REHVA REPORT

Built environment facing climate change

REHVA Workshops at CLIMA 2019
Bucharest, Romania, 26-29 May 2019

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Federation of European Heating, Ventilation and Air Conditioning Associations

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REHVA, the Federation of European Heating, Ventilation and Air Conditioning Associations represents over 120 000 HVAC experts in 27 European countries. REHVA is the leading professional organization in Europe, dedicated to the improvement of health, comfort and energy efficiency in all buildings and communities www.rehva.eu.

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WS 2: The Power of the Cloud

Workshop organizer:

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Presentations at the Workshop:

The Power of the Cloud

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Introduction and background

The past two decades have seen technology evolve at an astounding rate. Today, the full-scale computers integrate into tiny packages such as smartphones. The cost of computing has also decreased dramatically, laying the groundwork for today's internet of things (IoT). In recent years, the availability of cheap processors has made its mark on the building automation industry; processing capacity now penetrates to the component level. As a result, devices are more capable, and the ease-of-integration simplified. On-board communications are also becoming more standard, paving the way for on-demand, data-driven workflows. Access to the right data facilitates commissioning, operation and maintenance, reporting, and optimization.

The concept of cloud-connected buildings is becoming ubiquitous, particularly in the residential domain. Users interact with building systems using phones and tablets to monitor and change parameters remotely. In contrast, sytem monitoring and tuning are the responsibility of qualified super-users in commercial buildings where comfort and energy requirements are more stringent.

Monitoring in commercial buildings is key to performance optimization. For monitoring purposes, the cloud enables access to computationally intensive reporting and optimization algorithms developed by domain experts. It also provides simple access for authorized personnel and contractors responsible to keep the systems up and running.

The Power of the Cloud workshop focused on the power of cloud at the HVAC component level. The Energy Valve, a component level performance device, was presented to illustrate the benefits of system monitoring and optimization. Furthermore, the presentation demonstrated the benefits of powerless commissioning and showed the potential of augmented reality in future applications.

Summary of the presentations

Actuator Commissioning: Wireless and Powerless with NFC

Today smartphones are ubiquitous, and are perhaps the most recognizable example of wireless communication technologies. They are able to place phone calls, access the internet, and make financial payments. Wireless radios built into the phones enable these functionalities. GSM, Wi-Fi, Bluetooth, and NFC are all wireless technologies used that vary in range and data bandwidth as shown in **Figure 1**.

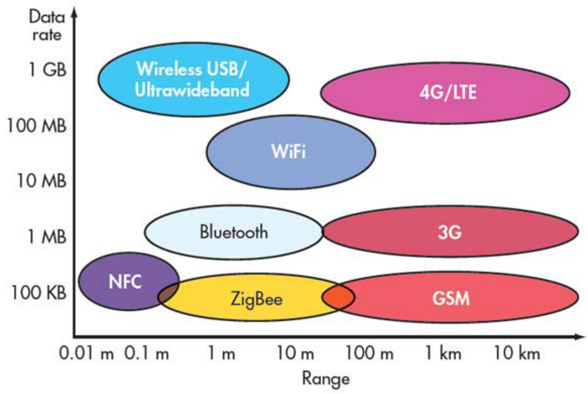

Figure 1. *Breakdown of wireless technologies. [1]*

Of particular interest is near field communication (NFC) which offers a low data transmission rate over a few centimeters. Found on virtually every flagship smartphone, NFC has the special property that it can provide the data and the necessary energy to communicate with a second device over the same interface. This means a smartphone can configure an unpowered actuator equipped with NFC by placing the two in close proximity as shown in **Figure 2**. This is beneficial on many job sites because device configuration may be required before power is available. Belimo products offer this functionality today.

Figure 2. *Smartphone configuring an unpowered Belimo actuator.*

Already a Reality: The Energy Valve Performance Device

Today performance devices already exist (**Figure 3**). The Belimo Energy Valve is capable of monitoring and optimizing energy efficiency thanks to the integrated ultrasonic flow sensor, two temperature sensors, and advanced logic. The flow control will reject any pressure fluctuation. The Delta-T Manager is capable of im-

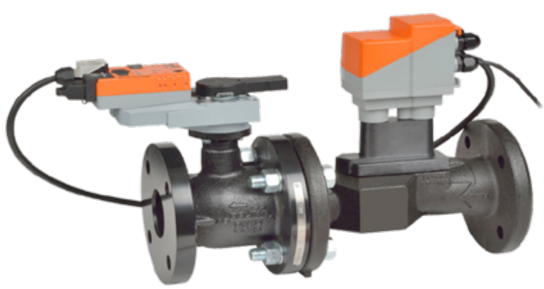

Figure 3. *Belimo Energy Valve performance device.*

proving the system temperature difference over the heat exchanger to combat delta-T degradation, a well-documented problem with many systems. Need to check something? Log on to the integrated web server where the user can set and see relevant configuration and operational information.

The Belimo Cloud, launched in 2017, augments performance devices in several ways. Important building operational data is securely stored and accessible to authorized users through their Belimo Cloud account. The high computing capacity of cloud servers allows complex algorithms to process device information in ways that are more meaningful.

An algorithm automatically generates quarterly reports for multiple devices, bundles them together, and creates an overview as shown in **Figure 4**. Delta-T optimization is supported through the user's Belimo Cloud account with a couple of clicks. The service enables customers to automate optimization without needing to understand the smaller details of a heat exchanger behavior; energy optimization and simplified usage go hand in hand.

Advanced Monitoring and Optimization

Cloud accessible data goes beyond reporting. Applications can use a standardized interface to contextualize data. The Energy Flow Map is a service that allows users to build a custom visualization dashboard. Simply log in, upload a floor plan, and drag-and-drop your Energy Valves to their appropriate locations. The data displayed is configurable as is the optional heatmap whose intensity changes with the amount of transferred heat. Graphs and overviews are also available.

Figure 4. *Bundled quarterly reports with overview.*

An example floor plan is shown in **Figure 5**. While data visualization is not new, its power should not be underestimated. Knowing where and how much energy is delivered is key to understand and optimize building performance. With the Energy Flow Map, it is simple to identify energy hotspots. Issues such as simultaneous heating and cooling are obvious.

An additional opporunity for cloud stored data is the capacity to look for complex patterns. Improving fault detection and diagnostics, an ongoing topic in the research department at Belimo, is one such application. The goal is to provide more context and understanding to warnings and errors detected by sensors. As an example, a performance device controlling heat transfer through a heat exchanger is used. The control valve modulates the valve position to control the fluid flow through the hydraulic circuit. In **Figure 6** we can see the duration of a FlowNotReached flag for a particular device, which clearly exhibits a pattern.

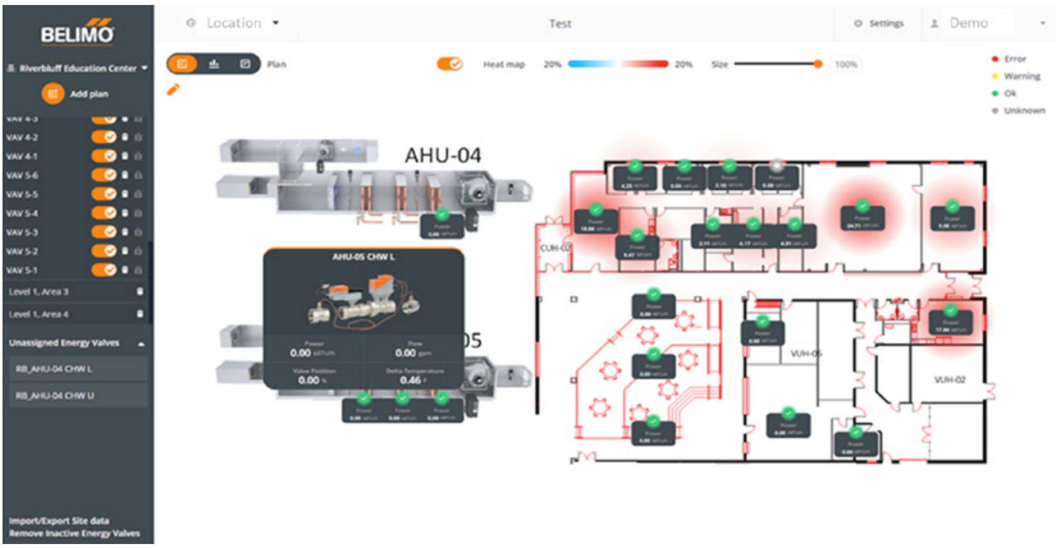

Figure 5. *Cloud connected energy flow map.*

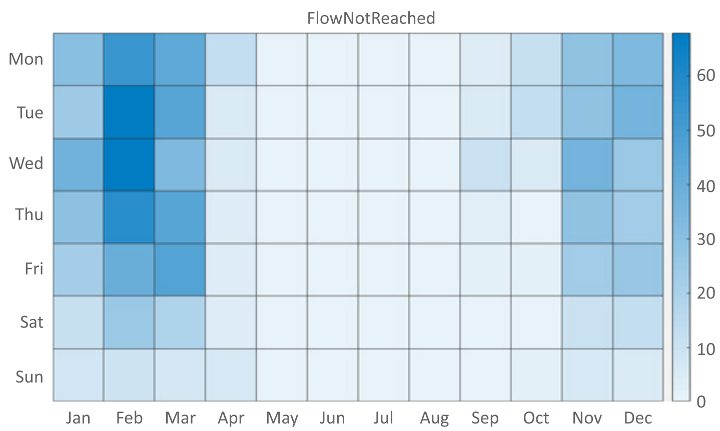

Figure 6. *Example of an Energy Valve FlowNotReached warning pattern.*

The flag indicates when a controller is requesting flow, but the valve opens fully without reaching the desired amount (very likely due to insufficient pressure in the system). Examining the figure conveys that the flag occurs most frequently on weekdays during cooler winter months. Since the valve belongs to a Belimo system, the application is well understood. Indeed, the example is a heating valve belonging to a hydraulic circuit with several other valves in parallel. By combining flags from multiple devices on the same hydraulic circuit, an enriched warning can be generated when multiple devices exhibit the same behavior. This patent-pending idea can be used to reduce the number of warnings from all devices, and provide a more meaningful feedback. Furthermore, the flow measurement signal can be analyzed to infer if there is no flow in the system (pump not working) or simply not enough pressure to provide the requested flow.

IoT: An Augmented Reality

Similar to wireless technologies, most modern smartphones are "augmented-reality-ready". This is due to strong support from Apple and Google who develop mobile operating systems and augmented reality (AR) software libraries. These libraries leverage cameras to build a 3D map of the observed environment that can recognize objects and where they are located. Digital information can then be augmented over the real world environment.

Belimo is researching how AR could be a useful tool for our customers and the building automation industry at large. Looking across our product range, none of our devices has a display (except for room thermostats), even though they contain settings and produce operational information. Augmented reality can bridge the gap. If you can identify a device and its information, AR can replace an integrated display with an average smartphone. AR, in combination with other technologies, recognizes where the device is located through the camera, and can augment the device with its operating information as shown in **Figure 7**.

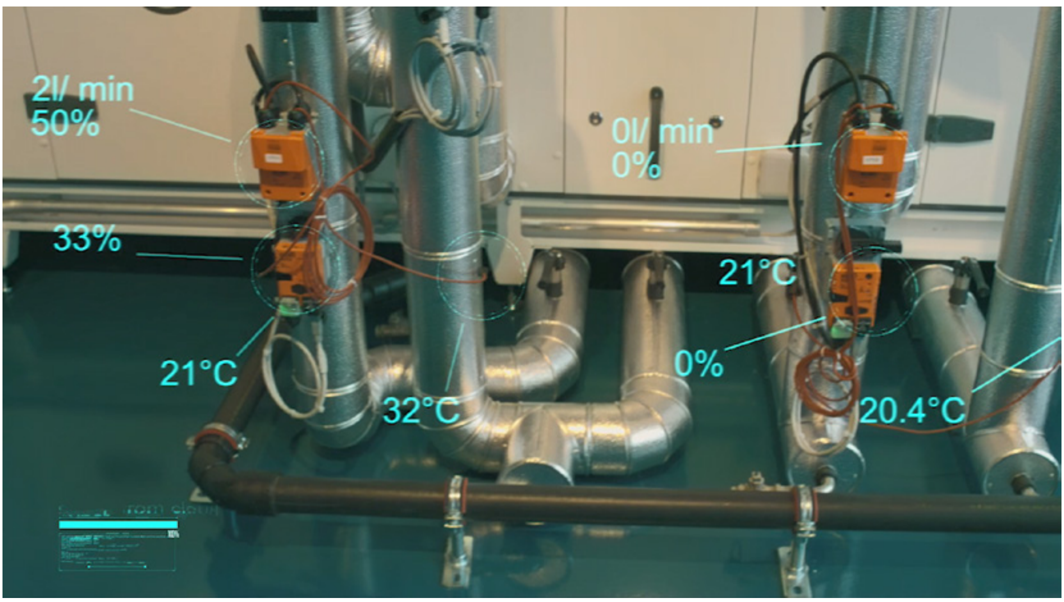

Figure 7. *Illustration of augmenting reality with real time information at the sensor location.*

The smartphone accesses the display information by recognizing a unique device identifier (e.g. QR-Code) and connecting its data, typically stored on the cloud. When data is stored locally on the device, a wireless connection to the device is instantiated.

Discussion and main results

Wireless technologies and the cloud combine to bring many benefits. Powerless commissioning, reporting, and optimization is a reality, while automated FDD and AR are in active research and development.

There is a consensus that warnings and errors are issued too frequently, causing them be perceived as a nuisance and therefore ignored. It is important to find a path forward to expose the most critical failures and identify their root causes. The cloud enables such solutions.

Augmented reality can connect via various wireless technologies and act as a display for devices with no visual feedback. This is a work in progress, but the benefits are clear.

Conclusions and future work directions in the field

Common smartphones are packed with technologies that enable powerful interactions with component level building devices. Near field communication allows a phone to configure and read information from an unpowered actuator; this technology can be found in devices today. Using built-in augmented reality software libraries, phones can replace traditional displays by overlaying information onto the device through the camera. This research paves the way for new and exciting ways to visualize and interact with real-time building information.

Cloud connectivity integration into components and sensors provides the basic elements to meaningful automation. Fault detection, diagnostics and optimization can leverage the computing power of cloud servers. The combination of automation and advanced algorithms to understand building behavior means that building operators will be able to focus on the high-level operational information that matters.

References

[1] Figure 1: https://www.mwrf.com/active-components/nfc-prepares-wide-adoption

WS 4: Why people matter? User stories for designing successful deep renovations and sustainable human-building interactions

Workshop organizers:

Huygen Engineers & Consultants

University of Ljubljana

Chair:

Dr. Simona D'OCA, Huygens Engineers & Consultants, The Netherlands, s.doca@huygen.net

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Dr. Dan Podjed, University of Ljubljana, Slovenia, dan.podjed@iri.uni-lj.si

Presentations at the Workshop:

1. ***TripleA-reno Customer Journey***
   Dr. Simona D'OCA, Huygens Engineers & Consultants, The Netherlands
2. ***MOBISTYLE user centric approach***
   Ana Tisov, Huygens Engineers & Consultants, The Netherlands
3. ***We Don't Need Another Hero! Really?***
   Dr. Dan Podjed, Institute for Innovation and Development of University of Ljubljana, Slovenia

Introduction and background

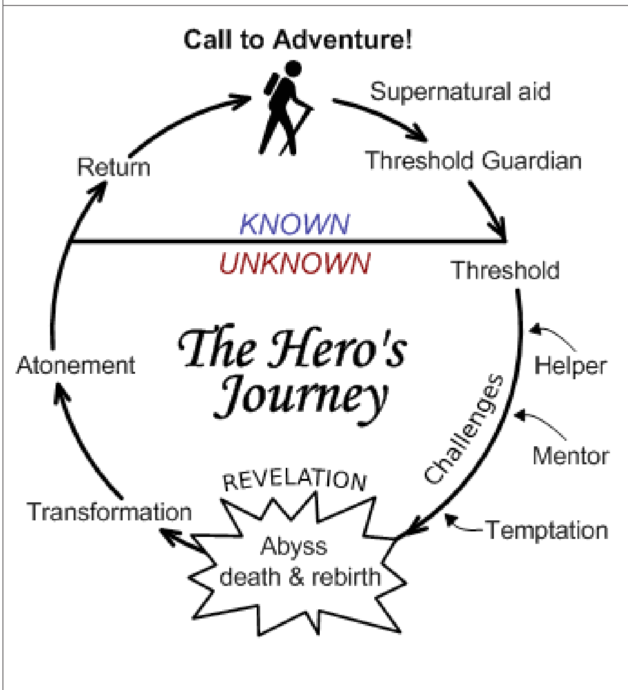
H2020 MOBISTYLE and TripleA-reno Projects are adopting a people-centred approach to reduce final energy usage in the EU building stock, thus going beyond the limited focus on technology-driven solutions alone. This approach is supporting the upcoming perception within the field of energy and buildings that people (and not buildings!) consume energy – including the important effect of the behaviour of people living or working in buildings together with the values, habits and motivation factors connected to energy usage. In a broader perspective, the *human factors* responsible for the success of reduced energy consumption, enhanced building performance and user comfort and health, must be taken into consideration.

During this 1 ½ hour workshop we discussed the TripleA-reno approach to make renovation more affordable and attractive and brainstorm on the way how we engage people (users, stakeholders, designers, engineers, etc.) involved in renovation processes through gamification features. In a dynamic interaction with the audience, the workshop will explore how acceptance, usability and co-design of advanced retrofit solutions can be improved by leveraging on anthropology, social psychology, and cost-benefit research approaches. Additionally, learning

from the experience gathered in the MOBISTYLE project, the workshop engaged participants to reflect on how people-centred approaches have been implemented to support development of user friendly ICT solutions (game, dashboard) raising occupants awareness and informing them on how to reduce energy consumption, as well as improve occupants' comfort, health and wellbeing in residential and commercial buildings, from the building to the city scale.

Summary of the presentations

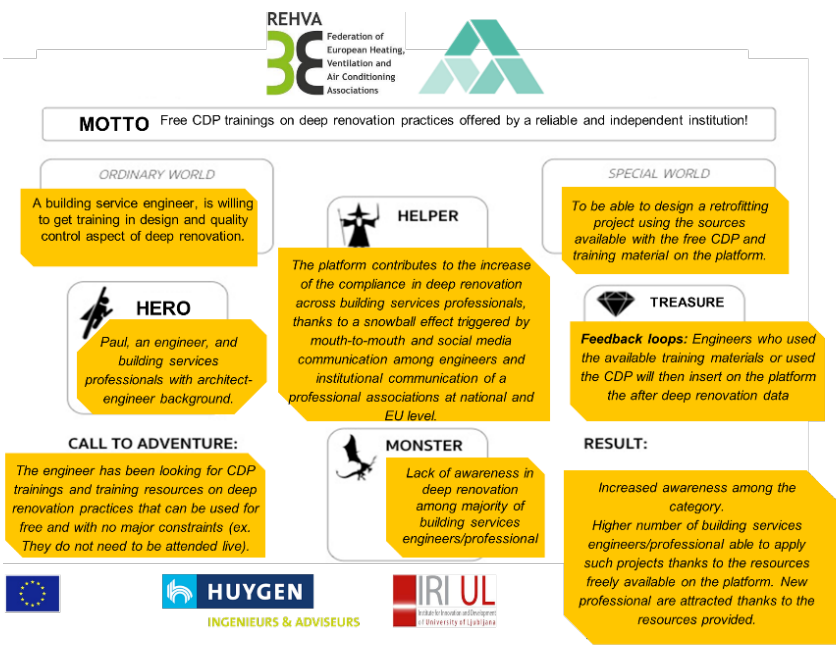
The opening presentation analyzed the characteristics of heroes and their role in initiation and support of broader social actions and activities. It attempted to describe (by examples of historical figures) why people were fascinated by some individuals (who were not necessarily formal leaders), why they followed their ideas and what were the underlying reasons for their appeal. Three main phases of the hero's journey were presented: 1. departure (separation), 2. initiation, 3. return.



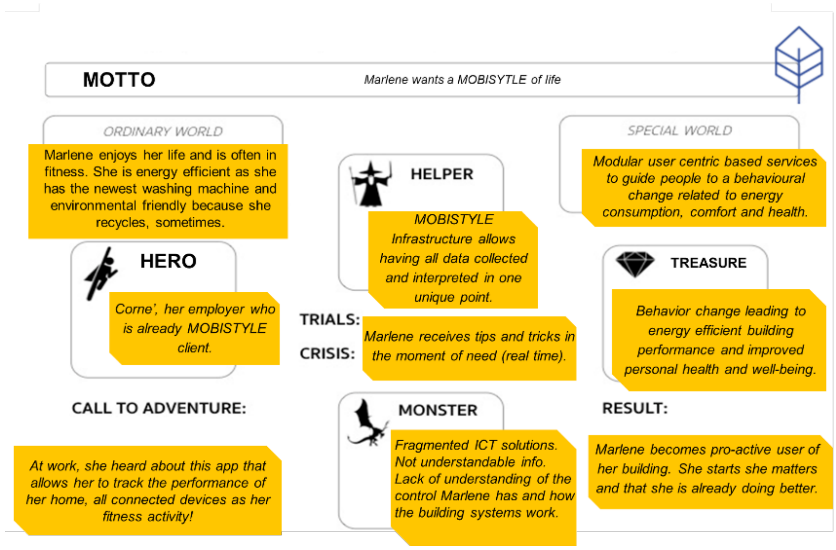
A storytelling approach is adopted to recollect the "hero" customer journey in deep renovation. These represent the perspective of different stakeholders. The final objective is to provide a clearer understanding of what solutions and services to be exploited trough a platform-based service.

The hero journey is the path suppliers and users follow in discovering, using and reviewing the TripleA-reno platform and the MOBISTYLE solutions. Focusing on the user journey helps to frame the experience of using the TripleA-reno platform and MOBISTYLE ICT solutions for the different stakeholders involved.

By asking the workshop participants to tell us their stories, we aim at elaborating directives and practical insights to support the TripleA-reno and MOBISTYLE project exploitation plans.



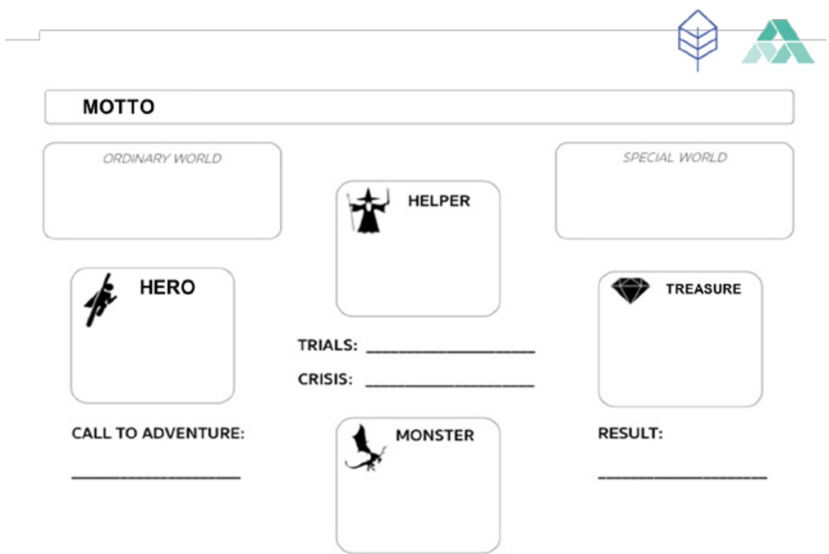
An example of the storytelling canvas for the usage of the TripleA-reno platform has been provided, i.e. by focusing on the experience of a REHVA member, a building service engineer, willing to get training in design and quality control aspect of deep renovation.



An example of the storytelling canvas for the usage of the MOBISTYLE system has been provided, i.e. by focusing on the experience of one of the MOBISTYLE users in the Netherlands getting a personalized combined information on building, home appliances, indoor climate performance through a single application.

Discussion and main results

This workshop delivered storyboards, based on the "hero's journey" approach, developed by the participants. Storyboards are concise narrative descriptions of one or more people using a product or service (the TripleA-reno gamified platform for deep renovation, the MOBISTYLE ICT tools) designed on the basis specific user needs, requirements, and expectations. These storyboards have the objective to put focus on people (users) rather than



solely on technology or business goals. The story boards filled in by the workshop participants explain how people think and behave in different contexts and how they make decisions, i.e. for initiating a home renovation or interacting with the building controls. These derived value propositions are presented as easy-to-understand and intuitive reasons why a customer should purchase / use the TripleA-reno and MOBISTYLE products and services.

The following storyboards have been collected from the workshop participants

Story 1 – Motto: Stimulate social housing tenants to use the systems control in a right way

Carl is very proud to live in an nZEB social house, but, as many times it happens to people who live in modern building, he doesn't know how to best use his dwelling, and which is the impact of his habits on energy use. Tired of this situation, Carl decided to improve his knowledge

With the help of some measure tools can be detected that tenants are not using their dwelling as designed. For this reason, it's very important to dispose of tools that provide feedbacks to occupants about their energy use or wastes. For example, info sessions on systems could be carried out to struggle the lack of knowledge of tenants. In fact, many times they have wrong habits because they didn't know how to manage their dwelling, or they think to do it well. With these tools, tenants would know how the system works and they could be proud of their building. A greater awareness of the place they are live in, would lead the occupants to have the control of their dwelling and to have a healthier environment. Consequently, this allow energy cost saving and happier tenants.

Story 2

Alice is working in a new office in a building owned by the municipality. She and her colleagues share an open-space office in which they don't feel comfortable sometimes. Also, they can interact with systems for improving thermal conditions. The energy manager hired by the municipality assessed energy consumptions, which are very high, related to a high cost for the municipality. Also, a new analytical tool makes evidence about the role of people on energy management of buildings. The energy manager told to Alice and the others that they are consuming too much and he wants to manage this issue on behalf of the municipality, keeping people in the comfort. To achieve this purpose, it's important having good knowledge of building behaviour and people habits in it.

Story 3 – Motto: Make our garbage clean again (Dan Podjed)

A Slovenian family with three sons lives in a multi-apartment building. This family is in contrast with the neighbourhood because they don't keep the common space clean and someone neither make separate waste collection. One day children made an excursion to the landfill of Ljubljana and they understood how important is recycling to have a cleaner and healthier environment. When they come home, they knew that the municipality fine the family for not having recycling properly. Therefore, children decided to start cleaning the garbage and to motivate neighbours to do the same thing. It was very difficult because there was pile of trash in front of their home and the neighbours didn't collaborate with them. But thanks to the help of a neighbour next door from Latvia, the three children managed to make their dwelling clean and to keep it healthier. In this story, trash is compared to energy. In fact,

many people don't care about energy wastage and make a bad use of it. But if they were more aware of the consequences of their habits, people would change their way of acting.

Story 4 – A new concept of comfort temperature (Loes Visser)

The common conception of indoor thermal comfort is 21°C, as suggested by Fanger theory. But thanks to researchers, it could be possible to have a healthier life through temperature training. It would allow a better vascular system flow and metabolism, but there are many impediments for his application. In fact, standards in build environment is very stringent and they're still focused on having a constant indoor temperature. Changing this concept is one of the main goals of Mobistyle platform, which could be useful to realize how dynamic indoor temperatures would lead to a healthier environment without major renovation.

Story 5 – I'm trapped as a captive energy user and I want freedom (Cerna Mladim)

Some people want to be able to control the IAQ parameters in their homes and to keep monitored their energy consumptions. For this purpose, energy audit can be used to give occupants the perception of how and how much their home consumes. It's also important to make this information the more accessible to the occupants, thanks to many dissemination tools (online or printed), and to make them able to understand the results. For making this process simpler, there are platforms which gave information tailored for user's benefits. Despite this, sometimes people are disoriented because energy suppliers are not interested in saving, so people must provide by themselves. But using helping tools, people could control their environment, have a healthier life, and have less energy costs.

Story 6 – Motto: One flat, different needs (Giulia Marenghi)

Margot and Clara are housemates and they share an old apartment with a bad IEQ (indoor environmental quality), so they thought that it should be renovated, but the landlord is not interested to solve this. To convince him, they tried to explain which changes are necessary, and the possible pros that the renovation could bring to his apartment, as first the added value on the building market. But the landlord is elderly, and he is not aware of renovation benefits. Luckily, Margot and Clara discovered the Triple-A Reno platform, which allows them to show to the landlord how renovation improves the value of the property and which benefits he could get as an owner. Thanks to this important tool, the apartment has been renovated and Margot and Clara live in a more comfortable and energy efficient apartment now.

Story 7 – Motto: Feeling at home and feeling green (Lucile Sarran)

John lives in a low energy home with his family. He loves his home because it's very comfortable, but he also knows that some of his habits are not very correct; for this reason, he wants to change the behaviour of his family for getting more environmentally friendly. In the beginning, John was very disoriented and started talking with his friends and to look for some information on the internet to inquire, until he hears about an interesting platform. He read some information about that and discovered that this platform informs about how to best operate HVAC systems in a very non-invasive way. He was impressed by this function, so he decided to try it. There were some difficulties, such as how to find information to be a virtuous user, but he had also some doubts because he has entrusted the comfort of the family to the platform. But after some time, he realized that thanks to the platform his

home is as comfortable and cosy as before, but it has become more energy efficient now. In fact, thanks to the platform John's family was able to fully understand the functioning of the systems in their house and, at the same time, systems have adapted their functionality on occupant's habits. At least, the platform allowed to have a house with better energy performance but also happier and improved occupants.

Story 8 – Motto: A helping platform when you're not in the field (Kyriaki Foteinaki)

George wants to improve RH levels in his home, but he needs help because he is quite inexperienced in this sector. Searching on the internet, he found a platform where he can insert some information about his dwelling, and it can advise him. Despite this, he had some problems in choosing the best option for him: in fact, he found many suggestions on the platform and he doesn't know which is the most value-for-money one. Anyway, George was able to understand which kind of renovation was the best for his needs, because the platform has many solutions classified according to budget and efficiency results. He has chosen a cost-effective targeted renovation or investment in new technology.

Story 9 – Motto: Reducing noise level in a flat (Valentin-Veron Toma)

Valentin's flat has been recently renovated in order to improve energy consumption and thermal comfort by using ETICS materials. But, as a result, the level of noise coming from the neighbours has increased. Discovering that a side effect of thermal insulation became a big problem for him, Valentin took the initiative to look for solutions not only for his flat, but for all the apartments in his condominium.

Valentin found some technicians from the Faculty of Installation's Engineering, who were interested to help him finding modern solutions to the indoor acoustic pollution caused by ETICS-based thermal insulation. Finding a solution was not easy, because of the lack of research on this topic in Romania, also the sparse evidence in international literature and the lack of practical solutions to implement. However, the team tried to use ICT-based solutions and new renovation materials for the acoustic insulation. Consequently, they achieved more acoustic comfort and higher level of well-being in order buildings such as those Valentin live in.

Conclusions and future work directions in the field

- A need for heroes and heroism still exists in the digital ("post-heroic") era.
- People like and respect role-models and trust individuals who were able to see the "abyss" of renovation and were able to return from the "hero's journey" of deep renovation.
- Hero's journey can be a path to designing people-centred and long-lasting solutions.
- The model, presented in the workshop, can be used for designing both digital and analogue solutions for supporting deep renovation.
- Examples from the workshop show that participants were able to efficiently and quickly utilise the storyboard canvass, visualise their personal situations in a clear and understandable way, and present it to workshop organisers and other participants.

Acknowledgement

We'd like to thank Giulia Marenghi and whole the REHVA staff for the support provided to the joint workshop organization.

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WS 5: Supporting dissemination and roll-out of the set of energy performance of building (EPB) standards

Workshop organizers:

EPB CENTER & REHVA & European Partnership for Energy and the Environment (EPEE) & European Ventilation Industry Association (EVIA)

Chair:

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Co-Chair:

Dick van Dijk, Senior Expert EPB Center, dick.vandijk@epb.center

Presentations at the Workshop:

1. ***The promising prospect of EPB standards and the revised EPBD***
   Pau Garcia Audi, European Commission, Pau.GARCIA-AUDI@ec.europa.eu
2. ***Introduction to the roll-out of the set of EPB standards***
   Jaap Hogeling, EPB Center, jaap.hogeling@epb.center
3. ***The national implementation process of the EPB standards in Romania***
   Iuliana Chilea, Director General, ASRO, Romania, iuliana.chilea@asro.ro
4. ***EN ISO 52016-1 Energy need calculation (heating/cooling) and calculation of indoor temperatures: hourly or monthly?***
   Dick van Dijk, Senior expert, EPB Center, dick.vandijk@epb.center
5. ***EN 16798-5-13 How to use the set of ventilation and cooling standards? Coordination issues with heat pump calculation (EN 15316-4-2)***
   Gerhard Zweifel Senior Expert, Consultant, Switzerland, gerhard.zweifel@hslu.ch
6. ***Synergies with linked EU projects: CEN-CE & ALDREN***
   Johann Zirngibl, CSTB, ALDREN & CEN-CE coordinator, johannzirngibl@aol.com
7. ***EPB Standards Community facilitated by REHVA***
   Andrei Vladimir Litiu, REHVA, avl@rehva.eu
8. ***Benefits and challenges of the roll-out of EPB standards. Industry perspective***
   Andrea Voigt, EPEE, a.voigt@epeeglobal.org
9. ***Ventilation related EPB standards and their contribution to deliver high IEQ***
   Claus Händel, EVIA, claus.haendel@evia.eu

Introduction and background

EU Member states are required to transpose and implement the Energy Performance of Buildings (EPB) policy in their country. Moreover, they are expected to use the EPB standards and report back to the European Commission (i.e. the revised EPBD requires Member States to fill in a few specific templates).

The EPB Center (www.epb.center) has been set up to support EU Member States with the uptake of the (CEN and CEN ISO) EPB standards, by providing tailored information, technical assistance and capacity building services for involved stakeholders.

The set of EPB standards, published in 2017, provide EU Member States a toolbox to help the implementation of the Directive and furthermore aim at higher transparency regarding the energy performance calculation methodologies. Each EPB standard has a template for a National Annex that enables Member States to tailor the methodology to the national situation and needs.

The main scope of this workshop is to inform and ask feedback on the implementation of EPB policy at national level. The organizers endeavour to help participants with the requirement of filling in the templates required by the revised EPBD. Additionally, they shall provide information and interact with participants for collecting feedback from professionals involved or interested in the EPB assessment and implementation.

Summary of the presentations

Mr Garcia Audi, Policy Officer at DG ENER, European Commission, highlights the promising prospect of EPB standards and the revised EPBD. He presents an overview of the new developments in the EU regulations related to energy efficiency and highlighted the main outcomes of the 2018 revision of the EPBD, such as a stronger role for long term renovation strategies, enhanced transparency of national building energy performance calculation methodologies, reinforcement of building automation and the introduction of a Smart Readiness Indicator for buildings.

The new obligation (EPBD Annex i) for Member States to describe their national calculation methodology following the National Annexes of the 'overarching' EPB standards (EN ISO 52000-1, 52003-1, 52010-1, 52016-1, 52018-1) aims to improve transparency and comparability. Mr Garcia Audi emphasizes, however, that this does not constitute an obligation on MS to adopt the EPB standards.

Also new in the revised EPBD is for instance the requirement to express the energy performance as primary energy use (kWh/m².y),–again- aiming to improve transparency, without interfering with the national competence to define primary energy factors.

The revised EPBD puts more emphasis on the need to ensure thermal comfort, indoor air quality and health conditions, including how these should be taken into account in the calculation of energy performance.

The presentation is concluded with an overview of a number of studies and contracts aiming to provide technical input as guidance for effective implementation of specific EPBD elements. For example, on the Smart Readiness Indicator and on the support to the use of the EPB standards.

With regards to the latter, Mr Garcia Audi calls all stakeholders to contact the EPB Center (www.epb.center) for any question related to the EPB standards, because a consortium, led by Mr Jaap Hogeling and centered around the EPB Center, has been contracted by DG ENER to provide answers and to prepare guidance and tools.

In his presentation, **Mr Jaap Hogeling**, director of the EPB Center, introduces the details of the three year Service

Contract with DG ENER: "Support the dissemination and roll-out of the set of Energy Performance of Buildings standards developed under Mandate M/480". Mr Hogeling explains the background and current status of the set of about 50 international (CEN and partly ISO) EPB standards. In particular he explains how each EPB standard can be tuned to fit to the national situation by making use of the specific choices offered

in 'Annex A' of each EPB standard; such choices are recorded in a 'National Annex' or 'National Datasheet' to that EPB standard.

Under this contract the EPB Center will provide support with filling in the National Annexes of the EPB standards, information about the set-up /structure and use of the EPB standards, FAQ on key issues, calculation tools and case studies for individual standards and practical examples tailored to the needs of different stakeholders.

The EPB Center also aims to provide a practitioners platform to share knowledge and support the ambitious uptake of the EPB standards.

Mrs Iuliana Chilea, Director General of ASRO, the national standards body of Romania, presents the national implementation process of the EPB standards in Romania. All published standards and standardization documents have been adopted as national standards by publication of the Romanian version. However, as also mentioned by Mr Hogeling, Mrs Chilea stresses that national annexes are to be produced, to make the standards applicable to the national situation. This requires e.g. acquisition of climatic data (which she fears is very costly), processing of these data, research activities and drafting of the annexes.

Four EPB standards have been selected, to start with. The current situation is that discussions are taking place with the competent authority (MRDPA) on the development of the first national annexes and a document "Methodology for the assessment of energy performance of buildings" is in preparation (MRDPA contract) and includes references to EPB standards. The application and use of EPB standards will be mandatory in Romania. Romania participates in the H2020 project U-CERT ("Towards a new generation of User centred Energy Performance Assessment and Certification; facilitated and empowered by the EPB Center"), starting in September 2019. Mrs Chilea expects that this project will assist and facilitate the development of the national annexes.

Mr Dick van Dijk, senior expert at the EPB Center, presents the main features of EN ISO 52016-1, the EPB standard to calculate the energy needs for heating and cooling and indoor temperatures. One of the key assets of this standard is that it comprises, side by side, both an hourly and a monthly calculation method. This enables countries to choose between these two. Mr van Dijk emphasizes that in this new standard the hourly method has been significantly improved compared to its predecessor, the widely used EN ISO 13790 from 2008, while at the same time it has been ensured that the number of input data to be supplied by the user for the hourly calculation method are kept the same as for the monthly method.

This makes it easy for a country to switch from the (often traditionally used) monthly method to the more powerful and realistic hourly calculation method.

In the past, the high heat losses dominated the thermal balance. In those days, the monthly calculation method was able to provide sufficiently accurate, transparent and robust results, by the use of one or two correction factors to deal with the dynamic fluctuations of heat losses and gains. Nowadays (for new buildings or major renovation) the heat losses are low and no longer dominating: the thermal balance has become much more dynamic over the

day and week. Under these conditions it is very difficult to find proper and robust correction factors for the monthly calculation method to deal with all kinds of dynamic effects (from e.g. solar blinds, ventilation, heat accumulation and systems). Ergo: the monthly calculation method becomes less accurate, less transparent and less robust.

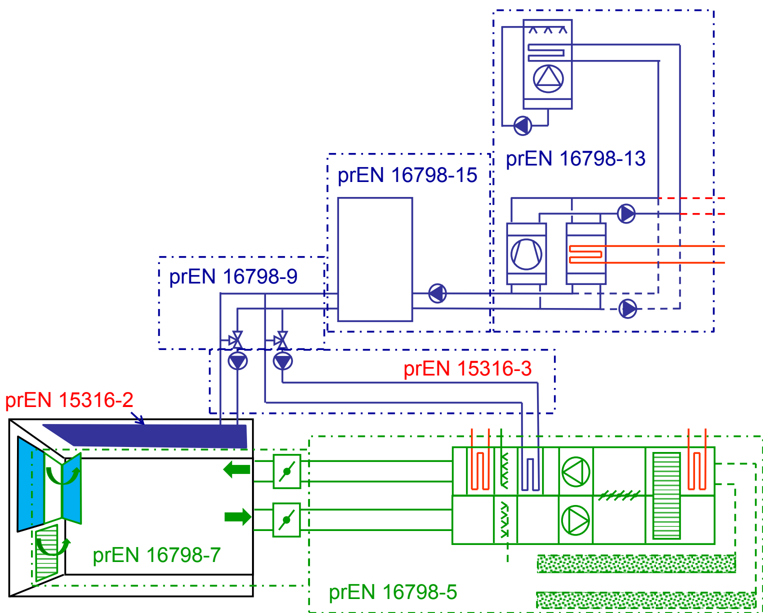
Van Dijk concludes that the hourly method in EN ISO 52016-1 is transparent, robust and reproducible (thus: fit for use in context of building regulations), is tailored to the goal and can be used to validate or find the limits of a monthly method. Moreover, it provides a bridge to interactive system performance calculation (using the "system specific calculation mode") via exchanging input and output to/from system standards on hourly basis.

An important aspect, regarding the revised EPBD, is that only with the hourly method it is possible to obtain a realistic indication of the impact of the 'smartness' of a building and on the indoor environment and thermal comfort conditions.

The monthly and hourly method are demonstrated side-by-side in a spreadsheet on EN ISO 52016-1. An updated version will soon be available at the EPB Center website.

Prof Gerhard Zweifel, Senior Expert at the EPB Center, introduces the subset of EPB standards dealing with ventilation and cooling: the elements covered by each of the standards and how these interrelate. He emphasizes the fact that system calculations become simpler when using an hourly calculation interval. Prof Zweifel also introduces the spreadsheets that have been developed in parallel with these standards to validate and demonstrate the calculation procedures and the input/output relations. These spreadsheets can be found at the EPB Center website. The spreadsheet on EN 16798-5-1 has been updated and will be made publicly available via the EPB Center website at short notice.

He continues with explaining some coordination issues related to the cooling and heating generation standards. Specifically, there is a need for further harmonization between EN 16798-13 (chillers) and EN 15316-4-2 (heat pumps) and clarification. A CEN ad hoc group has been established to deal with these issues. The EPB Center aims to facilitate this activity and to keep you up-to-date on the progress.



Mr Johann Zirngibl, CSTB, introduces two EU Horizon 2020 projects that are related (complementary) to the activities of the EPB Center: the CEN-CE and ALDREN projects. Both EU projects aim to facilitate transposition of revised EPBD.

Mr Zirngibl stresses that only a common European transposition will allow to be able to work on the" other side of the border", to have a "level playing field" (fair competition) for products and to get common databases / common information.

He uses as example the primary energy use as performance indicator required by the EPBD: due to national differences there is no comparability other than the name of the indicator. **ALDREN**'s main indicator will be based on a common definition and common calculation procedures, using the EPB standards. Another issue addressed by ALDREN is the need to link energy renovation to economic interests, such as improved health & well-being and improved productivity.

The **CEN-CE project** aims at an EU-wide qualification and training scheme for 'CEN standard Certified Experts' based on the EPBD mandated CEN standards, with the focus on the heating, economy and overarching EPB standards. Mr Zirngibl explains why it is important to have a training at European level.

The transposition of the revised EPBD offers the possibility for common implementation, considering technical progress and new challenges" instead of 34 national/regional different methods".

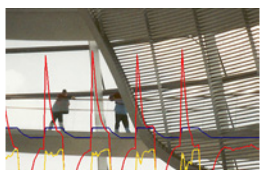
The CEN-CE and ALDREN projects are a step forward towards a common European method based on the EPB standards. With regard to this, Mr Zirngibl points to the early feedback received from Member States that a common European tool (software; now missing) could play an important role to facilitate the use of CEN standards and common transposition.

Mr Andrei Vladimir Litiu, REHVA, introduces the EPB Standards Community facilitated by REHVA and EPB Center and encourages all interested persons:

…to join the LinkedIn EPB Standards community:
https://www.linkedin.com/groups/13619324

BUILD UP
The European Portal For Energy Efficiency In Buildings

…to visit the BUILD UP topic Energy performance calculation procedures and CEN standards:



http://www.buildup.eu/en/topics/energy-performance-calculation-procedures-and-cen-standards

…and to share and connect others to the EPB standards community and remember to use the hashtag: #EPBstandards

Mrs Andrea Voigt, EPEE, the European Partnership for Energy and the Environment, adds the industry perspective regarding the benefits and challenges of the roll-out of EPB standards.

Mrs Voigt claims that the EU has put in place a robust framework, but there is a lack of implementation at national level. EPEE recommends 5 priorities for implementation at Member State level to unlock the potential of heating and cooling systems:

- Include inspection programmes in national renovation strategies and encourage follow up on inspection reports;
- ensure that BACS fulfill certain quality criteria and use EN 15232-1 to support implementation;
- use the set of CEN EPB standards;
- take into account part load conditions when inspecting, selecting and installing HVACR systems;
- use harmonized definition for high efficiency alternative systems, aligned with Ecodesign / Energy Labelling, and apply monitoring and control systems.

Mr Claus Händel, EVIA, the European Ventilation Industry Association, focuses on the ventilation related EPB standards and their contribution to deliver high indoor environmental quality (IEQ).

Mr Händel lists the various articles of the revised EPBD that address the issue of healthy indoor climate conditions, indoor air quality and comfort levels. He stresses that energy performance without definition of the indoor environmental quality (IEQ) makes no sense. Nevertheless, many EU Member States have no requirements on thermal comfort or indoor air quality (IAQ) for new buildings and no indicator for IAQ in the building EP Certificates.

He explains that IEQ requirements are provided in the EPB standards EN 16798-1 and EN 16798-3 and their accompanying technical reports. It is essential to know which indoor environment quality level you may expect with the assessed or expected energy performance level. Mr Händel continues with the presentation of some details of the common IEQ classification in EN 16798-1 (but with criteria for each level that are specified at national level), and some details of the classification of ventilation system design (in relation to outdoor air classes) for IAQ in EN 16798-3.

He concludes with a number of challenges for these two standards, such as the dual use for design and for energy performance calculation, the implementation of the revised EPBD, do the options for national choices fit to national legislation and to the requirements of the involved parties.

Discussion and main results

The presentations and discussions at the workshop were of interest for all sectors involved or interested in the EPB assessment and implementation: Member States, National Standardization Bodies (NSB), building professionals and students, industry and finance stakeholders.

The subjects covered a wide range of topics: implementing the set of EPB standards at national level, using the EPB standards in practice, conducting calculations for energy audits and energy performance certificates of buildings and building performance research.

The topics were presented and discussed from different perspectives covering the European Commission, EPB standard developers, national policy and implementation, industry and implementation support projects.

During the discussion specific technical details were discussed, e.g. on the primary energy factors and definitions of on-site and nearby in the EPBD and in the overarching EPB standard EN ISO 52000-1. Related to the implementation of an hourly calculation method, the JRC website was mentioned, hourly climatic data files for any location in Europe can be downloaded freely. These data files will be connected to the spreadsheet of the relevant EPB standard, EN ISO 52010-1.

A comment was made that more transparency on the national EPB calculation methods is a good first step, but that there is an urgent need for ensuring the quality of national calculation methods to ensure that the promised results will be reached and to raise confidence by the end-users. This triggered a discussion on the affordability of the method, the quality and availability of input data and the need for (national) guidelines on how to assess the input values.

Conclusions and future work directions in the field

The need and potential of the set of EPB standards to bring the EPB assessment methods in Europe to a higher level of transparency and quality and to create a level playing field was widely recognized.

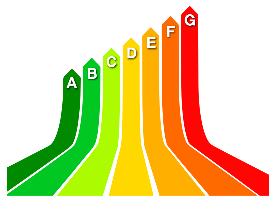
The European Commission issued a 3-year Service Contract to enable the EPB Center to provide:

- Support with filling in the National Annexes of the key EPB standards (including examples and FAQ);
- Information about the use of the EPB standards (including FAQs, tools and case studies on individual standards);
- Information on the set-up /structure of the EPB standards;
- Practitioners platform to share knowledge and support the ambitious uptake of standards.

It was concluded, and underlined by the many questions raised during the Q&A sessions that this technical support is very important and urgently needed.

In addition, it was recommended that options should be explored to come to an overall software tool to facilitate the use of CEN standards and common transposition.

A red thread through the presentations was the increased importance of the indoor environment quality. The revised EPBD provides the necessary framework and the set of EPB standards provide the tools (in the form of hourly calculation procedures and common classification). Now the Member States are requested to take the IEQ (more) seriously in their regulations.



Acknowledgement

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The sole responsibility for the content of the workshop and this report lies with the authors. It does not necessarily reflect the opinion of the European Commission.

References

All information, questions, tools, etc. on the set of EPB standards can be found at the website of the EPB Center: www.epb.center.

Development of specific instruments, specifically for deep renovation, based on the European Common Voluntary Certification Scheme for non-residential buildings (EVCS) is dealt with in the EU Horizon 2020 project ALDREN: www.aldren.eu.

EU-wide common large-scale training and qualification scheme for building professionals is being developed in the EU Horizon 2020 project CEN-CE: www.cen-ce.eu.

WS 8: REHVA-SHASE workshop on NZEB and ZEB Ready concepts in Europe and Japan

Workshop organizers:

REHVA & SHASE

REHVA
Federation of European Heating, Ventilation and Air Conditioning Associations

公益社団法人空気調和・衛生工学会
The Society of Heating,Air-Conditioning and Sanitary Engineers of Japan

Chair:

Jarek Kurnitski, Tallinn University of Technology, jarek.kurnitski@taltech.ee

Co-Chairs:

Gyuyoung Yoon, Nagoya City University, yoon@sda.nagoya-cu.ac.jp

Presentations at the Workshop:

1. ZEB current activities in Japan
Masaya Okumiya, Nagoya City University, Japan, okumiya@davinci.nuac.nagoya-u.ac.jp

2. ZEB best practices in Japan
HisaTaka Kitora, THE KANSAI ELECTRIC POWER CO, Japan, kitora.hisataka@a5.kepco.co.jp

3. NZEB best practices and European energy performance scale
Martin Thalfeldt, Tallinn University of Technology, Estonia, martin.thalfeldt@taltech.ee

4. Japanese energy assessment procedure and performance levels
Gyuyoung Yoon, Nagoya City University, Japan, yoon@sda.nagoya-cu.ac.jp

5. Comparison of energy performance requirements for Japanese and European office buildings
Jarek Kurnitski, Tallinn University of Technology, Estonia, jarek.kurnitski@taltech.ee

Introduction and background

Recent developments of nearly zero and zero energy requirements in EU and Japan were discussed and possibilities to benchmark European NZEB and Japanese ZEB Ready performance levels were analysed. A refence office building was used to simulate energy use in Oceanic and North European and Japanese Sapporo climate. When moving from one to another climate building envelope U-values were adjusted according to economic insulation thickness approach, and national input data and calculation rules were applied. The aim was to show how energy performance requirements are set and how these can be compared so that climatic differences, national input data and calculation rules are considered. The proposed methodology enables to benchmark energy performance requirements of these countries. More widely the results contribute to the development of a common energy performance scale applicable for European energy performance certificate enabling also global benchmarking of non-residential buildings.

Summary of the presentations

Masaya Okumiya introduced ZEB activities in Japan. In Japan, ZEB means net zero energy building that is more ambitious and longer-term target than European nearly zero energy building NZEB. It is planned to realize ZEB for all newly built buildings by 2030, and for that purpose high performance energy efficiency and renewable energy technologies should be used, see some examples in **Figure 1**.

Gyuyoung Yoon introduced Japanese energy assessment procedure and performance levels. Energy performance requirements in Japan are based on BEI indicator, which is the ratio of design and standard value representing so-called reference-building method. BEI = 1.0 is the minimum requirement and BEI = 0.5 is set for ZEB Ready with the aim to reduce primary energy by 50% compared to the present energy requirement, **Figure 2**.

Hisataka Kitora reported a case study building, Minami-Osaka Sales Office of The Kansai Electric Power Company, which is middle-size ZEB Office (8 floors, about 7 300 m², built 2014) with Optimal Control for Multi-split Type Air-conditioning System, **Figure 3**.

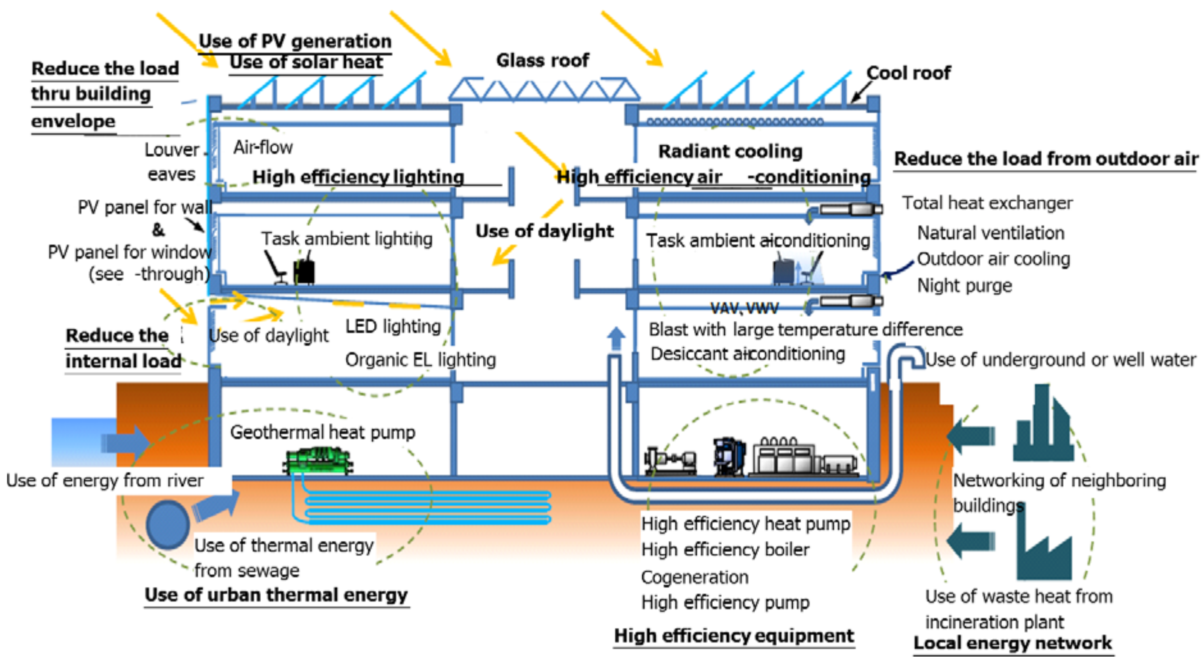


Figure 1. *Examples of technologies to be used in Japanese ZEB.*

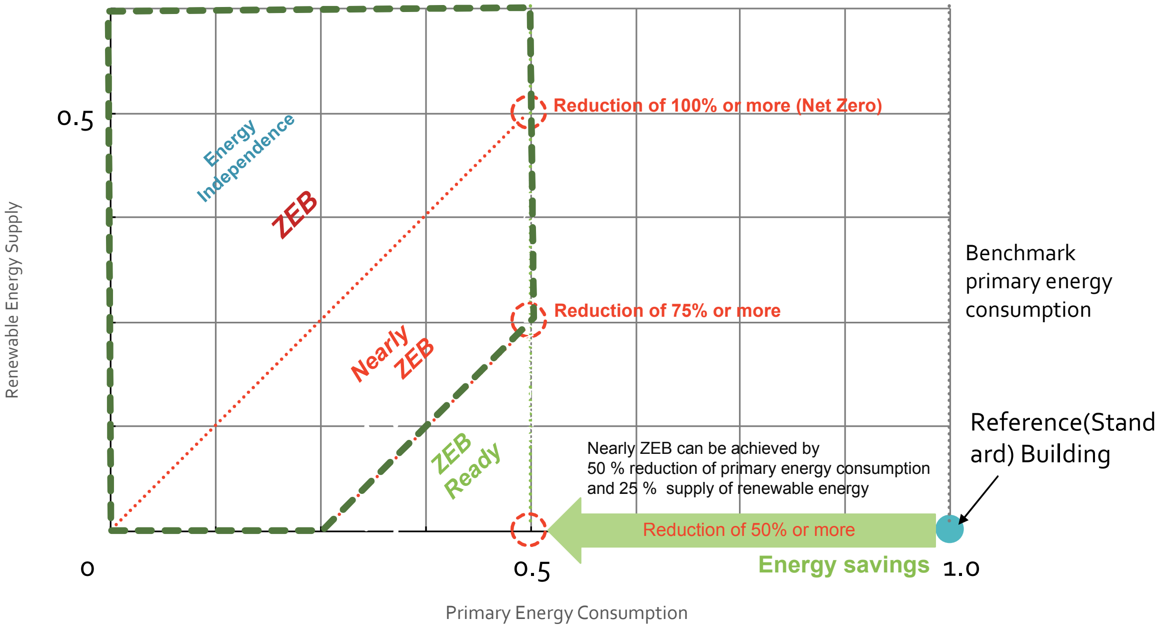


Figure 2. *Japanese ZEB definitions, ZEB Ready, Nearly ZEB and ZEB relative to the reference building (BEI = 1.0) which represents todays energy performance requirements.*

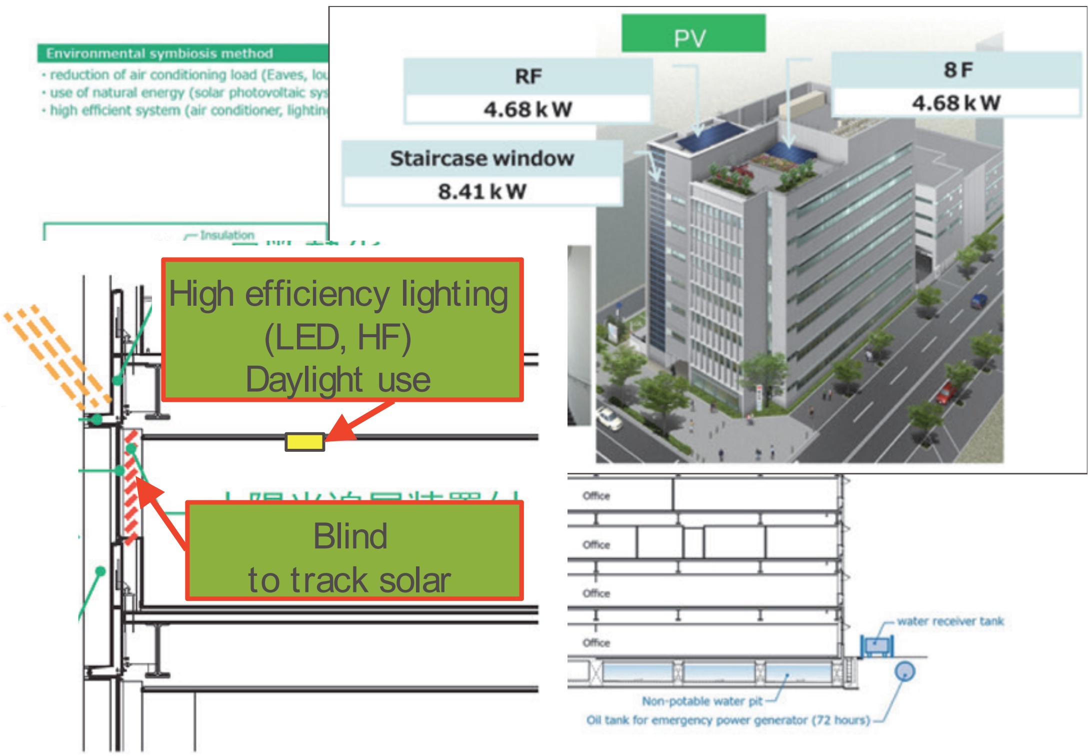


Figure 3. *ZEB case study building: office of The Kansai Electric Power Company.*

This building achieved BEI = 0.32 which means 68% energy saving resulting in between Nearly ZEB (BEI = 0.25) and ZEB Ready (BEI = 0.5). Delivered and primary energy are shown in **Figure 4**.

Martin Thalfeldt introduced typical NZEB office building solutions mostly from Northern Europe and ongoing REHVA Task Force on office buildings' EPC (energy performance certificate) common scale. This task force aims to develop primary energy scale with equal and energy performance levels in different climates. Most focus is put to cost optimal NZEB performance determination according to European standards methodology and input data with the aim to contrast the strictness of NZEB requirements in selected European countries.

Jarek Kurnitski reported REHVA – SHASE cooperation work of Japanese ZEB Ready and European NZEB performance levels comparison with the reference office building. Direct comparison of primary energy values is not meaningful because of different primary energy factors, climate and energy calculation input data, **Figure 5**.

Japanese value of 219 in **Figure 5** is high especially because of required humidification and high primary energy factor 2.71 for electricity. When Japanese ZEB Ready building was moved from Sapporo climate to French and Estonian climates with considering an adjustment of insulation thickness according to the climate, the results shown in **Figure 6** were achieved.

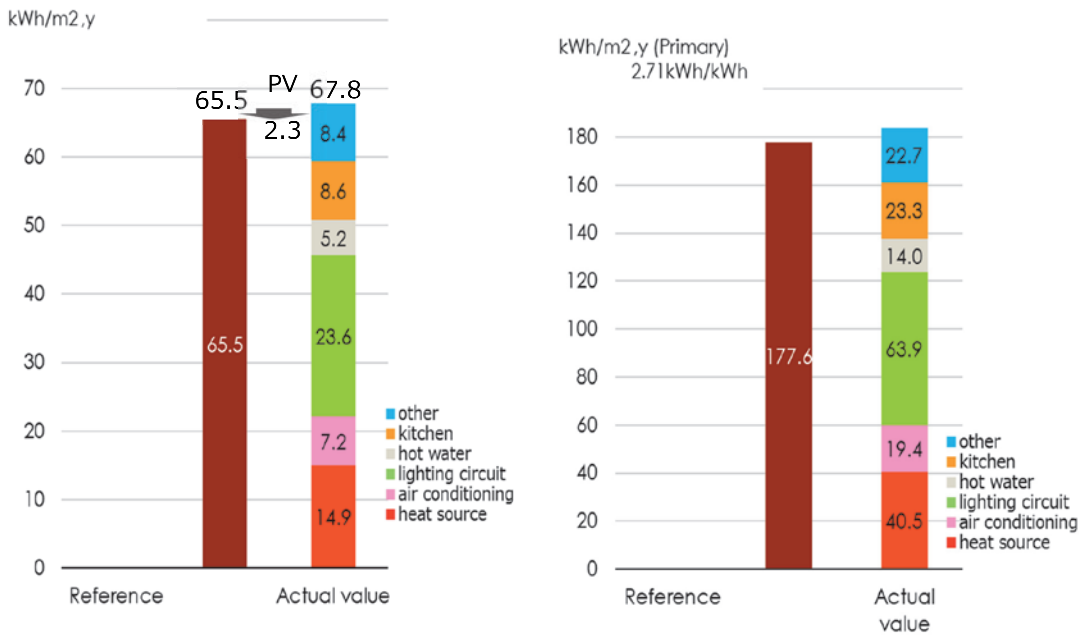


Figure 4. *The annual electricity use was 67.8 kWh/m², y and then subtracting the generation of 2.3 kWh/m²,y of PV it became 65.5 kWh/m²,y. The primary energy, calculated with factor 2.71 for electricity is 178 kWh/m², y.*

The results in **Figure 6** show that Japanese ZEB Ready, 219 kWh/m²a (Sapporo) resulted in 103 kWh/m²a in Estonia and 44 kWh/m²a in France (without humidification). When recalculated with European input data and primary energy factors (in right), it can be seen that Japanese ZEB Ready building configuration with ASHP complies well with European Commission NZEB benchmark, which is for Estonia (Nordic) 70 kWh/m²a (vs 63.9 achieved) and for France (Oceanic) 55 kWh/m²a (vs 57.4 almost achieved). In the case of district heating or gas boiler heat sources, Japanese ZEB Ready configuration would need some small improvements to comply with European Commission NZEB benchmarks.

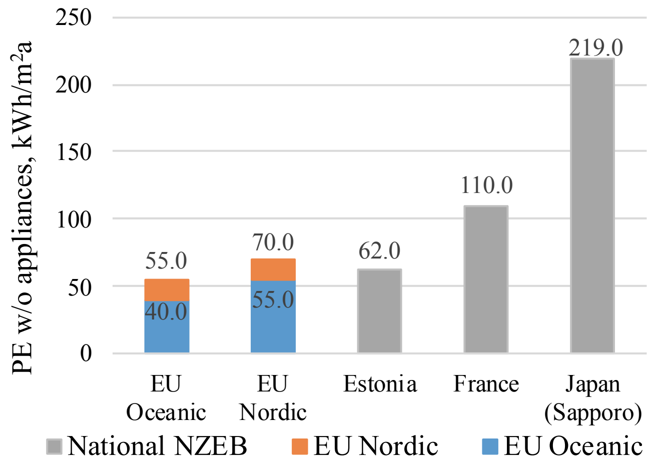


Figure 5. *Direct comparison of national NZEB requirements, Japanese ZEB Ready and EC recommendation of primary energy. Appliances are not included.*

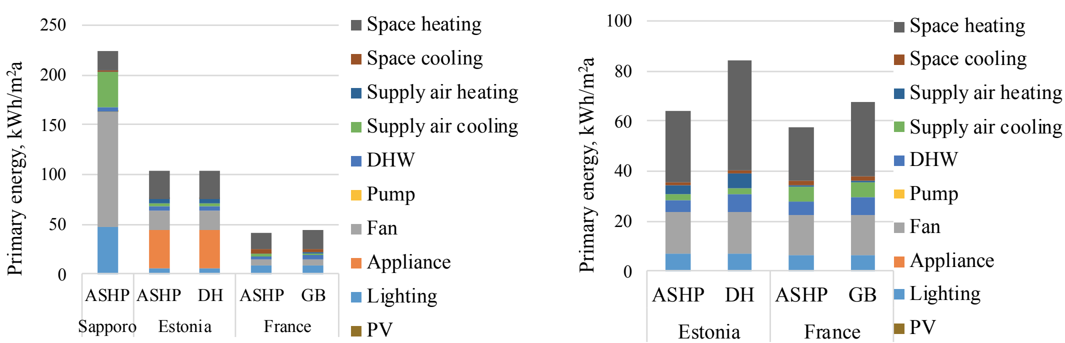


Figure 6. *Japanese ZEB Ready primary energy according to Estonian and French methodology and climate. With national input data (in left) and with European standards input data and primary energy factors (in right). ASHP is air source heat pump, DH district heating and GB gas boiler.*

Discussion and conclusions

Workshop concluded that current European Commission NZEB benchmarks and Japanese ZEB Ready are very close. In Japan, ZEB Ready means 50% reduction of current minimum requirement. From two European NZEB requirement compared, Estonian one fulfilled EC benchmark, but French NZEB requirement was clearly less ambitious than EC benchmark.

It was recognized that in Japan so far there are no regulation available for stringent energy requirements, but some subsidies exist for ZEB Ready, available both for non-residential and residential buildings.

European NZEB is very much driven by cost optimal approach, i.e. the NZEB should have the energy performance which provides lowest possible life cycle cost calculated as 20 and 30 years net present value for residential and non-residential buildings respectively. Cost optimal calculations and regulation updates are required by the EPBD directive after every five years, which be strong driver for development.

Japanese studies have shown that it is not easy to achieve ZEB although almost all affordable techniques were adapted. Typical for Japan, in the heating season, most of heating load comes from fresh air load and almost 30% of that is caused by humidification. For achieving more than Nearly ZEB performance, it is not possible to use common all-air-systems with high energy use for recirculation, thus new type of HVAC systems is needed.

Workshop identified the need to continue energy performance comparison so that the REHVA – SHASE cooperation will move from studied ZEB Ready performance level to more challenging Nearly ZEB level.

Acknowledgement

The cooperation and support for the research by REHVA Technology and Research Committee, Special Committee for Joint Study on NZEB between SHASE and REHVA, and The Society of Heating, Air-Conditioning and Sanitary Engineering of Japan (SHASE), is greatly acknowledged.

References

How to compare energy performance requirements of Japanese and European office buildings. Kaiser Ahmed, Gyuyoung Yoon, Makiko Ukai, and Jarek Kurnitski. In proceedings of CLIMA 2019, paper 435.

WS 9: Indoor Environment Design for Smart Buildings

Workshop organizer: *Halton*
Chair: *Anna Gagneur, Halton, Finland, anna.gagneur@halton.com*

Presentations at the Workshop:

1. ***Introduction to wellbeing and smart buildings***
   Anna Gagneur, Halton, Finland, anna.gagneur@halton.com
2. ***Future design and assessment of indoor environment***
   in place of Prof. Arsen Melikov, Technical University of Denmark (DTU) akm@byg.dtu.dk: Prof. Risto Kosonen, Aalto University, Finland risto.kosonen@aalto.fi
3. ***Halton Vario system design giving flexibility for smart indoor climate***
   Doctor Panu Mustakallio, Halton, Finland, panu.mustakallio@halton.com
4. ***Room systems as a service platform for smart buildings***
   Prof. Risto Kosonen, Aalto University, Finland, risto.kosonen@aalto.fi

Introduction and background

This workshop presents and discusses the intelligent indoor climate technologies for smart buildings. The workshop focuses to non-residential buildings. It starts from the overall target of providing and ensuring wellbeing for building occupants.

The need for paradigm shift in generating indoor environment that complies with the needs of smart buildings is presented. Design options focused on providing indoor climate for single or group of occupants in smart buildings is discussed. In such buildings, the design of indoor climate system sets boundaries for smart management of indoor conditions. Important question is how to assess indoor environment in future buildings. Current and future methods for control and assessment of indoor environment is presented and discussed.

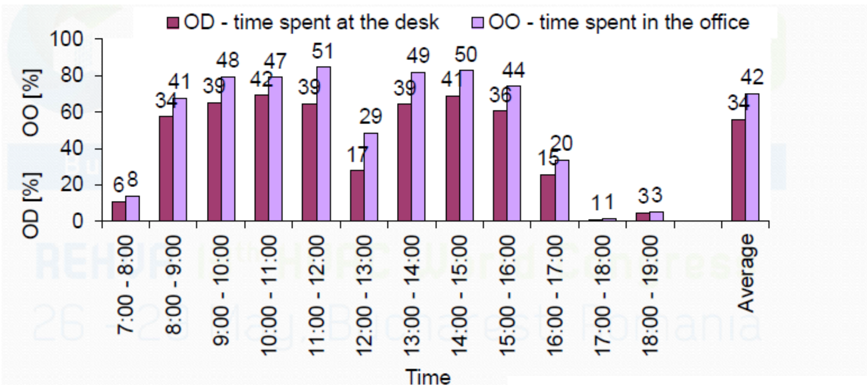
The design of Halton Vario demand based indoor climate system for smart office building is introduced. This design enables flexible variable airflow rates in spaces with different needs, based on intelligent room units with sensors and user interfaces. The system responds to floor layout changes and operates in energy efficient manner. Case study of Halton Vario system in European research project LowUp is presented.

Room systems as a service platform for smart buildings is introduced. The performance of the concept is demonstrated in seven meeting rooms of an educational building. The main benefits of the novel, smart system compared to the standard ones are the improved monitoring of the ventilation system performance, enhanced controllability of indoor climate in energy efficient manner, and improved users' perception on the indoor climate. Overview of the trends in smart management of indoor climate conditions with the Smart Readiness Indicator (SRI) for buildings as established by the European Union is presented.

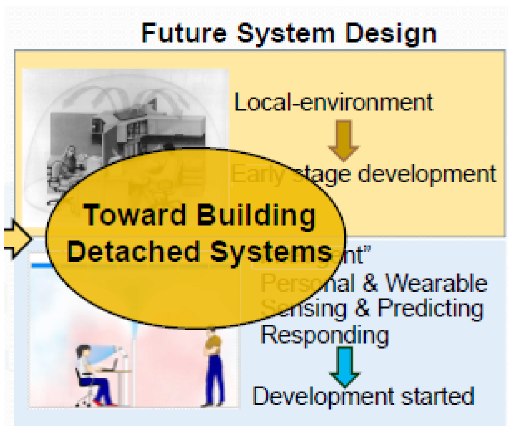
Summary of the presentations

The introductory presentation provided an insight into the workshop content as well as the topics of occupant wellbeing in the built environment and what makes buildings smart. The presenter briefly touched upon The WELL Building Standard and the business logic behind enabling wellbeing of building occupants.

The second presentation by Professor Risto Kosonen, replacing Professor Arsen Melikov, introduced the goals of good indoor environment design as "healthy, comfortable and work stimulating environment that creates the best environment for each occupant while minimizing energy consumption and not curtailing flexibility in space use with use of small and inexpensive HVAC systems." Important design principles to fulfill these criteria are removing of air pollutants, supply of heating, cooling and clean air on demand basis, controlling the air distribution and actively involving occupants in the process. Additionally, data was displayed to motivate for activity-based control of the indoor environment (image right).



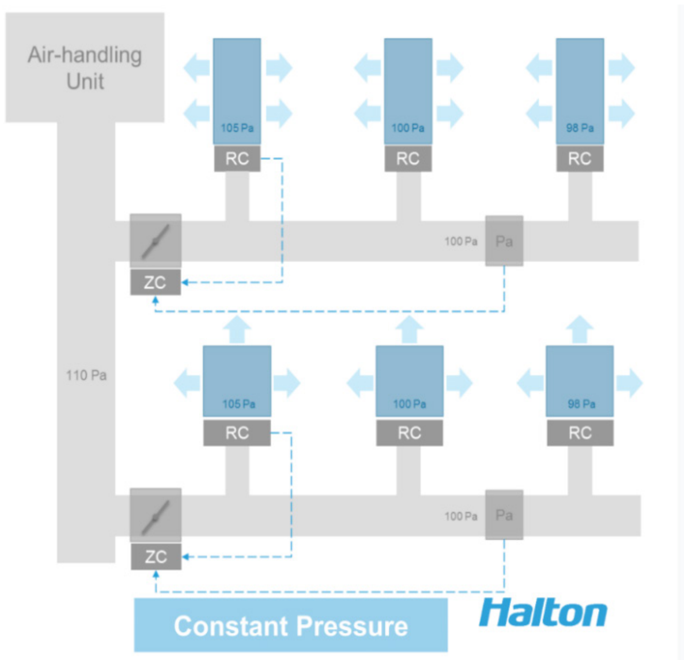
Various solutions for creation of the thermal environment in spaces were presented and the interaction principles discussed, considering the slow response time of radiant and convective systems in relation to the fast response time of thermal receptors in human beings and the slower changes to the body core temperature. It was concluded that the goals of individual comfort cannot be reached through the current approach and thus a paradigm shift is required. The shift should be towards detached systems that put the individual in focus with wearables and sensing technology in order to create local environment (image right).



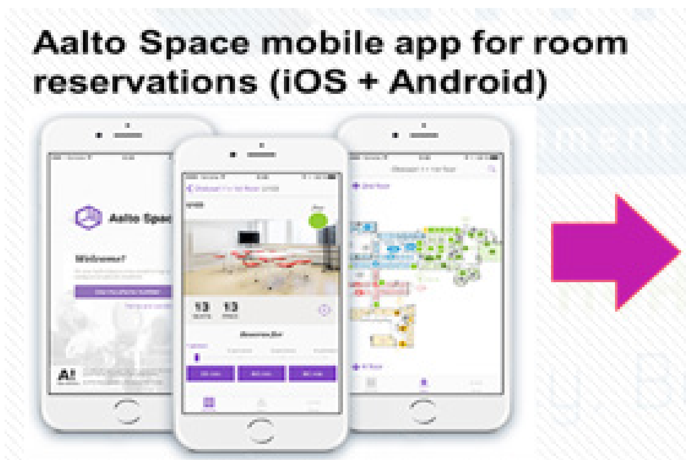
The third presenter, Dr. Panu Mustakallio presented the Halton Vario demand-based ventilation system for smart indoor climate control. Halton Vario is a demand-based system ensuring comfortable working conditions for occupants through user control, active terminal units, zonal and central system control, operating on constant pressure ductwork principles. The system operates based on occupancy, temperature and CO_2 readings, controlling the indoor climate automatically. Additionally, smart user control for single occupants or shared spaces is used to finetune the environment.

The basis of the system is constant-pressure ductwork, which is more cost-efficient over the building life cycle compared to traditional systems due to the demand-based operating principle, potentially saving up to 50% of energy costs with the average occupancy ratio of 40–50% when running only during occupied hours (image above). The active terminal units ensure comfortable throw patterns and supply airflow rates depending on space occupancy. Both air-water and all-air terminal units can operate as supply solutions. The operating principle of the user interface is democratic thermal control, which adjusts the thermal conditions based on the average preferences of all space occupants combined.

As the fourth presenter, Professor Risto Kosonen presented room systems as a service platform for smart buildings. The main topics of the presentation were incorporating smart HVAC-technologies to retrofitted buildings, integration of different systems into the building automation system, and evaluate how ICT-technologies and services can be used in old building stock through case examples.



Professor Kosonen shared insights from a demonstration project at the Aalto University Undergraduate Centre in Finland, where smart room systems were introduced in seven group working rooms. Through the space booking application, space users were able to adjust the heating setpoint and to boost the ventilation rates by manually overriding the automatic values (image of application above). Through the cloud service, the application controlled both the smart thermostat and the ventilation automation system. The integration of real estate IT services and building management system turned out to be a complex exercise. As a result of the user interface, space users were appreciated with the offered solution.



In addition to the above service, the pressure difference over the building envelope was monitored, which indicated significant under pressure during the night time when the ventilation with exception of the exhaust of sanitary spaces was turned off. Furthermore, the room occupancy was estimated based on CO_2 levels in the spaces and verified by physical observation. The results were 89% accurate. Conclusions of the studies were enhanced user perception of the indoor climate, enhanced energy efficiency through controllability and risk reduction in the buildings as a result of monitoring of ventilation system performance.

Discussion and main results

After the presentation by Professor Kosonen the following question came up: as radiant systems are so slow to react to people's changing needs, how can people change the space conditions quickly and how the system reaction time affects the user experience. The discussion went on to whether there are any personalized thermal comfort or ventilation devices in the market that are economically feasible or not. The conclusion was that such equipment had existed but were no longer available. It was also concluded that the current business model is not ideal for guaranteeing occupant comfort as initial cost savings usually steer decisions in the construction phase.

Personal comfort studies and devices were also concluded to be more focused on good air quality rather than thermal comfort, however air quality devices need to be very close to the subject otherwise they won't work properly which creates a cost and maintenance problem as a significant number of units would be required and maintained frequently.

It was discussed that constant pressure systems are good for demand-based operations as it is possible to steadily control terminal units in the system without affecting the complete ductwork. However, it was recognized that constant pressure systems are uncommon, likely due to inexperience of design teams.

After Dr. Mustakallio's presentation about demand-based ventilation systems and personal control, there was discussion on how hybrid systems work with radiant heat distribution and supply air integrated, considering thermal transfer principles and whether there is a benefit to the product functionality with this combination.

The presentation of the Halton WellMe user control application generated questions about how accurate indoor positioning and sensors are in the market and the conclusion was that the technology is evolving rapidly, and the quality is already sufficient for good enough positioning of people with the purpose of controlling their immediate environment. Dr. Mustakallio finally presented an ongoing EU research project LowUP with demand based chilled beam system in Spain integrating thermal energy storage, and advanced automation and monitoring the system utilizes low heating water temperatures and high cooling water temperatures. Thus, it is suitable for the sustainable thermal solution.

After Professor Kosonen's presentation the question came up of how it was possible to know what the user satisfaction of the Aalto University experiment was based on, whether it was

actual user satisfaction with the thermal conditions and air quality which the users were able to control, or the fact that they were provided control over their environment. Professor Kosonen also shared that the biggest challenge during the project had been IT integrations, as the implementation required broad cooperation between ITC and automation experts.

Followed by this discussion, the topic moved on to defining the line between personalized and automatic control, as it was recognized that sensoring technology might be inaccurate enough to provide data that does not fully enable correct automatic set points. An attendee from DTU shared knowledge of sensor studies that had showed insufficient quality of readings in many sensors. Professor Kosonen concluded that the most accurate control method would be through sensoring, bio sensoring, and occupant feedback.

The discussion turned back to the initial topic of personalized ventilation and thermal comfort devices, and it was again concluded that the business logic is complicated. Thinking "outside the box" may be required in order to establish a successful solution. The common opinion was that any space would require ambient ventilation despite implementation of personalized solutions, which generated discussion on how the personalized devices would then affect the ambient conditions. It was also mentioned that demanding spaces such as dealer workspaces in banks etc. already have implemented personalized solutions where heat loads are very high.

Conclusions and future work directions in the field

The main topics of the workshop discussion circled around individual thermal comfort and air quality devices, and it was concluded that such devices had existed in the market but proven complicated for several reasons and never achieved acceptance in the market. It was recognized that more research should be done in this area in order to present economically feasible solutions that would serve the individual and create a unique user experience.

In order to understand what personalized devices can do to the ambient ventilation and thermal comfort solutions, further studies are required also in that area.

Acknowledgement

The organizer acknowledges Aalto University and Technical University of Denmark for their contribution to this workshop. The workshop was supported by Business Finland.

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WS 10: Energy renovation of building stock towards nZEB levels: How to prepare the market for the challenge?

Workshop organizers:

Fit-to-NZEB project

iBRoad project

Grundfos Pompe Romania

Chairs:

Horia Petran, INCD URBAN-INCERC & Cluster Pro-nZEB, Romania, hp@incd.ro

Dragomir Tzanev, Eneffect, Bulgaria, dtzanev@eneffect.bg

Octavian Şerban, Grundfos Pompe, Romania, oserban@grundfos.com

Presentations at the Workshop:

1. ***Fit-to-NZEB: Policy implementation and innovative training schemes for retrofitting to nZEB-levels***
   Dragomir Tzanev, Eneffect, Bulgaria, dtzanev@eneffect.bg
2. ***iBRoad - My path towards an energy efficient home***
   Horia Petran, INCD URBAN-INCERC & Cluster Pro-nZEB, Romania, hp@incerc2004.ro
3. ***Smart Pumping Technologies in nZEB Buildings***
   Octavian Şerban, Grundfos Pompe, Romania, oserban@grundfos.com

Introduction and background

The aim of the workshop was to demonstrate the achievements of two complimentary international initiatives – the Horizon 2020 projects Fit-to-NZEB (Innovative training schemes for retrofitting to nZEB-levels) and iBRoad (Individual Building Renovation Roadmaps), supporting deep energy retrofit through developing streamlined educational schemes and individual building roadmaps for staged renovation, thus overcoming some of the main barriers for large-scale market uptake of energy efficient building retrofit around Europe. The applicability of new technological developments in the process and the opportunities that technologies bring for cost-effective renovations transforming the building stock was presented by one of the leaders in this area – Grundfos Pompe Romania, reflecting on the response of the business sector to the new policy development and social challenges.

Focusing of deep energy building retrofit, the workshop also included a dynamic interactive consultation session around topics like: increasing the demand for quality nZEBs, introducing innovative user-oriented building certification schemes, more informed and proactive market behavior, decreasing the performance gaps through large-scale improvement of the

skills of the building specialists at all levels, presenting technological developments focused on comfort.

The audience included professionals (from architects to representatives of construction companies), decision makers (central authorities) and technology suppliers.

Summary of the presentations

1. iBRoad - My path towards an energy efficient home

iBRoad works on lifting barriers to renovation by developing an Individual Building Renovation Roadmap for single-family houses. This tool looks at the building as a whole and provides a customized step-by-step renovation plan (iBRoad-Plan) over a long-term horizon (15–20 years).

2. Fit-to-NZEB: Policy implementation and innovative training schemes for retrofitting to nZEB-levels

The FIT-TO-NZEB project aimed to increase the competence and skills of the building professionals in all participating countries – Czech Republic, Romania, Bulgaria, Italy, Croatia, Ireland, Austria and Greece - through unique educational programs and pilot training courses, which will contribute to both the quality and the scale of the deep energy building renovations.

3. Smart Pumping Technologies in nZEB Buildings

Grundfos Pompe Romania presented the applicability of new technological developments in the process and the opportunities that technologies bring for cost-effective renovations transforming the building stock.

Discussion and main results

- Stability, engagement and a long-term vision are the main ingredients for having sustainable cities. Regulations, education and awareness are specifically needed for energy renovation of building stock towards nZEB levels.
- Everyone agrees that energy consumption in buildings should decrease and the comfort should increase, but without regulations both in Romania and Bulgaria there will be no large-scale results. Improvement of the legislative framework in the process of adoption of the new EPBD is needed. Romania started to work on drafting a long-term renovation strategy in which the level of ambition is planned to be high including the renovation at nZEB level.

- Besides regulations, education at all level of stakeholders is mandatory, with a focus on the general public (building owners) which must understand the importance of choosing sustainable solutions for increasing their comfort and building specialists at all levels. Education should target both the national education system and informal training and education, including on-site training and recognition of skills and knowledge acquired at the working site.
- Since the technology is available on the market and the number of experts is starting to grow, the best way to prepare the market for the challenge is raising awareness using good communicators and showing as many good practice examples.

Conclusions and future work directions in the field

Through presented content and its discussion-intensive format, the workshop contributed to a better understanding about relevant current tools and initiatives to facilitate deep energy renovation, while delivering specific recommendations for stimulating the market for deep energy building retrofit in several dimensions:

- Legislative: improvement of the legislative framework in the process of adoption of the new EPBD, including further instrumentalization of building certification;
- Skills-oriented: putting clear focus on the need for nZEB-oriented qualitative transformation of the training and educational system for building specialists at all levels, targeting both the national education system and informal training and education, including on-site training and recognition of skills and knowledge acquired at the working site.
- Market-oriented: involvement of major business actors in the process and support for introduction of new technologies, having positive impact on comfort, health, efficiency and market value of the dwellings;
- Policymaking: recommendations for future development of national and, where applicable, local support programmes in the light of the expected national long-term renovation strategies.

Acknowledgement

The Fit-to-NZEB and iBRoad projects have received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreements No 754059 and 754045.

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Reports published under iBRoad project, available at https://ibroad-project.eu/results/reports/

WS 13: Costs and benefits of antibacterial filter and its effects on energy saving, human health and worker productivity

Workshop organizer:

RHOSS

Chair:

Stefano Paolo Corgnati, Politecnico di Torino, Italy, stefano.corgnati@polito.it

Co-Chair:

Micaela Ranieri, Rhoss S.p.a., Italy, micaela.ranieri@rhoss.com

Presentations at the Workshop:

1. ***Rhoss commitment to the IAQ challenge: hence the development of biocidal filtration***
   Micaela Ranieri, Rhoss S.p.a., Italy, micaela.ranieri@rhoss.com
2. ***Costs and benefits of antibacterial filter and its effects on energy saving, human health and worker productivity***
   Cristina Becchio, Politecnico di Torino, Italy, cristina.becchio@polito.it

Introduction and background

Nowadays people spend about 80% of their time inside buildings and 30-40% in workplaces. For this reason, the Indoor Environmental Quality, as well as the sources of indoor-outdoor pollutants and their impact on human health and productivity, need to be investigated. The outdoor air pollution and the insufficient hygiene of HVAC systems often result in low quality of indoor air. The World Health Organization estimated that 50% of indoor biological contamination comes from the air-handling system. Furthermore, some studies demonstrated that the air filters are sources of pollution due to the accumulation and proliferation of bacteria on surface. In order to guarantee not only a better indoor air quality but also a lower health risk, and an increase in worker productivity, a new concept of biocidal filtration has been introduced. In this context, we explored how to integrate the health and performance effects on occupants into the economic benefits of the antibacterial filter. The research focuses on the evaluation of costs and benefits produced by the application of the antibacterial filter, comparing it with a reference one, by means of computing both direct and indirect costs. The results were carried out through a Cost-Benefit Analysis and a Monte Carlo Simulation, which allowed to demonstrate the goodness of the antibacterial filter in HVAC system.

Summary of the presentations

The present workshop developed totally thanks to the cooperation between REHVA, Federation of European Heating, Ventilation and Air Conditioning Associations, and Rhoss, Italian Company leader in the production and design of HVAC systems. The main goal of the workshop was to investigate a new approach in defining new paradigms related to the definition of Indoor Air Quality (IAQ). It was structured in three main section. The first one concerned a brief introduction by the Rhoss Company, showing their story and the development of their different products and solutions. The second section entered more in detail in generalized theoretical things, showing the results of the research activity performed in collaboration with the Energy Department of Politecnico di Torino. Finally, a discussion was open in order to get all the feedback related to this topic.

Rhoss commitment to the IAQ challenge: hence the development of biocidal filtration, (Micaela Ranieri, Rhoss S.p.a., Italy, micaela.ranieri@rhoss.com)

In the first part of the workshop, a presentation on Rhoss was illustrated in order to learn more deeply about the history of the Company and the different solutions offered to the customers in the field of Heating Ventilation Air Conditioning (HVAC) systems. First, the Company was born in 1969 with a heart quarter in Italy and three branches in Germany, France and Turkey respectively. Their turnover is active all over the Europe, but 48% is mainly focus in Italy. Furthermore, a Laboratory was shown as a great support for the developments of their technologies; one of the bigger laboratory all over the Europe, with more than 1 000 m² of surface, 1 500 kW of potential available to test the products and an indoor environment characterized by a temperature range from −20°C to +56°C. Second, all the technologies available in the market were presented, starting from terminal unit, as fan coil and heat recovery, chiller and heat pump, until air-handling units. The different installations of these solutions were shown, such as hotel buildings, hospitals, airports, commercial centers, residential and office buildings; they are all environments characterized by high concentration of people and, for this reason, they require a good Indoor Air Quality.

From this presentation, it was clear that the main goal of the Rhoss Company is to implement and to optimize the air quality inside the buildings. It is common take for granted that keeping fresh air from outside will increase the indoor air quality, but it depends on the quality of the external air. For this reason, in order to improve IAQ, Rhoss stressed the necessity to introduce air filtration in HVAC system. In this context, the follow question was submitted to the audience: is it always-sufficient pressure and standard filtration in order to increase the IAQ in a building? In order to answer to this question, the speaker shown that the biggest problem related to standard filtration system is its inefficiency against bacteria and their proliferation on the surface. The Company proposed an easy solution in order to overcome this issue; the introduction of an antibacterial media inside the filter itself. Thanks to the cooperation with the National Research Council (NRC), they found a new way to kill the bacteria, called cytometry. This biophysical laser technology could exactly understand, before and after the filter, which was the percentage of bacteria lived in order to certificate the filter's performance. In this way, Rhoss Company presented their innovative filtration system, the antibacterial filter, characterized by an abatement capacity of Gram-negative bacteria (Escherichia Coli) of 53% and Gram-positive ones (Staphylococcus Aureus) of 98%, in comparison with a reference filter. Finally, the main air filtration systems produced by the Company were shown; starting from standard pre filter ISO course in 55%, until ISO ePM 50%, ePM 70% and ePM 85%.

The presentation resulted in some comments. Is it possible to support innovation introducing new paradigm in order to set up indicators that are also able to understand the effectiveness of this technology in terms of energy, comfort, health and well-being? It is possible to define new ways in evaluating these innovative technologies in order to highlight that the socio-economic benefits can totally repaid its higher investment costs?

Costs and benefits of antibacterial filter and its effects on energy saving, human health and worker productivity, (Cristina Becchio, Politecnico di Torino, Italy, cristina.becchio@polito.it)

The second part of the workshop went more in detail in the research activity and try to answer to the previous questions, showing different application of the antibacterial filter. This research was performed in collaboration with some researcher of the Energy Department of Politecnico di Torino.

The speech was opened with a brief introduction to the scenario in which the research developed; it concerned the revised Energy Performance of Building Directive (EPBD), introduced in 2018, that stressed the importance to improve the quality of life, especially occupants' health and productivity. In this way, resulted essential to consider not only the development of energy efficiency but also the indoor environmental quality of the building. After this introduction to the scenario, the research goal was illustrated; the aim was to demonstrate that the higher investment costs of a new technology just placed on the market, in this case the antibacterial filter, could be totally repaid by socio-economic benefits in terms of energy savings, human health and worker productivity. In the application different case studies were included: office building, school gym, school building, hotel and hospital rooms. The methodology shown by the speaker consisted in a comparative analysis between the technical features of antibacterial filter and a reference one on the market. First, a re-

view on the main financial valuation tools established Life Cycle Cost (LCC) analysis as the optimal method in order to evaluate the main costs related to air filtration systems, not only in terms of investment costs but also considering the energy, maintenance and disposal costs during the life-cycle of the filter. Second, a development on socio-economic analysis allowed to quantify in terms of money the benefits related to the antibacterial filter in term of energy savings, human health and worker productivity. Finally, the results were established through a Cost-Benefit Analysis (CBA), an analytic technique used in investment decision in order to select the most profitable project in terms of the society convenience.

To enter more in detail, in terms of technical features the main difference between the antibacterial filter and reference one was that the last one is ineffective against bacteria. Contrary, the bactericidal capacity of the antibacterial filter was evaluated on two bacteria: Staphylococcus Aureus for which has emerged an abatement capacity of 98%, and Escherichia Coli for which has shown an abatement of 53%. Furthermore, the antibacterial filter can remove molecular outdoor pollutants in a range from 1% to 20%, compared with the reference filter.

About financial valuation tools, Life Cycle Cost (LCC) analysis was applied in order to consider the investment costs of both filters, the energy, the maintenance and the disposal costs during a calculation period of 10 years. The following tables shows the main results of the LCC (**Table 1**) and the main input data used in the analysis (**Table 2**).

About economic evaluation, two different field of research were considered; one related to health benefits and the other one related to productivity benefits.

Table 1. Annual costs for each filter and LCC results.

	ANTIBACTERIAL FILTER	**REFERENCE FILTER**
Investment Cost (MEDIUM size)	150 €	65 €
Maintenance Cost	40 €/year	
Disposal Cost	4 € (increase 5% per year)	
Energy Cost	156 €	244 €
Initial – Final Pressure	70 Pa – 250 Pa	80 Pa – 450 Pa
Average Pressure Drop	130 Pa	203 Pa
LCC results	**1 934 €**	**2 682 €**

Table 2. Main input data used in LCC analysis.

INPUT DATA	
Parameter	**Assumed value**
Air flow Rate	1 m^3/s
Calculation period	10 years
Energy cost	0.10 €/kWh
Interest Rate	6%
Running time	6 000 hours
Fan efficiency	50%

First, in order to evaluate health benefits, a medium size for both filters and a constant external airflow rate were considered. Two respiratory diseases, pneumonia and meningitis, due to the tested bacteria, Staphylococcus and Escherichia Coli, were considered. In order to evaluate the health benefits, Cost of Illness (COI) was established as the optimal technique able to evaluate benefits of antibacterial filter as avoided costs. Direct costs are related to hospitalization or antibiotic treatment costs of the different respiratory diseases. Indirect costs are evaluated in terms of Human Capital Approach (HCA) that allowed to attribute an economic value for each day of absence from work due to the sick patient. **Table 3** and **Table 4** show the main parameters considered for the estimation of direct and indirect costs.

Table 3. Parameters for direct health costs associated with pneumonia and meningitis used in Cost-Benefit Analysis

DIRECT COSTS per patient	€
Cost of antibiotic treatment for pneumonia	37.50
Cost for outpatient management for pneumonia	182
Daily cost of hospitalization for pneumonia with complications (CC) in adults (>17 years)	3 558
Daily cost of hospitalization for pneumonia without complications (CC) in adults (>17 years)	2 291
Daily cost of hospitalization for meningitis	8 067

The direct costs for the hospitalization and antibiotic treatments are calculated following the formula:

$$Direct\ costs = Medical\ treatment\ x\ Abatement\ capacoty\ x\ Period\ spent\ x\ Morbidity\ events$$

where the *medical treatment* cost is equal to the cost of antibiotic or hospitalization; the *abatement capacity* is the antibacterial filter capability to reduce bacteria responsible for pneumonia and meningitis; the *period spent* reflects the time spends in the place where the filter is installed (in terms of working days or study days); the *morbidity events* represent the disease cases in the investigated case study.

Table 4. Parameters for indirect costs associated with workers' productivity used in Cost-Benefit Analysis

INDIRECT COSTS per patient	€
Average gross daily wage NOT received in the tertiary sector (OFFICE building)	125
Average gross daily wage NOT received in public administration (SCHOOL building)	97.54

The indirect costs for the hospitalization and antibiotic treatments are calculated following the formula:

$$Indirect\ costs = Daily\ salary\ x\ Hospitalization\ days\ x\ Morbidity\ events$$

where the *daily salary* corresponds to the wage for different workers according to the case studies, the *hospitalization days* represent the average period of hospitalization to carry out the treatment.

Second, in terms of productivity benefits, a medium size of the antibacterial filter, a large one of the reference filters and a constant indoor concentration of pollutants were considered. In this case, the investment costs of the reference filter resulted higher because it was necessary to use air-handling unit with a higher size. In order to evaluate the performance of employees in an office building, the relationship between ventilation rate and relative performance was considered. The relation was calculated using the formula below:

$$RP_v = (5.56 \times 10^{-8}) \times v^3 - (1.48 \times 10^{-5}) \times v^2 + (1.49 \times 10^{-3}) \times v + 0.983$$

where RPv is the relative performance and v is the ventilation rate (l/s per person). The reference filter has to increase the ventilation rate in a range from 1% to 20% in order to work as the antibacterial filter. The results in terms of productivity benefits range from 27.50 €/year per person to 110 €/year per person.

Finally, the main results of a Cost-Benefit Analysis were presented; first, an incremental analysis was performed in order to evaluate health benefits. In this case, if the benefit cost ratio was major than 1, the benefits related to the antibacterial filter were higher than the one of the reference filters. The results of the application in an office building, characterized by 67 employees and medium size filters, are shown in the table below (**Table 5**).

Second, a comparative analysis was assumed in order to calculate the impacts on productivity. In this case, a cost benefit ratio for each filter was performed; if it is major than 1 its means that we have benefits. The results of the application in an office building, characterized by 67 employees, are shown in the table below (**Table 6**).

Table 5. Main results of incremental Cost-Benefit Analysis.

		REFERENCE FILTER	ANTIBACTERIAL FILTER
COSTS	Investment cost	65 €	150 €
	Energy cost	244 €/year	156 €/year
BENEFITS	Energy Savings	–	88 €/year
	HEALTH	–	83.33 €/year
Benefit Cost Ratio		**17.85**	

Table 6. Main results of comparative Cost-Benefit Analysis.

		REFERENCE FILTER	ANTIBACTERIAL FILTER
COSTS	Investment cost	913 € (80 €+833 €)	150 €
	Energy cost	244 – 292.8 €/year	156 €/year
BENEFITS	Energy Savings	–	88 – 136 €/year
	PRODUCTIVITY	–	1 842.5 – 7 370 €/year
Benefit Cost Ratio		**0.06**	**22**

Discussion and main results

The discussion was opened with few comments by the chair, focusing on the methodological approach used in the research activity in order to monetize all the co-benefits deriving from the application of the antibacterial filter.

The main topics of discussion are summarized below:

1. *The potentialities related to the methodological approach of Cost-Benefit Analysis (CBA) applied in the research activity*. Through this field, it was possible to show the efficiency of this evaluation tool that allow expressing in terms of money (€) the benefits related to the new technology just placed on the market. Furthermore, the results carried out from the CBA are easier to be understood also from non-expert people; contrary, the Multi-criteria Analysis, another socio-economic evaluation tool, provides outcomes only in a qualitative way and so difficulty readable by common people.

2. *The existence of a different average pressure drops between the antibacterial filter (130 Pa) and the reference filter (203 Pa)*. It was stressed that the benefits in terms of energy saving depend on this evidence. This point should be clearly addressed during the evaluation.

3. *The way in order to assess co-benefits in terms of health, focusing on the effects considered in the evaluation of avoided costs*. The Cost of Illness is presented as the most suitable tool, in which benefits of the introduction of antibacterial filter are expressed in terms of avoided costs. The benefits are related to the fact that these costs are considered only in the case of reference filter because with the antibacterial one there was the possibility to completely act against the bacteria that cause the respiratory diseases.

4. *The energy costs considered in the evaluation of Life Cycle Cost of the filters*. In the research activity, only the electricity of the fan was considered; the costs related to the air-handling unit were omitted because in the analysis only the costs that represent a difference were considered.

Conclusions and future work directions in the field

In conclusion, the discussion previously presented allowed to capture which could be the possible future developments of the research. In detail, the following topics could be further developed in this research activity:

- The investigation and the application of other evaluation methodologies, such as Multi-Criteria Analysis (MCA). This approach could be introducing in the analysis in order to assess other benefits that resulted impossible to monetize.

- The application of the previous evaluation models, especially productivity benefits assessment, in different climatic zone and country.
- The introduction of occupant behaviour in the productivity benefits evaluation. In this research activity, the impossibility to interact with the system represented a boundary; it could be interesting to include also the effects of occupant behaviour and role in the Monte Carlo Simulation. Some monitoring dates, as occupant behaviour in office building, are required in order to implement the analysis.

Acknowledgement

We want to extend special thanks to Rhoss Company that has made possible the development of this research and to Leonardo Prendin, Rhoss Marketing Director. Thanks also to Carola Lingua (Politecnico di Torino) for the contribution to the development of this research activity.

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Cristina Becchio, Marta Carla Bottero, Stefano Paolo Corgnati, Federico Dell'Anna, Valentina Fabi, Carola Lingua, Leonardo Prendin, Micaela Ranieri, "The effects of indoor and outdoor air pollutants on workers' productivity in office building". Proceedings of 13th REHVA World Congress CLIMA 2019, 26-29 Maggio 2019, Bucharest, Romania.

WS 14: Towards optimized performance, design, and comfort in hybridGEOTABS buildings

Workshop organizer:

HybridGEOTABS

Chair:

Prof. Dr. Lieve Helsen, KU Leuven/ EnergyVille

Co-Chair:

Eline Himpe, UGent

Presentations at the Workshop:

Introduction to hybridGEOTABS project – challenges and opportunities of hybridGEOTABS buildings

Dr. Eline Himpe, UGent

Part I – Focus on hybridGEOTABS primary distribution systems

Indoor Environmental Quality benefits of radiant systems

Dr. Ongun Berk Kazanci, DTU

TABS in hybridGEOTABS buildings

Dr. Qian Wang, Uponor/DTU

PCM ceiling panels as a renovation solution in hybridGEOTABS buildings

Dr. Ongun Berk Kazanci, DTU

Part II – Design challenges of hybridGEOTABS buildings

Innovative procedures for the optimized design of hybridGEOTABS buildings

Dr. Jelle Laverge, UGent

Prof. Wim Boydens, Boydens Engineering

Introduction and background

HybridGEOTABS is a combination of geothermal heat pumps combined with thermally activated building systems. This concept includes a number of advantages: TABS deliver a high level of comfort, geothermal heat pumps are a sustainable energy source, the system reach a high energy efficiency, the combination of GEOTABS with secondary heating and cooling systems also give a good financial costs and more optimized balance within the different energy sources. Th objective are to optimize the performances, demonstrate the innovations and take away barriers that prevent GEOTABS to be more implemented. The project is a Horizon 2020 innovation action, started in September 2016 and will see its conclusion in September 2016.

Summary of the presentations

The three main concepts that evolve around the project are optimization, demonstration and exploitation.

Optimization:

- optimization of the design of hybridGEOTABS buildings, aiming to the optimization of energy efficiency, comfort and financial cost. This will result in a new hybridGEOTABS handbook.
- optimization during the operation: use of a better way of controlling the system with MPC, optimizing energy costs, CO_2 and energy efficiency. The estimation is a reduction of 10–25% of the energy use compared to ruled based control (RBC), The setup of MPC is a challenge, the partners are therefore developing a toolchain to reduce develop and commissioning efforts.

Demonstration:

There is a number of case study buildings: n. 2 offices buildings, n. 1 elderly home, 1 multifamily building and n. 1 school. These buildings are GEOTABS buildings working with MPC. The case studies will demonstrate hybridGEOTABS, implement MPC and test the design method. The assessment is focused on KPIs such as energy&environment, IEQ, health and productivity, and financial cost. The virtual test bed will then assess the performance of the system to identify the real improvements in the long term. Different European climates are considered as well as differentiate building stock for a total of more than 1 000 m².

Exploitation:

Take away barriers mean a cost benefit analysis, improving commercial attractiveness. The industrialization strategy is also important towards the development of the single components (pre-engineering and fabrication). The aim is then to broaden the application of ’hybridGEOTABS.

This work of optimization, demonstration and exploitation want to bring ’hybridGEOTABS close to European market and improve the sustainability and the performance of the building stock.

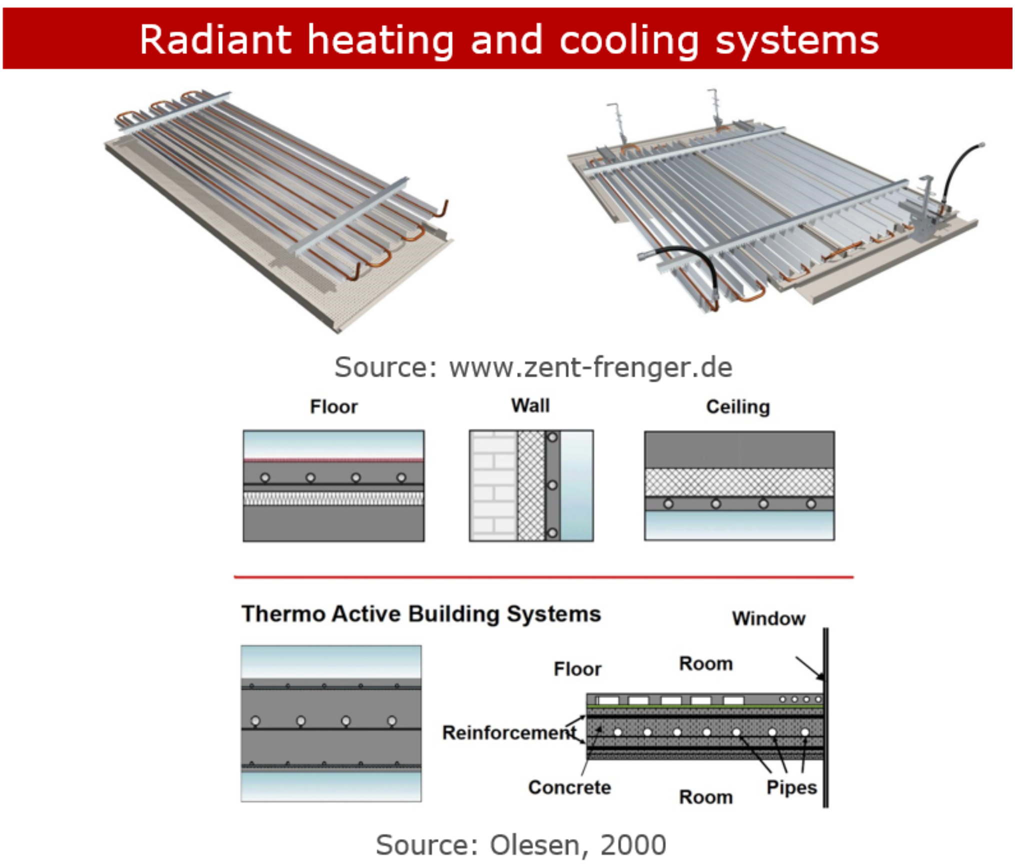
Most of time is spent indoors for the average person, so the buildings should provide a comfort, healthy and stimulating indoor environment with the lowest possible energy use. Three main components are considered in heating, cooling and ventilation: generation, distribution and emission. Indoor thermal units are elements that use different mechanism and media to emit and remove heat or moisture from indoor spaces (through radiation, convection or a combination of both). Depending on different thermal units there will be different thermal indoor conditions. There are usually three main types of radiant systems working with water as a mean of heat transfer: radiant heating and cooling panels, pipes isolated from the main building structure, thermally activated building systems (TABS). Radiant systems are working on low temperature heating and high temperature cooling cycles.

A more traditional mean for radiative system is air, that regulates the indoor environment through convection. Three types of systems also in this latter case: mixing ventilation, displacement ventilation and personalized ones. Having different systems, the aim is to keep the indoor temperature near to a set value. TABS, compared to air ventilation systems where there is the need to cool as soon as there is a demand, spread the cooling load throughout the day (see figure below)

Benefits of radiant heating and unit system is that they are integrated in the building, reducing the risk of draft, less space and cleaning requirements and uniform temperature distribution.

TABS are heating and cooling systems based on radiation, with pipes embedded in the main building construction elements (concrete slabs or walls). The application is not for residential buildings usually (school, public buildings, offices, healthcare). Temperature controlled water activates the whole building structure, where in warmer climate regions systems may be integrated with supplementary measures for cooling and in cold climate regions secondary systems for heating are needed.

The integration of TABS with energy supply systems constitutes the concept of the project, where the water temperature is near the ambient one and the energy efficiency reaches high

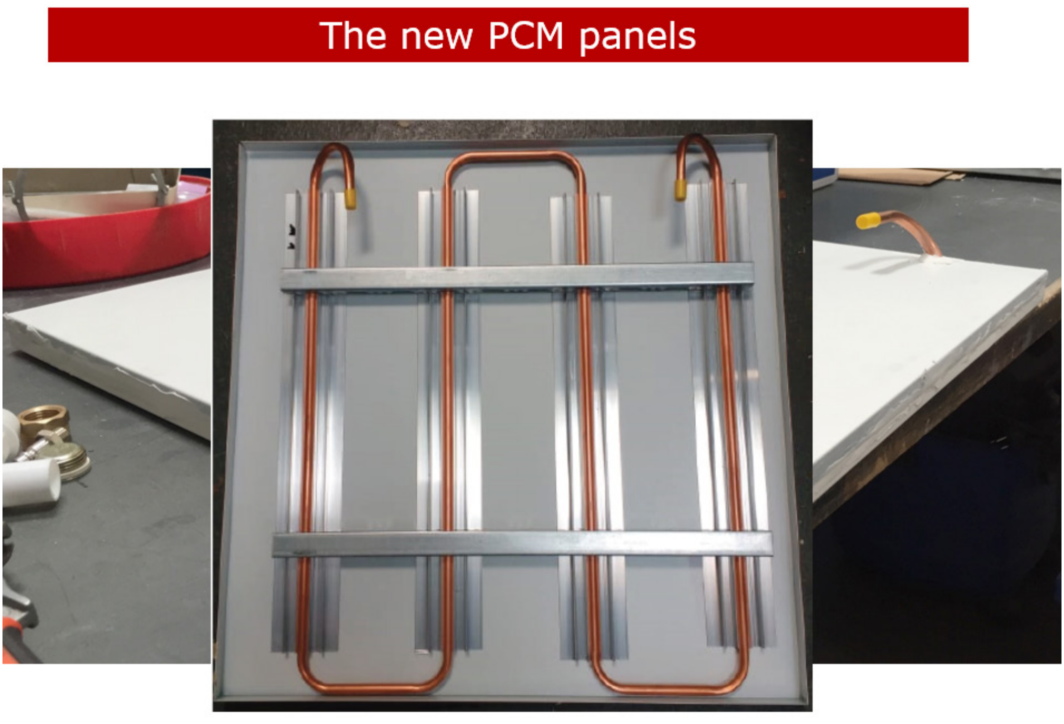


energy in the range of a heat pump COP, due to low-temperature heating and high temperature cooling. This is integration is also suitable for renewable energies (geothermal, solar). On a practical level, pipes are embedded in the concrete using different arrangements of TABS (see figure below)

The idea is to use a ceiling panels or radiant ceiling panel filled with phase-changing materials as a renovation solution in hybridGEOTABS project.

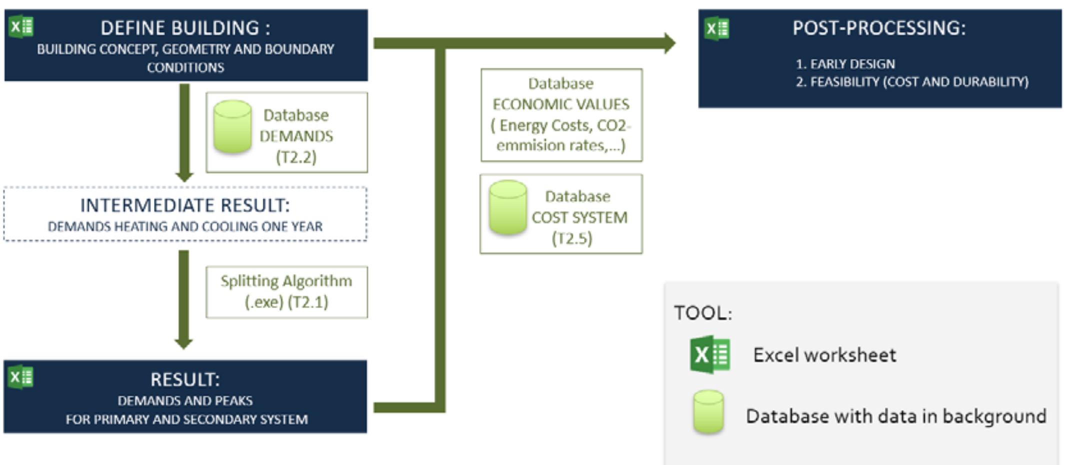
TABS benefits are the integration of renewable energy resources thanks to low temperature heating and high temperature coolings, reduce total energy uses and spreading the peak loads throughout the day. The interest is to find similar systems to TABS for renovation cases. The proposal is radiant ceiling panels with phase change materials (PCM). PCM can use as means organic or inorganic materials, they can be used passively or in an active way, they can increase thermal mass, and, in hybridGEOTABS case, they are used for temperature control of indoor spaces and the management of the cooling load. Main goals are the development of a new solution to address implementation limitations and constraints as well as to characterize the performance of the new PCM panels by climate chamber measurements and parametric analyses through validated simulation models.

PCM are commercially available products and the challenge is to fill these panels with phase changed materials. Once set, the project chose a case study to work on with using PCMs. The outcome is to demonstrate their usage next to the performances of TABS, through simulations. The results shown from the demo case demonstrated that both systems are very similar in terms of primary energy use and in the percentage of hear removal from the indoor space.



Considering the thermal environment distribution during occupied hours the comparison between the systems is showing slight differences but the overall picture is still in the range of a close approximation of TABS and PCMs. The ongoing work is now focusing how PCM work under different cooling loads, flow rates and supplied water temperatures.

One of the goals of the project is to develop easy to use guidelines for HVAC engineers with the goal to develop design tools that will help the designer team. In addition to this the focus is also on the level of hybridity of the system, understanding how much an occupant can rely on GEOTABS or on more conventional installations. The decision-making process must consider a fair level of playing field especially in the early project design stage that is the stage where the concept is chosen. There is in fact an interaction among lots of elements hard to quantify in a very early stage. Starting therefore from the initial project, the application of GEOTABS is surely an advantage, so the question to answer to is how far we can use integrated hybrid systems. Along the feasibility process different steps needs to be taken starting from boundary conditions on geometry and estimation of loads (cooling and heating). Therefore, from an initial assessment the level of the hybrid systems that could be used can already be studied. What to transform in guidelines is exactly the process of these early stages. Once the assessment is completed, defining the characteristics of the building, the level to reach in the project is to define the difference between the pattern of primary and secondary systems. In this way it will be possible to rely on a database of practice that is inserted in the step of post-processing (energy costs, CO_2 emission rates, cost system…). The assessment of performance will be translated in hybridGEOTABS in an easy to use approach.



The design method is mainly based on an analysis of the building stock, concentrating on 4 types of buildings, offices, elderly, schools, multifamily. The database wants to describe buildings in these four categories extracting archetypes up to building energy simulation models and their load duration curve. The comparison is with what was built in the last 15 years for the same buildings typologies and it is not just based on data from the building stock from the government but also on industrial partners data portfolio of completed projects. The focus is also on the distribution of the heating and cooling loads, trying to extrapolate typical sizing data related to the different elements installed in local HVACs.

Once raw data are obtained, they are standardized for the different building types (standard hydraulic schemes, drawings, tender documents) and then predefined with steps towards optimized combinations.

Three climate zones are taken into consideration with variations in terms of properties of building envelope that are also categorized into three groups (A, B, C). Same scenarios are categorized also for occupancy, internal gains, controls for shadings etc. Simulations are then running these inputs and processed through a clustering configuration.

Discussion and main results

The designing guidelines of hybridGEOTABS will be available on the website after the end of the project, while a REHVA guidebook will be developed on the designing and operation of hybridGEOTABS.

The project starts from ground level, and the focus of the project is not on the different type of ground heat exchange but more on the integration of ground heating sources, control and TABS.

Partners have an engineering background, but still they do have to find a common field to work together on topics such as energy savings and energy efficiency. On the architect's side is also important to find a sustainable design that fits certification guidelines, but on the side of the aesthetical results they do not like to see pipes and radiators that are running throughout the building. Therefore, the advantage of TABS, is that they are hidden, and the architect has much more space and freedom to decide how to play with internal environments. In addition to this the flexibility of TABS give to architects the possibility to choose different system orientations when it comes for example to the design of "wings" of a building.

The residential building case study that the project is considering just TABS and not a secondary system. So, there is not possibility to implement the controls that balance the action of the secondary system. The studies are also working on indoor environmental quality measurements, but on this building, there is not possibility to develop an MPC study.

There is also an on-going collaboration with an international energy agency project on epidemiology, with partners focusing on different building stock analysis and the results will be also applied to these residential buildings.

The input data from the project are characteristics that are not subjected to a pre-evaluation, but they are assessed according to the real type of building. Therefore, there is a combination with the dynamic simulation that the project is doing in the building stock analysis. The user does not have to run a simulation but needs to provide input data to then compare them to the closest ones in the building database. Therefore, the project is varying a lot building sizes and shapes to find the ones that are close to the need.

Conclusions and future work directions in the field

A complete understanding of the IEQ and user satisfaction in hybridGEOTABS buildings will provide suggestions for improving the comfort, health and productivity of the occupants.

PCM are demonstrated to work like TABS, having similar benefits, they can be applicable in renovation of buildings, and they have the potential to be coupled with renewable energy resources. Still there is a lack of design dimension and control methodology that are needed to be studied further as well as long term measurements and a detailed economic analysis.

Currently there are studies comparing radiative versus convective systems suggesting evidence that that first ones are providing higher or equal thermal comfort then the second ones. There is also a tendency towards higher satisfaction with indoor environment in radiant systems. Within hybridGEOTABS the idea is to compare the behavior of demonstration buildings before and after the implementation of MPC. The objective will be a quantification of the difference between the real and the thermal indoor environment sensed by the building management systems and the quantification of the effects of MPC on IEQ.

The goal is to be able to start with little information to have basis in the early design stages when you do not have the time nor the resources nor the information to elaborate an estimation but just to make a prediction in terms of investment cost and sizing related to the different components in the building.

There is a part on the building level that needs set points adjustments but it is not only on hybridGEOTABS that projects partners are building their business on because they have a lot of different energy concepts that they are developing and that can be exploited in the project.

It is a conscious choice not just to do an optimization, because it limits the architecture, but the aim is to demonstrate that all buildings deserve a part of hybridGEOTABS.

If you use a GEOTABS it should be integrated and designs since the beginning and architects like this kind of approach. Once the system is installed it can be considered an actual renewable source or a potential one, without having single components installed just to satisfy sustainability guidelines but to really have an integrative system able to interact with the building behavior.

WS 16: The Business and Environmental Value of BIM

Workshop organizers:

DosetIMPEX

ALLBIM NET

Chair:

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Co-Chair:

Lucian Dan MORARU, ALLBIM NET, Romania, dan.moraru@allbim.net

Presentations at the Workshop:

1. ***Introduction in BIM. Definitions, showcases, best practices***
   Dan Moraru, ALLBIM NET, Romania, dan.moraru@allbim.net
2. ***Common Data Environment - PDF based collaboration. Case studies***
   Alin Epure, ALLBIM NET Dubai-UAE, Emiratele Arabe, alin.epure@me.com
3. ***Towards net-zero hospitals in the Netherlands – ASHRAE-REHVA Guidebook: Towards Energy Neutral Hospital Buildings***
   Wim Maassen, Royal HaskoningDHV, Netherlands, wim.maassen@rhdhv.com
4. ***Building information modeling of a hospital building***
   Ioan Silviu Dobosi, DOSETIMPEX, Romania, ioansilviu@dosetimpex.ro

Introduction and background

Building Information Modeling (BIM) can be summarized as the process that begins with the development of an intelligent 3D model to capture, explore and maintain planning, design, construction and operational data in order to better inform decision making for building and infrastructure projects. BIM developed from a modern approach of designing to a “digital revolution” in the architecture, engineering and construction (AEC) sector, proving its undisputable benefits in every step of a project’s lifecycle. This modern approach is based on the use of a shared digital representation of a constructed object (including buildings, bridges, roads, factories, etc.), namely a single, connected model that improves communication within the design and construction teams, investors and managers. The aim of this workshop was to bring forward to the audience the Business and Environmental Value of BIM, using examples from completed projects and emphasizing saving opportunities such as: reduced design rework, reduced construction/rework costs and sustainable facility management and building operation. The larger and more complex the project, the greater the opportunity for savings, because of the greater probability of error and change elimination, meanwhile putting a brick in building a sustainable and eco-friendly AEC sector.

The workshop put in discussion the use of BIM in case of hospital building projects, emphasizing the main advantages of implementing this work procedure due to the complexity of such type of buildings throughout the entire life cycle.

Summary of the presentations

The first presentation was entitled **Introduction in BIM. Definitions, showcases, best practice**s and aimed at providing a clear definition of BIM and introduced several examples and best practices. The presenter, Dan MORARU is the manager of ALLBIM NET in Romania (in the past called Nemetschek România Sales & Support SRL), a company with approximately 25 years of experience in the AEC software industry, which in the last years have developed BIM software and engineering solutions. The main actors and information users within BIM were identified (**Figure 1**).

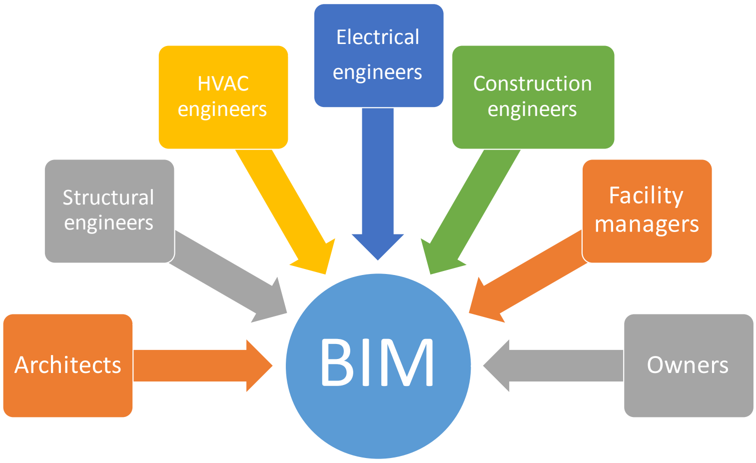

Figure 1. *BIM actors and information users.*

The second presentation, **Common Data Environment - PDF based collaboration. Case studies** was held by Alin Epure, engineer within ALLBIM NET Dubai, and shared the experiences on working with BIM for several complex projects in Dubai, among which the Opera House Office and Central Engineering Office. In this presentation, the focus was on the benefits of using BIM, mainly on the fact that the project management is significantly improved, and the necessary resources are reduced. An interesting observation stated that by using BIM in these two projects, approximately 6 900 kg of papers were saved in one year, which is the equivalent of 119 trees (**Figure 2**).

	A4	A3	A0	Total	
Opera House Office	250,000 pages	150,000 pages	18,500 pages	56,300 sq. m	4,500 kg
Central Engineering Office	80,000 pages	20,000 pages	21,000 pages	30,000 sq. m	2,400 kg

Figure 2. *Opera house paper consumption for engineering and construction in 12 months.*

The third presentation, **towards net-zero hospitals in the Netherlands**, was held by Wim Maassen and was focused on presenting the complexity of hospital buildings, emphasizing the need of proper research and development, share of knowledge and experiences to help hospitals take the right steps in energy transition. The content of this presentation was in line with the current global preoccupation of reducing the energy consumption of buildings as a step in the climate change mitigation. The EU's long-term objectives aim at achieving 80 to 95% greenhouse gas emissions reduction by 2050. Several case studies of existing hospitals in Netherlands were presented and assessed in terms of primary energy consumption.

The final presentation, entitled **Building information modeling of a hospital building,** was held by Ioan Silviu Dobosi, general manager of DOSETIMPEX. In this last presentation were approached some aspects related to the process of implementing BIM in the post-construction phase of a hospital building. A BIM protocol was developed which includes conventions and exigencies. Also, the Building Energy Modelling (BEM) based on BIM was discussed. BIM offers possibilities to break through the constraints of standard building energy modeling such as tedious model preparing, model inconsistency and encourages BEM into the digital building design process. The Building Information Modelling based Building Energy is particularly suitable for the early design phase, where the most appropriate and cost-effective methods for energy-efficient design and can be easily incorporated into building design process (**Figure 3**).

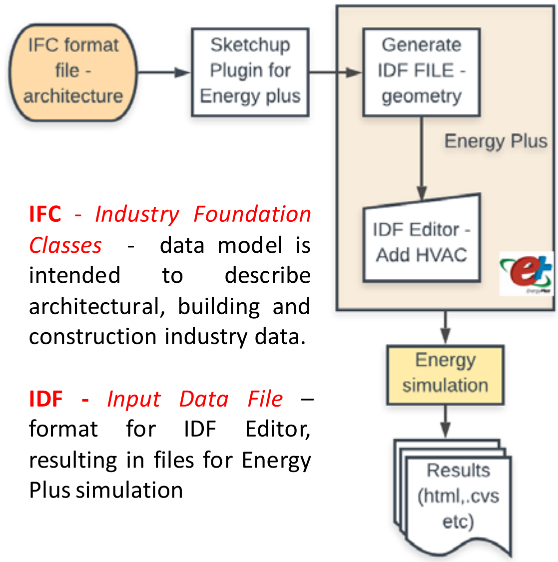

Figure 3. *Building Information Modelling (BIM) to Building Energy Modelling (BEM).*

Discussion and main results

The workshop's main objective was to provide strong motivation for specialists, investors and project managers towards adopting and implementing BIM as a work procedure for their projects. For those already familiar with BIM, it was a good opportunity to exchange opinions, share their experiences and establish collaborative connections. The main results of the workshop reveal that BIM is already a powerful engineering solution that is used in very complex construction projects worldwide. BIM can be extremely useful in so many ways, including in energy performance assessment of buildings. The development of building energy modeling based on building information modeling is currently at an initial stage. The existing literature sustains that there very few methods that can guarantee to generate reliable building energy models from building information models without errors. However, this way of work can improve the operability, speed the simulation and improve the accu-

racy of the results. Used in early design stages, Building Energy Modeling from Building Information Modeling can help to better integrate energy saving techniques and optimize the building form the energy performance perspective.

Conclusions and future work directions in the field

This workshop led to a series of conclusions related to the Business and Environmental Value of BIM. The implementation of BIM work procedure can provide benefits to all the actors involved in a construction project. Although BIM is becoming increasingly discussed and used, at present it is not clear how fast it will become common (if not mandatory) for building projects. In terms of requirements, there are several countries that already impose using BIM for certain categories of construction projects. As an overall conclusion of this workshop, BIM can be regarded as an effective way of increasing the sustainability of a construction project, throughout the entire project lifecycle by ensuring faster, safer, less wasteful construction and more cost-effective, sustainable operation and maintenance.

Nevertheless, for BIM to become a commonly used work procedure in construction projects, future work in this field is mandatory. First, engineers, architects, investors, project managers and building owners must acknowledge the power and benefits of using such a tool as well as the need of investing in software solutions and specialists in this field. Secondly, authorities must establish requirements that impose the use of BIM, especially for important and complex building projects such as hospital buildings, schools, special construction et. Finally, BIM and BIM standards should be introduced in the universities curricula in order to ensure that future employees in the AEC industry are prepared to engage and work in construction projects by using BIM.

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WS 18: REHVA-ISIAQ workshop on evidence-based ventilation needs and development process of future standards

Workshop organizers:

REHVA Technology and Research Committee

ISIAQ, the International Society of Indoor Air Quality and Climate

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Presentations at the Workshop:

1. ***Recent evidence on health and mental performance***
   Pawel Wargocki, DTU, Denmark, paw@byg.dtu.dk
2. ***ASHRAE 62.1 Indoor Air Quality Procedure vs. 62.2 approach***
   William Bahnfleth, Pennsylvania State University, USA, wbahnfleth@psu.edu
3. ***From performance criteria to design values: REHVA residential ventilation design procedure***
   Jarek Kurnitski, TalTech, Estonia, jarek.kurnitski@taltech.ee
4. ***Principles of New Finnish Ventilation Guidelines***
   Jorma Säteri, Metropolia University of Applied Sciences, Finland, jorma.sateri@metropolia.fi

Introduction and background

Recent research findings, their interpretation and meaning for ventilation system sizing was discussed with the aim to establish evidence-based design criteria of ventilation rates for residential and non-residential buildings. The workshop attempted to summarize existing evidence, possible knowledge gaps and to specify further actions what are needed to implement evidence-based ventilation rate values into future indoor climate standards such as in EN 16798-1:2019 and possibly in some other ventilation system standards. More specifically, the possibility to set up ventilation criteria which is based on the ventilation effects on acute health symptoms and mental performance is under interest, making a difference to perceived air quality based common approach. Some new results for instance isolating the effects of bioeffluents have made it possible to distinguish ventilation rates needed for health and comfort. Another question discussed was the question, how the research evidence typically available as ventilation rate L/s per person should be converted to residential ventilation design values which should be either in L/s per room or m² format, as occupancy

is typically not known for designers. In this field, a recent REHVA residential ventilation guidebook has proposed new design values based on common occupancy assumptions and category II indoor climate ventilation rate. Similarly, in Finland, ventilation guidelines have been recently updated based on practical design problems and long-time experience of the use of mechanical ventilation, and there are also prescriptive ventilation requirements in ASHRAE Standard 62.2.

Summary of the presentations

Pawel Wargocki summarized existing evidence on ventilation need. Standards CR 1752:1998, prEN 16798-1:2019 and ISO 17772-1:2017 operate with perceived air quality (body odor/ bioeffluents) based criteria of 4, 7 and 10 L/s pers in indoor climate categories III, II and I respectively. Recently it has been possible to distinguish the effect of bioeffluents as the only pollution source, **Figure 1**. Experiments with isolated bioeffluents show that the lowest observed effect level relevant for health symptoms and mental performance is CO_2 concentration of 1800 ppm corresponding to 4 L/s pers (effect on decision making performance).

450 ppm CO_2:	detection of bioeffluents
1,100 ppm CO_2:	no observed effect level (except the effect on $ETCO_2$ and perceived air quality and odor)
1,800 ppm CO_2:	lowest observed effect level (effect on decision making performance)
>3000 ppm CO_2:	range of adverse (negative) effects as regards self-estimated acute health symptoms, cognitive performance and physiological reactions

Figure 1. *Tentative dose-response relationship exposure for bioeffluents. (Source: Pawel Wargocki)*

In real buildings there are pollution sources in addition to occupants from building materials and occupants' activities. This increases ventilation need, and in dwellings, humidity control needs also to be considered. Summary of existing field studies is shown in **Figure 2**.

From field studies it can be summarized that:

- For health in dwellings, the minimum no-effect rate is ca. 6–7 L/s per person (1 L/s = 3.6 m^3/h);
- For schoolwork and office work, the minimum no effect rate 16–24 L/s person.

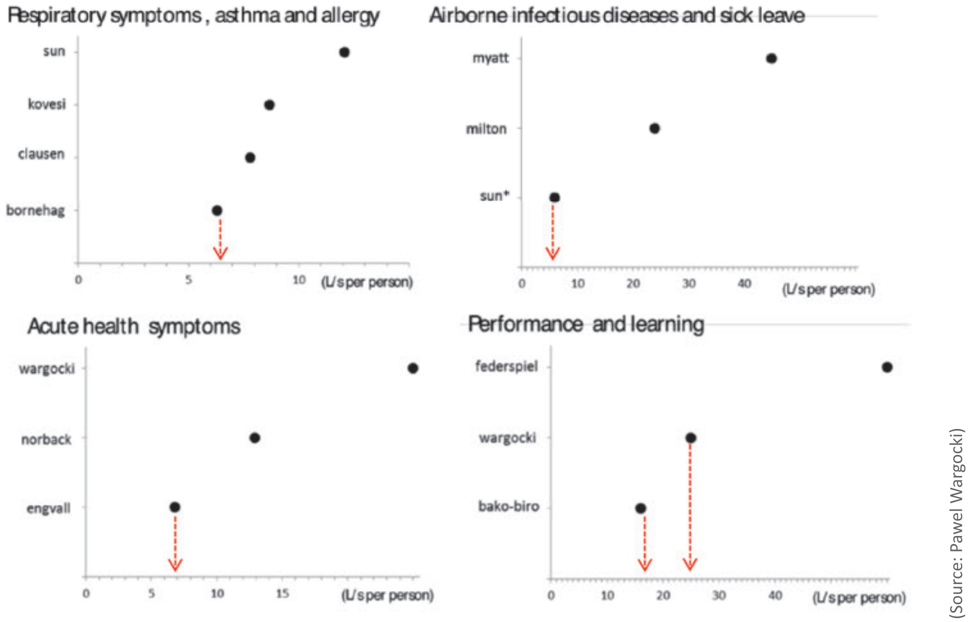

Figure 2. *Minimum ventilation rate for no effect on health symptoms and mental performance.*

William P. Bahnfleth introduced ASHRAE 62.1 Indoor Air Quality Procedure which is performance-based approach based on mass balance calculations to determine required ventilation rate. For residential ventilation, ASHRAE 62.2 ventilation requirements are prescriptive, depending on number of bedrooms (br) and floor area:

$$Q_{tot}[l/s] = 0.15\,[l/s/m^2]\,A_{floor}[m^2] + 3.5\,[l/s/br](N_{br} + 1)$$

This equation results in the total ventilation rate of a dwelling shown in **Table 1**.

ASHRAE 62.2 ventilation rates are lower than REHVA and Finnish values and there are no requirements how the total ventilation rate of the dwelling should be divided for different rooms, i.e. this is up to designer to make an adequate ventilation design inside the dwelling.

Jarek Kurnitski introduced REHVA GB 25 residential ventilation airflow rate selection procedure. This is based on prEN 16798-1 Category II

Table 1. ASHRAE 62.2 ventilation requirements for dwellings, total ventilation rate in L/s.

	Bedrooms				
Floor Area, m²	**1**	**2**	**3**	**4**	**5**
<47	14	18	21	25	28
47–93	21	24	28	31	35
94–139	28	31	35	38	42
140–186	35	38	42	45	49
187–232	42	45	49	52	56
233–279	49	52	56	59	63
280–325	56	59	63	66	70
326–372	63	66	70	73	77
373–418	70	73	77	80	84
419–465	77	80	84	87	91

values of 7 L/s pers and 0.42 L/s m² for which default occupancy and transfer air assumptions have been applied in order to end up with room-based supply and extract airflow rates. Room based airflow rates, **Table 2**, are needed because designers typically have no information about occupancy. All airflow rates are defined per room, the only exception is for living rooms where per m² part must be added to constant 8 L/s.

An example, how to apply airflow sizing procedure is shown in **Table 3** for one-bedroom apartment. Summing supply and extract airflow rates of the rooms results in almost equal

Table 2. REHVA airflow sizing procedure for dwellings.

	Supply airflowrate L/s	Extract airflowrate L/s	Air velocity[1] m/s
Living rooms[2] >15 m²	8+0.27 L/(s m²)		0.10
Bedrooms >15 m²	14		0.10
Living rooms and bedrooms 11-15 m²	12		0.10
Bedrooms <11 m², 3rd and the following bedrooms in large apartments	8		0.10
WC		10	
Bathroom		15	
Bathroom in one room apartement		10	
Utility room		8	
Wardrobe and storage room		6	
Kitchen[3]		8	
Kitchen[3], one room apartement		6	
Kitchen, cooker hood in operation		25	
Average airflowrate of a whole residence L/(s m²)	0.42		
Staircase of an apartement building, ACH	0.5		

[1]Maximum air velocity values apply at design airflow rate and supply air temperature in heating season conditions, in boost mode higher velocities may be accepted, see section 2.2.
[2]Transfer air from bedrooms may be reduced, 12 L/s is the minimum value
[3]Airflow rate in the kitchen when cooker hood is not in operation

Table 3. Airflow rate calculation in one-bedroom apartment. The determining airflow rate is marked with bold.

Room	Area, m²	Airflow rate, L/s (m³/h)		
		Supply	Extract	General air change
2.1 Room	3.0	-	-	
2.2 Kitchen	9.3	-	8 (28.8)	
2.3 Living room	16.2	12 (43.2)	-	
2.4 Room	3.7	-	-	
2.5 Bathroom	3.5	-	15 (54.0)	
2.6 Bedroom	11.5	12 (43.2)	-	
Entire apartment	47.2	-	-	47.2·0.42=20 (72.0)
Total		**24 (86.4)**	23 (82.8)	20 (72.0)

total airflows, and one extract airflow rate has been increased by 1 L/s to balance the ventilation. The total design airflow rate is therefore 24 L/s that corresponds to 0.73 ach air change per hour in this small apartment. Cooker hood operation (25 L/s required during operation) is another design task and operation mode not covered by this example. Kitchen extract air flow 8 L/s is general ventilation (cooker hood not in operation), but this may be taken through cooker hood. In the boost mode cooker hood extract flow rate must be increase to 25 L/s and total supply and extract airflow balance must be maintained for which technical solutions are described in the guidebook.

Jorma Säteri introduced new Finnish Guidelines for Ventilation Rates in dwellings. The basic ventilation rate is 6 L/s per person (instead of 7 L/s per person of REHVA) which has been used since 2012 in Finland. Room based ventilation rates are shown in **Table 4**.

As an explanation for **Table 4**, the outdoor airflow rates for the whole dwelling should be designed to meet following minimum requirements:

1) The outdoor airflow rate calculated over the whole floor surface area must be at least 0,35 L/s, m^2, and

2) the outdoor airflow rate for the whole apartment must be at least 18 L/s, and

3) each room must have an outdoor airflow rate at least 0,35 L/s, m^2, and

4) each residential room must have an outdoor airflow rate of at least 8 L/s. Bedrooms >11 m^2 floor area must have outdoor airflow rate at least 12 L/s.

5) If there is a sauna in the apartment, the total outdoor airflow rate must be increased by 6 L/s.

Table 4. Finnish outdoor and extract airflow rates for individual rooms.

Room	Outdoor airflow rate (dm^3/s)	Extract airflow rate (dm^3/s)	Notes
Largest or only bedroom / other bedroom over 11 m^2 floor area	12		
Other bedroom	$8^{1)}$		1) Air can partly be transferred from a bedroom
Other residential rooms like living room under 22 m^2 (not a kitchen)	$0{,}35^{1)}$ /m^2		
Kitchen, cooking area, kitchenette		$8\ (25)^{2,3)}$	2) Exhaust air flow rate of the kitchen hood at least 25 dm^3/s during cooking
Bathroom		$10^{3)}$	3) Air can be transferred from a bedroom
Separate toilet		$7^{3)}$	
Walk-in closet		$6^{3)}$	
Storage		$6^{3)}$	
Sauna in the apartment	6	6	
Utility room		$8^{3)}$	
Mechanical room		$3^{3)}$	

For different size of dwellings, the Finnish airflow rates result in total ventilation rates shown in **Table 5**.

Discussion conclusions

When comparing three airflow rate sizing procedures in dwellings, the results are quite similar, but there are differences in details. For 47 m² one bedroom apartment calculated in **Table 3**, ASHRAE 62.2 results in 21 L/s, REHVA GB 25 in 24 L/s and Finnish guideline in 20 L/s. Main differences in between REHVA and Finnish procedure are in base ventilation rate values, 7 or 6 L/s per person and whole dwelling 0.42 or 0.35 L/s m² respectively. In Finland, the experience from practice allows to conclude that 6 L/s per person is an appropriate value as a minimum ventilation rate. When generalizing this conclusion, it is important to know that very-low-polluting building materials are commonly used in Finland, thanks for local M1 labelling. As the use of very-low-polluting building materials is not necessarily the case in other countries, this fact well supports the use of slightly higher REHVA values. Generally, both values are well supported by the scientific evidence on ventilation need, which shows that for health in dwellings, the minimum no-effect rate is ca. 6–7 L/s per person.

REHVA and Finnish sizing procedures show the need for the development of standards. As in the design stage the number of occupants for a specific room is commonly not known, the room-based supply and extract airflow rate values are to be available for design. Current prEN 16798-1:2019 and ISO 17772-1:2017 have taken first steps to include airflow rate sizing procedure in dwellings and can be further improved by considering experience from REHVA and Finnish procedures.

Table 5. Minimum outdoor air flow rates in Finnish dwellings.

Floor area of the apartment (m²)	Outdoor airflow rate (L/s) based on number of residential rooms (rr)					
	1 rr	2 rr	3 rr	4 rr	5 rr	6 rr
20	18					
30	18					
40	18	20				
50	18	20				
60		21	28			
70		25	28			
80		28	28	36		
100			35	36	44	
120			42	42	44	52
150				53	53	53

Acknowledgement

This workshop was organized as a joint event of REHVA and ISIAQ with the aim to strengthen cooperation between practitioners and scientific society, and to find ways how scientific results should correctly addressed in guidelines and standards used in the design of buildings.

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Residential Heat Recovery Ventilation. Jarek Kurnitski (ed.), Martin Thalfeldt, Harry van Weele, Macit Toksoy, Thomas Carlsson, Petra Vladykova Bednarova, Olli Seppänen. European Guidebook No 25. REHVA 2018.

REHVA Guidebooks:

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No. 11 Air Filtration in HVAC Systems
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No. 29 Quality Management for Buildings
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