermittent occupancy. It is easy to decide that offices are occupied 10 hours per day, which is s a comfort requirement. Then you have to decide a default operation time of systems and if to allow a reduced time if an optimisation function is available. Another example is deciding all occupancy and use profiles.

Discussing and taking all these decisions takes some time and one must be sure that all chosen options are consistent before releasing the whole package.

So, work is going on and it will still take some time. Having everything ready in the second half of 2020 is an achievable target. ■

LG MULTI V S R32

The First R32 Compact Variable Refrigerant Flow System

Enjoy the benefits of a VRF system with:

- Intelligent control
- Eco-conscious low GWP refrigerant (R32) with less charge
- Higher seasonal efficiencies
- Design flexibility for restricted spaces

LG Business Solutions

MULTI V™ S

R32

Implementation of EN-EPB standards in Switzerland

GERHARD ZWEIFEL
Prof. em.
Consultant
e-mail: gerhard.zweifel@hslu.ch

Keywords: EPBD – CEN -standards

CEN-EPB standards and building energy regulations in a non-EU Country

As a non-EU country, Switzerland is not obliged to implement the EPBD, not even in the frame of the bilateral contracts. However, as a full member of CEN, the Swiss Association for Standardization (SNV) has – as all other CEN members – agreed to adopt all European standards and publish them as national standards. For the building area, this has been delegated to the Swiss Association of Architects and Engineers (SIA).

On the regulation side, the competence to set the energy requirements for buildings is on the level of the cantons, which means that in principle there are 26 energy regulations countrywide. In order to coordinate their procedures, the cantons have (as in several other political areas which are in the competence of the cantons) implemented a "conference of the cantonal energy directors" and on the level of the administrative officers the "conference of the cantonal energy specialist departments". The latter has developed and revised in several rounds the "sample cantonal energy regulations", a voluntary set of 11 modules with technical regulations, which can be used by the cantons to base their regulations on. One of the modules, the "base module", is recommended to be made mandatory, the final decision, however, can only be made on the cantonal level.

The current version of these sample regulations is MuKEn 2014 *. The implementation in the cantons is in different stages. Also, due to the different political processes and structure of laws and prescriptions, the way of implementation is different and may require public referendums in some cantons, whereas a governmental or parliamentary decision may be enough in other cases. In a few cantons, referendums have been lost and a second round with a revised proposal will be necessary. In others it passed, and the regulations are in force.

For the calculation methods and even in many cases for the requirements, the cantons are dedicated to relying on the standards by SIA "as far as possible". The have delegated members in the standardization committees.

* https://www.endk.ch/de/energiepolitik-der-kantone/muken

Structure of the energy related SIA standards

In respect of the energy calculations, the SIA standards follow the scheme as shown in the **figure** below.

For the "heated only" buildings (left side, the distinction is by intention not made on the base of the building use, but the majority of these will be residential buildings), the calculation is done by a monthly method, described in SIA 380/1:2016 on the base of EN ISO 52016-1. The calculation of the heating systems is described in SIA 384/3 (under revision), which refers for many issues (except heat pumps) to the EN 15316 series.

For the conditioned buildings (right side), where an hourly calculation is required, the tandem SIA 382/2 and Leaflet 2044 has been in place since 2011. Reference and use by the cantonal regulations have been increasing since then, but still is not nationwide. A software (SIA TEC Tool) had been developed and maintained, which supported this process. However, the adaption and updating of this software in the process of the revision of the standards is questionable for two reasons:

- The need for a fundamental revision requires considerable financial resources which have not been found so far;
- competing software has arisen on the market in the meantime.

The status of the revision of the SIA standards is shown in the **table** on the next page.

National annexes to EN's

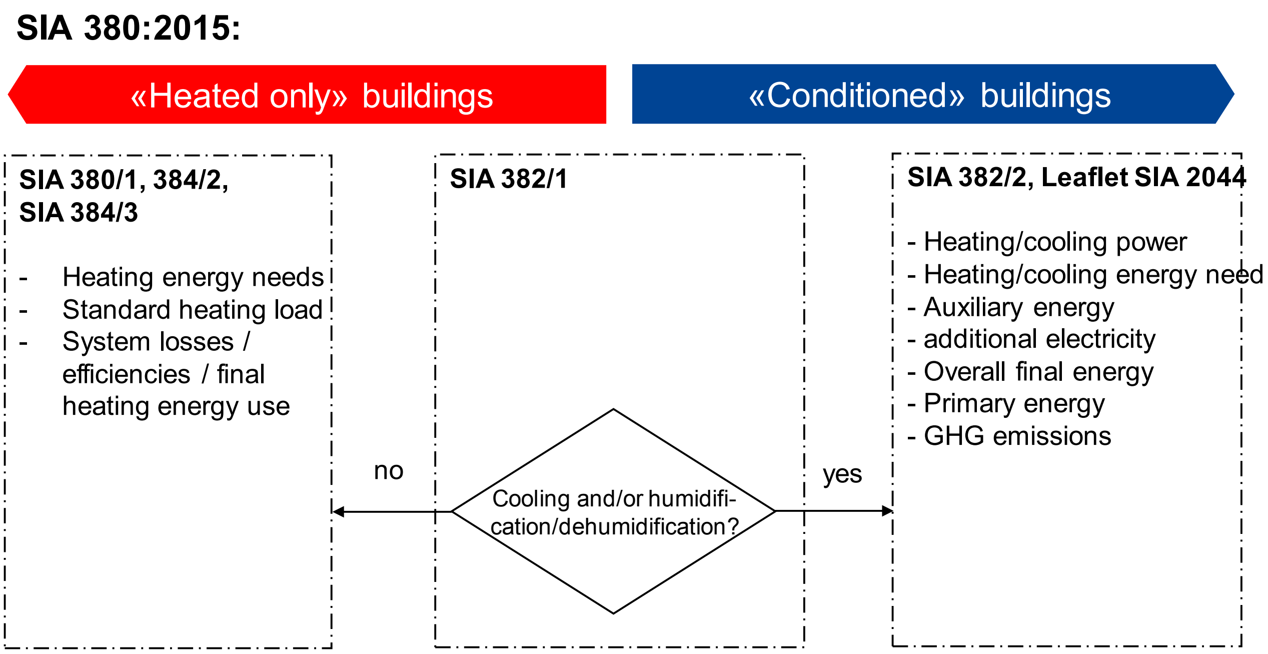
The national annexes to the CEN EPB standards have been (or are being) developed in the frame of the respective revision projects of the national standards:

- EN ISO 52000-1: Revision of SIA 380; done but held back in order to avoid conflicts with revised SIA 380.
- EN ISO 52016-1. Revision of SIA Leaflet 2044 (hourly method only; monthly method is only done by reference to SIA 380/1.
- EN 15316 series: revision of SIA 384/3 (although also partially referred to in Leaflet 2044).
- EN 16798 series: revision of Leaflet 2044.

A way for the national annex to EN 16798-1 is currently being looked for. This is complicated since a whole set of national standards are affected.

Dynamic simulations – pressure from industry

Unlike in the European standards, dynamic simulation software has been allowed for con-ditioned buildings in SIA 382/2 under some conditions as an alternative for the "standard" method of Leaflet 2044.



Standard number	Scope	Status	Referred EN(-ISO)	Notes
SIA 380	Basis for energy calculations	Under revision (started 2019)	52000-1	Reference areas and total energy balance method
SIA 380/1	Heating energy needs	Published 2016	52016-1 (monthly)	Monthly method "upgrade" from EN ISO 13790 by corrigendum in 2018
SIA 382/1	Requirements for ventilation and air conditioning systems	Under revision (started 2017)	16798-3	Decision criteria for need for cooling etc. will be moved to new SIA 380/2
SIA 382/2	Conditioned buildings – power and energy	Under revision (started 2019, to be published as 380/2)	--	Hourly method required, general requirements for methods (no prescriptive method, reference to 2044)
SIA Leaflet 2044	Conditioned buildings – power and energy – Standard calculation method	Revised (published 2019)	52016-1 (hourly), 16798 series, Partly 15316 series	Own methods for dynamic walls and for movable shading; for lighting reference to SIA 387/4 hourly
SIA 384/2	Heating load	Under revision (to be published 2020)	12831-1	
SIA 384/3	Heating systems calculations	Under revision (to be published 2020)	15316 series	Own method for heat pump calculations
SIA 385/2	DHW calculations	Revision to be started 2020	--	
SIA 387/4	Lighting energy calculation	Published 2017	--	Seasonal and hourly method; referenced by regulations
SIA Leaflet 2056	Electric energy calculations (except lighting)	New, published 2019	--	Mainly for the early design stage

In the building services design offices, building simulation is increasingly being used for the design process for several reasons:

- More reliable design data with less need for reserve;
- Better and easier to use software: some programs have very attractive and standards related "localisation" packages as well as BIM import facilities;
- Young people from the studies bring knowledge.

Based on this development, the industry also would like to have this accepted for building regulation conformity purposes, and the respective informal discussions are in process.

The readyness of the cantonal regulators for this discussion is very diverse and reaches from the quasy-acceptance to absolute refusal.

As one result of this development, it can be observed that the regulators would give precedence to a validation procedure against the development of a new software.

Outlook

As can be seen from the above tables, the revision of the Swiss standards according to the CEN EPB standards is in progress. In some areas it is done or nearly done. The last revised standards can be expected around 2021/22.■

The CEN Standards and the Implementation of the EPBD:
A Personal Perspective from the UK

ROGER HITCHIN
email: roger.hitchin@hotmail.com

Introduction

This article illustrates how the implementation of the EPBD in the UK has interacted with the CEN EPBD-related standards. The focus is on the UK story, but the some of the opinions and perspectives reflect discussions with technical advisors and civil servants in other countries. I was quite close to some of the decisions and the reasoning behind them but more distant from others. So, some of the views expressed are inferences, sometimes from 15 or so years ago. It is a personal perspective and in no way an official one: interpretations, including misunderstandings and errors are mine.

In the beginning ….

The EPBD was approved at the end of 2002 and entered into force early in 2003, by which time EU Member States needed to enact laws and regulations and develop administrative procedures. In some circumstances this could be delayed until early in 2006.

Some of the requirements of the Directive overlap with or can be implemented through pre-existing national procedures and regulations and procedures, and the Directive allows Member States flexibility in their compliance routes. Regulatory energy performance requirements were more highly developed on some countries than others. Where they existed, they were almost exclusively in the form of minimum performance requirements for specific elements of buildings, rather than the whole-building approach required by the Directive. The performance data for these elements was generally available from manufacturers or could be readily calculated. Calculations of expected annual energy consumption were used during the design of some buildings but were rarely applied to individual existing buildings (there was an informative system of "good practice" benchmarks for measured consumption in some countries).

In 2004 the European Commission gave CEN a "mandate" (M/343) [1] to produce standards to support the Directive. The basic scope of the Mandate was for a methodology for the calculation of the energy performance of buildings, methods of assessment for certifying buildings, and guidelines for methods of inspecting boilers and heating and air-conditioning systems. This resulted in the publication of EBPD-related CEN standards in 2007 and 2008.

The sequence of events, timing and scope were challenging for a several reasons:

- The purpose of the standards is not stated but must be inferred: who is expected to use them? Why are formal standards the appropriate vehicle? Would some other form of good practice guidance be more useful?

- A key element of the EPBD is a system of Energy Performance Certificates (EPCs), based on calculated or measured annual consumption, and required whenever a building is constructed, let or sold - with a maximum certificate life of 10 years. Given the relative numbers of building that are built, let or sold, EPCs will overwhelmingly be applied to existing buildings. For these buildings, information about their structure, the thermal properties of the materials used, and the dimensions is much more difficult to determine than for new buildings or the new elements in refurbished buildings. Any practicable building energy rating system requires trades-off between competing practical constraints such as data quality, and required consistency, precision and cost of implementation. The greater uncertainty of the available data for existing buildings means that the balance is likely to differ from that for new buildings. For existing buildings, the calculation element of the methodology is arguably one of its less challenging or critical components.

- The timescale to produce the standards was very demanding. The development of international standards is inherently time-consuming, and the standards were, in fact, developed remarkably rapidly. However, this timescale meant that there was no time (or resource) to test different options or explore the practical implications of decision. Since the coming-into-force date for the Directive preceded the mandate, any learning from experience could not be reflected but would have to be implemented later. Few of the standards-writers were directly involved in the national implementation of the Directive, so the opportunity for informal feedback was limited.

In 2005 the Commission launched a new instrument, the EPBD Concerted Action, with the objective of promoting dialogue and an exchange of knowledge and best practice between all 28 Member States and Norway. In order that the exchanges could be frank and open, the discussions were not in the public domain, although quite detailed overview reports were published.

In the UK …

Traditionally UK Building Regulations were concerned with health and safety rather than energy efficiency and were set locally. The first set of national building standards was introduced in 1965 but minimum insulation levels were not introduced until 1976. The required levels of insulation were subsequently increased and other requirements including air leakage testing were introduced, but there was no requirement to calculate energy consumption.

However, from the late 1970s, computerised methods of estimating the energy costs of dwellings started to be used outside the regulatory framework. Several versions of BREDEM – the Building Research Establishment Domestic Energy Model – were developed. These were initially used to support voluntary activities comparing annual energy costs (sometimes including appliances) in new and existing housing: to assess the suitability of designs of low energy homes in a "new town"; as a voluntary energy rating system using a relative cost index scale; by the energy supply industries to promote their form of energy supply as having the lowest running costs; and in a set of Government-published running cost guides. The core calculation in these calculations was a monthly, variable base-temperature, degree day procedure, with adjustments to reflect that some parts of the building are heated to lower temperatures than others, to allow for the impact of the thermal capacity of the building and also the responsiveness of the heating system. [2 3] A worksheet version, which can be calculated manually (but more commonly using a small computer), the Standards Assessment Method (SAP), was published in 1992 and cited in regulations in 1994. When the EPBD appeared, it was logical and low risk to use this as the calculation engine for dwellings. In 2005 a version with a simplified input but less scope to accommodate unusual types of construction (rdSAP – reduced data SAP) was introduced for use with existing dwellings.

There was no equivalent experience of calculation methods for existing non-domestic buildings and a new tool SBEM, the Simplified Building Energy Model, was developed. A number of options for the calculation engine were considered, including dynamic simulation, reduced parameter simulation and degree-day-based methods. The decision eventually taken was to base the tool on a monthly calculation procedure that was already in use in the Netherlands and was almost certain to be included in the EPBD-related CEN standards (eventually in EN 13790). An important factor in the decision was the knowledge that the methodology had already been used elsewhere and the standard was already well advanced. Eventually SAP was modified to use the same calculation procedure - although the mathematical formulations look very different, in most situations, they produce very similar results. [4] It was recognised that complex new non-domestic buildings are often designed with the aid of commercially available dynamic simulation tools and it was decided that, in principle and subject to satisfying a number of tests and conditions, their use should also be allowed.

A fundamental feature of the rating scale that makes this use of different methods possible – and has some other advantages - is the use of a "reference" building. This is a building with the same geometry, orientation and allocation of use patterns, and exposed to the same weather as the building being rated. (The glazed areas are not identical, in order to penalise "over-glazed" buildings). The reference building has defined elemental values – U-values, system efficiencies etc. For Energy Performance Ratings these are set to represent "typical" values for the building stock, and the rating is based on the ratio of calculated carbon emissions between the actual and notional buildings. For new buildings and major refurbishments, a "notional" building is used, with elemental values are chosen to reflect cost-effective performance. These are updated periodically. Provided that the performance standard is met, the designer retains flexibility to meet specific project requirements set by the site, planning permission or the user. This approach means that the energy rating value strongly reflects the physical characteristics of the building and its technical building services, even for classes of buildings that vary substantially in size and facilities such as hotels and mixed-use buildings. It also reduces (but does not eliminate) the impact of some types of error, such as incorrect dimensions or the allocation of activities to spaces: such errors apply both to the reference and actual building. (Sensitivity of the rating to differences in climate is also reduced).

For a given building, different calculation procedures – including different dynamic simulation models - generate different estimates of annual consumption. Since any systematic differences are applied both to the actual and the notional building their impact on the rating value is reduced. (Before being accepted for use for building energy rating, calculation tools are required to demonstrate that they produce values that are consistent with those from established tools for several example buildings.) This means that there would be no great difficulty in allowing the (optional) use of the dynamic energy calculation methods from the current CEN standards alongside the established commercial tools, though the incentive to do so is not easy to see.

Initial trials of data collection procedures showed that consistency between assessors could become a very significant issue. The EPC procedure therefore includes default values that the assessor can overwrite (and may then be asked to justify) and a database for construction elements (the assessor can define additional constructions)[5] . The user interface offers drop-down menus of options wherever practical – for example, of HVAC system types – and aims to limit the assessor choices to questions for which he or she can reasonably be expected to know the answer. There is also a structured database of standardised activities – each space in a non-domestic building has to have assigned to it a specific activity. This sets standardised operational parameters according to the activity and type of building in which the space exists (for example the periods of use of an office in a school differ from those in a commercial building).

The rating metric is based on calculated carbon emissions rather than primary energy (or price) because this is a key driver for environmental policy and is the metric in other areas of legislation: shadow prices for carbon have long been included in policy impact assessments. (Primary energy is difficult to align directly with most energy and environmental policy objectives and is defined differently and often opaquely in different countries).

Subsequently….

Member States had discussed difficulties with the "usability" of the initial standards within their national implementations at Concerted Action meetings. When the original version of the EPBD was replaced by a "recast" version in 2010, a new mandate to CEN was issued[6], to update and improve the standards. In addition, a Liaison Committee was established between CEN and the EPB Committee (representing the Member States) with the objective of better matching Member States' needs with the new standards.

The changes to the standards responded to some of these issues, notably by the separation of statements of methodology from explanatory text – albeit at the cost of there being more documents. The Liaison Committee had also investigated Member States' objectives for desired consistency, accuracy, time required and other aspects of Energy Performance Ratings. These factors largely depend on user interfaces, inspection procedures and the use of default values rather than to the issues explicitly stated in the Mandate – though the complexity of calculation methods does have a bearing. (The calculation standards introduced explicit equations for hourly-time step dynamic simulation calculations although this was not an explicit request.) [7]

Separately, the Commission contracted consultants to independently address the usability of the standards by applying them to example cases. This study "highlighted some weaknesses in the draft set of standards, and it seems that the complexity of the standards is overwhelming in some cases"…[8]. This complexity was partly due to their use of a "one-size-fits-all" approach which was considered to impose a detailed methodology even for relatively simple situations. It was noted that "the use of a reference building in the calculation can reduce the significance of systematic errors." This somewhat contradicts the emphasis on absolute – rather than relative – rating scales in the revised version of the EPBD which was adopted in 2018.

In the future …?

The EPBD-related CEN standards undoubtedly contain information that has helped Member States to develop their implementation processes. As with other countries, the UK made use of some elements of the standards, and of standards that were not developed specifically for the EPBD.

Given the flexibility allowed to Member States for implementation of the EPBD and the shortage of practical (or even research) experience with some of the directive's instruments, it would be very difficult for any set of guidance documents to adequately cover the whole procedure for producing Energy Performance Certificates nor to mandate specific methods. Formal standards additionally have constraints on their structure, language and scope and it would be unreasonable to expect them to cover all aspects of Member States' implementation needs.

A standard is defined as "…an agreed way of doing something…. [which is] the distilled wisdom of people with expertise in their subject matter and who know the needs of the organizations they represent….."[9]. It is not unreasonable to expect them to reflect the practical constraints surrounding their application. The timing of the first Mandate and the lack of practical experience at that time would have made this difficult, but Member States' were nevertheless having to develop procedures and a greater involvement by them in the development of the standards might have avoided some of the later complaints about their usability.

In 2017, the standards were described by the Commission as providing a "toolbox for better implementation" [10] (though this concept does not appear explicitly in the Mandates). This description reflects the way that the standards have been used by many

Member States, though a better analogy might be a set of pre-defined components. They do not (and probably could not) provide a complete set of components (or tools), a blueprint for the finished product, or detailed instructions for use.

By now Member States have well-established building performance rating systems in place, with the organisational and physical infrastructure necessary to support them. Any significant change of procedure will have consequences and costs, not least because the 10-year life of Energy Performance Certificates means that substantial changes could undermine comparability between older and newer certificates. But other procedural changes could be introduced with limited impact on the rating values. The important issues now are less about calculation methodologies and definitions but more about usability and impact. It seems likely that useful ideas for such improvements will most reliably come from practical feedback from different national implementations and will probably address issues that are not (and probably could not be) effectively addressed by standards. Some starting points were suggested by the consultants who considered usability in the context of example cases. They pointed out that some of the input data has little impact on the final building rating and its accuracy is therefore relatively unimportant and suggested that sensitivity calculations be carried out to identify which information could be omitted (or fixed) in which circumstances. (Some Member States have now initiated such studies). They also suggested that simpler calculation procedures were likely to be acceptable for some types of building.

There is a need for a continuing process of exchange and review of the experience of different MS (and of potential MS). For example, while the EPBD allows the use of measured energy consumptions for rating purposes (and this approach is used to some extent), the resulting ratings are fundamentally different in nature to those based on calculations. There is general acceptance that the two approaches are complimentary, but still uncertainty about how best to extract value from their joint use. The Concerted Action format has proved to be a workable means of providing such communication but might usefully be more focused on “lessons learnt” and outstanding issues and complemented by additional independent studies. ■

References

1 M/343 Standardisation mandate to CEN, CENELEC and ETSI for a methodology calculating the integrated energy performance of buildings and estimating the environmental impact https://ec.europa.eu/growth/tools-databases/mandates/index.cfm?fuseaction=search.detail&id=221.

2 Uglow, C. E. (1981).The calculation of energy use in dwellings, Building Services Engineering Research Technology 2(1), pp. 1-14.

3 Anderson, B., Clarke, A.J., Baldwin, R., and Millbank, N. O. (1985). BREDEM - BRE domestic Energy Model: background philosophy and description, BRE Report BR 66. Watford: BRE.

4 Roger Hitchin. Monthly utilisation factors for building energy calculations Building Serv. Eng. Res. Technol. 2017, Vol. 38(3) 318–326.

5 Roger Hitchin. A guide to the Simplified Building Energy Model (SBEM): What it does and how it works. BRE Trust report 24 2010 https://www.brebookshop.com/details.jsp?id=325419.

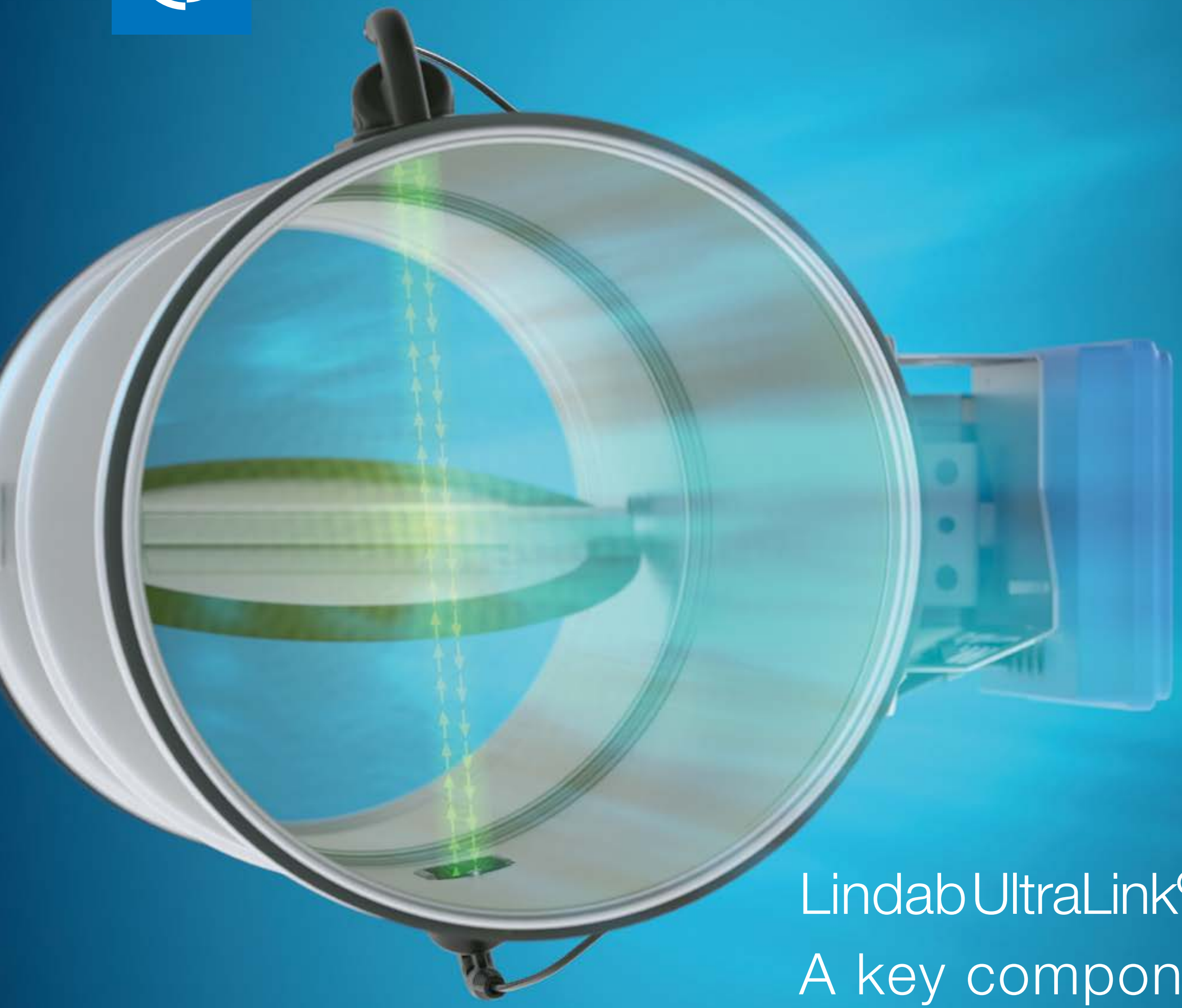
6 M/480 Mandate to CEN, CENELEC and ETSI for the elaboration and adoption of standards for a methodology calculating the integrated energy performance of buildings and promoting the energy efficiency of buildings, in accordance with the terms set in the recast of the Directive on the energy performance of buildings (2010/31/EU) https://ec.europa.eu/growth/tools-databases/mandates/index.cfm?fuseaction=search.detail&id=465.

7 See for example https://www.epbd-ca.eu/outcomes/CT_Reports_14-04-2011/CT4_Procedures.pdf; and https://www.epbd-ca.eu/outcomes/2011-2015/CA3-CT-2015-4-Cost-optimal-levels-web.pdf.

8 see https://epbd-ca.eu/ca-outcomes/outcomes-2015-2018/book-2018/ct/technical-elements.

9 British Standards Institute https://www.bsigroup.com/en-GB/standards/Information-about-standards/what-is-a-standard/.

10 Paula Rey Garcia “Adoption of CEN standards on EPBD: toolbox for better implementation”, EPBD Review and Wellbeing in Buildings Light and Well-Being in Buildings 11 October 2017, Brussels https://www.lightingeurope.org/images/publications/presentations/presentations-well-being-buildings/5_Paula_Rey_Garcia_-_light_and_well_being_in_buildings.pdf.



Lindab UltraLink®

A key component for any demand controlled ventilation system.

Ultrasound technology for precise and reliable measurement and regulation of airflow

The UltraLink controller is a new volume flow regulator developed to deliver an optimal indoor climate to minimum energy consumption.

With the UltraLink controller you have the possibility to create a more efficient and optimized ventilation system with low maintenance costs.

The use of EPB standards in EPBD implementation in France

JOHANN ZIRNGIBL
e-mail: johannzirngibl@aol.com

EMILIEN PARON
(CSTB)
e-mail: Emilien.PARON@cstb.fr

General status and the way the EPB standards are playing a role in the EPBD implementation in France

French experts involved in the French building regulation and national EPBD implementation contribute also to the EPB standards development at European level. Therefore, the French building regulation and transposition of the EPBD and the EPB standards are in line regarding the principles and the general structure.

But sometimes the French regulation differ in the details, mostly due to different timelines and already existing national methods. The differences depend on the type of standards.

Standards related to the building envelope are mostly based on European standards because there is a longer experience in standardisation and lobbying of the industry to have common rules in a common market. Also, the first attention in energy performance were focused on the building envelope in the French building regulations.

The situation is a different for technical building systems (e.g. heating, ventilation) because these standards have been worked out more recently.

Also, the definition of indicators (e.g. primary energy, renewable energy ratio) differ from the European standards (e.g. EN ISO 52000-1). The French indicators have been defined at national level with a strong commitment of the building authorities to be in line with the energy policies of the French government.

The French building regulation fulfil the requirements of the EPBD. The legal requirements defined in the framework of the Energy Performance of Building Directive are quite general. Just the type of indicator is mentioned (the primary energy) without any additional details how to determine it. The EPB standard EN ISO 5200-1 is precise, but the standard is recent (published in 2017) and there is no obligation to use it at national level.

Thanks to the support provided by the European Commission to help Member States in the transposition of the EPBD, for example by developing the EPB standards (Mandate 480), by providing European wide detailed climate data or harmonised product characteristics (Ecodesign Directive, EPREL database), etc , the tendency in France is to use the work made on European level also at national level.

How the French national method is reported as required in Annex 1 of the EPBD?

The French method is compliant with the European legislation as described very generally in Annex 1 of the Directive. To get a more precise idea about the national methods, the revised Directive ask Member States to describe their national calculation methodology following the national annexes of the overarching standards, namely EN ISO 52000-1. Hereafter some examples are provided how the French method could be described by using this annex. The example is structured by main chapters (e.g. chapter A1, A2) of annex A / EN ISO 52000-1.

Chapter A.2 References

Table A.1 indicate the reference documents. The reference document for the French method is the "méthode Th-BCE". The correspondence with the chapters of EN ISO 5200-1 of this method is provided in **Table A.1**.

References (extract from Table A.1).

Reference	Reference document	
	Number	Title
M1-1 & 3 M1-5	Chapter 1	Generalities
	Chapter 3	Description of the calculation method
M1-4,7 & 9	Chapter 3.4	Regulation outcomes and indicators
	Chapter 14	Results
	Chapter 15	Summer comfort
	Chapter 16	Part of renewables in the energy consumption

No EN or ISO standard is mentioned in **Table A.1**.

Chapter A.3 Overarching preparation steps

The **Tables A.2** to **A.10** can be all filled in to describe the French method. Additional comments are provided for a better understanding of the differences. The example of **Table A.6**, related to zoning, shows that the description allows to see the differences between the national method and EN ISO 52000. It provides information on how deeply the national calculation methods take into the different characteristics of building zones.

Differentiation of space categories (Table A.6).

Choice		
Type	Choice	Comments
Differentiation of space categories in a building	Yes	Several levels of differentiation: • "zone of usage" (related to the building category e.g. office, hotel) • "group", group of spaces with the same thermal characteristics • "space" space needed for the definition of internal gains

Chapter A.4 Method

The tables in this part of Annex A of the EN ISO 52000-1 are closely linked to the calculation method and its parameters. For example, **Table A.16** allows to see the choices made in the different Member States.

In the current version of the French regulation, which will be revised in 2020, only the total primary energy factors f_{Ptot} is considered. It will be changed in 2020.

France has common assessment border for all building. It is the lot were the building is located (in the EN ISO 52000-1 it is more related to the building). Therefore, the energy carriers located on-site are not counted at this assessment border. The on-site delivered energy is directly deducted from the final energy consumption.

France also defines limits for exported energy.

Weighting factors based on gross or net calorific value (Table A.16).

	Energy carrier	f_{Pnren}	f_{Pren}	f_{Ptot}
Delivered from distant				
1	Natural gas			1
2	Oil			1
3	Coal			1
5	Wood			1
4	Electricity			2,58
Delivered from nearby				
6	District heating[1]	1 – RatENR_rdch	RatENR_rdch	1
7	District cooling[2]	2 – RatENR_rdfr	RatENR_rdfr	1
Delivered from on-site				
8	PV electricity	Non-applicable: the quantity of energy coming from an on-site source is considered directly by the deduction from the final energy consumption. For the calculation of the indicator Cep the whole produced PV electricity is considered as exported (see hereafter)		
9	Thermal Solar			
10	Geothermal, aerothermal, hydrothermal (heat pumps)			
Exported (renewable energy)				
11	Calculation of Cep (consumption in primary energy)			2,58
	Calculation of BEPOS and RER for the first 10 kWhep/m²year			2,58
	Calculation of BEPOS and RER for more than 10 kWhep/m²year			1
Exported (non-renewable energy)				
12	Calculation of Cep			2,58
	Calculation of BEPOS	Non-applicable: the exported energy is not considered, but the energy needed to produce the exported energy is also not counted.		

1 Each district heating network declare his specific ration of renewable energy called RatENR_rdch.

2 Each district cooling network declare his specific ration of renewable energy called RatENR_rdfr.

Is the production/ preparation of the national annexes progressing and how this is influencing the chosen national options?

Even if the mandatory French method is comparable to EN ISO 52000-1 regarding the general principles, due to the differences in the details, Annex A cannot be completely used to parameter the national mandatory method (and vice versa). Therefore, it is very unlikely that the public authorities will ask to produce a national annex.

But the EN ISO 52000-1 can also be used on a voluntary basis, for example for voluntary certification schemes. In that case the national annex could be worked out by the national standardization body AFNOR. This decision was not yet taken.

France is preparing a new update of the building regulation. In this context the EN ISO 52000-1 has been analysed. It is planned to get closer to the EN ISO 52000-1 especially for the definition of indicators. For example, as mentioned before, by using the primary energy factor to distinguish between renewable and non-renewable primary energy.

Resume

Around 30 pages (the double of Annex B defining the default values in EN ISO 52000-1) are needed to describe the French method by using Annex A of EN ISO 52000-1. Again 30 pages more are needed to give a better understanding on the indicators used and the calculation method itself.

The description of the national methods required by the revised EPBD by using as common structure the Annex A of EN ISO 52000-1 is surely a first step towards more transparency and the quality assessment of national methods.

High quality building (as NZEB's) need high quality methods and especially high-quality tools. Maybe the European wide certification of these tools (software), with reference the EPB standard, could be the second step. ■

uponor
Exclusive distributor in Europe

PHYN

Speak the language of water

The connected, whole home leak detection monitor with an automatic water shutoff that really works. Phyn Plus protects your home from leaks, diagnoses issues with your plumbing and gives you powerful insights into how you use water.

Protect your home from leaks.
Conserve water. Save money.

Lear more: www.phyn.com

Status of implementation of EPBD and CEN EPB standards in Romania

CĂTĂLIN LUNGU
Prof. Assoc.Dr.eng.
Deputy Dean of FII-UTCB
Vicepresident of AIIR & REHVA

1. General information

1. Code of the energy performance calculation methodology - Mc001
2. Mc001 will probably enter into force by the end of 2019/beginning of 2020
3. CEN (EBP) standards are used, except for the group of standards for BAC
4. monthly calculation is used (hourly only if an accredited software is used)
5. there is no concrete methodology for software accreditation
6. there is no adapted software for the new Romanian Mc001
7. building or building unit (standard type) and apartment (simplified type)
8. there is a comparison to a reference building (no differentiation among building categories)
9. some of the excel files provided by the EPB Center are used for creating calculation examples in the Romanian methodology

2. Minimum thermal transmission, solar factor and energy requirements for Romanian buildings

a) Residential

***Table 1.** Minimum heat transfer coefficients (corrected for the bridge effect).*

BUILDING COMPONENTS	U'_{max} [W/m²K]
Outside opaque walls	0,40
Windows	1,10
Ceilings over the top floor, under terrace or attics	0,14
Floors over the unheated basement of cellar	0,35
Joint walls	0,90
Floors on the ground (ground level)	0,22
Floors at the bottom of the heated basements	0,21
Outside walls of the basement (underground)	0,35

Table 2. Recommended values for the solar factor of the glased components of the residential buildings.

Solar Factor, g – glased elements					
Orientation	Climatic zone				
	I	II	III	IV	V
Exposed to the solar radiation	0,30–0,37	0,33–0,43	0,37–0,47	0,43–0,50	> 0,50

For the residential buildings, the simultaneous mandatory conditions for energetic design are:

a) U' ≤ U'max [W/(m²K)] for every building element,
b) G ≤ GN [W/m³K], G-global coefficient for thermal insulation, GN- rated global coefficient for thermal insulation (reference values)
c) The annual primary energy consumption for heating qyear ≤ qyear,max, where for buildings with height < P+4E, qyear,max=153 kWh/m²an and for buildings with height ≥ P+4E qyear,max=117 kWh/m².y.

Table 3. Rated/reference values for GN.

Floor numbers **N**	**A/V** [m²/m³]	**GN** [W/m³K]	Floor numbers **N**	**A/V** [m²/m³]	**GN** [W/m³K]
1	0,80	0,39	**4**	0,25	0,14
	0,85	0,41		0,30	0,15
	0,90	0,43		0,35	0,16
	0,95	0,44		0,40	0,17
	1,00	0,46		0,45	0,18
	1,05	0,47		0,50	0.19
	≥1,10	0,48		≥0,55	0,19
2	0,45	0,29	**5**	0,20	0,13
	0,50	0,18		0,25	0,14
	0,55	0,20		0,30	0,15
	0,60	0,21		0,35	0,16
	0,65	0,21		0,40	0,17
	0,70	0,22		0,45	0,18
	≥0,75	0,22		≥0,50	0,18
3	0,30	0,14	**≥10**	0,15	0,12
	0,35	0,16		0,20	0,13
	0,40	0,17		0,25	0,14
	0,45	0,18		0,30	0,15
	0,50	0,19		0,35	0,16
	0,55	0,20		0,40	0,17
	≥0,60	0,21		≥0,45	0,17

b) Non-residential

Minimum requirements for EPB:

- for the building components, the condition refers to the maximum heat transmittance U'max [W/(m²K)];
- for the overall building
  a) overall coefficient for thermal insulation, G1 [W/(m³K)] (if G1 ≤ G1ref then the building respects the minimum requirements principle);
  b) annual primary energy consumption for heating.

G1ref [W/(m³K)] is calculated using the next formula:

$$G1_{ref} = \frac{1}{V}\left[\frac{A_1}{a} + \frac{A_2}{b} + \frac{A_3}{c} + d \bullet P + \frac{A_4}{e}\right] \ [W/(m^3K)]$$

Table 4. *Maximum annual primary energy consumption for heating, all climatic zones.*

Non-residential building	Maximum annual primary energy consumption $q_{year,max}$ [kWh/m²an]
Office buildings	60
Commercial buildings	101
Education buildings	123
Health buildings	149
Tourism buildings	81

where a, b, c, d and e have the values in **Table 5** and **Table 6**, according to the building category, the building typology and the climatic zone.

Table 5. *Coefficient values a, b, c, d and e for the category 1 buildings.*

Building type	Climatic zone	a [m²K/W]	b [m²K/W]	c [m²K/W]	d [W/mK]	e [m²K/W]
Hospitals, kindergardens, clinics	I	1,70	4,00	2,40	1,40	0,77
	II	1,75	4,50	2,50	1,40	0,77
	III	1,80	5,00	2,90	1,40	0,77
	IV	1,85	5,50	3,00	1,40	0,77
	V	1,90	6,00	3,10	1,40	0,77
Education and sport buildings	I	1,70	4,00	2,10	1,40	0,77
	II	1,75	4,50	2,50	1,40	0,77
	III	1,80	5,00	2,90	1,40	0,77
	IV	1,85	5,50	3,00	1,40	0,77
	V	1,90	6,00	3,10	1,40	0,77
Office and commercial buildings, hotels*)	I	1,60	3,50	2,40	1,40	0,70
	II	1,70	4,00	2,50	1,40	0,70
	III	1,80	4,50	2,60	1,40	0,70
	IV	1,85	5,00	2,70	1,40	0,70
	V	1,90	5,50	2,80	1,40	0,70
Other buildings (industrial buildings normal usage)	I	1,10	3,00	1,10	1,40	0,60
	II	1,10	3.00	1,20	1,40	0,60
	III	1,10	3,00	1,30	1,40	0,60
	IV	1,10	3,00	1,40	1,40	0,60
	V	1,10	3,00	1,50	1,40	0,60

*) for the accommodation spaces the rules for residential buildings apply.

Table 6. Coefficient values a, b, c, d and e for the category 2 buildings.

Building type	Climatic zone	a [m²K/W]	b [m²K/W]	c [m²K/W]	d [W/mK]	e [m²K/W]
Hospitals, kindergardens, clinics	I	1,50	4,00	2,00	1,40	0,77
	II	1,55	4,50	2,30	1,40	0,77
	III	1,60	5,00	2,60	1,40	0,77
	IV	1,65	5,50	2,65	1,40	0,77
	V	1,70	6,00	2,70	1,40	0,77
Education and sport buildings	I	1,50	4,00	2,00	1,40	0,77
	II	1,55	4,50	2,30	1,40	0,77
	III	1,60	5,00	2,60	1,40	0,77
	IV	1,65	5,50	2,65	1,40	0,77
	V	1,70	6,00	2,70	1,40	0,77
Office and commercial buildings, hotels*)	I	1,50	3,50	2,00	1,40	0,70
	II	1,55	4,00	2,30	1,40	0,70
	III	1,60	4,50	2,60	1,40	0,70
	IV	1,65	5,00	2,65	1,40	0,70
	V	1,70	5,50	2,70	1,40	0,70
Other buildings (industrial buildings normal usage)	I	1,50	2,90	1,00	1,40	0,60
	II	1,55	2,90	1,10	1,40	0,60
	III	1,60	2,90	1,20	1,40	0,60
	IV	1,65	2,90	1,30	1,40	0,60
	V	1,70	2,90	1,40	1,40	0,60

*) for the accommodation spaces the rules for residential buildings apply.

Note:

Non-residential buildings category 1 = buildings with continuous occupation or discontinuous occupation and high inertia (i.e. the inside temperature doesn't go under the normal operation value with more than 7°C in the time interval 0 AM to 7 AM).

Non-residential buildings category 2 = buildings with discontinuous occupation and medium or low inertia (i.e. the inside temperature can go under the normal operation value with more than 7°C during max 10 hours per day but at least 5 hours in the time interval 0 AM to 7 AM).

The glazed elements shall fulfil, besides the condition concerning the thermal corrected transmittance, the optional condition for the optimum solar factor g.

a) if there are outside shading devices to control the solar energy, then the solar coefficient g must be higher than 0,50;

b) if there are no outside shading devices, the values of the solar coefficient g are indicated in the **Table 7**.

Table 7. Recommended values for the solar coefficient of the glazed components for non-residential buildings.

Solar coefficient, g – glased building components					
Orientation	Climatic zone				
	I	II	III	IV	V
Exposed to the solar radiation	0,18–0,35	0,21–0,38	0,24–0,40	0,27–0,43	>40

If the glazed components are not exposed to the direct solar radiation, then solar coefficient g shall be > 0,50, no matter the climatic zone.

Energy requirements for Romanian nZEB

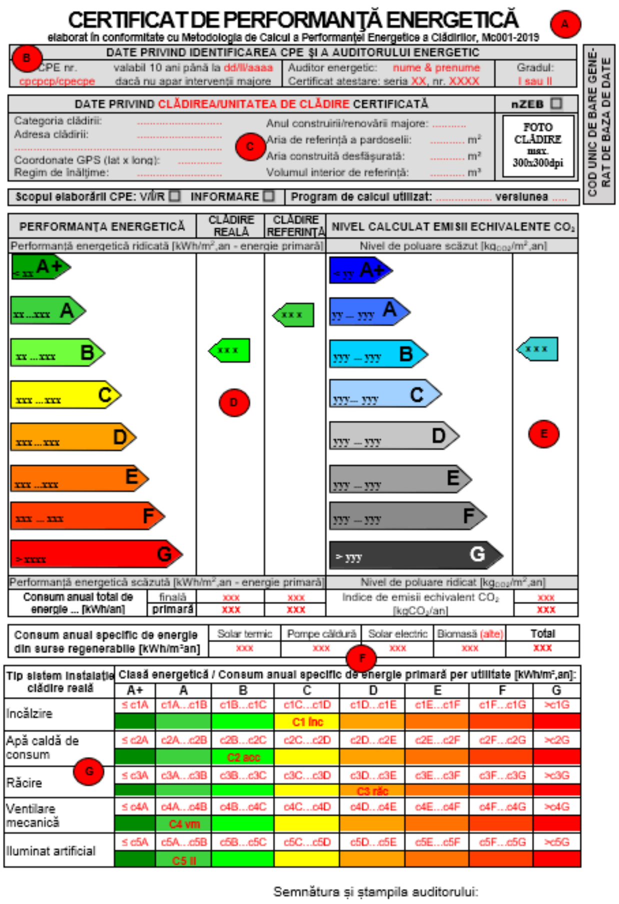
Table 8 gives the maximum total primary energy consumption (non-renewable and renewable sources) and the maximum CO_2 equivalent emissions for nZEBs.

Table 8. *Maximum total primary energy consumption (non-renewable and renewable sources) and the maximum CO_2 equivalent emissions for nZEBs.*

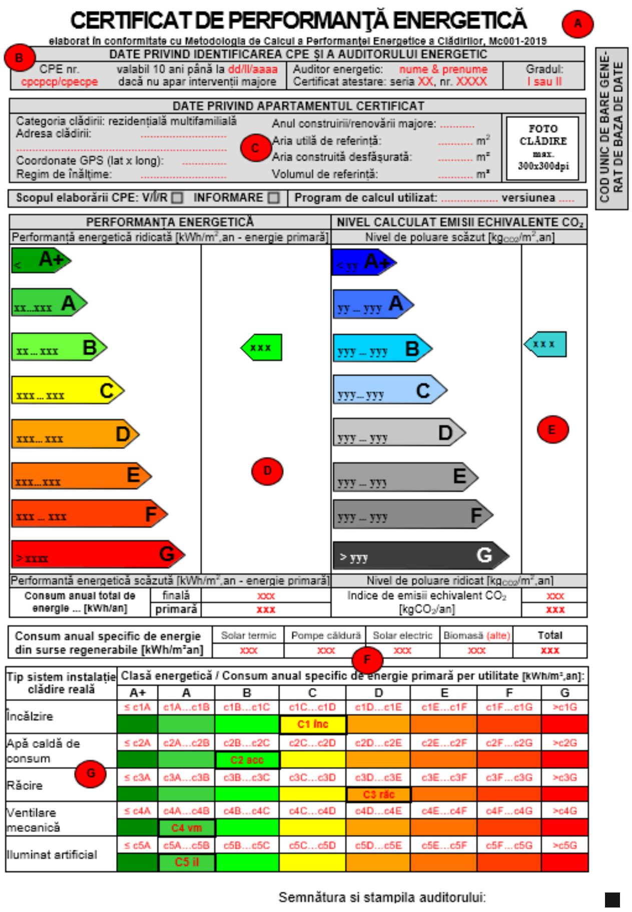
Zona climatică	Orizont	CLĂDIRI DE BIROURI		CLĂDIRI DESTINATE ÎNVĂȚĂMÂNTULUI		CLĂDIRI DESTINATE SISTEMULUI SANITAR		CLĂDIRI DE LOCUIT COLECTIVE		CLĂDIRI DE LOCUIT INDIVIDUALE	
		Energie primară [kWh/m²,an]	Degajări CO_2 [kg/m²,an]	Energie primară [kWh/m²,an]	Degajări CO_2 [kg/m²,an]	Energie primară [kWh/m²,an]	Degajări CO_2 [kg/m²,an]	Energie primară [kWh/m²,an]	Degajări CO_2 [kg/m²,an]	Energie primară [kWh/m²,an]	Degajări CO_2 [kg/m²,an]
I	31 dec. 2019	50	13	100	25	79	21	100	25	115	31
	31 dec. 2021	45	12	92	24	76	21	93	25	98	24
II	31 dec. 2019	57	15	120	35	97	27	105	28	121	34
	31 dec. 2021	57	15	115	30	97	26	100	27	111	30
III	31 dec. 2019	69	19	136	37	115	32	122	34	155	41
	31 dec. 2021	69	19	136	37	115	32	111	30	145	40
IV	31 dec. 2019	89	24	172	48	149	42	144	36	201	51
	31 dec. 2021	83	24	170	49	142	41	127	35	189	42
V	31 dec. 2019	98	28	192	56	174	49	152	38	229	57
	31 dec. 2021	89	24	185	53	167	48	135	37	217	54

3. Models of Romanian EPC (building/building unit & apartment)

EPC for a building or building unit (page 1):



EPC for an apartment (page 1):



Status of implementation of CEN EPB standards in Croatia

DAMIR DOVIĆ
Faculty of Mech. Eng. and Naval Arch., University of Zagreb,
Professor, PhD
email: ddovic@fsb.hr

Keywords: energy performance calculation, CEN EPB standards

Energy performance calculation in Croatia

Croatian methodology for calculation of energy performance of buildings is largely based on the first set of CEN EPB standards (ed.2008). As these standards were proved not to be unambiguous enough for direct use, the national calculation methodology was developed in 2011. in the form of so-called Algorithms (**Figure 1**) by the University of Zagreb. Five Algorithms[1] are written as a spreadsheet ready 'array' of formulas with the accompanying text describing sources for input parameters and connections with other parts of calculations.

The Algorithms were initially employed for energy certification of buildings purposes. Later in 2014. they were referred to in the Technical regulation. Since then, the Algorithms have been also used for verifying the minimum requirements on energy performance (i.e. for obtaining building permit), for assessing the feasibility of alternative systems and for reporting the cost optimal levels of minimum energy performance requirements.

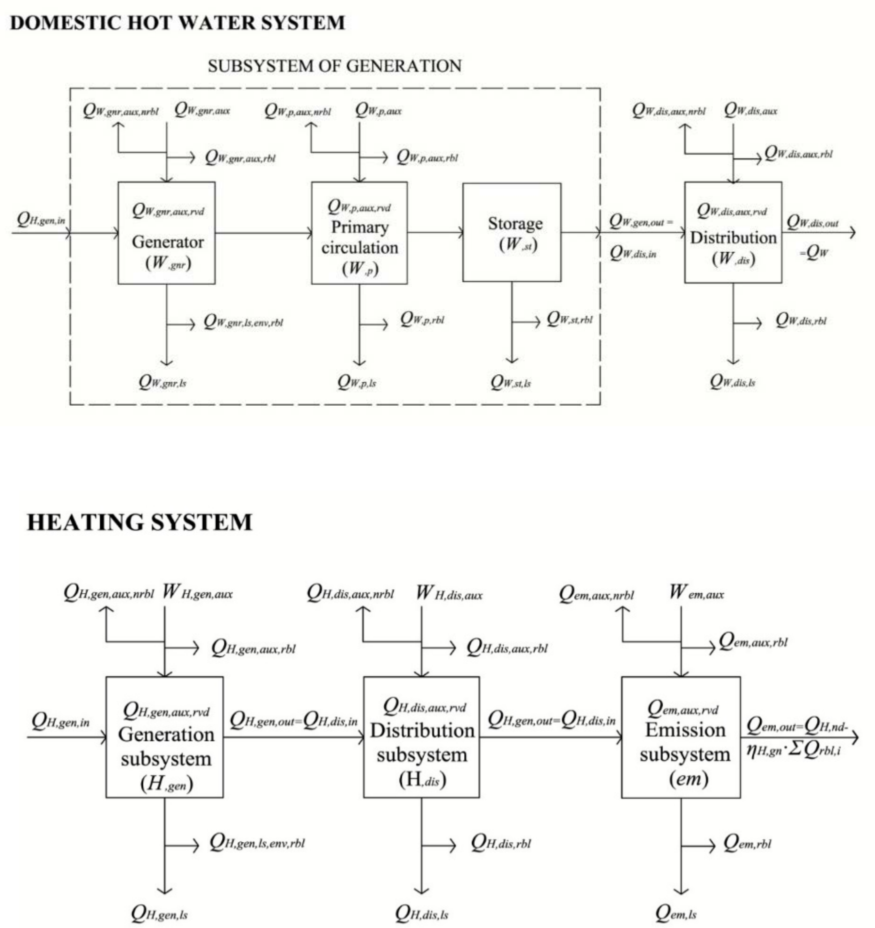


Figure 1. Division of space heating and DHW system into subsystems with input/output variables for calculations from Algorithms.

The list of standards used in Algorithms is provided in **Table 1**. Calculations of energy need for heating and cooling are based on the simple hourly method from EN ISO 13790. Calculations of most technical systems energy requirements are performed at monthly time step. A separate hourly calculation procedure was developed for humid air treatment in air handling units (AHU), as the corresponding EN standards provided only tabulated values. The procedure enables calculations for arbitrary indoor and outdoor conditions and a variety of AHU air treatment schemes (**Figure 2**).

The Algorithms were implemented (y.2017.) in the public (free) software MGIPU Energy Certifier (**Figure 3**) for energy performance assessment of nine types of buildings. The software is verified by

Table 1. *CEN EPB standards (2008) referred to in Technical regulation and/or Algorithms.*

Energy need calculation	
1.	HRN EN ISO 13790:2008 *)
2.	HRN EN 15603:2008
3.	HRN EN 15217:2008
4.	HRN EN ISO 6946:2008
5.	HRN EN ISO 13370:2008
6.	HRN EN ISO 13789:2008
7.	HRN EN ISO 14683:2008
Conv. tech. systems calculation	
8.	HRN EN 15316-1:2008
9.	HRN EN 15316-2-1:2008
10.	HRN EN 15316-2-3:2008
11.	HRN EN 15316-3-1:2008
12.	HRN EN 15316-3-2:2008
13.	HRN EN 15316-3-3:2008
14.	HRN EN 15316-4-1:2008
Altern. tech. systems calculation	
15.	HRN EN 15316-4-2:2008
16.	HRN EN 15316-4-3:2008
17.	HRN EN 15316-4-4:2008
18.	HRN EN 15316-4-5:2008
19.	HRN EN 15316-4-6:2008
20.	HRN EN 15316-4-7:2008
Ventilation systems calculation	
21.	HRN EN 15241:2008
22.	HRN EN 15242:2008
23.	HRN EN 15243:2008
Lighting	
24.	HRN EN 15193:2008

*) Simple hourly method

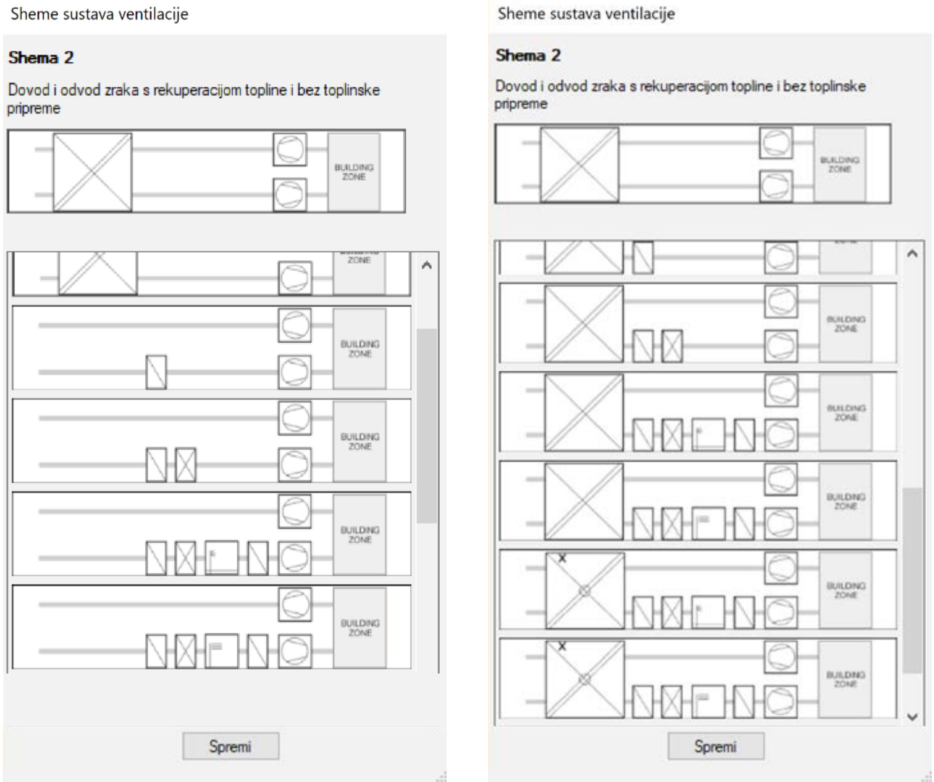


Figure 2. AHU air treatment schemes available for assessment in Algorithms/MGIPU Energy Certifier software tool.

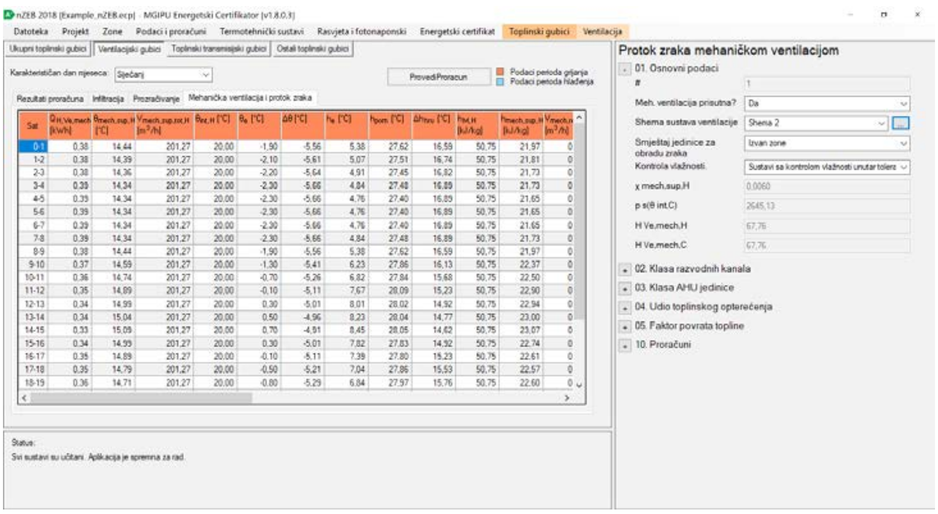


Figure 3. Example of the air treatment calculations in MGIPU Energy Certifier.

the University of Zagreb and it is primarily intended for energy certification purposes. The Ministry of construction and physical planning (responsible for EPBD implementation) plans to extend applicability of the software for other legal purposes (energy permit) by introducing climatic data for more geo locations.

Following the release of MGIPU Energy Certifier, a few commercial software packages based on Algorithms extended their calculations from only energy need ($Q_{H,nd}$ / $Q_{C,nd}$) to technical systems energy uses and included additional climatic data for more geo locations. There is no formal obligation to verify commercial software, but they are in most cases verified informally against the public software.

New EPB standards prospects in Croatia

The new set of CEN EPB standards (ed. 2017)[2] was implemented in the national standardization system shortly after the formal vote. Introduction of nZEB (nearly Zero Energy Buildings) calculations imposed a need for more accurate/sensitive calculation methodology with hourly time step. There is relatively strong opinion about this need among the experts and policy makers involved in EPBD related legal actions.

Therefore, the new set of CEN EPB standards is considered for adoption in the national regulation/methodology as soon as an appropriate and verified calculation tool is available on the market.

The Ministry of construction and physical planning is in favour of development of a common EU open source kernel, following the recent initiatives communicated between the member states representatives within the Concerted Action EPBD V[3]. The Ministry is not going to finance any new calculation tool (software) based on the new EPB standards.

The general impression is that there is a lack of knowledge/skills among engineers regarding EPB calculations, only energy certifiers are obliged to enrol the training courses. This is true especially in cases of more complex buildings and technical systems (e.g. buildings with more zones, different heat sources, alternative systems, etc.) as well as in the case of nZEB calculations. To accelerate implementation of the new (2017) set of EPB standards a 'user friendly' software shall be provided to engineers and energy certifiers to facilitate the performing of the overall calculation procedure. The calculation has been generally considered by the mentioned experts and policy makers to be too complex since the first release of the CEN EPB standards (and Algorithms). The next step forward in adopting the new CEN EPB standards is also work on describing the national calculation method according to Annexes A of the EN ISO 52000 series, which is about to be initiated. ■

References

1 https://mgipu.gov.hr/pristup-informacijama/zakoni-i-ostali-propisi/podrucje-energetske-ucinkovitosti/algoritam-za-izracun-energetskih-svojstava-zgrada-objavljen-15-svibnja-2017-u-obveznoj-primjeni-od-30-rujna-2017/8930.

2 For the total set of CEN EPB standards see: https://epb.center/documents/.

3 The Concerted Action EPBD (CA EPBD) addresses the Energy Performance of Buildings Directive (EPBD). It aims to contribute to the reduction of energy use in European buildings, through the exchange of knowledge and best practices in the field of energy efficiency and energy savings between all 28 European Union Member States plus Norway. See www.epbd-ca.eu.

Implementation of the EPB standards in The Netherlands including some reflections

JAAP HOGELING
EPB Center,
Weena 505,
3013 AL Rotterdam,
The Netherlands

DICK VAN DIJK
EPB Center,
Weena 505,
3013 AL Rotterdam,
The Netherlands

Development of new national energy performance of buildings calculation method (2017-2019)

By the end of 2017 NEN decided to update the existing national Energy Performance standards in The Netherlands. The planning was to finalise this work within roughly one year. This short time frame was based on the requirement in the EPBD to report to the Commission by March 2020. The new national method should be operational by 2020. It was estimated that final checking and preparing and distributing reliable software based on this national method should at least take one year.

It was clear from the beginning that this was a very ambitious time frame, in particular because the new methodology had to meet a number of demands that might not all have been covered by the existing method. Moreover, the goal was to develop a methodology that would be as much as possible in line with the European standards.

In order to decrease the risk of failing to meet the deadline, three decisions were taken:

1) To prepare, initially, a type of document that has a lighter approval procedure than a new national standard: a so called NTA, a national technical specification.
2) To appoint a few special teams of experts and stakeholders, each responsible for the (parallel) preparation of a specific section of the calculation procedures.
3) To ask these teams to start writing the document as much as possible in line with the EPB standards, but not by filling in the national choices according to the template of Annex A of each standard (-> National Annex or Annexes for each EPB standard), but by directly copying from the EPB standards and pasting into the draft national method the useable or applicable elements.

The teams working on the proposals had access to the set of Formal Vote versions of the EPB standards (not the final published EN or EN-ISO EPB standards) and they took over substantial parts of the different EPB standards. The results of the teams were combined into one working draft NTA and translated into Dutch for the parts that had been copied from the EPB standards.

During 2018/2019 the overall quality and consistency of the working draft NTA was reviewed and improved and further changes in the technical content were made were necessary. An Excel tool was developed to support this process. In parallel to the preparation of this determination method, the government worked on the formulation of the future minimum energy performance requirements. These requirements will consist of three levels: the so called BENG1 (BENG = NZEB), BENG2 and BENG3, more or less standing for the level of energy needs, energy use and renewable energy contribution.

Finally, the new national calculation methodology has been published by NEN in Dutch language dated June 2019 as NTA 8800, *Energieprestatie van gebouwen – Bepalings methode* (*Energy performance of buildings – Determination method*). A voluminous document of 980 pages (can be downloaded for free from NEN website).

The calculation procedures in NTA 8800 are in accordance with article 3 of the EPBD. The NTA 8800 makes use of the set of EPB standards as published by NEN as NEN-EN- and NEN-EN-ISO standards. As it is stated in the introduction to the document "*These EPB standards were leading, with national interpretation and addition where necessary and allowed*"

EPB standards and National Annexes; the recommended route from the European perspective

The time given to develop the new Dutch national method was very short. This was one of the reasons for the decision not to start by trying, one by one, to adopt the EPB standards by filling in the template with national choices as presented in Annex A of each of these standards.

This route, adopting the EPB standards by filling in the template of Annex A with national choices, was recommended by the Dutch experts involved in the preparation of the EPB standards. These experts were of the impression that quite some EPB standards were fit for adoption by The Netherlands. After all, during the development of the set of EPB standards (2011–2017) Dutch delegates, both from the technical side and from the regulatory side had spent quite some effort to review the draft documents and to submit comments that had led to many improvements of the standards and to additional choices that aimed to make the standards fit for use within the Dutch regulatory and practical context.

So, the route that would have been preferred by the Dutch experts involved in the writing of the EPB standards would have been to fill in the National Annexes, starting with the most important EPB standards, such as EN ISO 52000-1 (EPB overarching procedures) and EN ISO 52016-1 (energy needs for heating and cooling), etc. This would very likely have revealed that these EPB standards could be adopted without problem.

And if or when, for a specific EPB standard, they would have come to a specific detail for which the options provided by the template in Annex A would not cover the option that the experts and regulators in The Netherlands were looking for, then they could have flagged this as a point of attention for the next revision of the EPB standard.

Yes, it is true that in such a case the specific EPB standard is also not adopted: if a EPB standard is formally adopted in the building regulations, the National Annex of that standard has to be 100% in line with the template in Annex A of that standard. But the big advantage is, that in this case it is made fully transparent where the discrepancies are and what needs to be done to be able to adopt the EPB standard in the near future. So, both for the future prospects and for the maintenance of the national method this would be recommended.

The NTA 8800 in itself does not reveal the similarities and differences with the EPB standards. However, this does not mean that there is no information on the link between NTA 8800 and the set of EPB standards. This is explained in the next section.

So, in short one could say that by taking the templates of Annex A as a starting point it would have been clear that:

- for the (maybe only few, but probably the most important ones) EPB standards for which the National Annex could be filled in 100% in line with the template, the EPB standard could have been adopted without problem, with the standard and National Annex referenced in the regulations for that particular part of the calculation method;
- for those EPB standards for which the National Annex could not be filled in 100% in line with the template, but perhaps "for 80%", the EPB standard could indeed not have been adopted, so a National Annex would not be applicable. In such a case the content of the filled in Annex A, including the deviations from the template containing the deviating national options, would have been published as separate datasheets. In the context of the EPB standards these are called 'National Datasheets';
- for those remaining EPB standards that are relevant for the national methodology but that appear to be more fundamentally different from what is consid-

ered fit for the national regulatory and practical context, it could be problematic to fill in the template or even a part of it. In this case there is no alternative than to refer to a national calculation procedure for this part of the calculation.

But as said above, the "short track" development of the new national method led to the choice for a different route.

All-in-one document needed as national method?

One important argument for developing a national standard or equivalent document containing the national calculation method to assess the overall energy performance of a building is that for practical user you need an all-in-one document, written in the national language.

This cannot be denied, although some people say that in practice only the software tools are used that are based on the standards and "no one will read the standards anyway".

From the start of the development of the set of EPB standards it has been clear that such a need exists. But in fact there is no conflict between adopting the EPB standards plus National Annexes and having an all-in-one national document: it is not unusual to prepare a national application document that contains all the chosen elements of the EPB standards as given in the National Annex, with all the other input from the National Annex integrated; and translated. The EPB standards plus National Annexes are still the formal documents, but exactly the same calculation procedures is performed by using this (informative) national application document. If in the national document the source of the elements are tagged, maintenance, e.g. in case of revisions of an EPB standard, is also no obstacle.

Proposals from Dutch experts worked out in the NTA 8800 that could be considered as clarification or improvement of the EPB standards.

Of course, there are several issues where the Dutch experts succeeded in providing better solutions our more clear procedures as included in the current set of EPB standards. An example is the impact of solar shading on photo voltaic panels is more detailed than in the CEN standard, because NL has always, and still wants to take into account the more than linear deterioration of the output caused by partial shading of the solar panels, in case of certain types or poor arrangement of solar panels. Another example is the national methods for Heat Pump application which overcomes the shortcomings in information in EN 15316-4-2[1] (heating & DHW generation, heat pump systems) and EN 16798-13[2](cooling systems, generation). This is not surprising as CEN TC 156 & 228 already decided to install an ad-hoc group to look into these issues and provide advice for a short-term fix and long-term revision of these to standards. Further information on the Heat Pump issues is expected to be published in the near future at the EPB Center website.

More examples of good proposals could perhaps be extracted from the NTA8800 and the justification document, but this needs further study. It should be beneficial for the EPB expert community if experts around Europe working on the national implementation documents have the opportunity to publish possible improvement justification articles. This information could be used by the CEN Technical Committees to maintain and improve the EPB set of standards in the years to come.

NTA 8800 and National Annexes / National Datasheets

So, the NTA 8800 is an all-in-one document which is for a large part based on the EPB standards: where possible, procedures from the EPB standards were copied and pasted into the national document. Some national interpretations and/or national additions where needed if a particular EPB standard was not clear or not consistent, or if a specific Dutch building practice required a more simple or a more advanced methodology.

In order to keep track of the differences with the set of EPB standards, NTA 8800 itself contains references to the EPB standards. Moreover, during the development of NTA 8800, a justification document (June 2019, in total 104 pages) was prepared that explains where and why the method deviates from the EPB standards.

In order to meet the requirements of Annex I of the new EPBD, and after completion of NTA 8800, National Datasheets on EN ISO 52000-1, 52003-1, 52010-1, 52016-1 and 52018-1 have recently been filled in by NEN in cooperation with the experts involved in the development of NTA 8800.

However, these datasheets seem to be intended only for the reporting to the European Commission and not intended for use in practice, so there seems no necessity to check if the National Datasheets are correct and complete other than meeting the obligation from the EPBD. It is also not sure if these Datasheets will become publicly available at short notice.

Using a more advanced methodology

In theory one could try, but the national calculation software will not support this, to use the EPB standards in connection with the assumptions and choices of the not yet published national data sheets And even when you succeed to follow this road, the EP assessor has to prove that it is according the NTA 8800 which makes this road not practical.

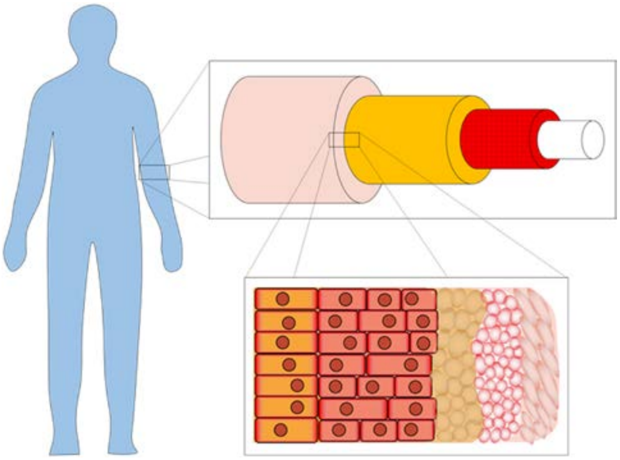
Future prospects

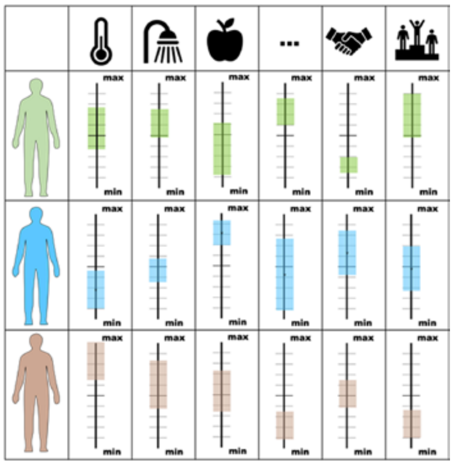
As said before, the new Dutch method had to be prepared in a very short time. Now that NTA 8800 has been completed it might be a good moment to analyse in detail to what extent the methodology now laid down in NTA 8800 could have been described in terms of (adopted) EPB standards and National Annexes. Both for the future prospects and for the maintenance of the national method this would be recommended. It would make the discrepancies more transparent and would show more clearly what needs to be done to be able to adopt the EPB standards in the near future. ■

References

1 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.

2 Energy performance of buildings – Ventilation for buildings – Part 13: Calculation of cooling systems (Module M4–8) – Generation.





Framework for a transient energy-related occupant behavior agent-based model

JAKUB DZIEDZIC
Norwegian University of Science and Technology., Institutt for energi- og prosessteknikk, Kolbjørn Hejes v 1B, Trondheim, Norway
jakub.w.dziedzic@ntnu.no

DA YAN
Tsinghua University, School of Architecture, 100084 Beijing, China

VOJISLAV NOVAKOVIC
Norwegian University of Science and Technology., Institutt for energi- og prosessteknikk, Kolbjørn Hejes v 1B, Trondheim, Norway

Keywords: Occupant behavior, Agent-based modelling, Building performance simulation, BOT-ABM, Occupant-centric building design

Abstract

Simulation of occupant behavior (OB) is a topic considered to be crucial for further advancement in building performance simulation (BPS). Previous (statistical and stochastic) approaches in attempting to re-create in-building human activities were not sufficient to capture subtle activity changes with significant influence on building energy performance. Development of

an occupant behavior agent- based model seems to be a promising direction because such an approach allows deploying a time- dependent, reactive model. The main purpose of the agent will be its presence in the simulated thermal environment and its ability to react once the thermal conditions are outside its established thermal comfort zone. Herein, the agent model has to provide a personification of its thermal comfort condition. To introduce such features for OB simulations in BPS, a new model framework was introduced. It will enable probing of the simulated state of thermal conditions and the "sensing" of it. If conditions are inside the required limits of thermal comfort, the agent will not react. Otherwise, if the state of the agent's thermal comfort crosses its threshold values, it will try to adjust its thermal conditions using local adjustment possibilities, e.g. simulated adjustment of the set-point. The fundamental input data for this agent model can be obtained by use of the depth registration camera for direct observation of occupants. Continued monitoring of occupant reactions in various thermal conditions will be a foundation for the development of the occupants' thermal profiles. Storage and compilation of such information will contribute to the detection of the parameters that are mandatory for the development of the transient energy-related occupant behavior agent-based model.

1. Introduction

According to the newest International Energy Agency annual report, thirty per cent of the globally produced energy is consumed in buildings [1]. A vast portion of this resource is explicitly consumed to match up with the expectation of its users. For the past forty years, researchers have investigated demand and the way the users exhaust energy. During that time, the topic has become mature enough to be considered a separate branch of scientific field related to the understanding of building energy performance. One of the milestones in the field of occupant behavior studies was a work presented by Fanger [2]. His work on the presented ideas and application proposition initialized the process of describing human interactions with the indoor environment. Still, due to the multidisciplinary nature of energy-related occupant behavior studies, it is difficult to develop a model that could apply to any and all conditions. Similar obstacles appear when it comes to a simulation of the different types of buildings. Lack of accuracy in existing models was noticed and pointed out in the work of Turner et al. [3]. In this, a comparison was made of the energy consumption results from building energy performance simulation and consumption during operation time (after it was built). Comparison have shown that only 30% of investigated buildings consume a similar amount of energy. It is possible to conclude that one of the reasons for such a mismatch is caused by underrating occupant influence on building energy consumption. It seems that the current resolution of monitoring occupant activity is not sufficient to capture energy-meaningful phenomena. The basic description of the occupant as a system user has to be more comprehensive, and it should allow the inclusion of a broader spectrum of occupant/building interaction. Such a conclusion can be made after reviewing Yan et al. [4]. As put forward by Hong et al., ontology is the classification of occupants regarding their energy-related behaviors [5-6]. The approach they present segregates a particular occupant's actions with regard to common behaviors that have influence on building energy performance. Among these are switching on/off the lighting or adjusting windows blinds. Such studies are a step towards transient agent-based modelling wherein a single agent represents the behavior of one person. However. to gain access to the more comprehensive overview of occupant's actions, it is a necessity to understand their demands and needs. As Wagner et al. notes, this can be done by way of statistical analysis of the group or occupancy state coupled with multi-sensing techniques [7]. Additionally, occupant-related studies should be supported by survey and interviews that allow a description of the personal preference of the person. The previously conducted work of Dziedzic et al. shows promising results regarding developing precision in indoor occupant profiling via depth registration camera [8]. A good example of the broad spectrum of data collections was shown in Jamrozik et al. [9]. Herein, collected observations of the human reactions to the thermal environment were enriched by inclusion of occupant socio-psychological data. With such a multidisciplinary approach, it is possible to track occupant motivation for chosen action. A precise socio-psychological description allows compilers to gather, cluster and detect trends among occupant personality. Hence, capturing data holistically regarding energy-related drivers can be used as an additional asset in the development of an action-driven model of occupant behavior.

Gaetani et al. provide a selection of models that are "fit- to-purpose" in order to show the current developmental level of occupant behavior modelling [10]. Based on the provided [10], it is possible to notice that most of the developed occupant behavior models are focused on one or only a few particular issues regarding occupant behavior. What is also notable is the lack of communication among the model developers and that this has brought about overlaps and absence of cross-modal communication. The idea of "fit-to-purpose" propagates understanding that each application has its optimum workflow resolution, and in the present, there is no solution for scalable applications regarding occupant behavior modelling. Similar conclusions were drawn in a work of Bing et al. [11]. The main challenge related to occupant behavior modelling, in general, is operational resolution. Occupant activity that could be considered as significant regarding energy use can be triggered by an event lasting only a few seconds, for example, a draft caused by the sudden opening of a closed door. Yet, exposure to a particular "incident" may have long-term implications, like adjustment of the thermostat. Capturing such phenomena requires a high observational resolution of occupant behavior. Previously developed models were not capable of portraying such events, because their initial resolution was beyond the ability to capture such an event.

The main disadvantage of any available OB simulators is that all of the spectra of actions are driven by probability or stochastic process. This means that occupant activity has no relation to the particular order of performance. Thus, there is a possibility to develop a "story-driven" or "action-reaction" understanding of simulated actions. This has come about by the input data for which previous models were compiled. The origins of limitations within previously developed models were engendered by the resolution of the data that they developed. Current models are capable of performing well on simulations that involve a group of occupants, such as shared lunch, or general occupancy of a room. Unfortunately, trying to identify a reason, meaning or driver of connected actions at the individual scale is impossible from such simulation results. Therefore, the actions triggers are also unknown. To fulfil all of this uncertainties, it is necessary to re-develop occupant behavior models so that it is possible to explore the reasoning for a particular action. To reach all of the expectation regarding model features, the need is to develop an agent-based model. Here, the simulated agent represents an occupant and it is equipped with an embedded complex behavioral engine capable of simulating reactions to the various conditions of the indoor environment.

The main aim of this paper is to highlight the core milestones of the model development process. Due to the complex structure of the proposed, developed solution, it is necessary to highlight potential outcomes and to open dialogue with the broader scientific community. The proposed framework of the model does not aim at the promotion of particular software or application. This work aims only to introduce to the wider audience, the possible structure for simulation of indoor occupant behaviors.

2. Framework

With regard to heating and cooling, to reach the collective expected requirement that allows generating a contextual response to the simulated actions, the simulated agent has to experience similar thermal conditions. In bringing this about, it is necessary to probe data drawn from the constantly changing physical properties of the indoor environment. This means that the model has to operate on transient indoor environment proprieties. This data can be acquired from a computational fluid dynamics (CFD) simulation or through a multi-zonal model. Because both of the simulation methods consume a significant amount of computational time (at least for now), it is recommended to perform a series of parametrical studies beforehand. As the simulated occupant behavior relays on reaction to the on-going environment condition, if environmental and physical properties are pre-simulated and the transition between states kept in order, such properties will not have influence upon the occupant behavior simulator. This implies that while the environmental conditions will influence the occupant behavior simulator, the simulated agent will not have influence upon the environment and the conducted actions by the agent will do so. Because this approach is based upon assumed model features, this approach is referred to as the 'building occupant transient agenda-based model' (BOT-ABM). The purpose of the model is to simulate more realistically the usage of the various energy resources. The agent (i.e. the simulated occupant) is brought into being by a collection of modules that re- create the routine activity of the building users. Herein, each individual module is responsible for the simulation of one specific behavioral feature. Moreover, all of the used modules operate in the same temporal resolution, and the general model architecture is designed in a parallel structure. As the solving of one particular time step will require the calculation of each activated module, this will increase the calculation time of each time step, but it will allow cross-communication between each of modules. Such a structure enables the development of co-depended scenarios where one particular phenomenon, such as spontaneous exposure to a cold draft, might generate a variety of BOT-ABM reactions. The general structure of this in the form of an information flow chart is presented in **Figure 1**. Individual module functionality will be briefly explained.

3. Modules

3.1 Movement simulator module

One essential feature of occupant activity is the ability to move around. Nevertheless, this occupant behavior feature is not explored enough about applicability in building performance simulations. In doing so, however, the simulation of direct movement will require a radical incrementation of the time resolution, which, subsequently, will increase required computational power need.

In contrast, simulation of all the transitions allows a precisely described occupant exposure to the indoor environment. Its green lights the gathering of data about the occupant position in time; therefore, it allows implementing the module that simulates interaction with an indoor environment. The full probing of environmental data will be brought about through the collective response of individual models. This part of the model provides for discretized positioning and transition of the human body, in time.

The Movement engine module itself is solely responsible for simulating the natural transition between point A and B. It will operate through any defined polygon, but to re- create realistic usage of the building, it has to operate within a furnished layout. Once the floor layout is fully designed, the simulated agent actions will be relayed to general placement. Herein, the furniture setting will be used as a coordinate system for the agent movement. The agent will then perform the intended performance task and will operate and interact with appliance in the same manner as would the building occupants. Data from such appliance usage could be collected via analyses of the plug load or through various Application Programming Interfaces (API). If the layout simulator is available, it will be possible to simulate the layout scenarios, to test various scenarios and to investigate which is producing the most energy efficient or most comfortable settings. Furthermore, it may allow testing how floor layout operational changes (like adding an extra, internal wall) may influence indoor air conditions.

Development of the layout generator has to be paired with the development of an extensive library of appliances and furniture designed for this purpose. This dataset must hold information about appliance dimensions, heat map localization (probability of the placement on a floor layout), potential activities that it may be used for and the zone wherein it is possible to interact within. All of these features are important for precise simulation of the building occupant activity. Appliance dimensions (Length, Height, Depth) and heat map localization will be used for appliance placement in a

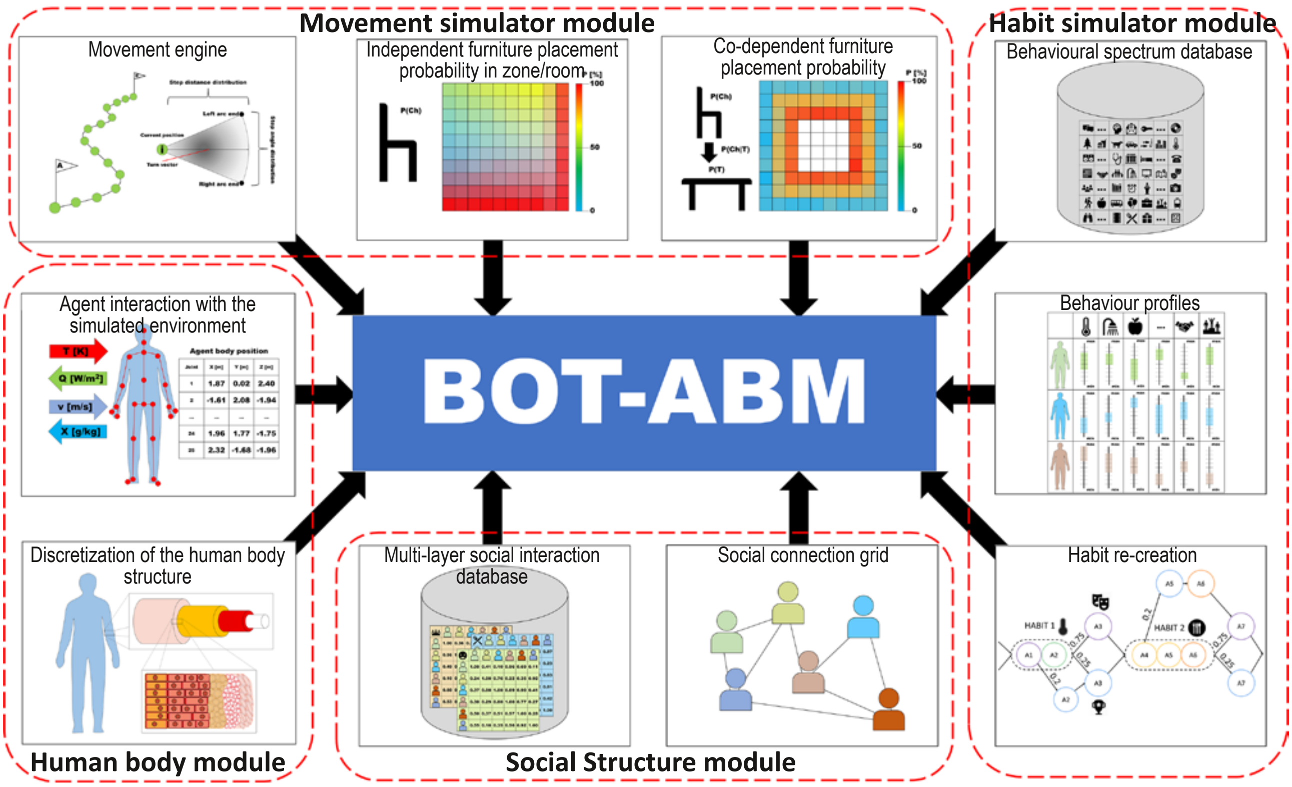


Figure 1. Building occupant transient agent-based model.

simulated layout, and for development of the geometry for final operational air volume. If the study is aiming at a parametrical analysis, the heat map localization feature will not be used. The list of potential occupant activities will be employed to enable a description of the appliance/furniture purpose, as well as to support the habit simulator and the physical environment sensing module. If the agent has to initialize an action, for example: prepare a meal, there are only a few appliance s that can support the execution of this task. The agent will be instructed to select one of the given options and fulfil the given "task/need". Once the procedure of appliance selection is done, the agent will find a pathway from its current position to the aimed goal which is the space/area where is possible to for interact to occur.

3.2 Habit simulator module

The purpose of the habit simulator module is to trigger activity. This module will cover most of the essential description of agent personalities and their way of utilizing the space. Description of agent habits will cover a wide range of activities connected with maintaining a portrait of occupant routine and of related activities. Additionally, it will try to include a possible spectrum of irregular activities that are non-explainable or could be considerate as unreasonable. This module will be designed to operate within three separate layers: Behavioral Spectrum, Behavior Profiles and Habit Re-creation.

The first layer (Behavioral spectrum database) will be used as general database source-set of potential activities. This database will deliver operational space for a selection of various behaviors. Thus, it serves as a pool of possible outcomes that can be triggered by any given condition at a moment. The spectrum and source of triggers may vary. These depend on the given situation – whether a sudden change of conditions or scheduled activity or simulated "loss of interest". The more extensive that this library of activities is, the greater the potential exists to simulate more sophisticated activity. This can be analyzed later so as to improve performance. Every time a simulated action is triggered, it is recorded on a simulation timeline. This activity allows for developing an understanding of the context of each conducted activity. Therefore, it will be possible to analyze simulated occupant behavior by way of a story-driven method. Such an approach will allow investigating building design that includes sensibility analysis of the potential group of building users, and, hence, an estimate of the potential energy demand that the group may require.

Second layer (Behavior profiles) will focus on an individualization of the activity, by generating an individual behavior profile description. Each particular activity has to be described by the following features: the conditions that triggers it, the spectrum object or tool that it has too interact with, the time that is consumed in conducting it, the mechanisms that must be operated, and the gain achieved. All activities have to be segregated into two sub-categories, cumulative sum-based or threshold-based. The functionality of the activities that are cumulative sum-based rely on the fulfilment of the task. Each utilized time unit of the selected task performance increases the cumulative sum. In contrast, threshold-based activities are triggered if the threshold of acceptance of the simulated conditions is crossed. Both of this action trigger engines that control agent performance. Attributes can be defined by the selected trigger engine and described by its operation values. For example, the simulation may test appropriate occupant reaction on a spectrum of indoor air thermal conditions. If the simulated occupant is "sensing" that the indoor environment is beyond its thermal acceptance level, it will react. Its action will aim at a return to the "comfort" state. To do so, it will have a spectrum of potential actions that will provide a return to the acceptance level of a given condition. To avoid infinite feedback loop, each conducted activity will have a "death band" functionality. Therefore, the simulated agent will be described with a certain acceptance reaction latency.

The simulated behavior of the agents will require behavioral specification. Each agent must be described by the constraining values of their "personal" preference with regard to the global "character" description. This part of agent description will be held by the behavioral profile layer (second layer). Here, selection of the "basic" human needs and desires can be transferred from the field of anthropology, wherein the study of human behavior modelling is a scientific pursuit. Through accessing this branch of natural science, it will be possible to define the fundamental features of occupant needs. The most applicable model that fits into the proposed model structure is that suggested by A.H. Maslow [12]. Pyramidal structure describing Hierarchy of Needs can be used as a template and be explored in terms of its applicability in building performance simulations. The selection of appropriate behavioral (anthropological) model and its modification, however, will not be elaborated upon in this paper. Whatever the anthropological model selected/modified for BOT-ABM performance purposes; all the features included in the description of occupant profile must be transferred to the Behavioral Spectrum layer of the habit simulator. This procedure will allow for direct communication between all of the layers included in this module.

The third layer (Habit re-creation) of this module will be responsible for a re-creation of occupant habit and daily routine. By way of applying this part of the module, it is possible to simulate a task that can be considered as mandatory, such as going to work or school. Proper usage of this layer will allow to control agent health maintenance and the strategies that are triggered by occupant activities related to hygiene and healthcare. It must be noted that everyone has a routine – a daily rhythm and way of organizing daily activity. The order of the actions taken depends on various conditions like lifestyle, personality or employment. No matter what kind of routine each person follows, the day timeframe limits the amount of actions that person conducts per day. This means that pinpointing this on a timeline and limiting its duration can describe daily activity.

Additionally, as habits are desires expressed through a series of actions, each conducted activity can be considered as being a derivative of habit and routine. The module that is responsible for the re-creation of occupant habit, can be looked upon as a binder for a series of actions. Additionally, as the order in which activities are followed plays an important role, this part of the module will hold "recipe" information about each habit. However, BOT-ABM will be designed to follow habit protocols if its basic demands, described in the previous layer (Behavior Profile), are balanced. This layer of the module will keep the agent following a daily routine without pointless wondering in uploaded space, zone or floor layout. It will also allow for tracking the overall understanding of the agent's action purpose.

In attempting habit and routine simulation, there is a vast range of activities that cannot be considered routine or habit. Because their nature is unpredictable, as pointed out by Strangers, there are specific actions that cannot be directly explained [13]. Irregular occupant behavior is defined as an act wherein the occupant consciously or unconsciously performs an action that does not fit in order or/and timeline of any routine. That is why the core description of conducted actions order cannot be completely fixed - it must hold space for potential irregularity. To do so, all the daily routines have to be described via a probability factor. This function is responsible for the scoring of the action inside one routine, regarding holding its order and timeline coherency. The higher the value of this probability factor, the larger the probability of habit re-creation inside the simulation.

3.3 Social Structure module

To re-create building occupant behavior, it is necessary to include their interaction with other occupants. No matter what kind of building is being simulated, the existence of the social grid inside it cannot be by-passed. Indeed, its magnitude can be only forgotten if the designed space of investigation concerns one individual. In the other cases, the way occupants interact with each other has to be included in the simulation. This module will hold information about the social connection between agents, and it will be responsible for assessing the degree of potential collaboration between each in various tasks/routines. Here, selection of assignment has to rely on a hierarchy of relationship structures inside the simulated space. It also has to allow for agent collaboration, as well as following the grading system of simulation. Of note, the simulation of occupant social network also depends on building purpose. If the simulation targets a residential building, the social connection must consider family structure.

The data about the social network in the observation space can be captured by way of the use of mobile telephone data streams. As shown by Ren, Ye. et al., this makes it possible to obtain information that allows for re-creating the social communication structure of the monitored occupants [14]. However, a combination of various measurement methods may allow developing a better general understanding of social connections in different types of buildings. Once such a knowledge base is obtained, it may be used automatically to allocate specific social networks to the appropriate buildings. Until then, this has to be done via the use of pre- defended networks and application of hierarchy.

3.4 Human body module

This module is responsible for the positioning of the human body inside the simulation environment. Here, a general projection of the human body can be used to probe data from a selected body part or point of the body. This feature can be used to calculate the radiant temperature of investigated body limb/area or the general exposition to airflow streams. The limitations of the probing depend upon the used simulation environment and the embedded equations. The higher the resolution of the indoor environment simulation, the more detailed the study. To simulate human body reaction, it is also necessary to investigate the kind of processes that are happening inside the body. An excellent example of a model that could be used for this purpose is that proposed by D. Wölki, wherein the human body is divided into nineteen parts, each part being composed of a few layers of the human tissue structure [15]. This approach shows promising results, but it must be improved in terms of simulation of the tissue composition. The current state-of-the art is that this model assumes uniform tissue distribution. To simplify modelling, uniform tissue distribution can be considered a good approximation, but for detailed study, such an assumption might be crucial. To provide a proper response to the habit simulator, the delivered input information has to be accurate in order to prevent agent misinterpretation. Hence, the more recent MORPHEUS model must be explored and assessed for simulation competence [15].

Besides sensing the environment, this module will be responsible for delivering information about agent activity level, clothing level and the related. Such information is crucial for the proper simulation of the energy-related occupant behavior in buildings. Knowledge about activity level will support indoor environmental simulation by delivering data dynamics of energy released by the human body to the investigated space. Additionally, it will be a marker for a proper re- creation of the pendular movement of agent body parts. Simulation of the clothing will be embedded in the same way. It will provide an overview of skin exposure to the indoor environment, but it will also be charged by the response system from the habit simulator module.

3.5 Information exchange and modules hierarchy

Access to all of the features that are provided thru each separate module requires an understandable architecture of information flow. Without a specific order of hierarchy, a collaboration between modules might produce a chaotic representation of the actions without meaning. Centralized structure of the BOT-ABM allows for modular applicability of the whole model, but whole information exchange is via its centralized mainframe. It can be considered as a historical database of the agent.

In presented BOT-ABM structure, two modules (Movement simulator and Human body) are responsible for direct interaction with a physical environment. Therefore, these modules are not producing a "decision" impulse for conducting a task by the agent. Both of these modules operate on two-way communication with a BOT-ABM mainframe, but each of these modules has a low position in a decision hierarchy.

Other two modules are responsible for taking care of socio-psychological side of the occupant behavior. The proposed model structure is aiming at a simulation of the individual occupant behavior. Therefore, Habit simulator module will play a critical role in a decision hierarchy. This module is not responsible for the probing of the data from the environment. They accumulate the collected information from the other modules, uses it as an input and process it with a defined personal trade. Generated output distributes information of an adequate response to the other modules.

Hierarchical position of the social structure module is hard to pinpoint directly. It might have a significant influence on a Habit and Movement simulator modules. It is also used as an information exchange port with other agents, which allows for a mutual collaboration of numerous agents while keeping their individual trades. Because the main aim of the BOT-ABM is to simulate individual occupant behaviors, Social Structure module has the lowest hierarchical position.

4. Discussion

The presented paper provides a brief overview of the occupant behavior simulator that potentially can be used in BPS. The proposed solution operates upon four different modules - each responsible for one facet of human activity. The main aim of this model is to re- create inside building occupant behavior. Due to the diverse operating resolutions of human beings and building structures, it is difficult to assume what kind of time resolution is optimal for simulation purposes. From the perspective of the building user, a one-minute resolution could be considered too shallow for portraying their behavior correctly. On the other hand, same resolution can be considered as too detailed if the perspective is set as annual building operation. Therefore, it is difficult to decide what kind of time discretization should be acceptable to portray events that could be considered as important from the perspective of the building user. Still, no matter what kind of operational resolution will be selected, the proposed structure allows exploring occupant behavior phenomena through a multi-disciplinary approach.

Social structure can equally influence building user behavior as does the sensation of thermal comfort. Therefore, the impact of this attribute cannot be ignored, but there are no available tools that allow for a numerical investigation of such. To by-pass, this issue, the proposed framework introduces a modular model structure that allows for non-invasive editing of the general model. This means that selected parts of the module can be modified, and the general compiler of the whole model will still be able to operate and communicate with the rest of the modules. Such model flexibility allows for a parametrical study of the many variables that must be included in any model. For example, it will allow for an investigation of the impact of the various social networks on energy usage inside a simulated zone/building. The same portion of study examples can be drawn via modification of the other modules.

5. Conclusions

This paper is an introduction to the core design of the Building Occupant Transient Agent-Based Model (BOT- ABM). The prescribed format of the paper does not, however, allow for an in-depth introduction of each module functionality, but it is crucial for outlining the most critical features of the model within the overall framework. Therefore, development of such vast human behavior model requires a multi-disciplinary team and proper feedback from future users. Development of a comprehensive model that capture advance functionalities of building users requires a lot of effort and long-term commitment. Therefore, it is necessary to rely on an existing framework. Presented framework is an effect of the extensive review of existing energy- related occupant behavior modelling methods. Summarized modelling approaches delivered by Dong et al. [11] and Da et al. [4] allowed to highlight missing pieces in OB modelling and address them. Formulation of this framework can be considered as a result of this investigation which is presented in this paper.

Similar efforts in the formulation of building agent-based model could have been conducted in the past, but there are no records in the available literature. Reasons for such absence is unknown, but it might be suspected that it was caused by problem complexity and lack of proper data. No matter what the reason was, publication of framework proposal will open a new platform to scientific communication and discussion which eventually will lead to the new occupant behavior model. ■

References

1. "*World Energy Outlook 2017.*" Organisation for Economic Co-operation and Development. (2018).
2. P.O. Fanger, "*Thermal Comfort -Analysis and Applications,*" Environ. Eng., pp. 128–133, (1982).
3. C. Turner, M. Frankel, "Energy performance of LEED for new construction buildings," New Build. Inst., vol. **4**, pp. 1–42, (2008).
4. D. Yan, ,W. O'Brien, T.Hong, X.Feng, B.H. Gunay. F.Tahmasebi, A. Mahdavi, ., "Occupant behavior modeling for building performance simulation: Current state and future challenges," Energy Build., vol. **107**, pp. 264– 278, Nov. (2015).
5. T. Hong, H. Sun, Y. Chen, S. C. Taylor-Lange, D. Yan, "An occupant behavior modeling tool for co-simulation," Energy Build., vol. **117**, pp. 272–281, Apr. (2016).
6. T. Hong, S. D'Oca, S. C. Taylor-Lange, W. J. N. Turner, Y. Chen, and S. P. Corgnati, "An ontology to represent energy-related occupant behavior in buildings. Part II: Implementation of the DNAS framework using an XML schema," Build. Environ., vol. **94**, pp. 196–205, Dec. (2015).
7. A. Wagner. W. O'Brien, B. Dong, Ed., Exploring Occupant Behavior in Buildings. Springer International Publishing, (2018).
8. J. W. Dziedzic, Y. Da, V. Novakovic, "Indoor occupant behaviour monitoring with the use of a depth registration camera," Build. Environ., Oct. (2018).
9. A. Jamrozik et al., C. Ramos, J. Zhao, J. Bernau, N. Clements,T. Vetting Wolf, B. Bauer, "A novel methodology to realistically monitor office occupant reactions and environmental conditions using a living lab," Build. Environ., vol. **130**, pp. 190–199, Feb. (2018).
10. I. Gaetani, P.-J. Hoes, J. L. M. Hensen, "Occupant behavior in building energy simulation: Towards a fit-for-purpose modeling strategy," Energy Build., vol. **121**, pp. 188–204, Jun. (2016).
11. B. Dong, D. Yan, Z. Li, Y. Jin, X. Feng, H. Fontenot, "Modeling occupancy and behavior for better building design and operation---A critical review," Build. Simul., vol. **11**, no. 5, pp. 899–921, (2018).
12. A.H. Maslow, "Preface to Motivation Theory," Psychosom. Med., vol. **5**, no. 1, (1943).
13. Y. Strengers, "Home Automation" in *Smart Energy Technologies in Everyday Life,* London: Palgrave Macmillan, (2013), pp. 116–134.
14. Y. Ren, M. Tomko, F. D. Salim, J. Chan, M. Sanderson, "Understanding the predictability of user demographics from cyber-physical-social behaviours in indoor retail spaces," EPJ Data Sci., vol. **7**, no. 1, p. 1, Jan. (2018).
15. D. Wölki, "*MORPHEUS: Modelica-based implementation of a numerical human model involving individual human aspects*," RWTH Aachen University, Aachen, (2017).

Built Stock Explorer

– an interactive platform for data-driven energy planning

RUSLAN ZHURAVCHAK
Norwegian University of Science and Technology
Department of Energy and Process Engineering
Kolbjørn Hejes v 1B, 7491 Trondheim, Norway
ruslan.zhuravchak@ntnu.no

NATASA NORD
Norwegian University of Science and Technology
Department of Energy and Process Engineering
Kolbjørn Hejes v 1B, 7491 Trondheim, Norway
natasa.nord@ntnu.no

HELGE BRATTEBØ
Norwegian University of Science and Technology
Department of Energy and Process Engineering
Kolbjørn Hejes v 1B, 7491 Trondheim, Norway
helge.brattebo@ntnu.no

Keywords: energy performance, built stock, data visualization, stochastic forecasting, uncertainty analysis

1. Introduction

The achievement of environmental and energy-related targets for nations and communities relies strongly on understating the energy performance of buildings that comprise the existing built stock. Such information is essential for developing more accurate models, aimed at forecasting the expected stock changes [1] and evaluating the feasibility of energy efficiency measures [2]. A variety of modelling and assessment methods [3], based on such information, enable to carry out "what-if" analysis and to define the feasible strategic energy pathways to follow. Such pathways may aim at the increase of energy performance, achieving economic benefits, environmental impact reduction or a combination of these.

The accuracy of forecasting and screening techniques, however, is hindered by uncertainties behind the complex and dynamic structure of built stock. Large-scale energy modelling of any kind must account for these uncertainties, summarized and informed by the appropriate statistical means.

This article aims at familiarizing the reader with Build Stock Explorer (https://buildingstockexplorer.indecol.no/) – a web platform developed for interactive analysis and visualization of key variables associated with Norwegian built stock. The user has a possibility to extract relevant statistical information, which can be used further for stochastic simulation, uncertainty and/or sensitivity analysis. An application is based on the Norwegian Energy Performance Certificates (EPC) dataset, has three visual elements and several features that are important for developing built stock models. These are elaborated further in the article.

2. Data and data management

EPC scheme is considered as a powerful mechanism to engage market forces to support the progress towards high energy performance in communities [4, 5]. Hence, the Norwegian EPC scheme has been in place since 2010 intended to ensure Nation's compliance with the Directive 2002/91/EC, improving the building energy awareness and the promotion of

Table 1. Descriptive statistics on the dataset - central tendency, dispersion and shape of the distribution.

	Construction year	Heated floor area (m^2)	Energy use ($kWh \cdot y^{-1}$)	Energy intensity ($kWh \cdot m^{-2} \cdot y^{-1}$)
Count		72169		
Mean	1981	686.43	144 224.00	156.34
STD	35	2 513.49	608 568.60	79.34
Min	1800	12.00	500.00	0.34
25% percentile	1960	65.00	7 999.00	105.02
50% percentile (median)	1989	91.00	12 596.00	134.56
75% percentile	2012	168.00	23 436.00	188.93
Max	2018	66 255.00	26 118 006.00	1 354.18

low-energy use. During six years of operation, more than 670 000 certificates were issued (20% of all dwellings). Certificates are obtained by the building owners through on-line registration of related data which is followed by automated validity checks of data entry. The scheme applies to both residential and non-residential buildings that are being sold or rented out [6]. Some users voluntarily reported the real total annual energy use for the building/dwelling. Only a subset of the EPC dataset where such information has been specified was used further in the application. A postprocessed dataset contains 72 169 records corresponding to 25 largest Norwegian cities.

Among the key variables that the applicants reported are four continuous, summarized in **Table 1**, and three of categorical type, namely city, building category and building type. Building category, 13 unique values, corresponds to the primary use purpose of the building whereas building type contains architectural or component-related information (25 unique values).

To enable intuitive and flexible operations on the dataset at the interface level, yet preserving computational efficiency and robustness, data management follows the scheme illustrated in **Figure 1**. "City", "Category" and "Type" components are the dropdown lists that support multiple items selection and therefore, enable comparative analysis. "Construction year", "Heated area" and "Total energy use" are the range sliders for slicing the dataset according to the user's interest.

With the structure shown in **Figure 1**, the user has the freedom to make changes at any component and see the updated results immediately, without following a predefined sequence of steps. This is achieved by linking every node with the final subset directly. For more intuitive use, categories of buildings available for selection are only those matching the criteria specified at a higher level in this hierarchy. The same applies to building type, which is the child node of "Category" component.

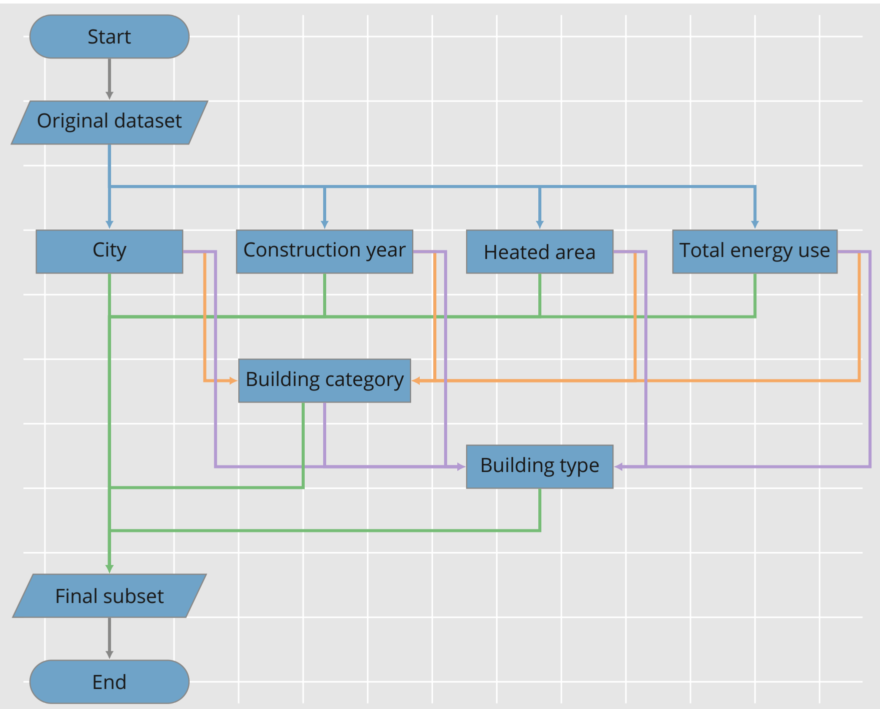


Figure 1. Data management hierarchy.

3. Key features

Given that the user selected and adjusted the dataset to their interest, Built Stock Explorer offers a comprehensive statistical toolset and the visualization of the dataset in three views:

- 3-dimensional scatter plot
- Univariate distribution plot
- Pairwise correlations plot

To display the data of various orders of magnitude, a logarithmic scale can be used optionally.

Three-dimensional scatterplot shown in **Figure 2** illustrates the three essential continuous variables: construction year, heated floor area (m²), and total energy use (kWh · y^{-1}) per building type selected. This view gives a general outline of how many records are selected, what are the magnitudes and trends between these variables.

Univariate distribution plot shown in **Figure 3** communicates the information on built stock variability and computes the essential statistical parameters related to central tendency and variance for the selected subset. The user can also experiment with matching a specific type of theoretical probability density function (PDF). An extra feature enables to find the best distribution function automatically. The algorithm iterates over 25 common distribution types, estimates their parameters, evaluates the goodness-of-fit and eventually selects the best one. The metrics for selecting best fit is the minimal Sum of Squared Residuals (SSR):

$$SSR = \sum_{i=0}^{n} (y_i - f_i)^2$$

where y_i is the value of the data-specific probability density and f_i - the value of theoretical PDF accordingly over 100 intervals.

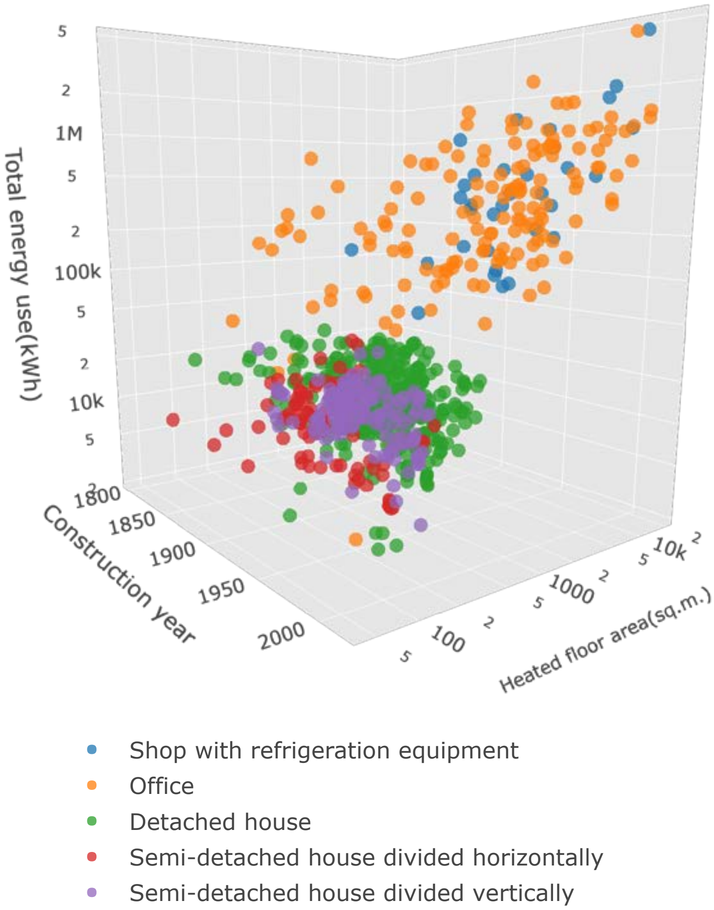


Figure 2. 3-dimensional scatter plot of sample subset.

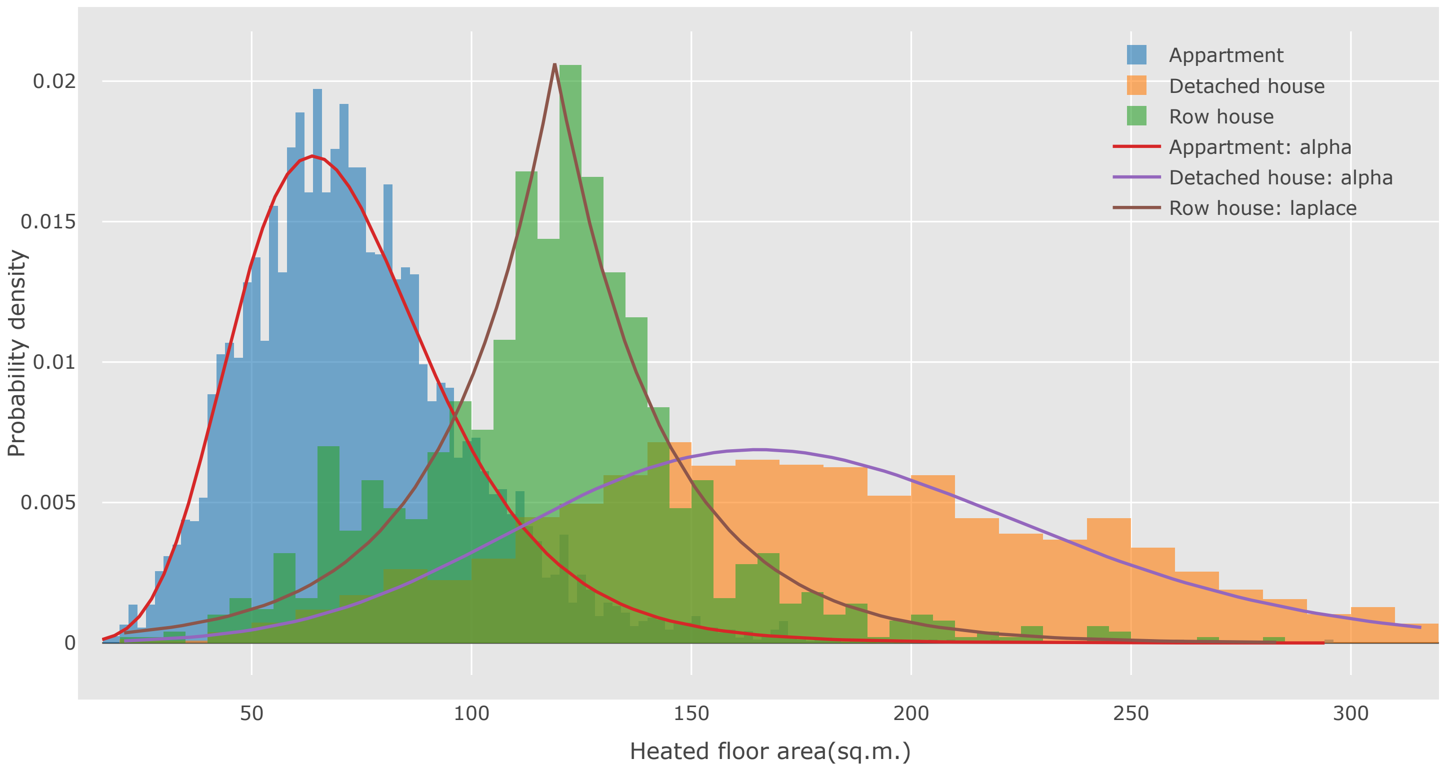


Figure 3. Univariate distribution plot of sample dataset and the corresponding PDF fitted.

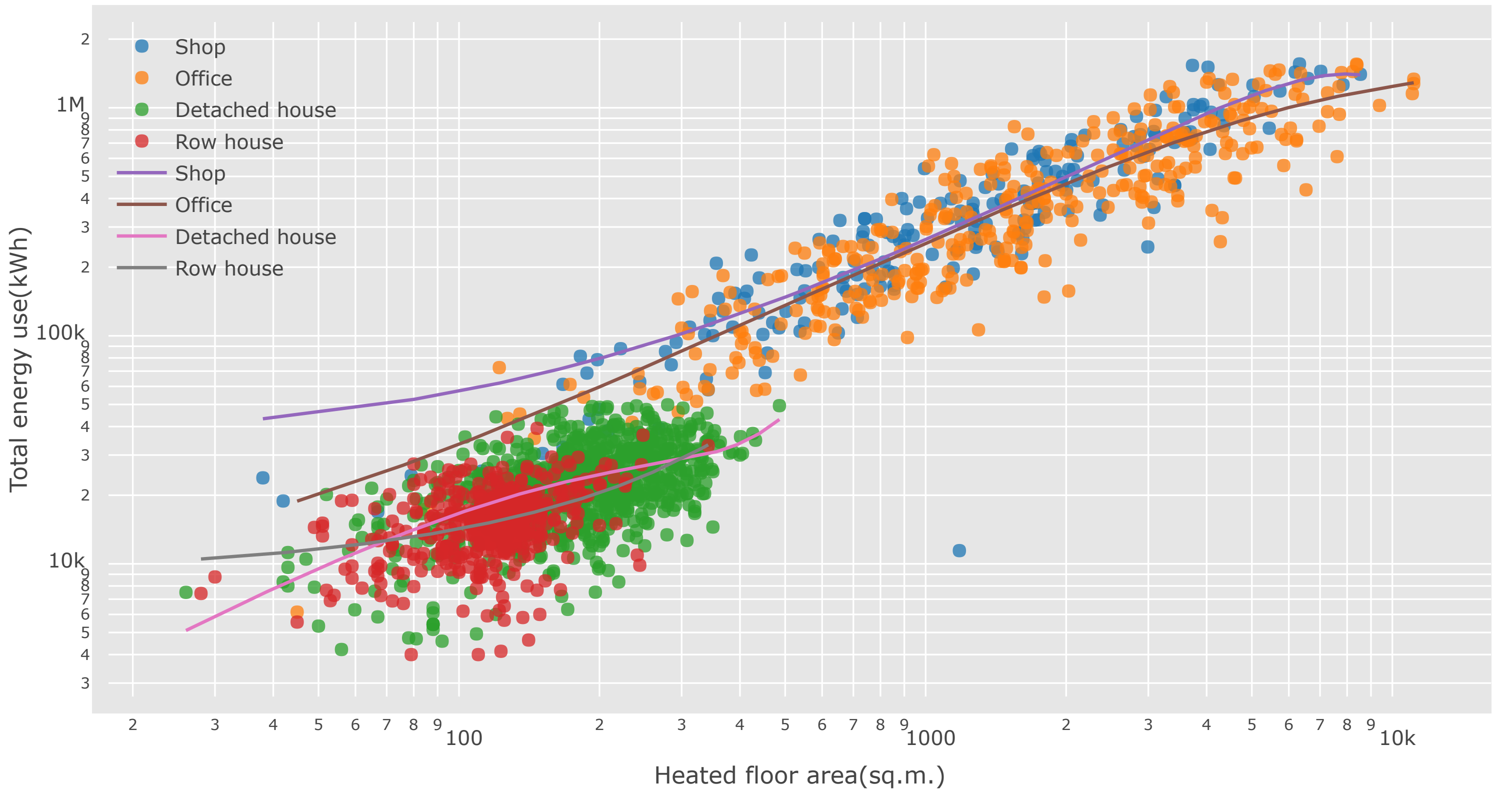


Figure 4. 2-dimensional scatter plot of sample subset and 3-rd order polynomial fit.

Probability density histograms and PDFs, specific to sample buildings types and variable ranges are illustrated in **Figure 3**.

The third view mode enables to explore pairwise correlations between the variables of interest with **two-dimensional scatter plot**, see **Figure 4**. It is possible to find both linear and non-linear (up to 5th order) relationships with interpolating polynomial fit of a form:

$$p(x) = a_n x^n + a_{n-1} x^{n-1} + \cdots + a_2 x^2 + a_1 x + a_0$$

where is x the variable under consideration, n is the order of the polynomial, and a are polynomial coefficients.

4. Conclusions

Heterogenous structure and dynamic development of built stock make it challenging to establish energy pathways for cities and urban districts to follow. With data-driven methods, however, uncertainties in building energy use and its key driving variables can be incorporated into modelling practices. At its current step development progress, Built Stock Explorer offers a statistical toolset for quantifying these uncertainties and the means for communicating them visually. ■

5. References

1. Sartori, I., N.H. Sandberg, and H. Brattebø, *Dynamic building stock modelling: General algorithm and exemplification for Norway.* Energy and Buildings, 2016. **132**: p. 13-25.
2. Nord, N. and S.F. Sjøthun, *Success factors of energy efficiency measures in buildings in Norway.* Energy and Buildings, 2014. **76**: p. 76-487.
3. Swan, L.G. and V.I. Ugursal, *Modeling of end-use energy consumption in the residential sector: A review of modeling techniques.* Renewable and Sustainable Energy Reviews, 2009. **13**(8): p. 1819-1835.
4. Li, Y., et al., Review of building energy performance certification schemes towards future improvement. Renewable and Sustainable Energy Reviews, 2019. **113**: p. 109244.
5. Prieler, M., M. Leeb, and T. Reiter, *Characteristics of a database for energy performance certificates.* Energy Procedia, 2017. **132**: p. 1000-1005.
6. Brekke, T., O.K. Isachsen, and M. Strand, *EPBD implementation in Norway. Status in December 2016.* 2018, Enova, Norwegian Water Resources and Energy Directorate (NVE), Norwegian Building Authority (DIBK).

Ventilation standards and regulation upgraded due to new insights on IEQ supporting innovative ventilation technics in the Netherlands

MARCO HOFMAN *)
BEng, ISSO, Netherlands Building Research Institute
Rotterdam, The Netherlands
m.hofman@isso.nl

*) Marco Hofman is chairing Dutch standards committee at national standards body (NEN) on building ventilation and air infiltration.

Dutch standards NEN 1087 and NEN 8087 for ventilation of buildings will change. Both standards will be merged into one standard which has been published as draft earlier this year: prNEN1087:2019[1]. In contrast with current versions, the new version of NEN 1087 will be applicable to all buildings: new or existing residential and non-residential buildings, and is expected to be anchored in the Dutch building regulations from the beginning of 2021.

Current standards for determining ventilation capacity of buildings, NEN 1087/8087, date from 2001. On many points their content is no longer in line with current insights of a healthy indoor climate and newly installed building ventilation systems. This is the main reason why NEN 1087 and NEN 8078 have thoroughly been redesigned in the past years.

Buildings have to provide protection against factors that can harm people's health in a negative way. When it comes to good air quality not all 'danger' comes from outside. Recent research in the Netherlands, among others from TNO, show that it is mainly the indoor air quality that can cause health problems. The indoor air is often more polluted with more particulate matter and higher CO_2 concentration than the outside air. This is relevant because people live most of their time in buildings. However, the regulations on ventilation have been unchanged for many decades in the Building Act in the Netherlands. In more recent years, when it comes to regulation, more attention is still paid to the energy performance of buildings.

The Dutch Building Act[2], once established to guarantee safety and health of people in buildings, urgently needs to be revised with regard to a healthy indoor environment. The NEN standards committee "Ventilation and air tightness of buildings" has therefore been working in the past years to renew the standards 1087/8087 which are required to follow according to the Dutch Building Act. A draft version of the new standard was presented to the market this spring. The responses received are currently being processed. The new standard is expected to be delivered at the end of 2019, after which it is expected to come into force by the beginning of 2021 via the building regulations.

What are some major changes in standard prNEN1087:2019 as well in future regulation?

Merging NEN 1087 and 8087 with EU standards as basis

To begin with, the scope of the NEN 1087 standard will change. In the existing situation there are two standards with determination methods for building ventilation: NEN 8087 (for ventilation capacity in existing buildings) and NEN 1087 (for newly built construction). Both standards are primarily developed and defined for residential buildings but are also declared applicable to other buildings in the Building Act. In the new situation the two standards will be integrated: the new NEN 1087 will apply to all buildings: new and existing. Within the standard, specific requirements are formulated for the various building types: residential and non-residential buildings, and for low-rise and high-rise buildings. Compared to the previous versions, the emphasis has shifted more to the application of building regulations in projects than to the specific testing of ventilation components, like grilles in residential ventilation. Looking at ventilation in a building as a whole (the complete ventilation system) has become the central starting point in the new standard. This is logical due to coordination and development of many CEN standards with determination methods of ventilation systems and components. These have been accepted and published in the Netherlands as NEN-EN standards and are used as reference for the new NEN 1087.

Table 1. *Ventilation System Type (VST).*

VST	Roomtype	Air exchange provision		Abbrev.
1	Habitable spaces	Supply	Natural direct supply	NDS
		Extract	Natural indirect extract	NIE
	Exhaust spaces	Supply	Natural indirect supply	NIS
		Exhaust	Natural direct exhaust	NDE
2	Habitable spaces	Supply	Mechanical indirect supply	MIS
		Exhaust	Natural direct exhaust	NDE
	Exhaust spaces	Supply	Mechanical indirect suply	MIS
		Exhaust	Natural direct exhaust	NDE
3	Habitable spaces	Supply	Natural direct supply	NDS
		Extract	Mechanical indirect extract	MIE
	Exhaust spaces	Supply	Mechanical indirect supply	MIS
		Exhaust	Mechanical direct exhaust	MDE
4	Habitable spaces	Supply	Natural direct supply	NDS
		Exhaust	Mechanical direct exhaust	MDE
	Exhaust spaces	Supply	Mechanical indirect supply	MIS
		Exhaust	Mechanical exhaust	MDE
5	Habitable spaces	Supply	Mechanical direct supply	MDS
		Extract	Mechanical indirect extract	MIE
	Exhaust spaces	Supply	Mechanical indirect supply	MIS
		Exhaust	Mechanical direct exhaust	MDE
6	Habitable spaces	Supply	Mechanical indirect supply	MIS
		Exhaust	Mechanical direct exhaust	MDE
	Exhaust spaces	Supply	Mechanical indirect supply	MIS
		Exhaust	Mechanical direct exhaust	MDE
7	Habitable spaces	Supply	Mechanical direct supply	MDS
		Exhaust	Mechanical direct exhaust	MDE
	Exhaust spaces	Supply	Mechanical indirect supply	MIS
		Exhaust	Mechanical direct exhaust	MDE

New ventilation classification type

Secondly, the classification type of the various ventilation systems is changed. The existing classification of systems in A, B, C and D was primarily based on available techniques.

Due to technical innovations, this classification has become increasingly complex and less transparent over the years. The division is replaced by a division into seven numbers indicated with VST, Ventilation System Type. This is based on all possible ways in which fresh air can be supplied, flow through and be extracted from the building. This makes the layout robust for technical innovations. The new classification is also in line with the European nomenclature which is currently being used by the European Ventilation Industry Association (EVIA[3]).

Air exchange performance assessment method

Another important change in NEN 1087 is the addition of a completely new chapter which deals with the assessment of the air exchange performance of the different types of ventilation systems. In addition to only an assessment of the individual components, this Indicative Determination Method for Ventilation Performance (IBVP in Dutch) is now included. The aim is to provide the expected performance of the entire ventilation system with a comparison figure, the so-called Air Exchange Performance (AEP[4]). That makes it possible to compare different ventilation systems and to make results transparent and clear to the customer. Despite the absence of requirements of ventilation system performance in building regulation the complete performance assessment is included in full in the standard. Future regulation can adopt to the performance assessment method.

Ventilation capacity in master bedroom in future regulation

It is expected that future building regulation will set further requirements for the ventilation of the main bedroom in dwellings. Such a requirement is missing in the current regulations.

As a result, it may happen that a mechanical ventilation system switches to the lowest airflow during the night, after which the air quality in the (master) bedroom is far below standard. This is particularly a risk in modern airtight dwellings and commonly used mechanical ventilation systems which are controlled by only one CO_2 sensor, placed in the living room. In the new building regulations, it is proposed by many stakeholders and ventilation research to include a minimum guaranteed ventilation capacity of 50 m^3/hour in a bedroom intended for two people.

More strict requirements for cooking exhaust

For new building regulations it is also proposed to set stricter requirements for cooking exhaust. In the current Building Act, 75 m^3/hour is the minimum to be installed capacity for extracting cooking air, damp and gases. The capacity of 75 m^3/h is based in particular on the removal of moisture. This does not consider contamination of the indoor air with fine dust. Ventilation research by TNO[5], among others, shows that the concentration of particulate matter in airtight dwellings can be very high after cooking if the removal of cooking fumes is insufficient. In order to not only extract moisturised air, but also particulate matter, an exhaust capacity of at least 300 m^3/h is required. Naturally, the same capacity is needed for the supply of fresh air. This must be taken into account in the ventilation design and calculation.

To achieve this high capacity, a cooker hood with a direct exhaust to the outside is considered as most effective. Although these high ventilation rates cost energy, the loss is limited because cooking only happens for a short time a day.

Higher than minimum ventilation capacity…

Dutch building regulation include minimum ventilation requirements. The installed ventilation systems in buildings are required to meet these minimum requirements. To receive a building permit these requirements have to be met. The new NEN 1087 also offers the possibility to implement ventilation systems with higher ventilation capacity. Ventilation capacities that are not mandatory due to the building regulations, but are advised for ventilation systems referring to European standards, e.g. by EN 16798-1[6].

Market actors that want distinguish themselves by offering higher comfort and indoor air quality levels to their clients have always the possibility to do so, but will now be supported with this new standard to specify the offered comfort and IEQ level. ■

References

1 https://www.nen.nl/NEN-Shop/Norm/NEN-10872019-Ontw.-nl.htm.

2 Bouwbesluit 2012, (publication date July 2019), Voorschriften met betrekking tot het bouwen, gebruiken en slopen van bouwwerken.

3 https://www.evia.eu/position-papers/.

4 REHVA journal February 2019, Including air-exchange performance in building regulation.

5 TNO 2018 R11055 VentKook, Ventilatiesysteem met goede kookafzuiging.

6 EN 16798-1:2019 en, Energy performance of buildings – Part 1: Indoor environment input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics – Module M1-6.

Demand controlled filtration, a high potential energy savings measure for cleanrooms?

PAUL MOLENAAR
Eindhoven University of Technology, Department of the Built Environment, Building Performance IEQ-Health.

Kuijpers PHF Services B.V., Controlled Environments, 's-Hertogenbosch

MARCEL LOOMANS
Eindhoven University of Technology, Department of the Built Environment, Building Performance IEQ-Health

PAUL JOOSTEN
Kuijpers PHF Services B.V., Controlled Environments, 's-Hertogenbosch

HELIANTHE KORT
Eindhoven University of Technology, Department of the Built Environment, Building Performance IEQ-Health

In cleanrooms, high ventilation rates are being used. This is in line with the available guidelines [1]. Normally the required air flows are applied 24/7 so the environmental cleanliness is not compromised. This therefore is an energy-intensive activity. As production is of higher economic importance than energy savings, cleanroom operators have put product safety and product yields first, giving energy efficiency a lower priority. The study described in this article challenges the applied air change rates and more specifically the need for applying these rates 24/7. The research is based on real-life (in-situ) examples of pharmaceutical cleanrooms.

The need for high air change rates in cleanrooms depends partly on the type of usage and time span. As a result, at the moment, a GMP B room consumes up to 25 times more energy than a non-classified room [2]. Is the ventilation rate used representative? Often this is still a question. Actual particle generation generally remains an uncertain parameter during the design process [3]. Therefore, an engineer will built in some safety margins with regards to the capacity.

To optimize the air change rate in cleanrooms, while maintaining the same air quality performance, several options were investigated: night reduction, particle concentration controlled ventilation and occupation-based controlled ventilation. The main research question was to what extent energy use reduction is possible when applying adapted air change rates in current and future cleanrooms. In this research attention is on pharmaceutical cleanrooms. The research is part of the graduation work of the first author at Eindhoven University of Technology [4].

In order to answer the research question, measurements were carried out in various GMP (pharmaceutical) cleanrooms. These measurements were carried out over a longer period and with different occupation. A full description of the method applied can be found in [4]. In addition, a simulation model was developed based on [5] to investigate the particle concentration when applying different air change strategies.

Figure 1 shows a typical result for the measured particle concentration as a function of time. Results of two particle counters (PC1 and PC2) are displayed, as well as the cleanroom occupation as a function of time. The number of persons at a given moment can be read from the right-hand axis. This cleanroom was designed for GMP C. Therefore, the particle concentration during use should not exceed the value of $3.52 \cdot 10^6$ particles/m³ [≥ 0.5 µm].

In **Figure 2** the distribution of the particle concentration in the cleanroom as a function of the number of people in the cleanroom was derived from the measurement data for one of the cleanrooms. This is shown in a box plot. Outliers are shown by the 'dots'.

Figure 1 shows that particles only are measured when there is human activity in the investigated cleanroom. In general, the measured concentrations remained one order magnitude lower than required according to GMP. The peaks indicate that the source position and transient activities can result in a non-uniform contaminant distribution. This is representative for the other cleanrooms that were measured as part of this study.

When everybody has left the cleanroom, the particle concentration reduces to zero within 20 minutes (theoretically this depends on the recovery time, based on the

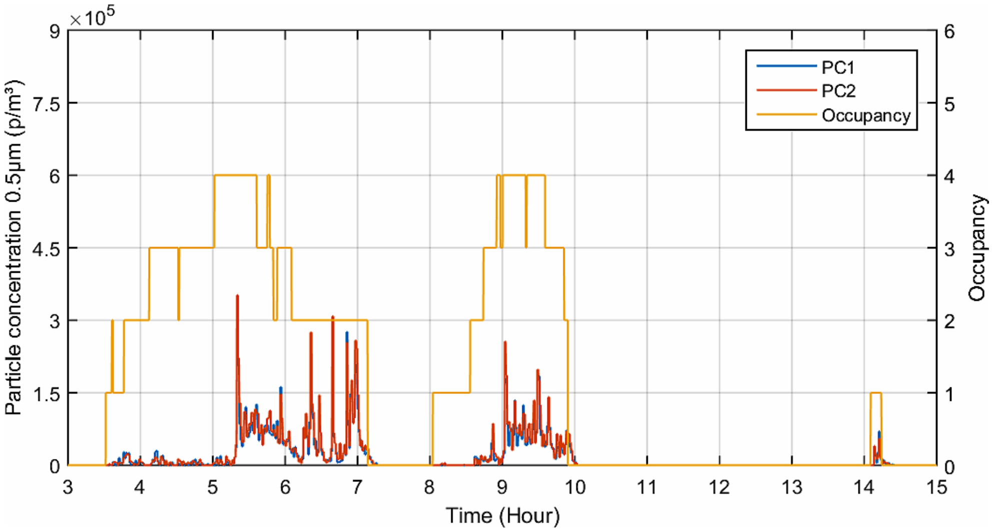


Figure 1. Measured particle concentration and the amount of people present [right axis] in an investigated cleanroom for a period of 12 hours.

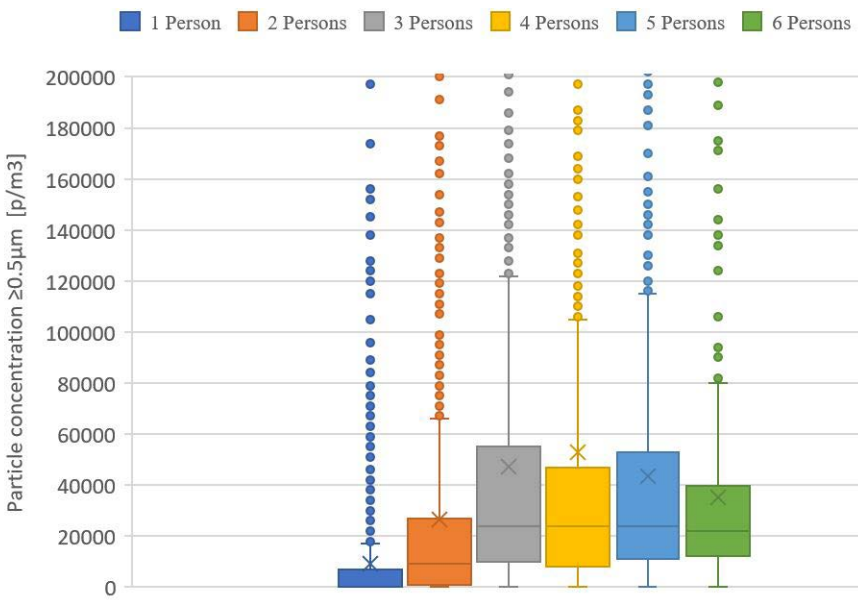


Figure 2. Boxplot of the measured particle concentration in relation to the amount of people present in one of the investigated cleanrooms.

air change rate used). In all investigated GMP rooms, a near-zero particle concentration (particles ≥ 0.5 µm) is measured when no employees are present in the room. This shows that for the investigated cases the persons in the cleanroom, and their activities at that time, are the only sources of contamination. This, of course, is important to confirm when consideration is being given to adapt the ventilation rate.

Figure 2 shows that the particle concentration does not show a linear correlation with the number of persons in the room. An increase from 3 to 6 persons does not lead to significant differences in the particle concentration. A possible explanation for this outcome is that at the beginning and end of a shift people are starting up and cleaning up (in this case) the production. Because not everyone starts or stops at the same time, fewer people may be present in the cleanroom when starting up or cleaning up. During these activities, however, it is likely that more particles will be produced. This can be seen in **Figure 1**. At the end of the day, when only one cleaner is present, relatively high particle concentrations are measured.

Figure 3 shows an example of a simulation result using Demand-Controlled Filtration (DCF) based on information obtained from the measurements ('Reference'). For the simulation case ('DCF') the design value air change rate (20 h^{-1}) was applied when the cleanroom was occupied, regardless of the number of persons present. When empty, an air change rate of 6 h^{-1} was applied instead, starting 30 min after the occupancy sensor indicated no presence of persons in the room.

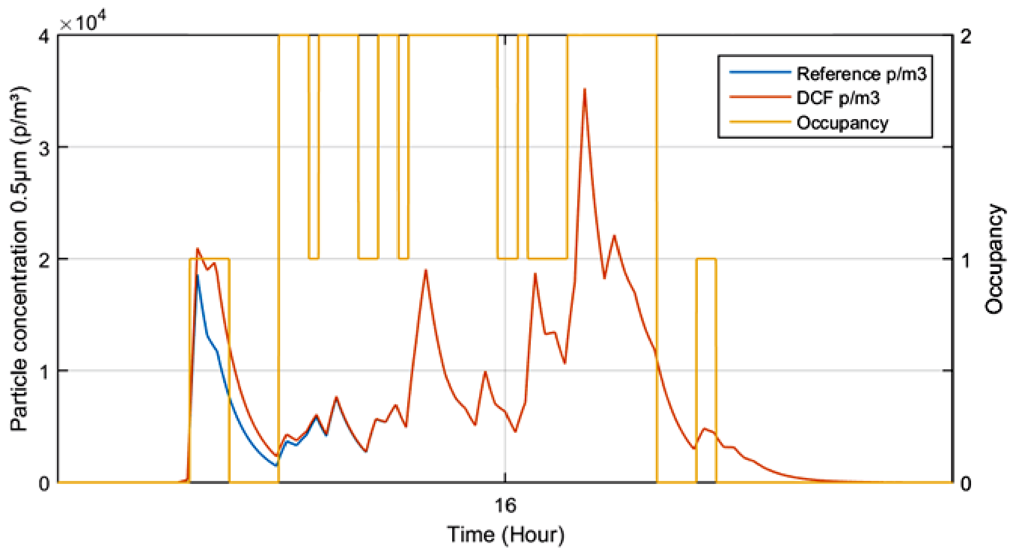


Figure 3. Simulation result of demand-controlled filtration (DCF) (GMP requirement < 3.5x10^6 particles).

Table 1. *Calculated fan energy savings for the investigated cleanrooms.*

Cleanroom	% of time occupied	ACR setback % of time	Overall fan energy savings
Facility H: Room B	1.8%	96.1%	93.6%
Facility H: Room C	3.2%	88.9%	86.8%
Facility R	22.5%	70.0%	68.1%

This ensures that, with the given ventilation rate, the particle concentration returns to zero. The important assumption, which was confirmed from the measurements, is that the persons in the room and their activities are the single sources present. Also, sources from outside are assumed negligible. **Table 1** shows the potential energy savings when this strategy is applied to the various cleanrooms that were investigated. The energy savings only refer to the savings in fan energy, assuming the affinity law. The outcome will also positively affect the energy required for conditioning the supplied air.

Figure 3 shows that demand-controlled filtration (DCF) is able to keep the performance of the cleanroom at the desired cleanliness level, similar to full-time ventilation. However, at the start of occupation a higher concentration is calculated than in a continuous situation. This relates to the time required to control the system to the desired (designed) level. For the case shown, it takes 150 seconds for the system to achieve the desired ventilation rate.

Based on the assumption that demand-controlled filtration is possible, **Table 1** shows that significant energy savings on fan energy are possible. These savings of course have a close relationship with the use-time of the cleanroom and certainly appear interesting for the investigated pharmaceutical cleanrooms. To emphasize, these savings can be achieved while maintaining the cleanroom's performance in terms of air quality.

Instead of control based on presence, the air change rate can also be directly based on the particle concentration in the cleanroom. The measurements indicated that it was not always possible to correlate a significant increase in particle concentration with an increase in the number of people present in the cleanroom. The particle concentration usually is measured locally using a particle counter with a relatively low flow rate (0.1 cfm). This means that locally higher or lower concentrations can be measured which may not be representative for the room as a whole. This is caused, among others, by the ventilation efficiency and the position of the source(s) in the room. In addition, the measured concentration fluctuates regularly as a result of the (transient) activities (see peaks in **Figure 1**). This may result in an unstable or delayed control.

Controlling the ventilation rate based on occupation therefore seems to be most straightforward and effective at the moment. Implementation is simplified when light motion sensors for the lighting already are installed. This system then can also be used to achieve the desired ventilation rate. After half an hour, for example, in which no detection of people has taken place, ventilation can be reduced to a lower level. In this way, the recovery time (typically < 20 min for such a room) is also taken into account and the cleanroom continues to function according to the requirements. When applying this solution, an active pressure control must be present in the cleanroom to maintain the pressure hierarchy. This must be guaranteed, even when not in use, to prevent contamination from outside. Recent follow-up work has shown that requirements on pressure hierarchy may not need to be as strict as generally assumed [6].

Reducing energy consumption for ventilation (and recirculation; DCF) through occupancy-based control is particularly effective in rooms that are only used for certain production processes and therefore have regular and slightly longer interruptions in occupancy. In this investigation it appeared that a GMP B room was only in use for 1.8% of the time during the measurement period. Meanwhile, the room was continuously ventilated at 40 h^{-1}. Saving more than 90% on fan energy consumption in this case seems straightforward. In the investigated cleanroom facility that had a more normal occupancy pattern of 40 hours per week, energy savings of 68% on the fan energy consumption remains possible. Note that all results shown are for particles ≥ 0.5 µm.

Summary

To achieve the required air quality in cleanrooms, large air flow rates are being used, often 24/7. In order to reduce (fan) energy consumption for ventilation, possibilities were investigated to reduce the air change rate while not compromising air quality performance: night reduction and control based on particle concentration and on occupancy. Measurements were performed and simulations were used to assess the potential. The outcomes show that up to 90% energy savings are possible for the investigated pharmaceutical cleanrooms when applying control on occupancy. These results are explained from the limited use-time of the investigated cleanrooms. In addition, they showed over-sizing based on the actual sources present. Occupancy control is considered most practical and effective for the cases that were investigated. ■

References

[1] ISPE, Baseline Guide: Volume 3 Sterile Product Manufacturing Facilities, vol. 3 (2011).

[2] Fedotov A. Saving energy in cleanrooms. Cleanroom Technol. vol. 22. no. 8. pp. 14–18 (2014).

[3] Khoo CY, Lee CC en Hu SC. An experimental study on the influences of air change rate and free area ratio of raised-floor on cleanroom particle concentrations. Build. Environ. vol. 48, no. 1. pp. 84–88 (2012).

[4] Loomans MGLC, Molenaar PCA, Kort HSM, Joosten PHJ. Energy demand reduction in pharmaceutical cleanrooms through optimization of ventilation. Energy and Buildings. Vol.202 (2019) https://doi.org/10.1016/j.enbuild.2019.109346.

[5] Whyte W, Whyte W en Eaton T. The application of the ventilation equations to cleanrooms Part 1: The equations. Clean Air Contain. Rev., vol. 12, no. October, pp. 4–8 (2012).

[6] Ludlage B. Optimizing Energy Demand during the Non-Operational Hours in a Cleanroom. Thesis. pp. 39. Eindhoven University of Technology, Eindhoven (2019).

An accurate model to design displacement ventilation in office rooms

NATALIA LASTOVETS
Doctoral student
Aalto University, Finland
natalia.lastovets@aalto.fi

RISTO KOSONEN
Professor
Aalto University, Finland and
Nanjing Tech University, China
risto.kosonen@aalto fi

PANU MUSTAKALLIO
Research Manager at Halton OY
Kouvola, Finland
panu.mustakallio@halton.com

Thermal comfort estimation and airflow rate calculation for displacement ventilation (DV) directly depends on indoor temperature prediction. Inaccurate estimation can result in 2–3 °C temperature difference compared to the target design values, which could lead to poor thermal comfort in the occupied zone. The paper presents a more accurate model to design DV.

Keywords: Displacement ventilation, temperature gradient, simplified model, internal heat loads, mixing height

Modelling of displacement ventilation

First implemented in industrial buildings displacement ventilation (DV) has gained extensive use in commercial buildings. In DV systems, cool air is supplied into the occupied zone of the room near the floor at low velocity and then entrained by buoyant plumes over any warm objects. As a result, a two-layer room air temperature profile, stratified and mixed, is developed. Ideally, the cleaner outdoor air movements utilised by thermal plumes transport heat and pollutants to the layer above the occupied zone. The transition level between a mixed upper layer and stratified layer is called mixing height. Controlling the mixing height position is one of the most challenging tasks in DV system design.

Since in office buildings cooling requirements are important, the temperature-based design method is applied in this case. An accurate temperature gradient calculation is essential for DV system design, since it directly relates to the calculation of supply air flow rate. Several simplified nodal models were developed in order to estimate the temperature stratification in rooms with displacement ventilation. Five models with different approaches were chosen to be analysed and compared with the proposed one: the Mundt (Mundt, 1996), the Nielsen (Nielsen, 2003), the Rees (Rees, 2001), the Mateus (Mateus et al, 2015) and Nwe nodal model (Lastovets, 2018). Some of the models are already implemented in the various building simulation programmes The Mundt and the Mateus et al. models are implemented in EnergyPlus and the Mundt model is also available e.g. in IDA ICE. However, validation and development of the calculation methods have been based mainly on measurement using low ceiling height (below 3 m), while displacement ventilation is usually applied for high-ceiling rooms. Also, the previous studies have not covered typical head loads and office layout that exist in office buildings. As a result, the calculation methods based on these studies are not able to correctly predict the occupied zone temperature (Kosonen et al., 2016). It leads to poor thermal comfort and inadequate sizing of the ventilation system. In the paper, the main factors affecting the temperature gradient in office rooms with DV are presented and analysed based on the experimental results.

Effect of the ceiling height

The test setup to analyse the DV performance in the room (20.8 m² floor area and room heights of 5.12 m and 3.33 m) with different flow elements is shown in (**Figure 1**).

The case with the lower height was organized so that the whole ceiling was moved down together with the exhaust diffuser, heated foils and light units. The internal heat loads consist of heated cylinders representing persons, heated cube-shaped boxes representing computers, heated foils on wall, floor and ceiling representing solar load on window at different levels and fluorescent lighting units. The temperature profiles are measured from four locations (P1-P4 in **Figure 2**) at ten heights with calibrated PT100 sensors (accuracy ± 0.2 °C). Surface temperatures were measured with Testo 830-TI-infrared thermometer (accuracy ± 0.1 °C). Supply and exhaust air flows were measured with air flow rate measurement device MSD 100, that was calibrated with an orifice plate to reach the accuracy ±3%.

The measured data of the temperature gradient for the typical indoor heat loads were compared with the calculation results of the selected simplified nodal models: the Mundt, the Nielsen, the Mateus, the Rees and New nodal model. The results of the corresponding measurements and calculations are presented at the **Figure 2**.

In the cases with low level loads, heat sources the major part the gradient exists in the occupied zone regardless of the room height. The influence of the room height on the vertical temperature difference is essential in the cases with high-level heat loads, when the temperature

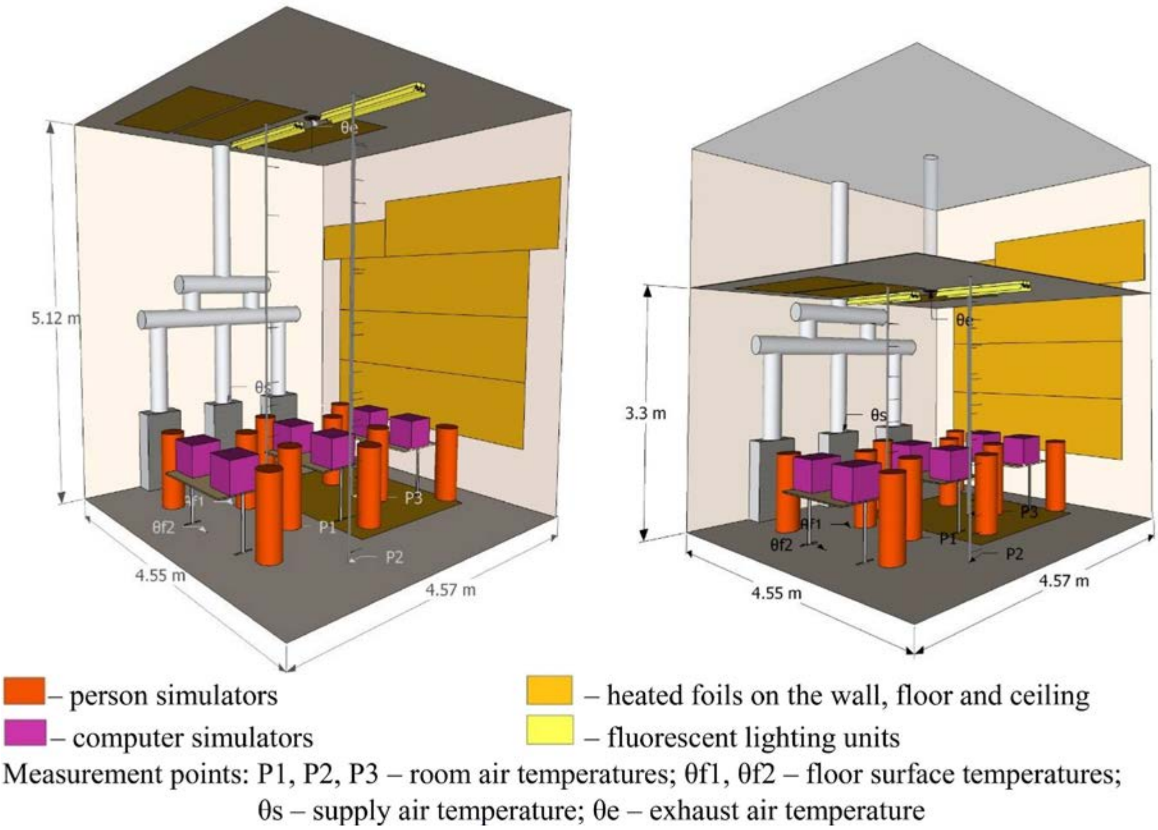


Figure 1. Measurement setup to study the effect of different room heights and heat loads.

tends to stratify over the mixing level. However, for the cases with only vertical heated surfaces, air flow rate is more influential on the temperature gradient in the rooms with different heights

Effect of office layout

In addition, the model was validated with the experimental results published by Arens (Arens, 2000) for open-plan and cubicle-style office arrangements.

The test room layout is shown in the **Figure 3**. The open-plan office case was measured with the partitions dividing the workplace, whereas the cubicle-style office includes them. The supply air is delivered from two opposing air diffusers, whereas the exhaust grille is located overhead at height of 5 m. The internal heat loads were modelled by

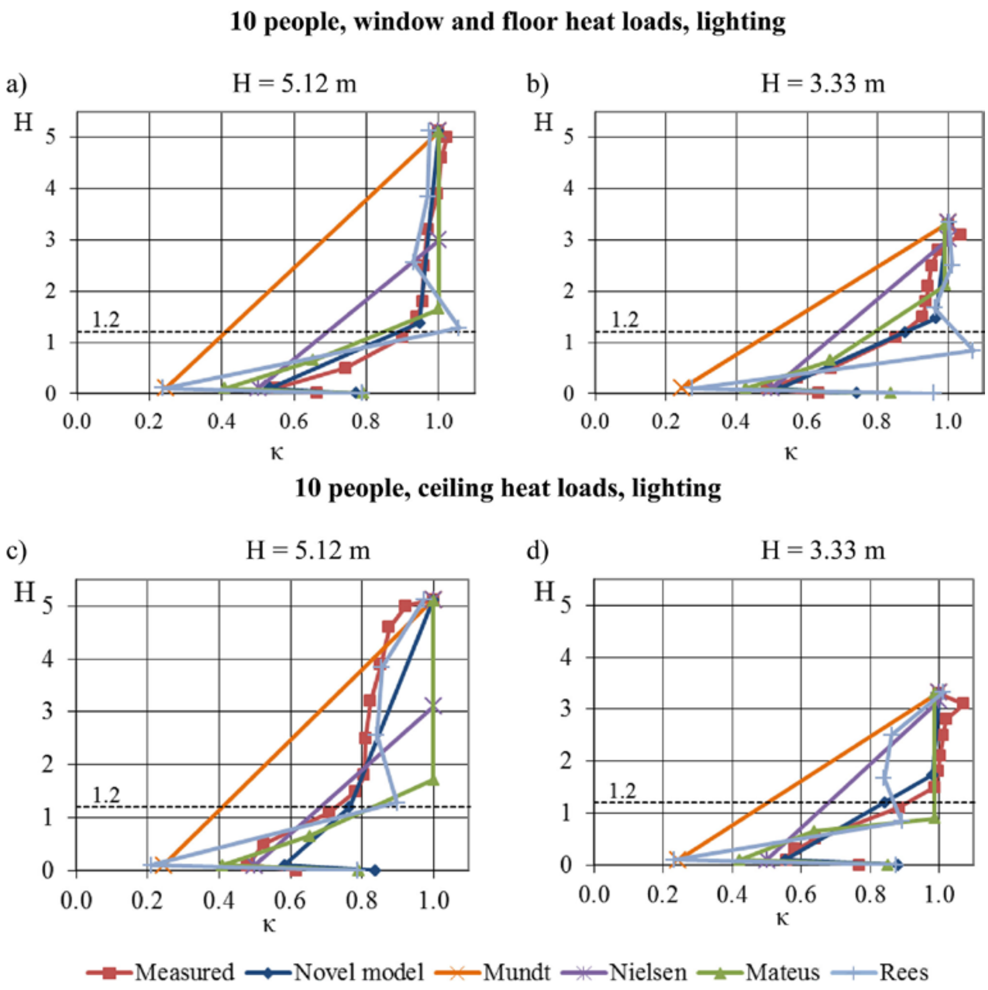


Figure 2. Measured and modelled temperature gradients for the rooms with different heights and heat loads.

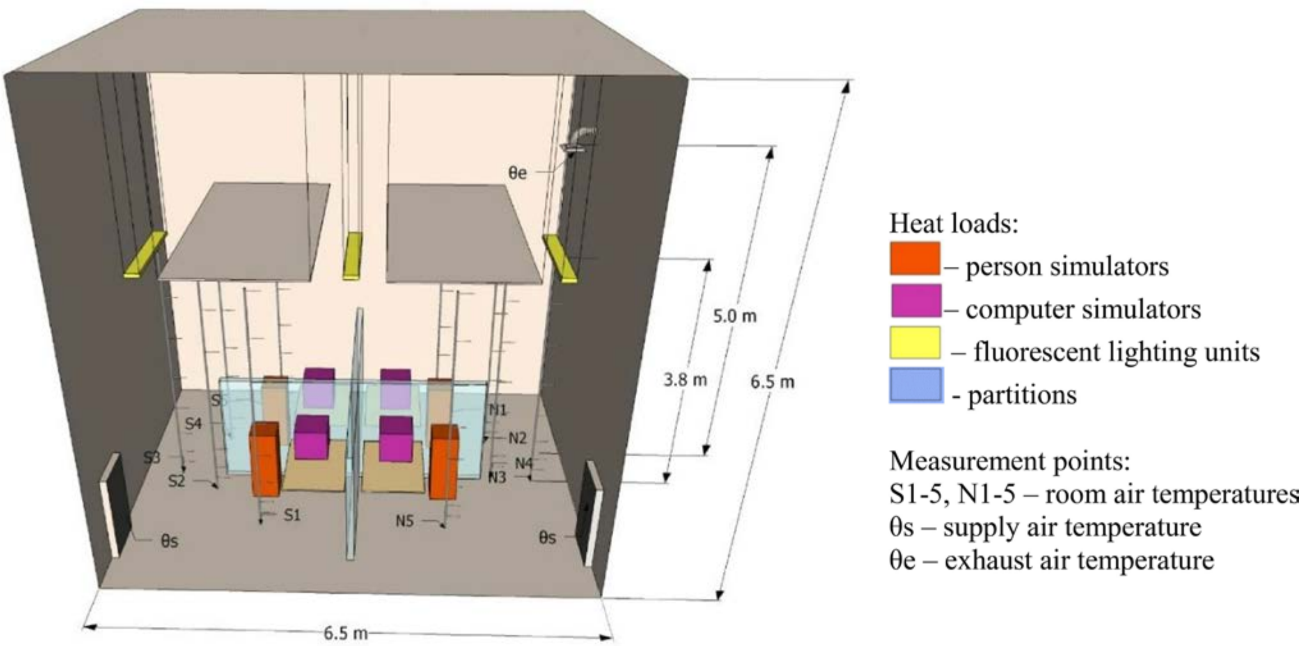


Figure 3. Measurement setup to study the effect of different room heights and heat loads.

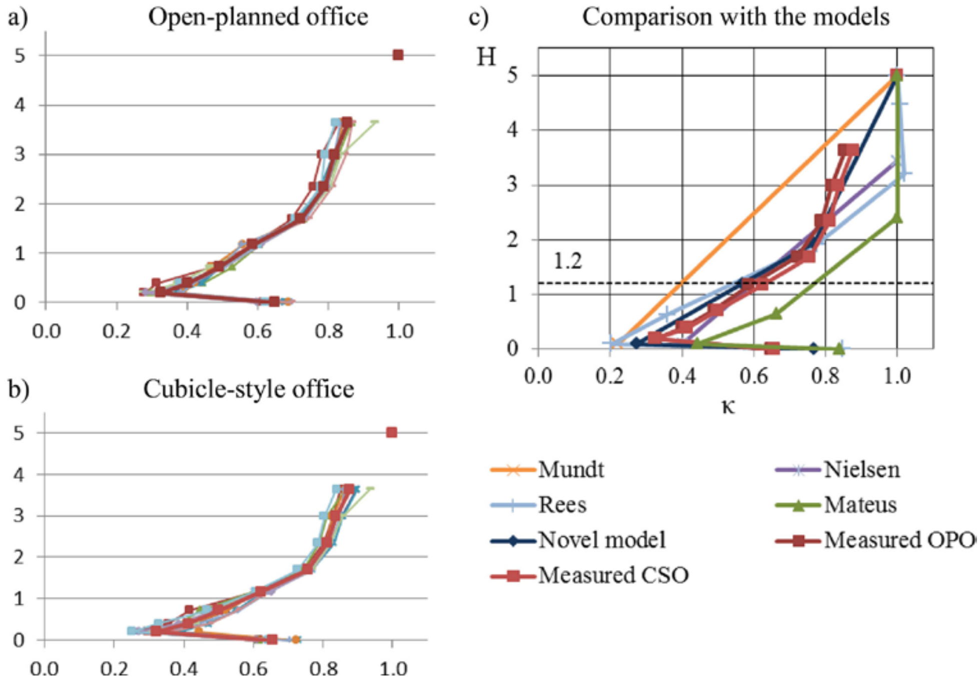


Figure 4. Measured and modelled temperature gradients in different place of the room.

rectangular person and computer simulators and 3 rows of lighting units. The room height is 6.5 m, whereas the fluorescent lighting fixtures were located 3.8 m above the floor. Air temperature measurements were conducted with 0.6 mm diameter copper-constantan thermocouples with a ± 0.2 °C accuracy at each of the ten positions indicated during each test.

An arrangement of office layout has some effect of the thermal stratification in rooms with DV (**Figure 4**). Despite the fact that the vertical temperature gradients tend to be similar throughout the room, the office furniture that prevents even air distribution increases unevenness of temperature stratification in low zone of the room.

Conclusions

In the present study, five simplified nodal models are analysed and validated with the experimental results in two measurement setups. In addition, the effect of the room heights and locations of the indoor heat sources were studied for the typical office environment. The experiments demonstrate that displacement ventilation provides even temperature gradient throughout the simulated office room spaces. The influence of the room height on the vertical temperature gradient is significant in the cases with high-level heat loads. The new nodal model demonstrates an accurate calculation of the vertical temperature difference for the typical heat loads office layouts. ■

References

Arens AD. (2000). *Evaluation of Displacement Ventilation for Use in High-ceiling Facilities*. Cambridge: Massachusetts Institute of Technology; 2000.

Kosonen, R., Lastovets, N., Mustakallio, P., da Graça, G. C., Mateus, N. M., Rosenqvist, M. (2016). *The effect of typical buoyant flow elements and heat load combinations on room air temperature profile with displacement ventilation.* Building and Environment, 108, 207-219.

Lastovets N., Kosonen, R., Mustakallio, P. (2018) *Comparison of simplified models to estimate temperature gradient in rooms with displacement ventilation*. Proceedings of Roomvent and Ventilation 2018, Espoo, Finland, 499-504.

Mateus, N. M., da Graça, G. C. (2015). *A validated three-node model for displacement ventilation.* Building and Environment, 84, 50-59.

Mundt, E. (1995). *Displacement ventilation systems – Convection flows and temperature gradients.* Building and Environment, 30(1), 129-133.

Nielsen, P. V. (2003). *Temperature and air velocity distribution in rooms ventilated by Displacement Ventilation. In proceedings of Ventilation 2003*, The 7th International Symposium on Ventilation for Contaminant Control, Sapporo, 691-696.

Potential of the MPC hybridGEOTABS concept for buildings: Libeznice school

As a part of hybridGEOTABS project, Libeznice school is one of several demonstration cases that employs geothermal heat pump with Thermally Activated Building Systems (TABS) combined with Model Predictive Control (MPC) algorithms for heating and cooling. Benefits and potential of such a system is presented in this article.

Keywords: hybridGEOTABS; geothermal heat pump; TABS; Model Predictive Control; integrated design solutions



EUGENE KACHALOUSKI

JIŘÍ CIGLER

LUKÁŠ FERKL

hybridGEOTABS

– Model Predictive Control and Innovative System Integration of GEOTABS in Hybrid Low Grade Thermal Energy Systems

hybridGEOTABS is a four-year project started in 2016 by an active team of SMEs, manufacturers and research institutes. The project, led by the University of Gent, is a Research and Innovation Action funded under the EU's Horizon 2020 programme.

The goal of hybridGEOTABS is to optimise the predesign and operation of a hybrid combination of geo-thermal heat-pumps (GEO-HP) and thermally activate building systems (TABS), alongside secondary heating & cooling systems, including automated Model Predictive Control (MPC) solutions.

To know more about the project visit www.hybridgeotabs.eu and contact hybridgeotabs@ugent.be

hybridGEOTABS project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723649.

Description of Libeznice school

This is an elementary school for 240 pupils in 8 class-rooms, which also serve as the premises for afterschool activities. The building is designed in an annular shape on one floorwith an eccentric round atrium, surrounded by a multifunctional foyer, integrating a corridor, children's lockers and a common area. The annular shape is inspired by ourSolar System. The school's cafeteria has a flexible layout allowing easy rearrangement, creating space for performances by the Elementary Art school, or lectures with film screening.

The building is called "Rondel" and represents our Solar System with the Sun in between and 8 planets around.

Technical systems

From the technical installations point of view, the building is equipped with a TABS heating and cooling system (one circuit in the ceiling of the building), independent low-temperature ventilation units for each classroom and a hot water circuit. The source of energy is a ground coupled heat pump with heating power of 55 kW and cooling power of 65 kW. There are 6 boreholes on the primary side of the heat pump. The heat pump operates in the three regimes:

i) heating;
ii) passive cooling;
iii) active cooling (compressor is active).

Libeznice school building.

The GEOTABS system is controlled by a predictive controller (MPC) that takes into account weather forecast, model of thermodynamics of the heat pump and TABS. Moreover, spot market electricity prices are included in the MPC problem formulation which results in a higher consumption, in situations when the price of electricity is low (surplus of the electricity in the grid), and lower consumption in other moments (demand side management). The algorithms benefit from the huge thermal capacity of the TABS system.

Each classroom is equipped with an air handling unit (AHU), with the air inlet passing through the recuperation unit, which decreases energy use by ventilation. The commonly used areas (corridor and cafeteria) has its own AHU. The heat for the AHU is supplied by the secondary side of the heat pump, whereas cold is provided either by the heat pump in active cooling mode or by the borefield in passive cooling mode.

Further, during the summer period when the heat pump operates in active cooling mode, i.e. providing cold on the primary side to the cold emission systems, it releases heat from the secondary side to the borehole, thereby the heat pump regenerates the borehole. In its turn the regeneration of the borefield has positive influence on the heat pump operation during the heating season.

Building performance

The measurements over 2018 show the heat delivered by TABS was 30.3 MWh/a corresponding to 30.3 kWh/m².a, at the same time values for the cooling delivered were 28.7 MWh or 28.7 kWh/m².a.

System integration/MPC

The MPC strategy applied optimises energy flux supplied to the TABS to keep the room temperature in the required band by means of pre- and over- heating the building. The algorithms employ the model of building dynamics, thus with weather forecast (and other disturbances) , provided the model optimises all the system's heat/cold sources and operates in the most efficient way. The controller chooses operation mode of the building with respect to the required temperature set points (heating, active cooling, passive cooling, and heat injection to the borefield. By these means MPC shifts heat pump operation towards the period of lowest electricity price, and reduces peaks load demands, both of which have positive reflectance on the heat pump coefficient of performance (COP).

Table 1. *Technical specifications of Libeznice.*

Net Floor Area	1,000 m²
Conditioned Floor Area	1,000 m² (area that is heated and/or cooled)
Average U-value of building envelope	0.27 W/m².K
Geothermal borefield	6 boreholes 120 m depth
Total Annual Thermal Energy Use	92 MWh heating, 10 MWh cooling
Domestic Hot Water Heating System	Heat pump provides heat both for TABS and domestic hot water preparation
Ventilation	Decentral
Primary heat production	55 kW geothermal heat pump
Primary cold production	Passive: geothermal borefield, active: 65 kW geothermal heat pump
Secondary heat/cold	Air handling units
Auxiliary heat production	Electric boiler 24 kW
Thermal storages	500 litre hot water storage tank, 500 litre cold water storage and 500 litre domestic hot water storage

Demonstration buildings

The school in Libeznice is one of multiple demonstration building candidates within the EU-H2020-hybridGEOTABS project where MPC may be demonstrated. These demonstrations will show what the actual energy savings, thermal comfort and flexibility values are and thus validate the true potential of the MPC hybridGEOTABS concept. ■

Acknowledgement

Funded by the European Commission under the Horizon 2020 Programme: project number 864242 (proposal name "MPC-; GT").

MOBISTYLE makes energy efficiency understandable by providing users attractive personalized information on energy use, indoor environment, health and lifestyle

ANA TISOV
Huygen Engineers and Consultants
Maastricht, the Netherlands
a.tisov@huygen.net

ROSAMARIA OLIVADESE
DEMO Consultants
Delft, the Netherlands
Rosamaria@demobv.nl

DENA ARABSOLGAR
Research & Development Dept. @ Holonix Srl
dena.arabsolgar@holonix.it

MARIA MARGOUDI
HighSkillz Ltd,
London, UK
maria.margoudi@highskillz.com

Most of today's buildings are equipped with sophisticated building automation systems and sensors. They measure large amounts of different building performance data types (mostly related to building's energy performance or thermal comfort). This data is commonly used for energy management of large commercial buildings. However, this data is often not available or understandable to the building users, especially residents. Experience shows that promoting the importance of a building's energy efficiency as such is not an attractive driving factor for changing everyday habits and lifestyle of the building users. However, changing the user's behaviour towards more energy efficient building usage could contribute towards achieving one of the main targets of European Union: reducing energy consumption and eliminating energy wastage. Combining information on energy use with other relevant information such as the indoor environmental quality, personal health and eventually combined with other attractive life style information can be used to catch the interest of consumers and even more importantly change their behaviour and maintain their new habits and interest in the long term.

How can we make sure (or increase the probability) that end-users actually start using the developed tools and change their behaviour towards a better tomorrow? In order to answer this question, the MOBISTYLE project was developed.

The overall aim of MOBISTYLE is to raise the awareness of people and motivate behavioural change by providing attractive personalized combined knowledge services on energy use, indoor environment, health and lifestyle, by ICT-based solutions. Providing more understandable information on energy, health and lifestyle will motivate end-users to change their behaviour towards optimized energy use and provide confidence in choosing the right thing. It will offer people more and lasting incentives than only information on energy use. At this moment, we have developed 3 tools in the MOBISTYLE project: An expert tool, a dashboard and a game. In this article we will tell you about the expert tool and the dashboard we have developed for this and how they work.

The Dashboard

How & why we developed this dashboard

The Dashboard is a tool that allows different kind of users to receive information about the buildings they interact with, through specific authentication. Different kinds of parameters are received by the building through sensors, and they are shown into the tool. The purpose of the dashboard is to:

1. Actively involve users
2. Raise awareness in users
3. Motivate change behaviour
4. Stimulate energy usage reduction and IEQ improvement
5. Give as much information as possible
6. Create a feedback loop that improves knowledge and awareness into users

When people are living in building, they generate a lot of different of building information. But they have no access to them in an easy manner, or it's not available at all. I.e. in houses: energy consumption data are available only reading directly the meter which is usually not in the apartment, or in the consumption bill; in shared buildings as offices and universities: energy consumption data are not available to occupants.

IEQ is even less monitored in buildings.

Even if energy and IEQ information can be accessed in an easy manner, people usually don't know how to change their behaviour in order to improve performances.

The development of the dashboard

The first version of the dashboard was developed as "things connector" with the objective to connect appliances and to show real time data. The things connector had been shown as a first mock-up of the dashboard to partners through focus groups. A list of suggestions coming from potential users had been produced. The Dashboard was tested both in the Italian and Slovenian demonstration case and, in general, it was very much appreciated. Appreciations came mainly for the opportunity to see different groups of data all together in a single virtual space, including energy consumption of different objects, spaces, and appliances health, and IEQ. Some suggestions for improvements had been received, mainly related to the fact that showing numbers is not a user-friendly solution. Something more visual was of interest and it was suggested to add trends about data changes during time. So easy to understand widgets and active suggestions notifications had been proposed as improvements.

Who will use the dashboard?

The Dashboard Is thought for organizations that manages different rooms and buildings, such as: Housing associations, real estate agencies, municipalities, contractors, hospitals, elderly people rest houses, universities, offices, hotels & short rent apartments. Users can be owners, managers, occupants.

Thanks to the dashboard, users will be able to have access to different rooms and to different data through highly personalized dashboards. Users also receive suggestions about how they can improve performances, reduce energy consumption and improve IEQ.

Using the dashboard

The development of the MOBISTYLE dashboard has defined following features:

1. Customizable sensorized entity structure
2. Articolated users / actors structure
3. Customizable suggestions management

Customizable sensorized entity structure

Sensorized entities can be rooms, apartments, buildings, single smart appliances, personal wearable devices, and so on. It refers to any entity which can be sensorized. The sensorized entities structure is made of: *Sensorized entity type*, which defines the structure and behaviour of a group of similar entities, and a single instance of the sensorized entity.

For each sensorized entity type it is possible to define:

1. The list of type of sensors available;
2. The list of type of data to be shown to users;
3. The structures of all the dashboards, which can even be more than one, i.e. one per kind of user.

For each sensorized entity, as for example a single room of a hotel which has 3 identical rooms for 3 different guests, it is possible to define:

1. The entity type it refers to;
2. The sensors instantiation available in the specific entity (i.e. in the specific room);
3. The users connected able to visualize information in the dashboard;
4. The eventual hangout that lock the access to users after a defined period of time.

Articulated Users / Actors Structure

There are different types of users and different types of dashboards to visualize data based on the role of the user and their associated entities. Users can be classified in three categories:

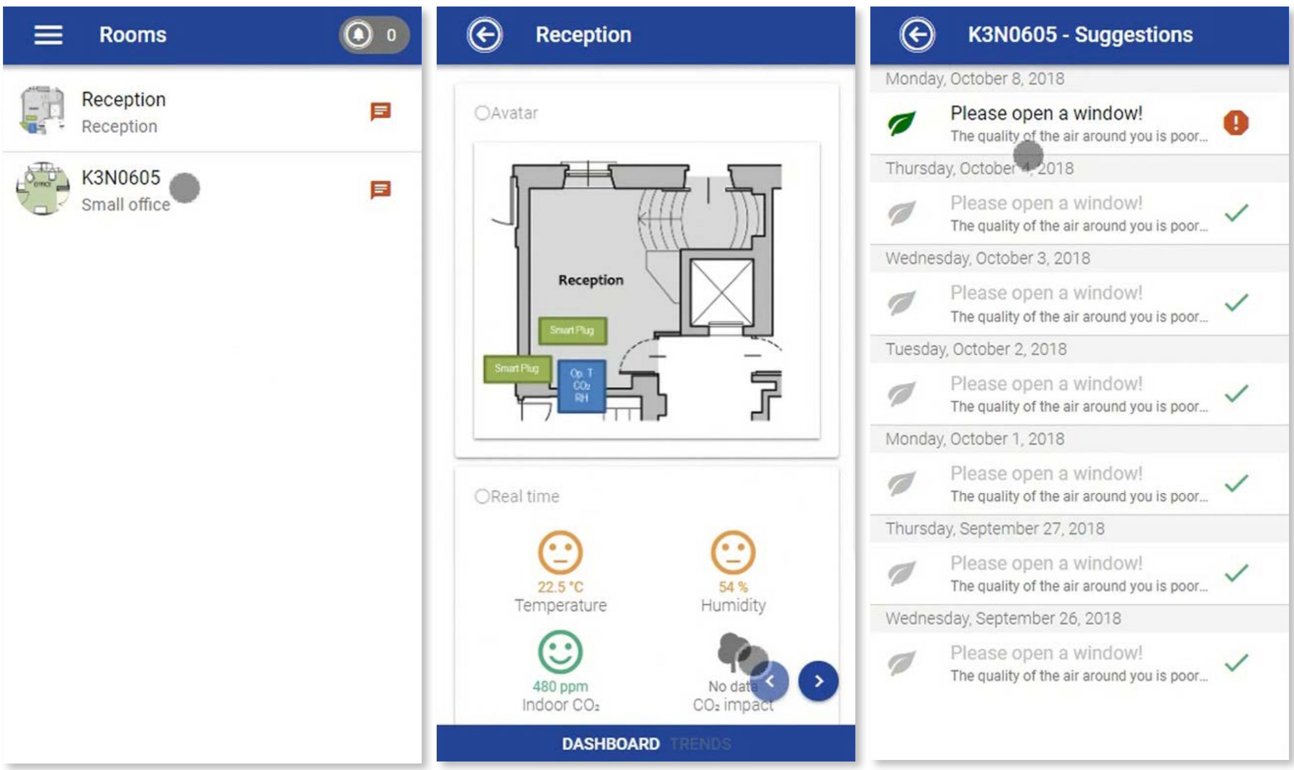
- **Admins:** specific for case holders, there is a SuperUser in charge of the overall management of the entities and creation of the dashboard to be shown to the users. The admins are in charge of the account management and they have permissions to create or remove users linked to their organization. They can create new entity types and connect them to the sensor interface. Simple IT skills are required for the role of Admin.
- **Managers:** specific for case holders, it has most of the privileges of the admin, but not the creation of new entity types. Roles:
  - o Their first role is to create single sensorized entities, starting from the sensorized entity types created by the company admin.
  - o Then they are able to create and modify specific dashboards (i.e. one for the admin/manager, one for the Mobistyle user).
  - o They can allocate users to sensorized entities and relative dashboards and allow and remove access permissions, as the Admin.
  - o They can even create new suggestions types for each sensorized entity type.
- **Users:** Users are the receivers of the suggestions. They can access MOBISTYLE user dashboard and visualize all the sensorized entities data they are connected to, for the time they are allowed to. They cannot change the dashboard structure. They receive the suggestions and notifications for the sensorized entity they are connected to.

Customizable suggestions management

For each sensorized entity type, the admin and the moderator are able to create different suggestions type. **The suggestions type** is the group of rules that enables the creation and deactivation of suggestions. Each suggestion type is related to a single parameter. They are described by:

- A symbol and color code
- A message title
- A message content
- Starting rules (parameter + operator + value)
- Ending rules (parameter + operator + value)

The single instantiation of the suggestion is created according to the rules, and for each single sensorized entity. It is visible to all the users that have access to the sensorized entity, only for the period of time in which they are allowed to access.



How we use the dashboard

The dashboard is actually in effective usage at the Slovenian and Italian demo cases, which are respectively a University and an Hotel. The professors at the university are testing the usage of the desktop application, having connected their personal office room. In the Italian case the guests of the hotel are involved to download the mobile app and to use it during their stay at the hotel. Testing activities are ongoing and they will be grouped and analysed at the end of the validation process.

The game

The MOBISTYLE Game App is a gamified app for behavioural change on energy use and for awareness creation on associated health benefits. The aim of the Game App aligns with the overall aim of the MOBISTYLE project of raising consumer awareness and motivating a behavioural change on energy use, indoor environment, health and lifestyle.

The App translates collected data from the home sensored environment into more understandable information for the home residents.

The design of the MOBISTYLE Game App followed the project's people centric approach, hence there was a close collaboration with the demonstration case holders (Denmark and Poland) and support from the consortium health and energy experts.

First, in close collaboration with project partners, HighSkillz defined the intended behaviours to be incentivised via the MOBISTYLE Game App. Then following iterative feedback loops with experts and end-users the design and development of the solution was informed. During this process a set of tools were used in order to facilitate the discussion, explain concepts and collect feedback, such as storyboards and different types of mockups. Following this approach all the MOBISTYLE Game App mechanics and objectives were validated by the consortium domain experts.

Who will use the game?

The MOBISTYLE Game App addresses the two residential demonstration cases (Poland and Denmark) and it is meant for home residents.

The MOBISTYLE Game App follows an approach centred on home-specific conditions and actions, based on the concept of maintaining a "healthy" home. This means that all users of the Game App associated with a specific home will share the same state and progression.

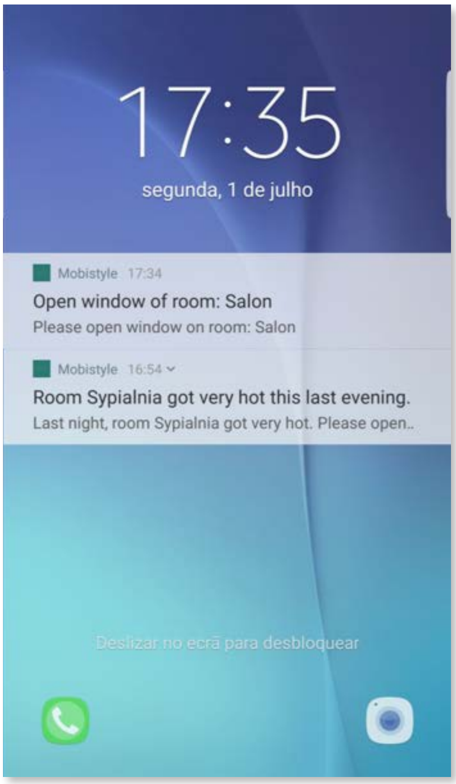
Using the game

Goals and Missions

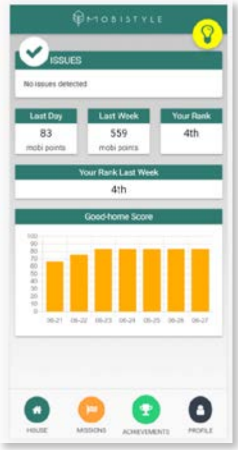
The adopted gamification approach for the MOBISTYLE Game App is focused on home-centric sensorized gamification, aiming to influence the user behaviour on energy efficiency, indoor environmental quality and health. Towards this goal the MOBISTYLE Game App incorporates a set of goals on energy efficiency for its users.

Each one of these goals is linked to relevant energy missions – actions encouraging user behaviours. The Game-App incorporates two types of missions:

- Real-time missions: When certain adverse conditions are detected, digital "nudges" that encourage the user to take recommended actions are triggered. Such missions refer to indoors temperature, relative humidity and CO_2 levels.
- Deferred missions: In these missions a period of time is analysed in order to provide recommendations for the next similar period.

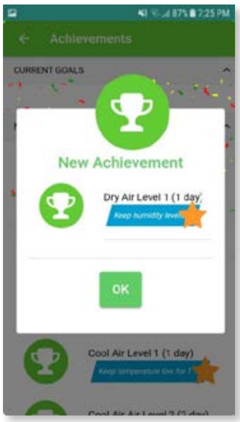


In addition to focusing on behaviours that can be triggered and detected via sensorized data, there is also a strong focus on providing notifications and actions' recommendations that are relevant to the user. This approach reduces the likelihood of users abandoning the Game App due to disturbance from indiscriminate alerts leading to the app being ignored or even uninstalled.



Points and Ranking

The implemented score is based on "MobiPoints", which is an indication on how close a home is to being "healthy". A top level in MobiPoints means that no mission or problems were detected in any of the rooms. Based on their MobiPoints the users are also shown their home's ranking in their region.



Achievements

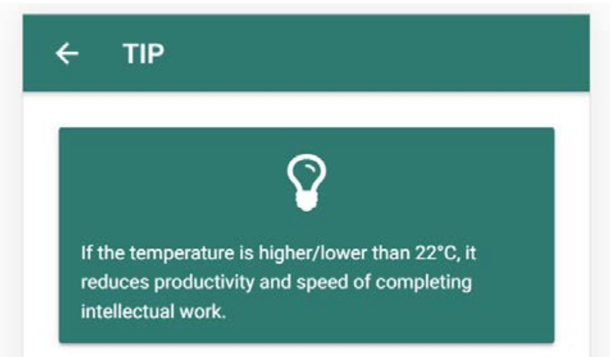
Achievements refer to long-term sequences of actions where the user is consistent in achieving certain goals over a period of time (streak). Achievements have the form of medals for healthy CO_2 air levels, temperature values and relative humidity levels inside the homes.

Reports

The MOBISTYLE Game App user is provided with intuitive chart-based information on their home performance. These reports are tied to recommendations whenever possible.

Tips

In addition to the goals and missions related to energy efficiency, the user is also provided with a list of health tips to encourage healthier lifestyles in association to energy efficient behaviours.



How we use the dashboard

The design and development within the scope of the MOBISTYLE project resulted in five goals being assigned to the Polish demonstration case and four goals for the Danish demonstration case. These decisions were informed by the available sensors and data for each demo case, as well as the sensor-based gamification approach.

The Expert tool

How & why we developed the expert tool.

Within the MOBISTYLE project, the need to develop the Expert Tool came directly from the experts within the consortium who needed to access the data from the different demonstration cases in order to perform the expected analysis assessing the behavioural change of the building users after putting into place the MOBISTYLE approach and tools.

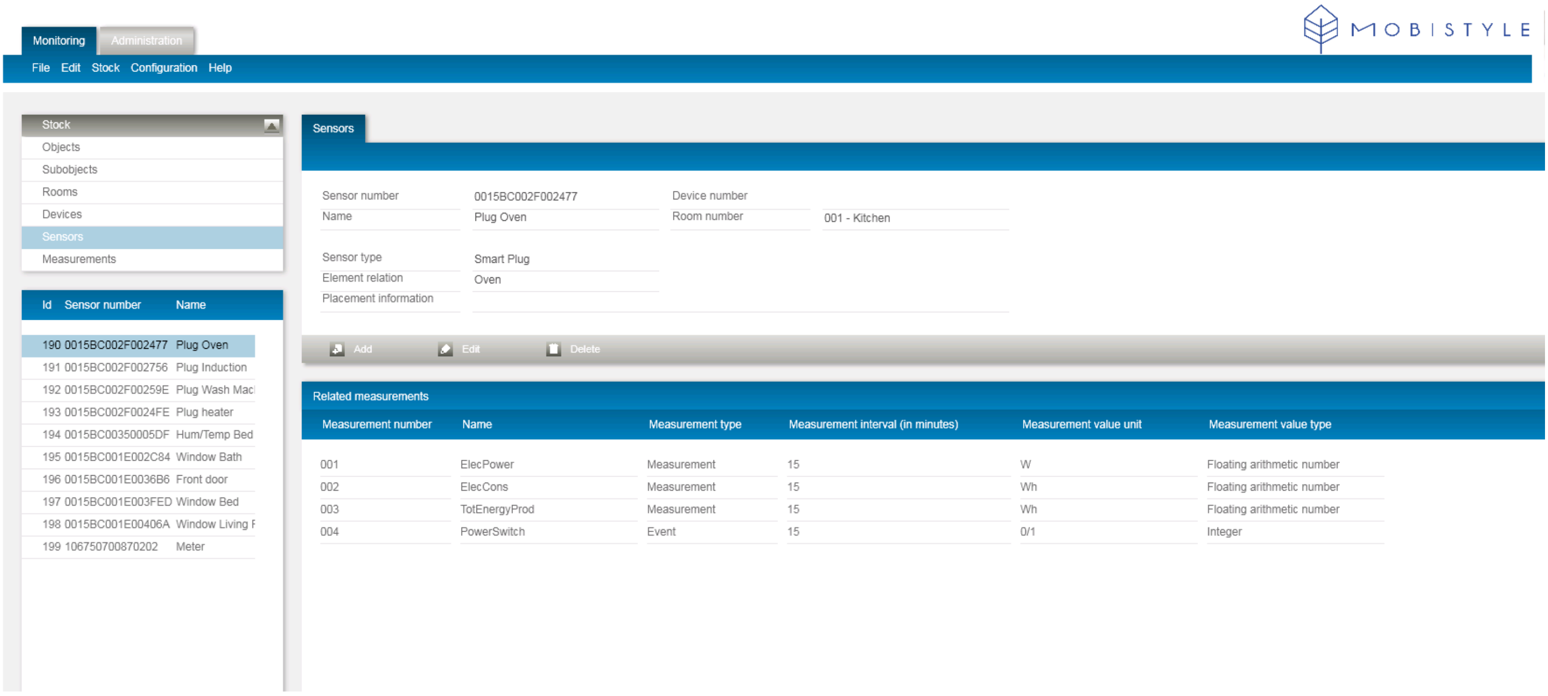
Due to low cost sensor techniques the amount of data collected from various physical quantities is expanding rapidly. In the construction sector, building managers and owners deal with a lot of different data and information – such as sensors data, smart meter data, and energy bills – coming from different sources and available in different formats. Nevertheless, in some situations this data is easy accessible, available or readable; whereas in other situations the required data can be difficult to extract and difficult to interpret in a homogeneous way.

For whom is the expert tool?

The Expert Tool is built upon the existing RE Suite software package developed and commercialized by the consortium partner DEMO Consultants. In general terms the Expert Tool will be an additional module to the RE Suite package for real estate asset management.

Within the consortium as well as outside it, the Expert Tool has as main target groups real estate owners and managers – such as housing associations, real estate agencies, hospitals – i.e. all those entities who need to access an heterogeneous and consistent amount of data and information to monitor the performances of a building and plan maintenance activities.

Within the MOBISTYLE project, the Expert Tool allows the visualization and management of a big



amount of data available in the different demonstration cases. The experts are able to filter the information they need, to calculate pre-defined KPIs, but also to set up their own KPIs. The Expert Tool is design in such a way that it fixes only some boundary conditions, giving the freedom to the user to filter information, make simple calculations, and export the data in the most suitable way.

Using the expert tool

The Expert Tool has 3 main purposes:

1. Data management: the expert has access to the data for visualization, filtering and validation purposes.
2. KPI calculation: the expert is able to visualize and download KPIs on energy, comfort and health.
3. Support the needs of third parties tools: the expert will be able to export the data in the most suitable format. This functionality guarantees the interoperability between the Expert Tool and the other software programs used by the expert for evaluation and analysis purposes.

The expert tool aims to supply experts with the dataset(s) they need. Its purpose is not high-level analysis, but rather offering experts access to data for use in their own tools. As such, a simple retrieve-and-save-to-disk operation would fulfil the basic theoretical requirements. However, this method quickly proved being insufficient. Therefore, following questions were considered:

- What if an expert only needs part of the set?
- How will an expert know if the result matches their expectations?
- Must they dive into the dataset's depths and do a preliminary analysis?
- How will they even know what to query if they do not know what a dataset looks like?
- What if they need a different kind of aggregation than the predefined ones for the calculation of the KPIs?

To answer these questions, the Expert Tool offers dataset constraints through the use of filtering conditions. Moreover,

- It offers quick verification through visualisation of dataset summaries;
- It offers insight in data sources and their current status;
- It offers the possibility to quickly calculate basic KPIs such as the cost for electricity consumption;
- It offers the possibility to customize the type of aggregation for the calculation of KPIs;
- It exports a verified dataset in some format that is useful to the expert's tools. ■

U-CERT
User-Centred Energy Performance Assessment and Certification

Co-funded by the Horizon 2020 Framework Programme of the European Union

H2020 U-CERT project
– breeding ground for the next generation Energy Performance Assessment and Certification

ANDREI VLADIMIR LIȚIU

U-CERT (Towards a new generation of user-centred Energy Performance Assessment and Certification; facilitated and empowered by the EPB Center[1]) is a Horizon 2020[2] project funded by the European Union under Grant Agreement 839937[3] and running between September 1st 2019 and August 31st 2022. REHVA and EPB Center are among the 15 U-CERT team members together with 9 REHVA Member Associations (involved directly or indirectly).

Keywords: EPB standards, smart readiness indicator, user-centric, building asset rating, building operational rating, next generation energy performance certificates.

Specific challenge[4]

Under the Energy Performance of Buildings (EPB) Directive[5], all EU countries have established independent energy performance certification systems supported by independent mechanisms of control and verification. However, current practices and tools of energy performance assessment and certification applied across Europe face a number of challenges.

Assessment processes and certificates have to become more reliable, user-friendly, cost-effective, have comparable good quality and be compliant with EU legislation in order to instil trust in the market and incite investments in energy efficient buildings. They have to increasingly reflect the smart dimension of buildings and at the same time, facilitate convergence of quality and reliability of Energy Performance Certificates (EPCs) across the EU. The building energy performance methodologies should also ensure a technology neutral approach, be transparently presented making use of International and European standards, in particular the set of ISO and CEN EPB standards[6] developed under Commission mandate M/480[2] aimed at enabling the presentation of national and regional choices on a comparable basis.

These next-generation energy performance assessment schemes will value buildings in a holistic and cost-effective manner across several complimentary performances: envelope performances, system performances and smart readiness (i.e. the ability of buildings to be smartly monitored and controlled and, to get involved in demand-side management strategies). The assessment should be based on an agreed list of parameters/indicators, such as e.g. calculated annual final energy use, share of renewable energy used, past (climate corrected) final energy consumptions and energy expenditure, comfort levels or the level of smartness. The assessment methods should increasingly take into account output measures of performance (actual measured data) making use of available and increasing number of building energy related data from sensors, smart meters, connected devices etc.. These new schemes should contribute to improving the effectiveness of certificates, by demonstrating how these could be strengthened, modernised and best linked to integrated national/regional certification schemes within a framework that aids compliance checking and effectiveness of financial support.

U-CERt's objectives

U-CERT has the following five measurable objectives:

1. Stimulating and enabling the co-creation and implementation of the new generation of EPC schemes with a wide based support;
2. Enhancing the new certification schemes to be more practical, reliable, understandable and desirable by a holistic and user-centred approach;
3. Making the new certification schemes easily accessible for a wide range of users and stakeholders by the services of the EPB Center;
4. Providing evidence of applicability and usefulness of developed schemes by testing the U-CERT approach in selected cases;
5. To foster the EU-wide uptake by motivating and activating EU interest groups and national certifying and standardisation bodies.

U-CERt's overall concept

U-CERT builds upon recent actions for developing a holistic energy performance assessment and certification. It will rely on previous and ongoing initiatives, including existing voluntary holistic environmental performance rating schemes. Additional indicators related to health and well-being based on e.g. EN 16798-1 'Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics' will be considered and added in this project to the EPC framework to assess indoor air quality and comfort in the scope of building performance improvement. It should be salient in this day and age that indoor environment has also an impact on the market value of buildings.

U-CERT will start with identifying the specific barriers and the possible drivers to use a next generation of Energy Performance Certificates (EPCs). To make EPCs more user friendly, better reliable and trustworthy an anthropology-based approach will be applied, using among others focus groups of each user group. Following this holistic approach U-CERT will create added value and enable enhanced building value (by reliable and 'desirable' energy performance certificates) and make the energy assessment process more cost-effective.

Manufacturers of products used in buildings having an impact on the Energy Performance of Buildings and their systems, are required to declare relevant product information according to the rules and requirements for energy labelling and ecodesign[7]. The data included in these product declarations (labels) are in many cases insufficient or not directly useable as input value for the EPB calculation procedures as included in the set of EPB standards and in future national annexes. To bridge this gap, support for the relevant stakeholders, i.e. designers and energy performance assessors of buildings and HVAC systems, manufacturers of these products, need support and assistance. They are not always aware of this information gap neither in the position to deliver the additional data needed for a correct energy performance assessment lacking the sufficient knowledge. U-CERT will develop services to bridge this information gap by publishing procedures and offering guidance to suppliers on how to develop and deliver the data needed for EPB calculations.

U-CERT facilitates the shift to the next generation EPC paradigm by taking the Smart Readiness Indicator (SRI) to the practical level and developing an optimal recipe of SRI functions that a given building should have installed to enable building operational rating based on the calculation methodology of the EPB standards (measured building data → weather and behaviour normalization → building operational performance).

The U-CERT Building Operational Rating solution is envisaged as a cloud-based service, accessible through any web browser with a user account, that would enable an evidence based decision-making process. The building assessor would have access to the backend of this interface for conducting all the necessary calculations (partly automated) using calculated input data (import from national EPC database, EPB standards and product data) for the Building Asset Rating and measured input data (EPB Standards and SRI functions) for Building Operational Rating. The end-users can browse through relevant information displayed in the front-end. Additionally, the building assessor could provide advice suggesting improvements in behaviour and/or recommending building performance improvements.

The visualization of these Building Asset Rating, Building Operational Rating and advice for building performance improvement by the end-users shall constitute a valuable trigger point for actually applying the building performance improvement(s). The Building Operational Rating will prompt users to access the interface on a seasonal or annual basis. Furthermore, the end-users can access the interface and visualize the information whenever wanted.

Once a building performance improvement is applied this would be fed in the Building Operational Rating solution and its impact shall be quantified in the next Building Operational Rating exercises.

The U-CERT Building Operational Rating solution will be stored on the cloud and shall be easily accessible as needed by national authorities (e.g. compliance check and verification, evidence-based policy making), financial institutions (e.g. loan surveillance, additional channel to new clients), researchers interested in building stock characteristics and other stakeholders.

Furthermore, continuously calculating building operational performance based on measured building data will allow continuously improving building performance and quantifying the effects of individual steps of a e.g. Building Renovation Roadmap/Passport.

The U-CERT Building Operational Rating solution would also create a valuable feedback loop for improving the quality of services offered by building designers and contractors. Moreover, building professionals could develop new services, benefit of closer and more frequent contact with their clients and prepare for the future market shift from products to services.

Lastly, financial institutions might be interested using the U-CERT Building Operational Rating solution interface as a mandatory condition when offering loans for building performance improvements.

How to stay informed about U-CERT activities

U-CERT's website and social media accounts will be ready by the end of 2019. Continue following REHVA's communication and dissemination channels to be among the first who will visit U-CERT website, subscribe to U-CERT's newsletter and start following U-CERT on your preferred social media. ■

References

1 https://epb.center/

2 https://ec.europa.eu/programmes/horizon2020/en

3 https://cordis.europa.eu/project/rcn/222747/factsheet/en

4 https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/lc-sc3-ee-5-2018-2019-2020

5 https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-performance-of-buildings/energy-performance-buildings-directive

6 https://www.rehva.eu/activities/epb-center-on-standardization/epb-standards-energy-performance-of-buildings-standards

7 https://ec.europa.eu/info/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/energy-label-and-ecodesign/rules-and-requirements_en

CONFERENCE

REHVA BRUSSELS SUMMIT 4-5 November 2019

4th-5th November 2019
Sofitel Brussels Le Louise, Avenue de la Toison d'Or 40, 1060 Brussels, Belgium

Delivering healthy, zero-carbon buildings by 2050?

REHVA is delighted to invite you to the official REHVA Brussels Summit held on 4-5 November 2019. The REHVA Brussels Summit is an occasion for professional networking amongst REHVA Members, Supporters and stakeholders within the field of buildings, energy efficiency and IEQ. The event consist of two days, the first day will be held at the Maison des Associations Internationales, and the second at Sofitel Brussels Le Louise Hotel

The summit will be focussing on REHVA's latest activities, through several committee meetings, as well as organising EU project workshops on *EU level professional qualification scheme on CEN-EPB standards*. In this year's topic of the conference, "Delivering healthy, zero-carbon buildings by 2050 will present EU policies for a decarbonized economy with high performing and healthy buildings. The aim is to discuss what is needed in the HVAC and building sector to deliver on these ambitious targets with focus on practical implementation with the following sessions below:

SESSION 1 – EU policies for healthy, zero-carbon and sustainable buildings by 2050

A new government took over the leadership of the EU. Climate and energy challenges remain. What are buildings related priorities? Speakers from the European Commission will present policy updates impacting buildings and the HVAC sector:

- Energy and climate agenda of the new European Commission
- EPBD updates - Smart Readiness Indicator
- Resource efficiency requirements for buildings and the HVAC sector

SESSION 2 – Building performance certification to bridge the finance gap

We have all the technologies to deliver healthy, sustainable and decarbonised buildings. Still the transformation is not happening. One of the reasons is the finance gap, the lack of trust and common language among building professionals and investors. This session will bring together engineers, building certification organisation and investors to share perspectives, followed by a moderated panel discussion.

- What triggers investors to invest in sustainable construction and energy retrofit projects?
- Monitoring building quality & performance to de-risk investment (QUANTUM and QUEST)
- Aggregating sustainable investments, investors experience with energy performance contracting
- The DGNB sustainable building certification scheme
- A European voluntary building certification scheme tackling IEQ & real performance (ALDREN)

SESSION 3 – HVAC product efficiency & drinking water systems

HVAC products must comply with new EU regulatory requirements and systems tackling also climate goals. This session will present these from the perspective of leading HVAC manufacturers.

- Ecodesign updates: space heating boilers and combination heaters Review study space/combination heaters "Lot 1"
- Circular economy and the resource efficiency requirements in the HVAC sector
- New EU regulation on Drinking water & a new REHVA guidebook on Hygiene in drinking water systems

Between session 2 and 3, REHVA will also invite its participants to a networking lunch to discuss innovative and practical ideas.

General info on Public Transport (Metro, Bus, Tram)

The conference venue is well located with many links for transportation. You have several tram stations. The 8 and 93 can take you towards the centre as well as Louise metro where you can find metro links across all of Brussels. You can buy your tram/metro tickets at various ticket booths at metro stations and several tram and bus stops. The flat price for a single journey is 2.10, or you can purchase a 24-hr day ticket for 7.50 EUR. You can also plan your routes on Brussels transportation website STIB in the link https://www.stib-mivb.be/index.htm?l=en ■

REHVA BRUSSELS SUMMIT
4-5 November 2019

CONFERENCE

Tuesday 5 November 2019, 9.30 –16:30
Sofitel Brussels Le Louise, Avenue de la Toison d'Or 40, 1060 Brussels, Belgium

Delivering healthy, zero-carbon buildings by 2050?

AGENDA

09:00	*Registration and coffee*
09:30	Welcome and opening **Frank Hovorka**, REHVA President
	SESSION 1 - EU policies for healthy, zero-carbon and sustainable buildings by 2050 Chair: **Frank Hovorka**, REHVA President
09.40	Energy and buildings on the policy agenda of the new Commission **Paula Rey-Garcia**, Buildings and Finance team leader, DG ENER, European Commission
10:00	Smart Readiness Indicator updates **Stijn Verbeke**, Senior Researcher, Vito
10:15	TAIL - a pragmatic IEQ indicator for building certification (ALDREN project) **Pawel Wargocki**, Associate Professor, DTU
10:30	Questions and discussion
10:45	*Coffee break*
	SESSION 2 - Building performance certification to bridge the finance gap Chair: **Frank Hovorka**, REHVA President
11:00	What triggers investors to finance sustainable building projects? **Frank Hovorka**, REHVA President
11:10	ALDREN certification: translating building performance into financial asset **Johann Zirngibl**, CSTB, ALDREN coordinator
11:25	Quality Management and technical monitoring to de-risk sustainable investment **Stefan Plesser**, synavision, QUANTUM / QUEST coordinator
11:35	DGNB certification for sustainable buildings. **Christine Lemaitre**, CEO, DGNB
11:45	Aggregating sustainable investments / LAUNCH results **Caroline Milne**, Communications Director, Joule Assets
12:00	Panel discussion & questions **Moderator: Anita Derjanecz**, REHVA Managing Director
12:30	*Networking Lunch*
	SESSION 3 - Sustainability, product efficiency & drinking water systems Chair: **Prof. Jarek Kurnitski**, REHVA TRC chair
14:00	Assessing building sustainability performance **Josefina Lindblom**, Policy Officer, DG ENVI, European Commission
14:20	Resource efficiency in the HVAC sector s **Ansgar Thiemann**, Business Development Manager, DAIKIN
14:40	Ecodesign review study on space heating boilers and combination heater **René Kemna**, Director, VHK
15:10	The upcoming EU Drinking Water Directive **Ilari Aho**, Vice President, UPONOR
15:25	Hygiene of drinking water systems - a new REHVA Guidebook **Christian Schauer**, Head of the Drinking Water Department, Viega
15:40	Questions and discussion
16:00	Closing remarks

REHVA 3RUSSELS SUMMIT 12-13 November 2018

CONFERENCE

Tuesday 5 November 2019, 9.30 –16:30
Sofitel Brussels Le Louise, Avenue de la Toison d'Or 40, 1060 Brussels, Belgium

About the event co-funders

ALDREN

ALDREN ALliance for Deep RENovation in buildings

www.aldren.eu

@H2020_ALDREN

The ALDREN project is a 3 year- long project, which begun in November 2017. The project consortiums main objectives are to promote the European Common Voluntary Certification scheme (EVCS) as a backbone along with the whole deep renovation process of non-residential buildings. This procedure encourages the transition towards NZE non-residential building stock. Within this project, holistic tools and procedures are required when evaluating the overall benefits from building deep renovation. As well as advocating for renovation, the project also promotes health and comfort for occupants in buildings. REHVA's involvement with ALDREN is developed through REHVA's Technology and Research Committee. This is implemented though trainings which are organised to communicate the ALDREN procedure underpinning the building renovation passports across HVAC engineers in Europe.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n. 754159

QUEST

QUEST

QUEST- Quality Management Investments for Energy Efficiency is a three-year long EU funded project funded whom focus on investments in sustainability and energy efficiency by investigating empirically risk grading factors that influence energy performance in buildings. QUEST will create a set of tools that will evaluate the energy performances of these advancements which can simply be practiced to all types of sustainability and energy efficiency investments as well as covering project design-construction-operation risks. Financial institutions applying the QUEST toolkit will be able to reduce risk related to wrong assessment of buildings energy performance which will allow a significant increase in return on investment for the sustainable buildings sector.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n. 846739

Quality Management for Building Performance

quantum Quality management for building performance

www.quantum-project.eu

@QUANTUM_H2020

QUANTUM is a four year-long EU funded project, started in January 2016. The underlying concept of QUANTUM is that the gap in buildings predicted and monitored performances is not caused by a lack of technology or conceptual intelligence, but by a lack of quality. The consortium targets to reduce this gap by developing and demonstrating pragmatic tools and services for Quality Management (QM), supported by three ICT-driven tools. These tools enable effective QM in all relevant services within the building life cycle, by addressing 1) specification and automated validation of Building Management System functions, 2) in-situ energy metering combined with online data analysis, 3) evaluation of perceived users' comfort via web-based questionnaires. The overall core mechanism is to "design for testability" by specifying transparent performance targets with cost effective testing methodologies.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n. 680529

CLIMA-med 2020

The 10th HVAC Mediterranean Congress, **CLIMA-med 2020**, will be held in Lisbon, from the 17th to the 19th of May 2020, following the General Assembly of REHVA that will previously take place in the same city.

The CLIMA-med congress is nowadays integrated in the 3 years cycle of REHVA related conferences (Clima, CLIMA-med and Cold Climate) and is under the responsibility of a set of five HVAC associations of Southern Europe countries, that assure the membership of the respective countries in REHVA:

- **AICARR** (Associazione Italiana di Condizionamento dell'Aria, Riscaldamento e Refrigerazione), from Italy:
- **AICVF** (Association des Ingénieurs en Climatique, Ventilation et Froid), from France;
- **ATECYR** (Asociación Técnica Española de Climatización y Refrigeración), from Spain;
- **OdE** (Ordem dos Engenheiros), from Portugal;
- **TTMD** (Turkish Society of HVAC and Sanitary Engineers), from Turkey.

CLIMA-med 2020 will be hosted by Ordem dos Engenheiros, and will have as its motto "**Towards Climate-Neutral Mediterranean Buildings and Cities**", intending to represent a meaningful contribution to the solution of the problems posed to humanity by Climate Changes.

Papers related to the various topics that are related to the challenge of providing well-being to people in buildings in a sustainable way and in a scenario where resilience and adaptation will surely be required are very much welcome to the congress. The following topics are identified:

- Solutions for the Resilience to Climate Changes
- Sustainable Energy use in Buildings and Energy Efficiency
- Renewable Energy Applications
- Buildings Management, Maintenance and Commissioning
- Indoor Environmental Quality
- Ventilation Systems
- Standardization & Regulations
- Advances in Systems and HVAC Equipment
- Modeling, Simulations and Integrated Design
- Nearly Zero Energy Buildings and Districts
- Buildings Retrofitting
- Internet of Things and Buildings Monitoring Solutions
- Occupants' Behaviour

Inclusiveness will also be a major aim of the Congress organizers, which means that there is a desire and openness for participants to expand their geographical area of origin to other Mediterranean countries or to other parts of the globe with similar climates.

Important Dates

- Deadline for the submission of abstracts: **30 November 2019**
- Notification of acceptance of abstracts: **15 January 2020**
- Deadline for the submission of final papers: **15 February 2020**
- Notification of the acceptance of final papers: **15 of March 2020**

Congress Chairman: Serafin Grana (OE)

Scientific Committee President:
Manuel Gameiro da Silva
(OE & University of Coimbra)

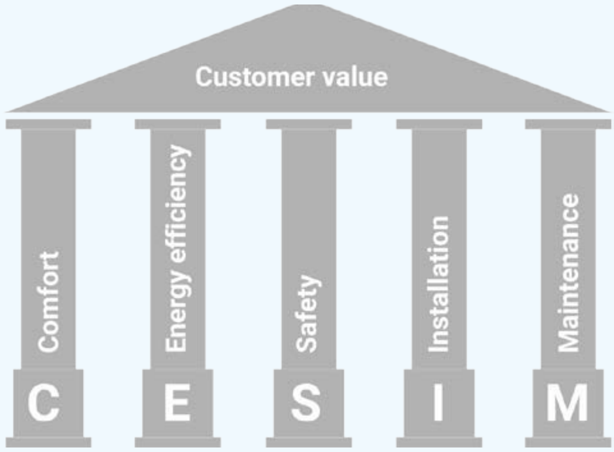
Small devices, big impact

Sustainability and customer value in focus

CSR (Corporate Social Responsibility) is a key term for company ethics. For Belimo this principle forms the basis for further development of sustainability and customer value in the area of building technology with sensors, valves and actuators. We are well aware of the big influence our "small" Belimo devices have on comfort, energy efficiency, safety, installation and maintenance.

As a member of the UN Global Compact, Belimo directly contributes to the Sustainable Development Goals (SDG). By incorporating the UN Global Compact principles into strategies, policies and procedures, Belimo is not only upholding their basic responsibilities to people and the planet, but also setting the stage for long-term success of our industry.

With CESIM, sustainability and customer benefits are connected and visualized. CESIM is derived from the first letters of the words Comfort, Energy (efficiency), Safety, Installation and Maintenance and, for Belimo, constitutes the pillars of sustainable HVAC system design – based on the motto "Small devices, big impact".



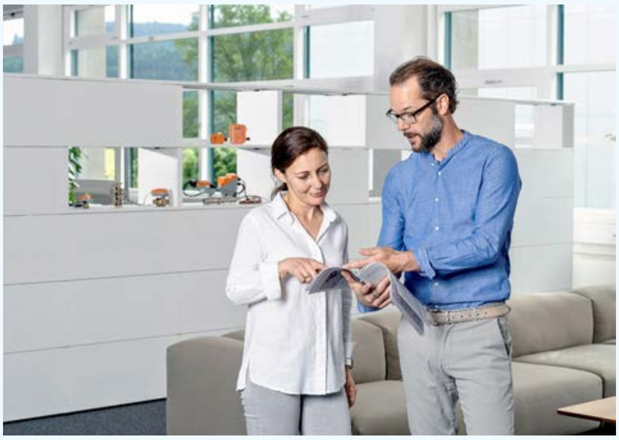
Belimo combines Corporate Social Responsibility with customer value via the five CESIM pillars. This is done with an awareness that small products by Belimo have a big influence on the functioning of HVAC systems.

Innovations redefining comfort

The first pillar represents room comfort. This has a considerable influence on the well-being and productivity of human beings. Whether this is in the workplace, at school or at home. With a precisely controlled room environment, comfort is considerably influenced, among other things, by use of innovative sensors, variable volumetric flow control (VAV) and pressure-independent control valves. With its innovative solutions, Belimo is setting standards for optimal, stable room comfort.

Energy efficiency delivered

An important point in the context of sustainability is energy efficiency, which is the second pillar of CESIM. Intelligent control of heating, cooling and ventilation systems makes a considerable contribution to the energy efficiency of buildings. This means only as much energy is produced as is also needed.



Room climate has a considerable influence on the well-being and productivity of human beings. With innovative products by Belimo, room climate can be influenced considerably.

Belimo optimises its products in order to reduce energy requirements for buildings as much as possible. For example, with energy-efficient actuators, air-bubble tight closing ball valve technology or the all-in-one solution, Belimo Energy Valve™.

Uncompromised safety

Safety in buildings is the third pillar. High quality and reliability of the product solutions used is essential for the protection of human lives, buildings and tangible assets. Safety actuators by Belimo help save human lives and contribute to minimizing damage to property or equipment. Technology that can saves lives includes, for example, smoke control damper actuators and fire damper actuators with the patented Safety Position Lock™ function, which keeps the damper securely closed in case of fire.

Premium quality spring-return actuators and actuators with electrical emergency control function are also distinguished by their entirely reliable operation. Combined with the integrated fail-safe, they prevent hazardous situations and thereby increase operating safety. The Belimo range also includes very fast running actuators to ensure strict requirements for ambient conditions in production areas, laboratories or other sensitive areas. They ensure reliable, quick and low-noise opening and closing of air dampers.

Experience installation ease

The fourth pillar concerns installation: ease of installation and fast commissioning save time and reduces the workload. Belimo does its utmost to significantly reduce installation times. For this reason Belimo actuators and sensors are easy to install and mostly without tools. This also includes the unique protective housing of Belimo sensors, which also correspond to the IP65 / NEMA 4X protection standards.

Belimo offers a comprehensive product range of sensors, valves and actuators – also for retrofit applications. With our NFC-capable actuators, the effort for commissioning is significantly reduced. Smartphone-supported configuration is even possible when the actuator is not connected to the power supply. Manual written protocols are no longer required.

Belimo also offers a fast and efficient delivery service. We make sure our customers receive the desired product at the right time and at the agreed location.

Lasting performance, backed by world class support

The challenges in maintenance are becoming increasingly diverse. The last CESIM pillar is dedicated to this topic. Lower maintenance work and professional customer service have a lasting effect on the efficient operation of a building. All field devices by Belimo are low-maintenance and many of them even maintenance-free. They are tested thoroughly before dispatch and have a five-year warranty.

Innovative Belimo solutions are setting standards here too. The efficiency of HVAC systems can be optimized, and their maintenance minimized, by real-time monitoring and high data transparency, such as when using Belimo Energy Valves™. Using the cloud connection, device data can be viewed at any time and updates implemented automatically. The cloud connection also enables even better support by our experts. In addition, reports with detailed analyses of trend, energy and performance data of the Belimo Energy Valve™ are regularly sent to recipients defined by the customer.

Belimo offers comprehensive customer service and excellent support over the entire product lifetime. We place particular emphasis on fast and effective service.

For further information, see belimo.com/cesim or contact your Belimo partner. ■

United Nations Global Compact

The UN Global Compact is the world's largest sustainability initiative for companies.

It is an appeal to companies to align strategies and operations with universal principles on human rights, labour, environment and anti-corruption and take actions that promote societal goals. The vision of the initiative states: "At the UN Global Compact, we aim to mobilize a global movement of sustainable companies and stakeholders to create the world we want."

For further information, see https://www.unglobalcompact.org/

How can high-quality humidity and temperature transmitters help improve your data center PUE?

Power usage in data centers represents a share of global electricity consumption that is steadily growing. A recent figure for the US puts data center electricity use at 1.8% of the national total. A large proportion of that energy use – over and above what the computer equipment is using – comes from cooling. Another environmental consideration is clean water used for evaporative cooling. Many schemes aim to reduce data center power usage efficiency (PUE) towards an ideal ratio of one, including some using artificial intelligence.

One of the most important requirements to reduce cooling costs is to measure conditions properly in the first place. The first things to consider are:

- What do you want to measure? Do you, for example, need to control air-side economizers or evaporative coolers? This might influence what humidity parameters you need from the instrument.
- Where will you measure it? The installation location should be representative. If you want to measure the outdoor humidity and temperature, the sensor should be placed in a location with free airflow, away from any surfaces that might radiate heat and disturb the measurement.
- How accurately do you need to measure? Consider the requirements of your control system. When selecting instruments to fulfill these needs you should also consider long-term drift and your service schedule.
- Choose an instrument designed for the desired installation location. For outdoor measurements you will need purpose-designed transmitters that can cope with outdoor conditions.
- How will you verify and maintain your measurement instruments? All instruments need periodic checking, so will you do this with in-house trained personnel, use a third-party service, or have a few extra instruments and rotate them with factory calibration? How easy is it to do these periodic checks with your chosen kit?

LARS STORMBOM
Senior Product Manager
Vaisala Oyj

There are a few types of humidity and temperature transmitters that are typically used in data centers: outdoor humidity sensors, duct humidity sensors, and wall or space humidity sensors.

Outdoor Humidity Sensors

Outdoor humidity and temperature sensors are used with airside economizers and cooling towers. The most advanced economizer control paradigm is to use the differential enthalpy (heat content). You measure the enthalpy of the outside air and then use the return air to control when to recondition the hot return air and when to use the outside air.

Outdoor humidity sensors with wet-bulb temperature output indicate directly when evaporative coolers can be used. The wet-bulb temperature indicates the temperature that can be reached with evaporative cooling; if the outdoor humidity is too high the rate of evaporation is low and the cooling effect too low.

One of the most important parts of an outdoor humidity and temperature sensor is the solar radiation shield, which reduces the influence of heat from the sun on the measurement. Seemingly small design changes can easily cause 1–2 °C extra heating in unfavorable conditions.

Outdoor sensors are also subjected to everything Mother Nature might throw at them, including icy rain and heavy winds. A data center runs 24/7/365, so failure is not an option!

A suitable outdoor humidity sensor will have a good solar radiation shield. Observe the black lower surfaces of the plates, which are essential to keep the sensor cool.

Duct Humidity Sensors

Duct humidity and temperature sensors are used on duct and air-handling units to measure and control the condition of incoming air and measure the return air from the data center. They are used to complement outdoor humidity sensors so that the enthalpy difference between the return air and the outside air can be calculated. Some of the duct sensors may be subjected to harsh conditions if installed inside humidifiers or inlet air ducts.

When you install the devices, consider how you will make regular checks. It is often easy to add a port for a reference probe during installation. In this way, you can easily introduce a reference probe to the duct and compare the reading to the duct sensor.

Wall or Space Humidity Sensors

Wall or space sensors measure the actual conditions inside the data center. Humidity conditions are usually benign; however, the rate of change can be fast in response to load level fluctuations and when switching between reconditioned air and free cooling. As the airflow around these sensors is typically slower than for duct sensors, the response time to temperature changes is slower. There might also be outgassing from cables and other equipment running at ever-higher design temperatures, which may cause drift in some humidity sensors. With rapid temperature fluctuations it might be a better choice to use dew point temperature as a humidity control parameter as it doesn't depend on the temperature of the sensor.

You also need to consider what conditions you are measuring and using for control purposes, as the temperature and humidity will be dramatically different before and after the heat load (cold or warm aisles). You can get high-quality instruments that measure conditions with high accuracy – devices with 0.1°C and 1%RH accuracy are readily available, but moving the sensor slightly can cause much larger changes.

Even small measurement errors can cause significant increases in your energy bill, so it pays to get quality instruments and maintain the measurements in a good condition. Careful consideration of the installation location also pays off. ■

REHVA

Federation of European Heating, Ventilation and Air Conditioning Associations

MEMBERS

Network of 27 European HVAC Associations joining 120 000 professionals

REHVA Office: Rue Washington 40, 1050 Brussels - Belgium

Tel: + 32 2 514 11 71 - info@rehva.eu - www.rehva.eu

Exhibitions, Conferences and seminars in 2019-2020

Exhibitions 2019

3-5 September	ISH Shanghai & CIHE	Shanghai, China	https://www.hk.messefrankfurt.com/content/ishs_cihe/shanghai/en/visitors/welcome.html
2-5 October	ISK-SODEX 2019	Istanbul, Turkey	www.sodex.com.tr/en
21-23 November	REFCOLD	Hyderabad, India	http://www.refcoldindia.com/

Conferences and seminars 2019

12-15 July	ISHVAC 2019 - 11th International Symposium of Heating, Ventilation and Air-Conditioning	Harbin, China	
18-22 August	ISIAQ	Kaunas, Lithuania	http://isesisiaq2019.org/
24-30 August	ICR 2019 - 25th IIR International Congress of Refrigeration	Montreal, Canada	https://icr2019.org/
2-4 September	Building Simulation Conference 2019	Rome, Italy	www.buildingsimulation2019.org
5-7 September	IAQVEC 2019	Bari, Italy	www.iaqvec2019.org
26-28 September	Annual Meeting of VDI-Society for Civil Engineering and Building Services	Dresden, Germany	
3-4 October	PZITS 100th Anniversary- Workshop- 'Practical side of sanitary installations and netwrosks designer and appraiser'	Warsaw, Poland	http://pzits.pl/100lat/gala-jubileuszowa/
15-16 October	AIVC 2019 Conference - From energy crisis to sustainable indoor climate	Ghent, Belgium	https://www.aivc2019conference.org/

Exhibitions 2020

27-29 February	ACREX	New Delhi, India	http://acrex.in/home
8-3 March	Light+Building 2020	Frankfurt, Germany	https://light-building.messefrankfurt.com/frankfurt/en.html
10-13 March	SHK Essen	Essen,Germany	https://www.shkessen.de/branchentreff/

Conferences and seminars 2020

1-5 Feb	2020 ASHRAE Winter Conference and AHR Expo	Orlando, Florida	https://www.ashrae.org/conferences/2020-winter-conference-orlando
4-6 March	World Sustainable Energy Days	Wels, Austria	https://www.wsed.at/en/world-sustainable-energy-days.html
12-14 May	13th IEA Heat Pump Conference	Jeju, Korea	http://hpc2020.org/
14-17 June	NSB 2020 Building Physics Conference	Tallinn, Estonia	www.nsb2020.org/
20-24 July	Indoor Air 2020	Seoul, Korea	www.indoorair2020.org
14-16 Sept	Roomvent 2020	Torino, Italy	http://roomvent2020.org/
14-16 Sept	AIVC Conference	Athens, Greece	https://www.aivc.org/event/14-16-september-2020-conference-athens-41st-aivc-conference

From 17 to 20 March 2020 at FIERA MILANO

A new lay out for the next edition of MCE – MOSTRA CONVEGNO EXPOCOMFORT 2020

The change will be at the very heart of the new floor plan for MCE 2020 following a new logic of HVAC systems design is underway, as a comprehensive framework in which products, solutions, and systems integrate themselves in terms of energy efficiency, saving and respect for the environment.

Milan, September 2019 – The organisation of MCE – MOSTRA CONVEGNO EXPOCOMFORT, the world's leading biennial exhibition dedicated to residential and industrial installations, HVAC&R and renewable energy scheduled for 17 – 20 March 2020 at Fiera Milano, is now moving into top gear. Technological innovation in terms of products, systems and solutions for comfortable living and strong internationalism, reign once again as the undisputed protagonists of MCE 2020, reaffirming the event leading position in an even more global context. Right now, MCE - MOSTRA CONVEGNO EXPOCOMFORT 2020 has registered over 1,500 direct exhibitors.

MCE 2020 will, once again, be an ideal showcase that will take visitors on a journey to through the most innovative technologies to understand the evolution of HVAC&R industry, where the new horizons for comfort increasingly, pass through the digital dimension of management and control, whereas the efficiency is bound more and more by the intelligent use of Information Technology for the optimisation of energy resources of buildings.

An evolution that will find its ideal stage in the new exhibition layout of MCE 2020, capable of creating homogeneity and continuity into the several industry sectors, giving value to the conceptual areas in a "unicum", different and one-of-its-kind, carefully studied to meet the needs of exhibitors and professionals alike always on the hunt for technological novelties. The exhibition space with an entirely new floor plan will go beyond the customary repartition into four macro areas, Heating, Cooling, Water and Energy, which in recent years has characterised the industry segments present at MCE. From Heating to Tools and Hardware, from Air-Conditioning to Refrigeration and Ventilation, from Sanitary Technology to Water Treatment, from Renewable Energy to Home & Building Automation and Electric Mobility.

"In the new exhibition floor plan, declared Massimiliano Pierini, Managing Director at Reed Exhibitions Italia, some product sectors are now closer to the other ones – thanks also to the linear structure of the halls of Fiera Milano – to guarantee continuity concurrently with a logical subdivision making the different commodity areas identifiable and of course, making the trade show easy for our visitors to go to see. I'm confident the entirely new layout will better tell the present and future trends of the market". In this context, **heating, ventilation, air-conditioning and refrigeration** areas will take up not only halls 13/15 and 22/24 as usual, **but also hall 9/11 together with THAT'S SMART space,** joining link between the heat and power environment. **The whole components sector** will be located **in hall 2/4,** adjacent to the entrance gate of the underground, and very close to the areas dedicated to heating, renewable energy, and plant design services (halls 1/3, 5/7 and 10), synergistic and complementary sectors.

As is now customary, MCE 2020, will be supplemented by a busy programme of conferences organised in collaboration with the leading trade associations, once again coordinated by the chair of the Scientific Committee Professor Vittorio Chiesa of Energy & Strategy Group, Polytechnic University of Milan.

Indeed, many initiatives will be on offer livening up MCE 2020 throughout the course of the four days. From Partner Country with Turkey as the special guest of the next edition to **Percorso Efficienza & Innovazione**, a short-list of the most cutting-edge products and solutions in terms of efficiency and energy savings made by the Polytechnic University of Milan on show at MCE, and a particular focus on MEP BIM.

Amongst the new features in store for this edition, a unique space dedicated to **Intelligent Water** stands out. On display, the most advanced technologies for the bathroom environment to good living together with special initiatives aimed at energy efficiency in the industry with the intention of bringing a number of new categories of professionals to the trade show.

The 2020 edition of MCE intends to embody the evolution of HVAC&R industry with all services made available by connectivity, control and management of living comfort.

All the latest updates on MCE- MOSTRA CONVEGNO EXPOCOMFORT 2020 will be available online on www.mcexpocomfort.it, and Facebook.com and Twitter.com MCE's pages. ■

41st AIVC – ASHRAE IAQ joint conference, 14-16th September 2020, Athens

Between the 14th–16th September 2020, the conference, which is organized by ASHRAE and AIVC will be held in Athens, Greece. The conference will be the 9th Tightvent and the 7th venticool conference.

The aim of next year's conference is to expand the Indoor Air Quality to Indoor Environmental Quality (IEQ).

The conference will discuss a range of topics below:

- Health and Well-being: Appropriate technical and operational definitions
- Performance Metrics: For all aspects of IEQ
- Interactions: Interactions between IEQ parameters
- Occupant Behaviour: How behaviour impacts IEQ and how IEQ impacts behaviour - psychological dimensions of IEQ
- Smart Sensors and Big Data: Sensor properties, data management, cybersecurity, applications
- Smart Controls: Equipment properties, commissioning, equivalence
- Resilience and IEQ: Responding to climate change and disasters
- Ventilation: Mechanical, passive, natural and hybrid systems
- Air Tightness: Trends, methods and impacts
- Thermal Comfort: Dynamic approaches, health impacts and trends
- Policy and Standards: Trends, impacts, implications

To learn more about next year's conference, please click on the link* view the website's full details as well upcoming updates of the programme and registration. ■

* https://www.aivc.org/event/14-16-september-2020-conference-athens-41st-aivc-ashrae-iaq-joint-conferenceto

CLIMA 2022; pencil it in!
15 – 18 May 2022
Ahoy, Rotterdam, the Netherlands

TVVL will organise the 2022 REHVA Annual Meeting & 14th REHVA World Congress CLIMA 2022 in Rotterdam

After the success of CLIMA 2019 in Bucharest, Romania, TVVL, the Dutch Society for Building Services and Technology, is pleased to announce that in 2022 they will organise the next CLIMA conference and the REHVA Annual Meeting. The agreement between REHVA and TVVL was officially signed on the 24th of March of this year. TVVL is honoured that the REHVA Board granted TVVL the organisation of the World Congress CLIMA 2022. The conference will be organised in collaboration with Delft University of Technology and Eindhoven University of Technology.

The event will take place from 13th till 18th of May 2022 in Rotterdam, the Netherlands. 'Its international appeal, diversity in architecture and the buzzing city centre makes Rotterdam the right choice for hosting CLIMA 2022', according to Atze Boerstra, Congress President for CLIMA 2022. 'What is even better is that the conference will be held in Ahoy Rotterdam, the location of e.g. the annual North Sea Jazz festival and the upcoming Eurovision Song Contest in 2020.'

Jaap Dijkgraaf, chairman TVVL adds: 'We are very excited to host the event in the Netherlands, as this is a great opportunity for TVVL and the entire sector to connect professionals, companies, branch organisations, students, knowledge institutes and governmental organisations. At CLIMA 2022 we hope to inspire and motivate professionals in the field of HVAC from all over the world.'

EYE ON 2030

From now to 2030 the world of HVAC will change radically. Fuelled by irreversible influences, the current demands on climate installations will change completely. 'We focus on four main themes,' says Olaf Oosting, member of the TVVL board. 'These four themes are Energy, Circularity, Digitalization and Health & Comfort. Everybody will agree that these four themes will have a huge impact. But how will they evolve from now till 2030? Which insights will we have with regards to the themes? And how do these themes relate to each other? Will they reinforce or delay each other? And how does the impact of climate installations relate to the building process and other influences? With these questions in mind, CLIMA 2022 will have its EYE ON 2030.'

Please visit www.clima2022.org and check out the first introduction video for CLIMA 2022 in Rotterdam, subscribe to the newsletter!

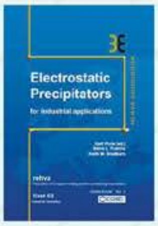
REHVA

Federation of European Heating, Ventilation and Air Conditioning Associations

EUROPEAN GUIDEBOOKS

No.01: DISPLACEMENT VENTILATION IN NON-INDUSTRIAL PREMISES

No.02: VENTILATION EFFECTIVENESS



No.03: ELECTROSTATIC PRECIPITATORS FOR INDUSTRIAL APPLICATIONS

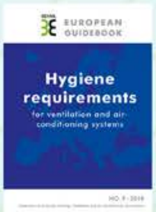
No.04: VENTILATION AND SMOKING

No.05: CHILLED BEAM APPLICATION GUIDEBOOK

No.06: INDOOR CLIMATE AND PRODUCTIVITY IN OFFICES

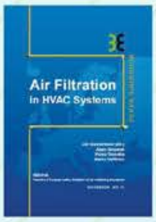
No.07: LOW TEMPERATURE HEATING AND HIGH TEMPERATURE COOLING

No.08: CLEANLINESS OF VENTILATION SYSTEM



No.09: HYGIENE REQUIREMENTS FOR VENTILATION AND AIR-CONDITIONING SYSTEMS

No.10: COMPUTATIONAL FLUID DYNAMICS IN VENTILATION DESIGN



No.11: AIR FILTRATION IN HVAC SYSTEMS

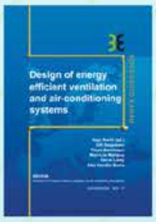
No.12: SOLAR SHADING

No.13: INDOOR ENVIRONMENT AND ENERGY EFFICIENCY IN SCHOOLS - PART 1

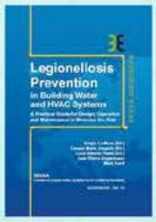
No.14: INDOOR CLIMATE QUALITY ASSESSMENT

No.15: ENERGY EFFICIENT HEATING AND VENTILATION OF LARGE HALLS

No.16: HVAC IN SUSTAINABLE OFFICE BUILDINGS



No.17: DESIGN OF ENERGY EFFICIENT VENTILATION AND AIR-CONDITIONING SYSTEMS



No.18: LEGIONELLOSIS PREVENTION IN BUILDING WATER AND HVAC SYSTEMS

No.19: MIXING VENTILATION

No.20: ADVANCED SYSTEM DESIGN AND OPERATION OF GEOTABS BUILDINGS

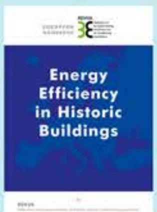
No.21: ACTIVE AND PASSIVE BEAM APPLICATION DESIGN GUIDE

No.22: INTRODUCTION TO BUILDING AUTOMATION, CONTROLS AND TECHNICAL BUILDING MANAGEMENT

No.23: DISPLACEMENT VENTILATION

No.24: FIRE SAFETY IN BUILDINGS

No.25: RESIDENTIAL HEAT RECOVERY VENTILATION



No.26: ENERGY EFFICIENCY IN HISTORIC BUILDINGS

No.27: HVAC COMMISSIONING PROCESS (REHVA-ISHRAE)

No.28: NZEB DESIGN STRATEGIES FOR RESIDENTIAL BUILDINGS IN MEDITERRANEAN REGIONS

No.29: QUALITY MANAGEMENT FOR BUILDINGS