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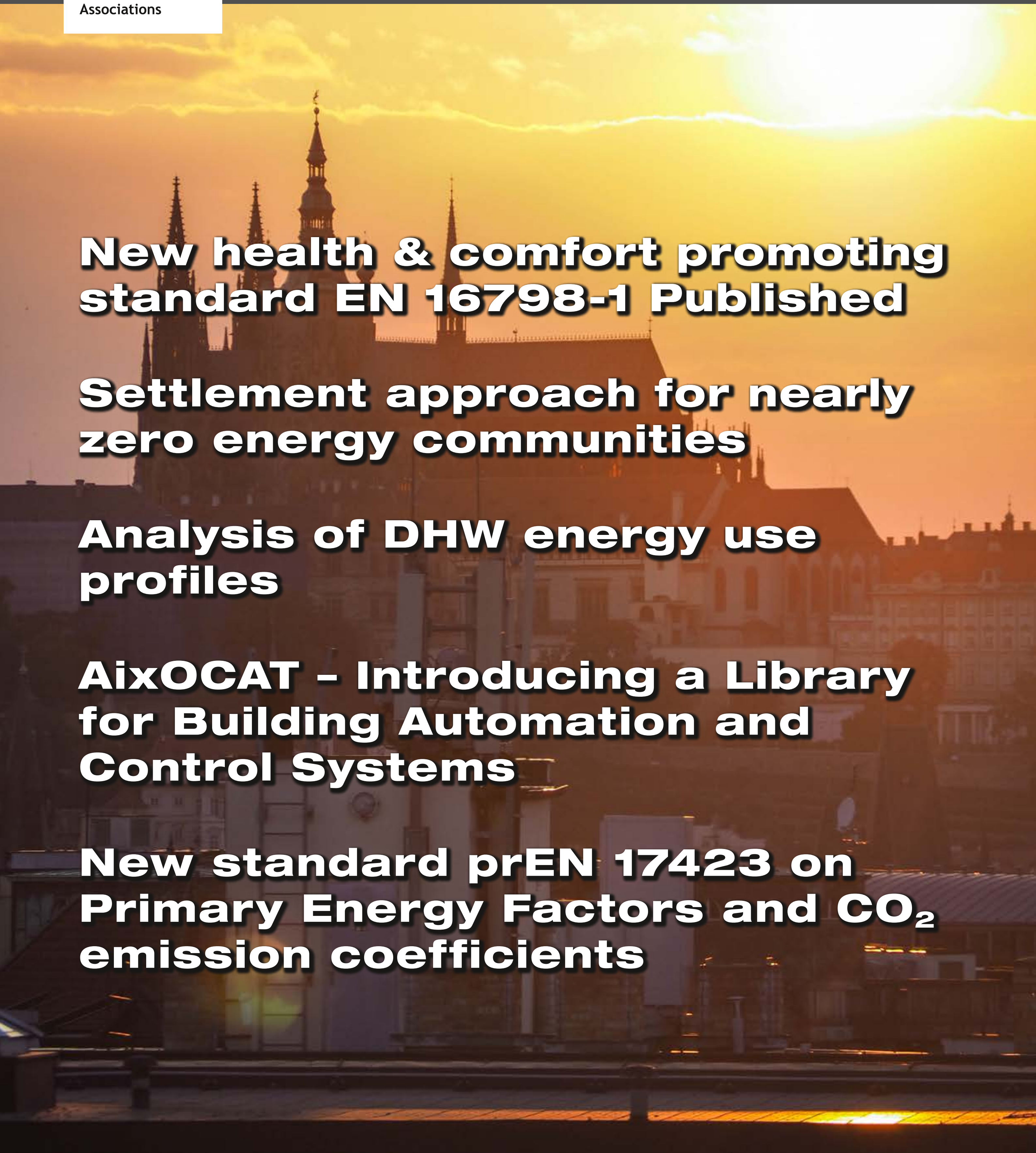

New health & comfort promoting standard EN 16798-1 Published

Settlement approach for nearly zero energy communities

Analysis of DHW energy use profiles

AixOCAT – Introducing a Library for Building Automation and Control Systems

New standard prEN 17423 on Primary Energy Factors and CO_2 emission coefficients

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From Energy Crises to Sustainable Indoor Climate

This is the theme of the AIVC conference to be held October 15-16 in Ghent, Belgium. REHVA Journals, Guidebooks, seminars have been addressing this theme the last decades frequently. This and the fact that this is the 40th AIVC conference makes this event a marker in history. It was announced by Bjarne Olesen in RJ 2015-05 that initiatives have been taken to establish the Indoor Environmental Quality Global Alliance (IEQ-GA). It is expected that the official public presentation of the IEQ-GA will be at this AIVC conference.

IEQ-GA

https://ieq-ga.net/

JAAP HOGELING
Editor-in-Chief
REHVA Journal

Six founding full-member organisations (AIHA, AIVC, AiCARR, ASHRAE, ISHRAE and REHVA) agreed to officially register IEQ-GA as an international global organisation. IEQ-GA is organized and operated for the purpose of bringing together professionals from various disciplines that deal with the indoor environment. IEQ-GA is dedicated to promoting the exchange of indoor environmental information, education and research for the safety and well-being of the general public. The IEQ-GA member-organisations will work together to create a common understanding and messaging of policy agendas and advocacy positions, research gaps, and research results and other collected information that can be transferred to practice in the form of standards, codes, guidelines or other means of dissemination in the widest understanding that support health and Indoor Environmental Quality in buildings and alike where the indoor environment is aimed at human occupancy.

The very recent publication of the last standard in the set of EPB standards developed under EU-Mandate 480 is EN 16798-1:2019 'Energy performance of buildings – Ventilation for buildings – Part 1: Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics - Module M1-6', marks also a step forward aligning IEQ and Energy Performance of buildings.

The publication of a BPIE report in October 2018 is also worth mentioning in this context. The title "The inner value of a building – Linking indoor environmental quality and energy performance in building regulation" promises a very interesting overview which this BPIE report does. The report still refers to several earlier published EPB standards like the EN 15251:2007 which is now replaced by the EN 16798-1 but this doesn't devalue this report. ■

New health & comfort promoting CEN standard

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In June 2015 the European Commission took the initiative to revise the European Performance of Buildings Directive (EPBD). The new version of the Directive (also referred to as 'EPBD recast') is first and for all meant to improve the energy performance of both new and existing buildings within the EU. With as end-goal: a decarbonized EU building stock in 2050.

The EPBD recast will lead to the introduction of and ameliorations in energy efficiency requirements in national building codes. EU countries have until 10 March 2020 to write the new and revised provisions into national law.

In the context of this CEN/CENELEC has developed a set of new EPBD standards (see also the article *'The 2nd recast of the Energy Performance of Buildings Directive (EPBD)'* by Jaap Hogeling and Anita Derjanecz (REHVA journal, issue 2, 2018). Most of these standards focus on aspects directly related to energy performance like methods to calculate energy use, inspection protocols or definition of e.g. climatic (outdoor) conditions.

What many don't know is that the Commission also asked CEN/CENELEC to (re)develop a standard that describes health and comfort related performance criteria that should be used in the context of energy calculations and assessments. The final version of this 'EPBD-IEQ' standard (IEQ stands for 'Indoor Environmental Quality') was officially published this spring (01-05-2019) under the name 'EN 16798-1:2019', full title: '*Energy performance of buildings – Ventilation for buildings – Part 1: Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics – Module M1-6*'.

EN 16798-1:2019 replaces EN 15251 and it focusses on parameters at category I, II, III level – sometimes also level IV (level I is best, III / IV is worst) for thermal environment, indoor air quality, lighting and acoustics. The standard explains how to use these parameters for building system design and energy performance calculations. It is part of a general series, EN 16798, that addresses overall aspects of building ventilation from the point of view of energy performance.

Besides the standard, a Technical Report, 16789-2, is also being developed to support and explain the background of EN 16798-1.

Table 1 describes some of the aspects and criteria used in EN 16798-1. The criteria are meant to be used in standard energy calculations for offices, schools, dwellings and other indoor environments that are primarily meant for human occupancy. The standard does so not by specifying design methods - leaving manufacturers free to provide their own - but instead it gives parameters that needs to be respected in the design and operation of heating, cooling, ventilation and lighting systems.

EN 16798-1 is a non-obligatory standard in the EPB standard series but EU member states can use elements from the standard to improve their national building codes. The standard gives guideline values that can be included in case e.g. a local building code does not have requirements meant to avoid that new or renovated buildings will be under-ventilated or have overheating problems or e.g. installation noise issues.

The overall objective in the long run is not just to make the EU building stock energy-neutral, the end goal should be to realize buildings that score well both in terms of energy performance and health performance. This new standard was developed to do just that: to guarantee that wellbeing and comfort of building occupants is systematically taken into account when new and existing buildings are (re)designed to improve their energy efficiency.

EN 16798-1:2019 'Energy performance of buildings – Ventilation for buildings, Part 1: Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics' can be ordered via your National Standardization Body.

This article is partly based upon a news item entitled '*New CEN standard: EN 16798-1:2019 on how to assess the energy performance of buildings*' on www.cen.eu and an article by Bjarne Olesen entitled '*Indoor environmental input parameters for the design and assessment of energy performance of buildings*' published in issue 6, 2017 of the REHVA journal. ■

Table 1. *Example criteria from EN 16798-1:2019.*

IEQ aspect	Building/space type	Category			Remark
		I	II	III	
Temperature range winter	Residential buildings (bedrooms)	21-25 °C	20-25 °C	18-25 °C	These are operative temperatures, assuming clo value of 0.5 in summer and 1.0 in winter, with activity level of 1.2 met
	Offices (landscape layout)	21-23 °C	20-24 °C	19-25 °C	
	Schools (classrooms)	21-23 °C	20-24 °C	19-25 °C	
Temperature range summer	Residential buildings (bedrooms)	23,5-25,5 °C	23-26 °C	22-27 °C	Additionally, also adaptive (less strict) upper temperature limits are defined
	Offices (landscape layout)	23,5-25,5 °C	23-26 °C	22-27 °C	
	Schools (classrooms)	23,5-25,5 °C	23-26 °C	22-27 °C	
Maximum CO_2 level (delta CO_2 conc.)	Residential buildings (bedrooms)	380	550	950	These are allowable ppm levels above outdoor levels
	Offices (landscape layout)	550	800	1 350	
	Schools (classrooms)	550	800	1 350	
Minimum lighting level E_m	Residential buildings (living room)	–			
	Offices (landscape layout)	500 lux			Values are in line with EN 12464-1
	Schools (classrooms)	500 lux			
Maximum system noise level L_{AeQ}	Residential buildings (bedrooms)	25 dB	30 dB	35 dB	
	Offices (landscape layout)	35 dB	40 dB	45 dB	
	Schools (classrooms)	30 dB	34 dB	38 dB	

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Ventilation efficiency of decentralized alternating residential ventilation units

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Decentralized alternating residential ventilation units are becoming increasingly widespread on the market. Some advantages, such as the comparatively simple retrofitting of existing equipment or relatively low investment costs, are obvious. But what about other aspects, such as ventilation efficiency, wind pressure stability and energy-saving potential? The publicly funded joint research project "EwWalt" is intended to answer some of the most urgent questions.

Keywords: ventilation efficiency, alternating, wind pressure susceptibility, heat recovery, dynamic pressure method

Mechanical ventilation is considered to play an important role in achieving the energy-saving targets for new construction and refurbishment of existing residential buildings, particularly in view of the possibilities for heat recovery and demand-based operation. In addition to the well-known ventilation units with continuous volume flow, decentralized alternating systems are increasingly being offered on the market, which are often also referred to as push-pull units. For heat recovery, heat storages are used with air passing them unsteadily in alternating manner (**Figure 1**).

In the extract air cycle, a storage mass is charged with the energy of the warm internal air. In the following supply air cycle, this energy is released again into the inflowing external air. Due to the necessary flow reverse, axial fans are typically used in these units. In order to achieve balanced air flows in relation to the room, at least two air flows are necessary, which work alternately in opposite directions. The two air flows can either be integrated in one casing (1 compact unit) or realized by two separate units which are coupled on the control side (2 single devices). In the second case, the devices can also be placed in different rooms.

Project "EwWalt"

In the case of alternating devices, there were still uncertainties as to how this concept should be evaluated in comparison to continuously operating devices due to a lack of science-based results. This applies to aspects such as ventilation efficiency, wind pressure susceptibility and the determination of energy parameters. These aspects were investigated in the publicly funded project "EwWalt – Energetische Bewertung dezentraler Einrichtungen für die kontrollierte Wohnraumlüftung mit alternierender Betriebsweise" (Energetic assessment of decentralized facilities for controlled ventilation with alternating operation). Under the leadership of RWTH Aachen University and with the project partners HLK Stuttgart and ITG Dresden, simulation investigations were carried out about indoor air flow effects, test methods for determining the characteristic values for the energetic evaluation were further developed and proposals for implementation in the standards were formulated.

Investigations on the function of alternating ventilation devices (based on numerical flow simulation)

CFD studies (Computational Fluid Dynamics) were carried out within the EwWalt project to compare the room air flows from the ventilation side, which are caused

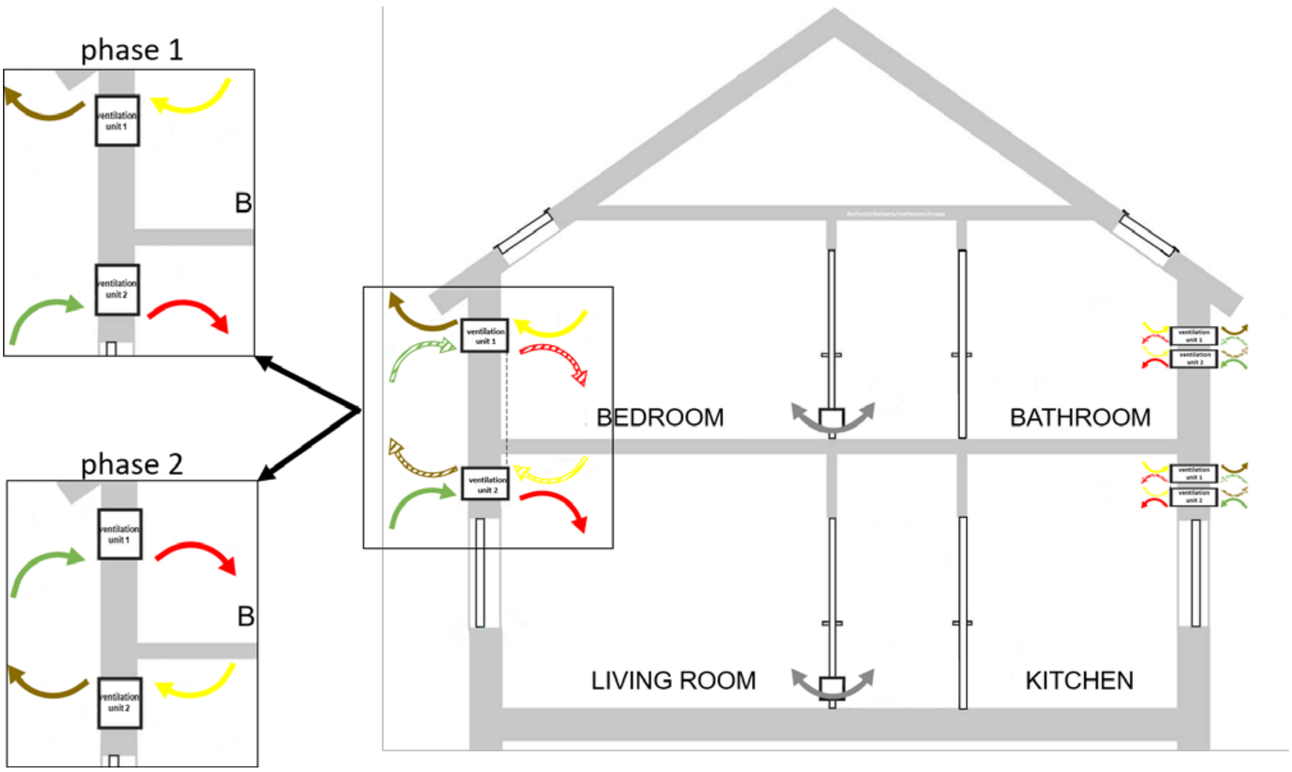

Figure 1. Functional principle of decentralized alternating ventilation units.

by decentralized alternating or continuous devices. With these calculations, it is possible to forecast the air flows that occur and, for example, to evaluate how long the air will stay in the building. These simulation methods were used in the EwWalt project to analyse the air exchange efficiency for all rooms in two different residential constellations (apartment & single-family house, see **Figure 2**). A small value for the air exchange efficiency, for example, indicates existing short-circuit flows.

In order to achieve a broad informative value of the results, several parameter variations were carried out. On the one hand, the local position of the ventilation units in the living area was varied; on the other hand, the ventilation volume flows for partial load behaviour were reduced. It was also investigated to what extent wind pressure on the building facade or an active exhaust air system in the building influences the operation of the ventilation units.

Since many different aspects like ventilation openings inside the building and wind pressure effect the volume flow rates which can be delivered by the ventilation devices, the so-called imbalance first had to be evaluated. For this purpose, the examined buildings were conceived as a duct network in a second simulation study, in which all ventilation components were modelled as flow resistances. This pressure-volume flow model calculates the final volume flows at all ventilation units, which are caused by disturbances such as wind pressure and ventilation system for bathrooms without windows. It was developed within the Modelica modelling language and coupled with the CFD model for the interior flow (**Figure 3**). The values for the effectively conveyed volume flows from the duct network simulation could thus be used as boundary conditions in the flow simulation.

The results coming from the duct network simulation showed that, for example, if the ventilation units were placed unfavourably across corners, relatively large pressure differences would be present at the ventilation units. The axial fans installed primarily in alternating ventilation units have flat pressure-volume flow characteristics, which means that even a slight pressure fluctuation has a strong influence on the volume flow conveyed. In partial load conditions and in case of strong wind, the volume flow can decrease to zero, which has a considerable influence on the heat recovery rate.

In contrast, the following CFD simulations under the various conditions all showed similar behaviour for ventilation effectiveness. Thus, a mixing ventilation characteristic with the typical air exchange efficiency

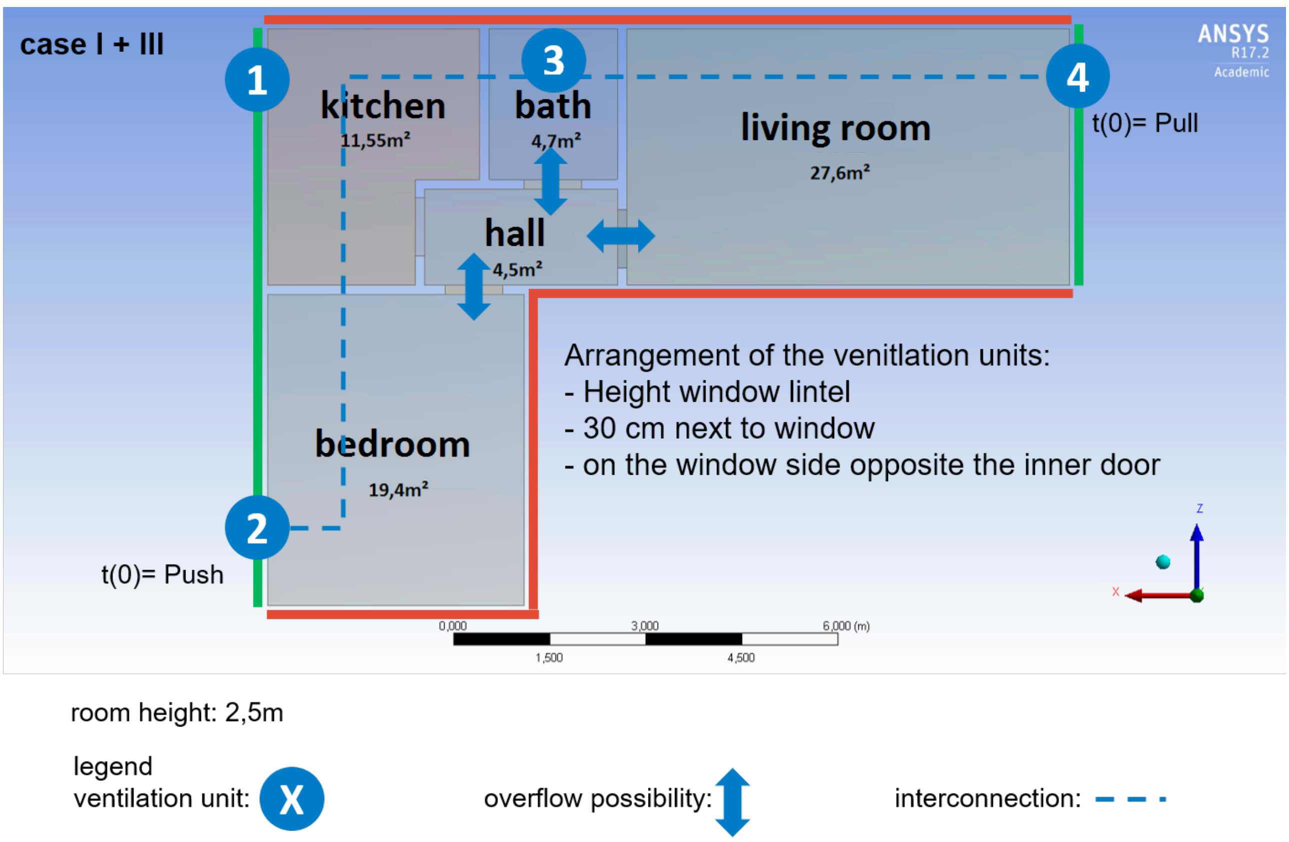

Figure 2. Floor plan and exemplary device constellation of the examined apartment.

of 0.5 was available in the individual rooms, almost independent of geometry, thermal conditions, volume flow and imbalance. Here, alternating ventilation units did not differ from continuously operated ones. Previous doubts that areas could be found in alternating operation – especially in corridors – that would not be supplied with fresh air by premature reversal of the ventilation direction could thus be eliminated.

Metrological investigations for further development and assessment of currently applied test methods for determining characteristic values

A great challenge during the test is the unsteady mode of operation during heat recovery. Therefore, it is not possible to use the methods known from continuously operating devices to determine characteristic values such as heat recovery, balance or air volume flow. For this reason, the air volume flow of continuous operation, which can be measured using a conventional method, has been used for simplification reasons up to now. The reduction of the mean volumetric flow due to the start-up and shut-down processes during the switching is neglected. In the EwWalt project a method was developed to measure the mean air volume flow also in alternating operation with comparable accuracy. The volume flow of the two strands is recorded over time using a dynamic pressure method (**Figure 4**).

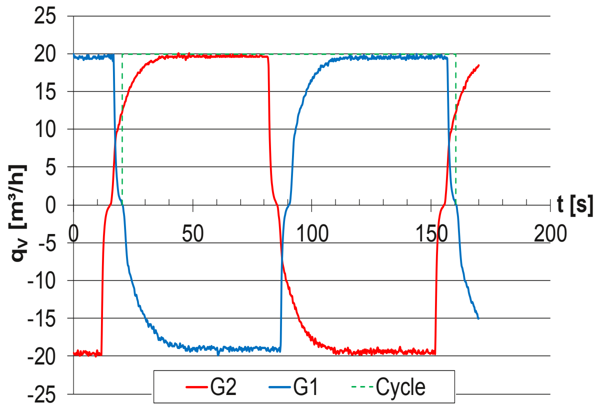

Figure 4. Example of volume flow curve measured in alternating operation.

An average volume flow in alternating operation can be determined from the measured curve. Comparative measurements have shown that in this case the average volume flow in alternating operation was approx. 85% of the volume flow in continuous operation. This method can also be used to determine the imbalance in alternating operation. This is a precondition for correct measurement of heat recovery.

Two methods are currently used to measure heat recovery. One method is described in EN 13141-8 *Ventilation for buildings - Performance testing of components/products for residential ventilation - Part 8: Performance testing of non-ducted mechanical supply and exhaust ventilation units (including heat recovery) for mechanical ventilation systems intended for a single room: 2014* (direct method),

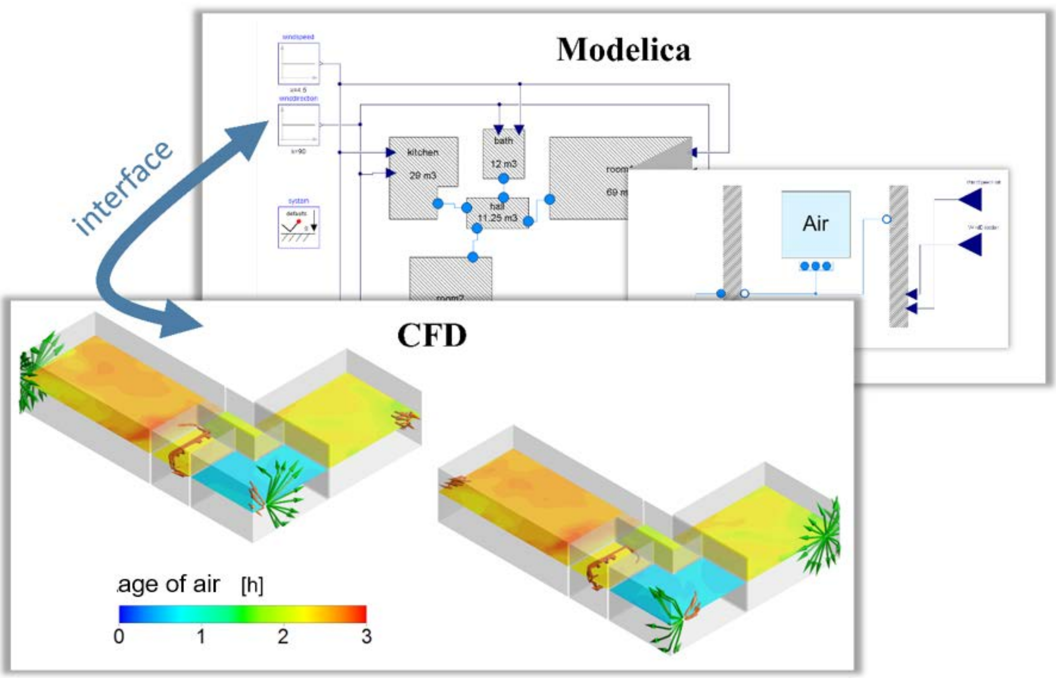

Figure 3. Interface between pressure-volume flow simulation and flow simulation.

the second method is used for DIBt (Deutsches Institut für Bautechnik – German institute of building technology) approval (purge air method). Both methods were examined in detail in the EwWalt project. For the direct method, the comparison measurements showed an increased measurement uncertainty of more than 8% due to the inhomogeneous temperature distribution of the air leaving the device (**Figure 5**).

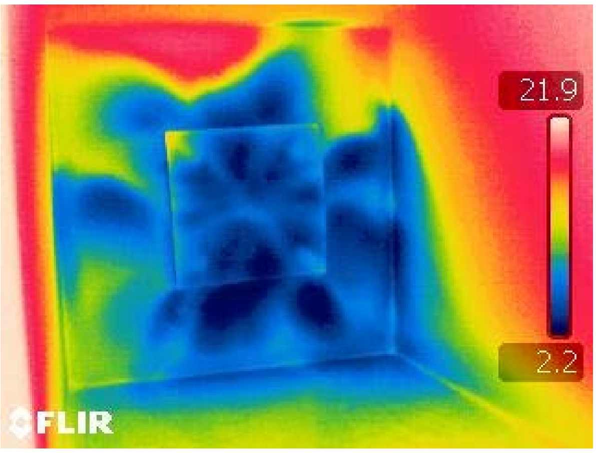

Figure 5. Qualitative visualization of the temperature distribution at the outlet of the device.

This uncertainty is prevented in the purge air process by homogenizing the air by mixing and turbulence before temperature measurement. A previously carried out inter-laboratory test of the DIBt resulted in a comparable exactness with this procedure as with the procedures for continuously working devices. The purge air method was further developed on the basis of the previously measured average volume flow to eliminate systematic disadvantages for compact units. With the help of the disbalance measured in alternating operation, the result of the thermal test can now also be corrected in analogy to the measurement of the continuous devices. During the comparison measurements, further parameters such as the purge air volume flow and the speed were optimized, so that the accuracy of the process could be further improved. A complete description of the purge air process provided the basis for its inclusion in the revision of the standard EN 13141-8 which is currently ongoing.

Results

The EwWalt research project was able to answer some of the most urgent questions on the classification and evaluation of decentralized alternating residential ventilation devices.

The recently achieved scientific results are based on investigations of the function of alternating ventilation devices based on numerical flow simulations. It was found that in all cases there is mixed ventilation practically independent of the room design. About the imbalance of the ventilation units and consequently also the effects of interference pressures (e.g. due to wind) on heat recovery, a correlation with the steepness of the unit characteristic curve could be demonstrated.

Parallel to the simulation, methods for the experimental evaluation of alternating ventilation devices were developed. With the developed method for air flow measurement in alternating operation it is possible for the first time to measure the effective air volume flow relevant for the design as well as the imbalance in alternating operation. For the determination of heat recovery, the direct method described in EN 13141-8 and the purge air method used for DIBt approval were analysed and compared in detail. Test boundary conditions are defined for the methods to improve the measurement uncertainty and comparability of the results.

From the results, useful characteristic values for standardization were identified and proposed for standardization work, e.g:

- a description of the purge air procedure for testing alternating ventilation units,
- a detailed representation of a standard-compliant design of alternating ventilation units about the positioning of the components and determination of the volume flows for typical constellations,
- an evaluation algorithm including characteristics for dual use of air,
- a normative concept for the consideration of start-up processes during alternating operation,
- an algorithm for considering wind pressure stability as a function of climate data in the efficiency of heat recovery, and
- further information on current standardization.

In the framework of the project, further topics essential for the well-founded evaluation of alternating ventilation units, such as moisture recovery, wind susceptibility or comfort evaluation, have been identified which should become the subject of further research activities. ■

Acknowledgements

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Active supply diffuser application in all-air heating systems

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Substantial reductions in energy use can be achieved by promoting low energy building technologies such as all-air systems. There is an idea that integrating active supply diffuser with all-air systems can potentially improve their performance. This paper numerically investigated the performance of an all-air heating system equipped with an active supply diffuser in a cell office, constructed based on Norwegian passive house, in terms of indoor air quality and thermal comfort of occupants. Simulations were performed using commercial Star-CCM+ software. The numerical results were validated using the available experimental data on the active supply diffuser from an office. The results showed that adopting active supply diffuser can avoid temperature stratification, which is the main reported issue in heating application of conventional all-air systems, and provide the thermal comfort with PPD ≤ 7% in most part of occupancy zone.

Keywords: All-air heating; active supply diffuser; temperature stratification; Indoor air quality; Archimedes number

Nowadays, low energy building technologies have drawn many attentions due their potential in substantial reductions of building energy use. The low energy HVAC systems can be considered as a practicable solution when the building space heating demands, especially in cold climate countries are really low. The passive house (PH) concept is an example in this point that aims at promoting the energy efficiency of buildings by significant reduction of space heating needs using a strict insulation level of building envelope. Consequently, it is reasonable to simplify the space heating system by covering both ventilation and space heating needs using a so-called all-air heating (AAH) system. The all-air heating means to supply warm air, usually at ceiling level, at a hygienic air flow rate. However, the system performance, depending on supply air temperature and flow rate, thermal load, and outdoor conditions, might not be desirable due to the presence of vertical air temperature gradient (temperature stratification) and poor indoor air quality (IAQ) due to ineffective mixing of supply air flow with the convective plum of occupants and equipment in the zone of occupancy.

In this regard, the AAH system performance was investigated by several research studies. Fisk et al. [1]

conducted several experiments with a ceiling supply/exhaust configuration and the results supported a significant short-circuiting of ventilation air between the supply air diffuser and return air. The same phenomenon was also reported by Offermann and Int-Hout [2]. A significant stratification of contaminants in the lower part of the occupancy zone [3], poor air distribution and temperature stratification [4], a stationary region in the zone of occupancy [5], and non-uniform distribution of air velocity and temperature [6] were other reported issues associated with the application of AAH. Therefore, the AAH system performance needs to be improved in order to be considered as a functional solution for HVAC system in cold climate countries.

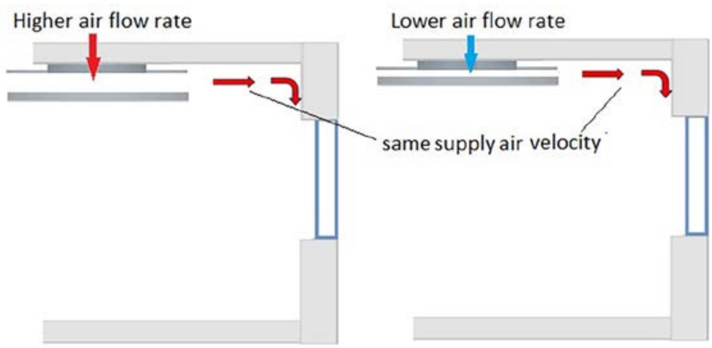


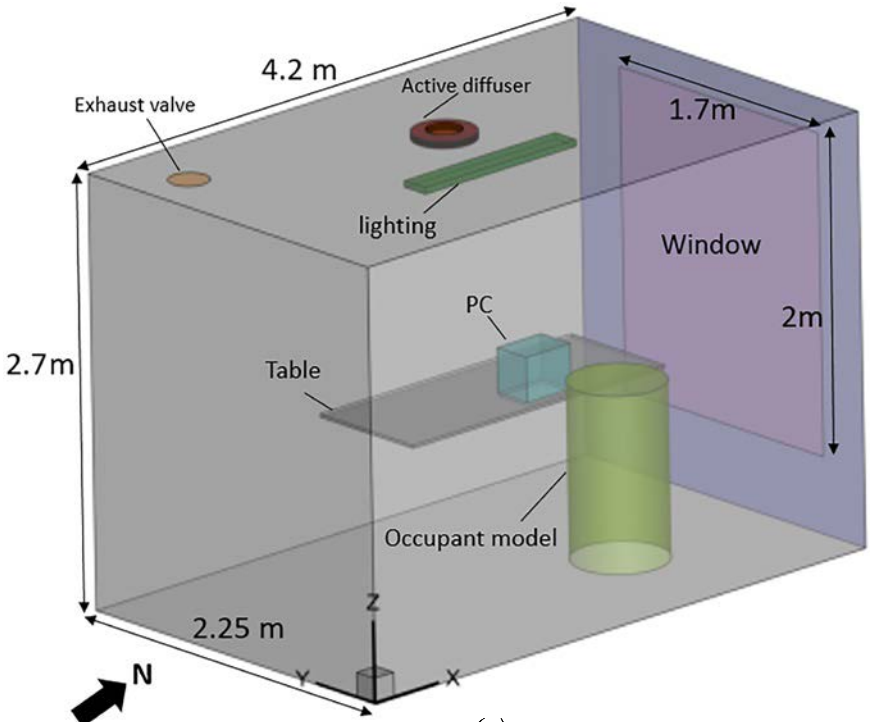
Figure 1. Conceptual schematic of active supply diffuser application in AAH system.

The aim of this study was to remedy the aforementioned issues in AAH systems using an active supply diffuser. The existing constant air volume (CAV) system could be converted to a variable air volume (VAV) system by installing active supply diffuser and isolating existing duct systems. **Figure 1** illustrates how the active supply diffuser functions. In typical VAV systems without active supply diffuser, the supply air velocity changes as the supply air flow rate changes due to constant supply area. This may increase the risk of draft in AAH systems, especially at low air flow rates. To solve this problem, the active supply diffuser will change the supply area proportional to the air flow rate so that a constant supply velocity is achieved for different air flow rates.

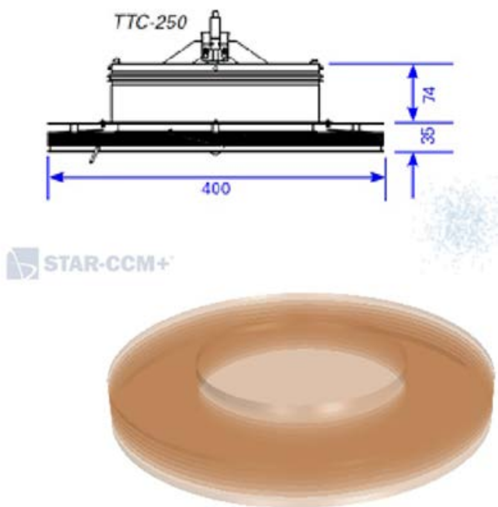
Methodology

Case study and boundary conditions

This study used Star-CCM+ software to analyze the performance of the AAH system equipped with the active supply diffuser in a cell office, constructed based on the Norwegian PH standard [7] and located in a Nordic climate. **Figure 2** shows the cell office configuration dimensions, and type of active supply diffuser. The active supply diffuser in this system was a TTC-250 active supply diffuser comprised of several moving plates [8]. For the boundary condition the inlet of the active supply diffuser was modelled using



(a)



(b)

Figure 2. (a) Cell office configuration and dimensions and (b) TTC-250 active supply diffuser.

constant air velocity profile. Pressure outlet with zero gage pressure was considered for the exhaust. Lighting, PC, and occupant were modelled using constant heat source boundary condition 136W, 120W, and 30W, respectively. The external wall, internal wall, window, floor, and ceiling were modelled using heat transfer boundary conditions calculated from the energy balance with overall heat transfer coefficients taken from the experimental study [9].

Performance index parameters

In order to evaluate the performance of AAH system with active supply diffuser the following parameters and index were defined:

■ Archimedes number (*Ar*): describes the characteristics of supply jet and was defined according to the Eq. 1

$$Ar = \frac{g\beta a_0^{\frac{5}{2}}(T_e - T_s)}{Q_s^2} \tag{1}$$

for mixing ventilation system.

where T_s was the supply air temperature, T_e was the exhaust air temperature, u_0 was the supply air velocity, and β was the coefficient of thermal expansion, a_0 was the net opening area of the supply, and Q_s was the ventilation air flow rate.

■ Predicted mean vote (PMV) and predicted percentage of dissatisfied (PPD) – show the thermal comfort of occupants. PMV examines the occupant thermal sensation according to seven scale points (from –3, cold, to 3, hot) with regard to six factors the air temperature, the mean radiant temperature, the air velocity, the air humidity, physical activity and clothing isolation level. PPD gives the thermal dissatisfaction predicted by PMV quantitatively. In order to have a favorable environment for a building with low energy use, the PPD should be less than 10% associated with $-0.5 < PMV < 0.5$ [10].

Numerical method validation

The numerical method was validated using the available experimental data. The details of experimental setup can be found in [11]. **Figure 3** indicates the location of experimental sensors and the comparison of air temperature and velocity obtained from simulations with the experimental data. It is observed that the results of simulations were in the uncertainty range of experimental data.

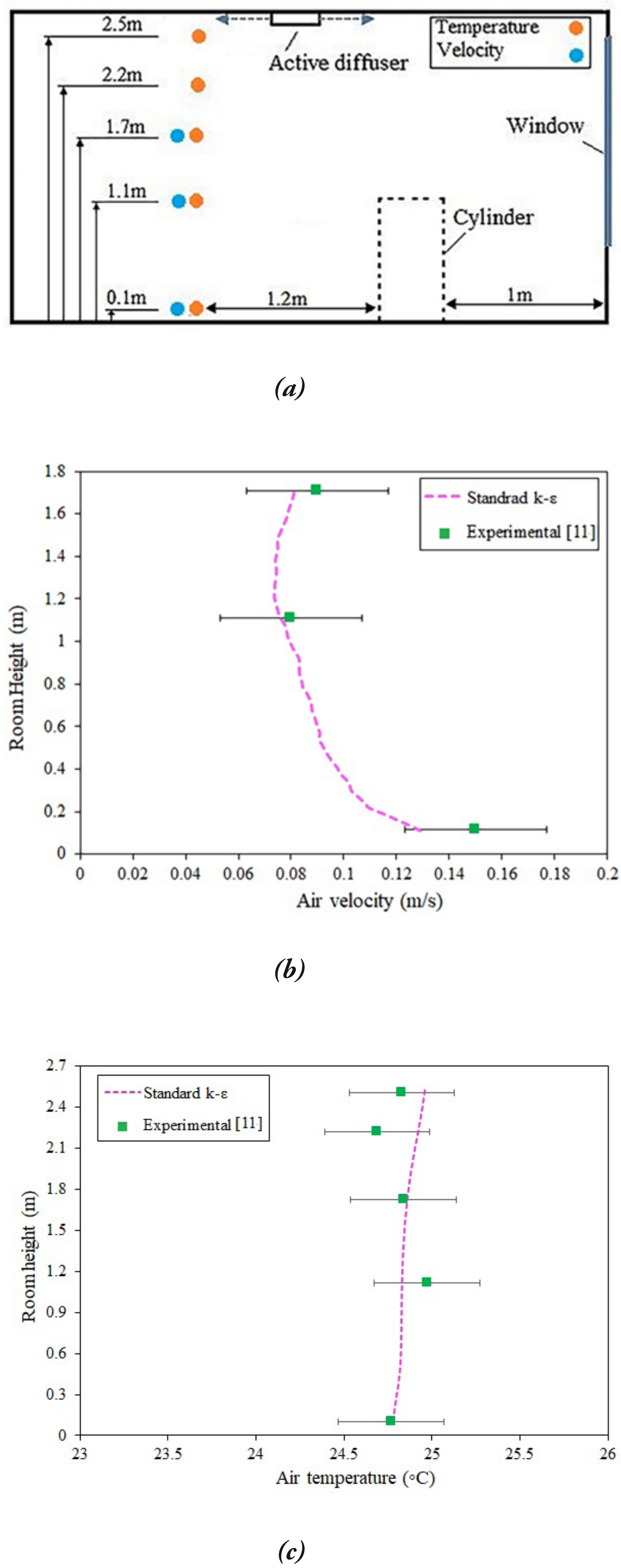


Figure 3. (a) location of experimental sensors, (b) air velocity and (c) air temperature variations at the measurement points.

Results and discussion

The performance of the system was analyzed for the most critical condition with the outdoor temperature −20 °C, which was the design outdoor temperature for Oslo, Norway, in the winter season [12]. The active supply diffuser was also operated under two different air flow rates: the minimum air flow rates required by the Norwegian PH standards and the maximum air flow rates for which the active diffuser could operate. **Table 1** describes the details of two scenarios. The negative Archimedes number shows that a negatively buoyant air was supplied.

Table 1. *The main parameters for the scenarios investigated in this study.*

Scenario	T_{out} (°C)	T_s (°C)	$\dot{V}_s$ (l/s)	*Ar*
S1	−20	24.8	49.4	-1.56×10^{-3}
S2	−20	26.4	16	-1.73×10^{-3}

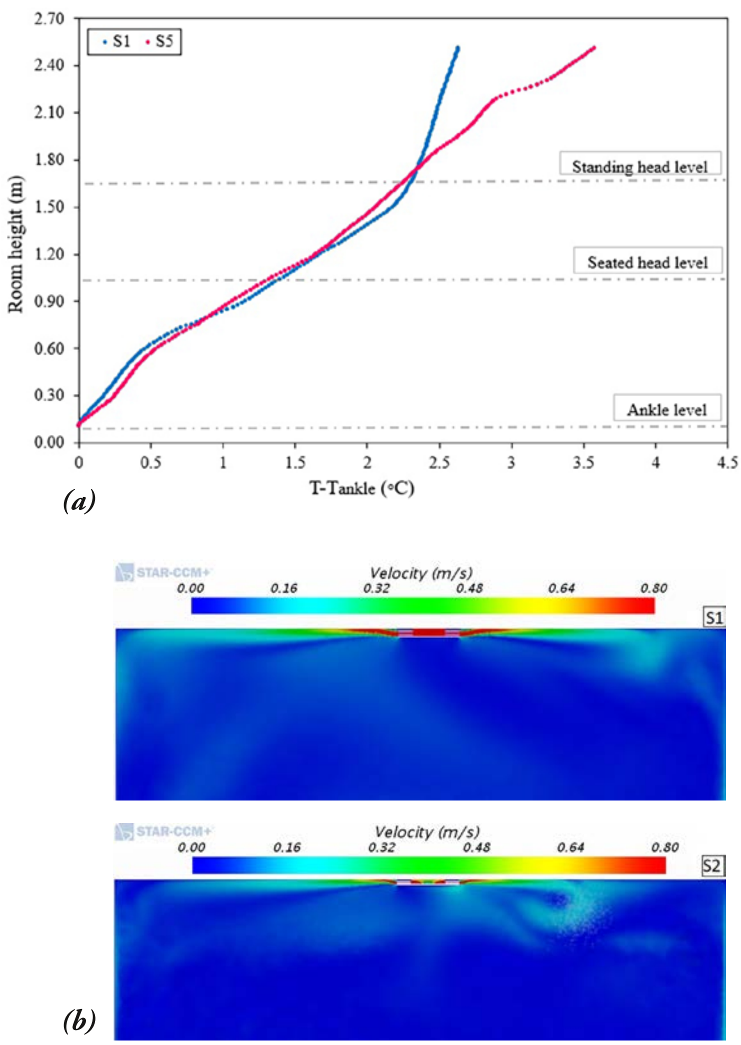


Figure 4. (a) Temperature stratification and (b) air velocity distribution for two scenarios in a plane passing through the window

Figure 4 illustrates the temperature stratification and air distribution for two cases. Maximum temperature stratification between seated head level and ankle level was around 1.5 K (**Figure 4a**), which was within the maximum recommended range by the EN ISO 7730 standard for the IAQ category II, indicating that active supply diffuser could avoid temperature stratification at both maximum and minimum air flow rates. This can be also seen in **Figure 4b** where the throw length towards internal wall (left side) was preserved by the active supply diffuser. However, the throw length towards window side (right side) was different due to interaction between cold current from the window and the supply jet.

Figure 5 illustrates the variation of thermal comfort indices for both scenarios. Using active supply diffuser could almost satisfy PMV requirement for both scenarios (**Figure 5a**) according to comfort category II [10]. The spatial distribution of PPD for both scenarios at three cross sections are shown in **Figure 5b**. The thermal comfort for both cases were always satisfied at the standard seated head level in the occupancy zone (1.1 m above the floor) with PPD ≤ 7% implying the decent performance of active supply diffuser in providing uniform distribution of supply air in the occupancy zone. However, some small region above that level located in the convective plume of occupant had higher PPD.

Conclusions

This study dealt with numerical simulation of IAQ in a standard cell office equipped with active supply diffuse and located in a Nordic climate country. Two different scenarios for maximum allowable and required minimum air flow rates were analyzed and the results showed that applying active diffuser at ceiling level could avoid temperature stratification, with maximum temperature stratification around 1.5 K, even at minimum air flow rates by changing the slot opening of diffuser. The thermal comfort analysis showed that both scenarios almost satisfied the average PMV requirements according to the comfort category II. Furthermore, spatial PPD values at the seated head level was less than 7% satisfying the requirements for the comfort category II. It is worth mentioning that the cooling performance of active supply diffuser would be interesting to be evaluated as the all-air system should also cover the building cooling load. ■

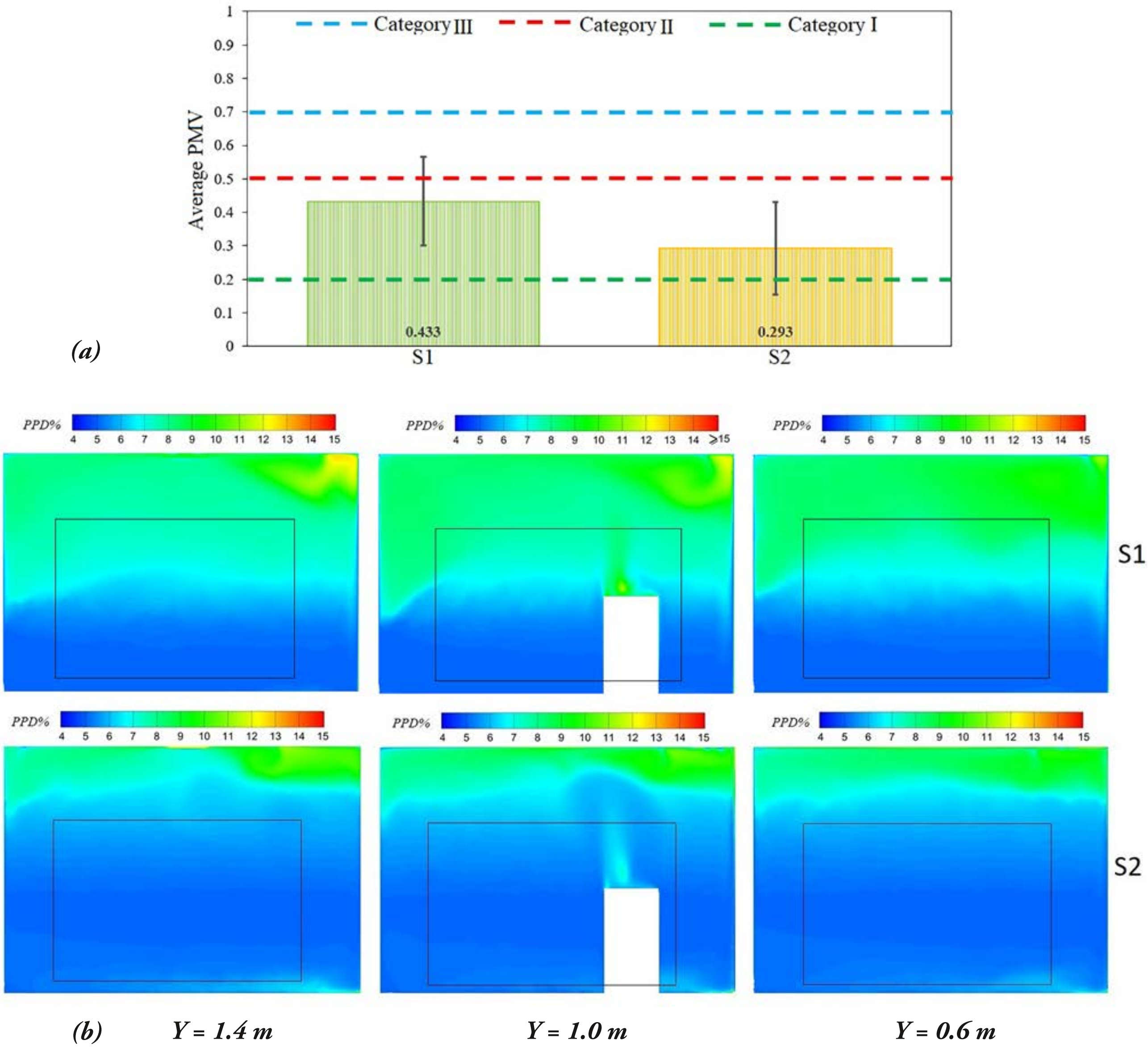


Figure 5. (a) Average PMV in the zone of occupancy and (b) PPD distribution in three cross sections

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Settlement scale analysis approach to reach nearly zero energy communities

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Looking at the recent developments, the European Union (EU) aims to become a zero carbon community. For the building sector, Energy Performance of Buildings Directive (EPBD) was recast in 2010 introducing the definition of the nearly zero energy building (NZEB) levels to construct all new buildings at this level by the end of 2020. The last revision of the directive in 2018 also promotes the renovation of the building stock to the NZEB levels. In the paper, it was proposed to define the nearly zero energy levels for settlements. This way, it was aimed to discuss the advantages and disadvantages of reaching the nearly zero energy levels at larger scales than single buildings. Settlement level studies, including the district energy systems, intended to reveal the energy efficiency measures which lead to optimal cost levels for more than one building. Key parameters were examined for a new settlement design which may be beneficial for the large-scale renewable energy system implementation and district energy system (DES) usage with high energy performance buildings.

Keywords: NZEB, Nearly zero energy settlements, district energy systems

Energy has been one of the key issues of all the states for financial balances, external affairs, and internal politics. European Union (EU), working on the subject since decades, has set several targets to reduce its external dependency, to secure clean energy sources, and to be a nearly zero energy community by 2050. Target years include 2020, 2030 and 2050, and each includes the strategies for energy efficiency, renewable energy usage, and greenhouse gas emission reduction rates [1].

EU's activities objecting the building sector energy efficiency can be reviewed mainly under the directives on the energy performance of buildings. The first one was published in 2002 to set and assure the minimum energy performance requirements for both new and existing buildings [2]. Energy performance of buildings directive (EPBD) was recast in 2010 introducing new terms as cost-optimal and nearly zero energy levels for building energy performance. Relatedly, it introduced a methodology framework, cost-optimal methodology, to determine these levels. EPBD 2010 also mandated throughout the EU all new public buildings, by the end of 2018 and all new buildings, by end of 2020, to be constructed as nearly zero energy building (NZEB) [3]. Lastly, EPBD was revised in 2018 which was primarily focused on increasing the building stock renovation rate to the required energy performance levels.

The aim of this paper is to discuss the advantages and disadvantages to reach a very high energy performance at settlement scale on the road to a zero carbon community. The discussion was based on the results of a case study which includes a virtual settlement level study explained under the "3 Case Study" title and further information can be found in detail in [4].

The case study basically has two phases. First, through the building scale studies, high energy performance levels which are supported by renewable energy systems were defined. This definition was practically made by the principles of the cost-optimal methodology of EPBD 2010. Secondly, settlement scale high energy performance was assured which is affected by building locations and distances between them, street orientations, district energy system configurations, etc. The main points of the approach were explained in the Method section.

Method

In the study, the cost-optimal methodology of EPBD was proposed to be adopted to settlement level analyses, aiming to reach high energy efficiency levels, not only in buildings but also at settlement scale. Relatedly, another objective was to research the possibilities of decreasing the global costs of high energy performance levels (NZEBs) of buildings to the optimal levels (cost-optimal).

As it is well-known, under the cost-optimal methodology, various energy efficiency measures (EEMs) are applied to a reference building (RB) and primary energy consumptions (PECs) are calculated or simulated for each measure. Besides, global costs (GC) of the building with each measure are calculated and PEC of the measure with the lowest GC is selected as cost-optimal level (CB) for that specific type of building in that specific climate type. After that phase, each nation defines the nearly zero energy levels for each building and climate type by considering the incentives, discounts, credits, etc. through their financial, social, energy politics and targets. The whole procedure is schematized in **Figure 1.**

As it comes to the settlement scale energy performance analyses, buildings and district energy systems (DESs) could be analysed together. Different energy levels for buildings and several district energy system alternatives can be combined for the analysis. Thus, as an energy performance indicator, primary energy consumption of the DES should be calculated or simulated. Here, it is focused on the community cost of the entire system, even the investors or managers of the buildings and DES managements are generally diversified. Community cost of the whole system includes the total investment costs of buildings and DES, cost of energy supplied from the grid and operation and maintenance costs of buildings and DES during a 20-year period. Similar to the cost-optimal methodology framework, the net present value method may be used for the global (community) cost calculations. Finally, the settlement configuration with the lowest global cost can be named as the cost-optimal settlement (CS) and the configuration with higher energy efficiency can be named as the highly efficient settlement (HES).

The proposed methodology is schematized in **Figure 1** below.

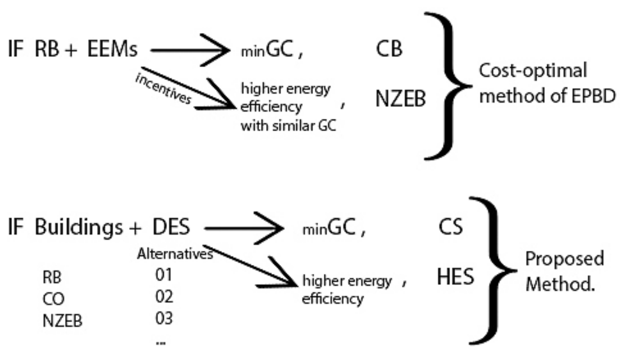

Figure 1. Schematic explanation of the proposed method.

Case Study

In the case study, the proposed methodology was applied to a virtual newly-designed settlement in Eskişehir, Turkey. 34 Residential, 7 offices and 1 light-industry building were included in the settlement and site locations were determined to optimize the solar gains for each building and to minimize the losses of the district energy system (DES) distribution network.

Reference buildings were designed to represent the existing building stock and according to Turkish national standards.

Cost optimal levels were determined by applying the cost-optimal methodology of EPBD. As nearly zero energy levels were not determined yet for Turkey, the building cost-optimal cases with renewable energy contribution were accepted as high energy performance (HEP) buildings.

DES alternatives were configured to include heating, cooling, and renewable energy systems. Thus, cogeneration units (CHP), boilers, chillers, and photovoltaic panels (PVs) were utilized to constitute the alternatives.

Results

As it was asserted, the cost-optimal methodology was applied to each reference buildings to reach the specific energy performance levels of buildings, which are cost-optimal and high energy performance levels. These energy performance levels will be used as demand inputs at the settlement level analyses.

The simulation results of the case study include basically both the building and settlement level primary energy consumptions, energy efficiency levels, and global costs. Building level results show the primary energy consumptions and improvement percentages for reference, cost-optimal and high energy performance levels of each building type.

According to **Table 1, 2, and 3**, the cost-optimal levels of each building type have about 40% of improvement compared to the reference cases. When it comes to the higher energy performance levels with renewable energy contribution, residential and light industry building have improvement above 60% while the office building's improvement is about 50%.

Settlement scale result given in **Table 4** is the aggregation result of each building in the settlement, thus it doesn't include the district energy systems. At the settlement level, cost-optimal level of buildings corresponds to 38% higher energy efficiency compared to reference buildings. This improvement ratio is 57% with high energy performance buildings.

Primary energy consumptions for all the settlement case alternatives were demonstrated together with global costs in the graph given in **Figure 2**. Reference

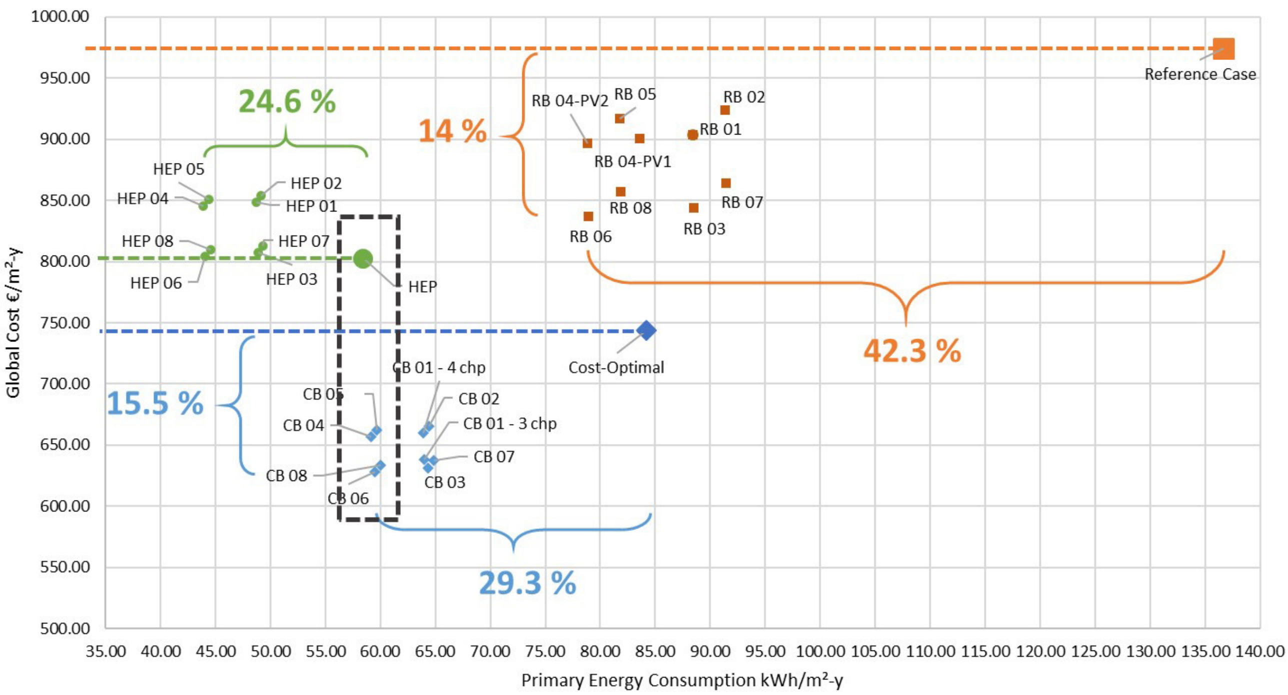

Figure 2. Primary energy consumptions and global costs of each settlement case including reference, cost-optimal, and nearly zero energy buildings and DES alternatives.

(RB), cost-optimal (CB) and high energy performance (HEP) points indicate the cases without DES, which were also summarized in **Table 4**. It can be seen from the graph that primary energy consumptions are being able to be decreased by DES connection for each building energy performance level. However, the effectiveness of the district energy systems was also decreasing while the building energy performance level increasing. More importantly, in the cases with nearly zero energy buildings, global costs of the cases with DES alternatives were higher than the case without DES. Here, it should be asserted that only the investment costs of the district energy system transformation of the buildings were included in the global costs, but not the removal costs of the old (building-specific) system.

In **Figure 2**, the settlement cases with and without DES can be also examined. Comparing the case of nearly zero energy buildings without DES and the case of cost-optimal buildings with DES alternatives 6 and 8 have nearly the same primary energy consumptions. However, comparing their global costs, the cases with cost-optimal buildings have much lower global costs. This comparison is summarised also in **Table 5** with some other cases. Thus, as a result, it can be asserted that connection of a settlement with cost-optimal buildings to district energy system carries the global costs to a lower level, which may be accepted as nearly zero energy level.

The same comparison between the settlement with high energy performance buildings and the case of cost-optimal buildings connected to a DES can be seen in **Table 5**. Here, it can be seen also the difference in investment costs. Constructing a settlement with cost-optimal energy levels of buildings and connect them to DES will be a more economic investment.

Discussions

Today, consumed energy throughout the world is still based on fossil sources. Thus, energy, like oil, natural gas, etc., is being transferred from a few producer countries to the consumer ones, which makes the most countries dependent on the external energy sources. Under these circumstances, several nations try to increase their overall energy efficiency to decrease this dependency and related energy expenses by legislative actions, setting long term goals. Additionally, investing in renewable energy sources which can be used locally, help to decrease the energy dependency and to increase energy efficiency, all at once.

Table 1. *Residential building primary energy consumptions for the reference, cost-optimal and high energy performance levels.*

	Reference	Cost-Optimal	HEP
PEC [kWh/m²]	96.84	61.71	36.50
Improvement	/	36%	62%

Table 2. *Office building primary energy consumptions for the reference, cost-optimal and high energy performance levels.*

	Reference	Cost-Optimal	HEP
PEC [kWh/m²]	175.00	105.63	88.83
Improvement	/	40%	49%

Table 3. *Light industry building primary energy consumptions for the reference, cost-optimal and high energy performance levels.*

	Reference	Cost-Optimal	HEP
PEC [kWh/m²]	392.34	231.51	117.10
Improvement	/	41%	70%

Table 4. *Buildings total primary energy consumptions for the reference, cost-optimal and high energy performance levels in the settlement.*

	Reference	Cost-Optimal	HEP
Total PEC [kWh/m²]	136.68	84.22	59.11
Improvement	/	38%	57%

Table 5. *Comparison of some settlement cases.*

	RB	HEP Case	HEP A04 Case	CB A06 Case
PEC [kWh/m²-y]	136.69	59.11	43.89	59.54
Improvement	/	56.76%	67.89%	56.44%
Investment Costs [€/m²]	333.78	528.59	635.51	379.25
Investment Cost Difference	/	58.36%	90.39%	13.62%
Global Costs [€/m²]	974.09	802.6	845.24	628.3

Buildings, including both residential and non-residential ones, are responsible for the one-third of the total primary energy consumption of the world [5]. So, increasing the energy efficiency of the building sector would help to increase the total energy efficiency. In the EU, buildings energy performance directives and related national standards have already become very strict for the buildings to be constructed or renovated to nearly zero energy levels.

At this point, research studies on building energy performance are recently focused on how to carry close the nearly zero energy levels to the cost-optimal levels. Settlement scale energy efficiency measures and district energy systems are inevitably being analysed for this purpose. In this study, it was shown also that district energy systems may carry a settlement with cost-optimal buildings to nearly zero energy levels.

The objection of this paper was to discuss the beneficial and unfavourable points of achieving a very high-performance level at settlement scale. A case study was completed to develop a methodology, but still different cases, such as climates, building types, standards for buildings and DES energy efficiency, should be studied.

The results of the case study showed that the settlement scale studies accelerate the process of achieving a (nearly) zero carbon community. Especially for the newly planned settlements, measures including the location pattern design to control the solar gains, wind effects, increasing the transportation efficiency, decreasing the district heat distribution losses, etc. will assist to reach the desired building energy performance levels. In the EU, NZEB levels are mandatory for all new buildings by 2021. The results of the case study showed that the DES usage carries the settlement case with cost-optimal buildings to nearly zero energy levels. Although the results should be tested by further studies, DES usage can be seen a potential to close the financial gap between nearly zero energy and cost-optimal levels. Another advantageous point for the settlement scale analyses and energy efficiency measures, larger renewable energy system installations may be utilized, especially for the new settlements. Dependently, more incentives may be obtained for larger scales of renewables, depending on the country-specific conditions.

Settlement scale measures may also be economically beneficial. According to the results, it was already discussed that the settlement with cost-optimal buildings served by a DES has nearly the same PEC with the settlement case with NZEBs, however, have less global cost. Furthermore, when it comes to investment costs, the same case has also less investment cost than the settlement with NZEBs.

Under the DES system, depending on the various combined heat and power system technologies, various energy sources, other than the natural gas and electricity, can be utilized for heating and cooling of the buildings. These sources may be organic wastes, wood chips, or other biomass products. This allows the utilization of the local sources, which decreases fossil fuel consumption, external dependency and energy costs. Also, DES allows being used different system types together which increases the flexibility of the system.

National politics and targets, as they define the boundaries, are very crucial while assessing the effectiveness of the DESs and settlement case measures. The proposed approach of the case study is based on the cost-optimal methodology of EPBD and requires the global cost calculations and nationally-defined nearly zero energy levels. The NZEB should be closely related to national energy targets and politics. In Turkey, NZEB level definitions for different building types and climate conditions are still being discussed and studied. The determination of the NZEB levels would affect the results of this study. Additionally, the regulations on DES are being prepared which will affect the determination of the reference case and pricing mechanisms included in this study.

In the case study, a newly-planned settlement was analysed. However, the conditions may be different for renovating an existing settlement to the required energy performance levels. Beginning with the building level energy efficiency measures, in existing settlements, it cannot be always possible to work on all the buildings in the settlement. Thus, it would take a relatively long period to reach the nearly zero energy targets. The most critical issue for an existing settlement, if no DES system installed already, would be the transformation for the DES system of the buildings. DES placement is important to diminish the distribution losses. Likewise, the building level energy efficiency measures implementations, the transformation of the existing mechanic equipment in all buildings may not be possible. Also, the investment and global costs of these transformations may create a limitation.

According to the case study results, DES connection of buildings was shown as beneficial for energy efficiency and global costs. However, in case of all buildings are forced to be connected to a DES, then monopolization problem may occur. The building owners or managers should have an independence to choose and/or to decide the building conditioning system. Some hybrid systems may be developed to allow the usage of both individual and district energy systems.

Additionally, the further legislative actions should be taken by authorities to prevent monopolization problems and also to regulate the high energy performance district energy systems. When the buildings have high energy performances, they require less energy. And this may create an undesirable market for the DES managers.

Lastly, for the further studies, existing settlement refurbishment cases should be analysed to confirm the effectiveness of the proposed methodology. In district energy system alternatives, more efficient cogeneration unit technologies due to alternative energy source usage, such as biomass, wood chips, etc., may be added. More importantly, DES managements and pricing mechanisms should be analysed for a sustainable development. ■

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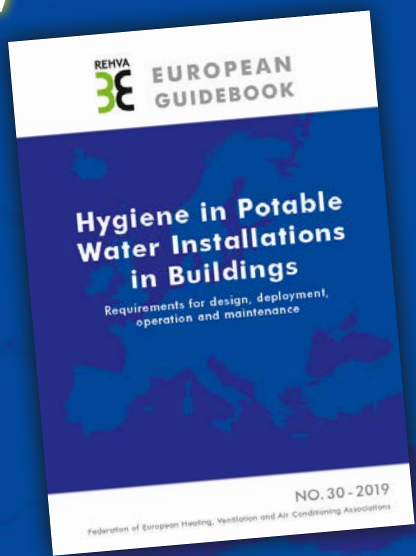

Analysis of DHW energy use profiles for energy simulations in a hotel located in Norway

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Domestic hot water (DHW) system is significant energy consumer in hotels. For this reason, energy modeling and simulations in hotels should provide an accurate and representative assessment of the energy performance of domestic hot water systems. The majority of dynamic simulation tools use DHW energy use profiles as the basic for estimating DHW energy needs. In this article, energy simulations in EnergyPlus software for a large hotel were carried out. All inputs in the EnergyPlus simulation model were adjusted according to Norwegian national regulations. Application of different DHW energy use profiles in the simulation model was explored. The profiles given in the national and international standards were compared with profiles obtained from measurements in the hotel located in Oslo, Norway. Simulations in EnergyPlus showed that application of profiles from measured data have higher accuracy then simulations based on standards. The results of the study may give indication for sizing and planning of DHW systems.

Domestic hot water (DHW) systems make a substantial contribution to the energy balance in hotels in Norway [1]. They are responsible for approximately 20–35% of the total energy use in these buildings [2]. Michopoulos, Ziogou [3] estimate that CO_2 emissions for hot-water use in the hotels remains quite high, 2.87–3.2 kg-CO_2/(person·night). Hot water usage is the second largest energy consumer in hotels after heating [4]. Recent studies emphasise that a large potential for increasing energy efficiency in buildings can be achieved by improving operation and design of DHW systems [4]. One of the aims of the simulation approach of DHW system performance is to estimate and predict the DHW volume and the energy use for hot water production in existing building, or in building at the design phase. This information is essential for sizing and optimising of DHW system and its components [5].

The DHW profiles are the basis for simulation of DHW systems performance in buildings, as well as useful instrument for understanding the process of DHW energy use in the buildings [6]. The profiles of DHW energy use show how the energy for DHW is used most of the time.

Building simulation tools may require diverse input data for DHW energy use simulation. In many simulation tools, average yearly DHW energy use profiles per m² of building area are applied as input for modelling. Other tools require three types of input data: average DHW use in l/(person·day), occupant number, and DHW usage profile. In addition, the default values for DHW supply temperature and cold-water temperature are considered for energy estimation. The so-called bottom-up approach requires a detailed information of occupant presence, profiles of occupant activities, available domestic appliance, corresponding technical details, etc. [7]. The methods based on detailed information about DHW use activities and DHW system, usually require extensive input data, which increases the complexity of obtaining this information and process of energy use estimation.

A comparative analysis of five different software calculation tools based on technical standards for predicting monthly and daily DHW consumption profiles in residential buildings are investigated in [5]. The deviation in results from measured data are –30% to +40%. Better estimations are obtained with methods based on standards specific to the country where measurements were done.

A better understanding of DHW energy use profiles and their application in simulation tools is a crucial factor in achieving energy savings in hotel buildings. Therefore, in this article DHW profiles based on measured energy use in the hotel in Oslo, Norway, were developed. The data comprises five years of hourly measurements of energy use for DHW. The obtained profiles, as well as profiles from national and international standards for heat demand calculation, were applied in simulation model of a representative hotel. The model was developed in EnergyPlus [8]. The possible benefits from using more accurate energy profiles were explained.

Methods

For modelling of the hotel, EnergyPlus model from the Department of Energy (DOE) Large Hotel model [9] was used. The model was adjusted according to Norwegian regulations and requirements.

For the analysis of DHW energy use in the hotel, it was considered few different scenarios:

1) DHW energy use was derived from profiles obtained based on measurements in the real hotel, located in Oslo.
2) DHW energy use was derived from profiles in ISO 18523-1 [10].
3) DHW energy use were derived profiles obtained from the technical specification SN/TS 3031:2016 [11].

The results of simulations based on different DHW energy use profiles were compered.

Description of the real hotel building

The parameters of the hotel are typical for Norway. The hotel reflects well the trends of DHW energy use in similar types of buildings. The building was renovated in 2007. The area of the hotel is 4 939 m². The building has eight floors with 164 guest rooms. All the guest rooms have bathrooms with toilet facilities and shower. According to the hotel management, employees use hot water for cleaning, and guests use hot water for personal hygiene.

In the DHW system, the hot water is circulated all the time to ensure fast delivery at each tap all the time. The hotel uses electric water heaters for DHW preparation. Data on energy use for DHW were collected during several years from an energy meter installed by the hotel owner. The meters measure electricity delivered to the DHW tanks. This means that both DHW needs and heat losses in the DHW system were included in the presented DHW energy use.

Description of the simulation model

It is supposed that a reference building simulation model represents the average building stock in a Norwegian geographical area in terms of building characteristics and functionality [8]. The model for the reference hotel was selected from the U.S. DOE database. The building in EnergyPlus present 7 floors: 6 floors above the ground level and 1 basement, see **Figure 1**. The total building area is 11 348 m². Based on the geometry and shape of the real hotel in Oslo, it was estimated that the model in **Figure 1** would fit well for the analysis. The weather data for Oslo, Norway, were used as input in this study.

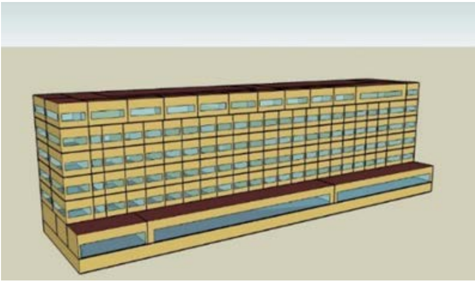

Figure 1. Reference hotel.

The modifications were done to conform the model to Norwegian national limits on building thermal properties, indoor comfort, and annual energy use. To initialise, the building parameters and schedules for human occupancy were used from the following national and international standards: ISO 18532-1, EN 15232, and NS 3031:2007 [10-12].

Results

DHW energy use profile based on measurements

Statistical data of energy use in the hotel show that DHW tap systems have significant impact on energy use in buildings. More specifically, in the observed hotel, DHW energy use constituted more than 20% of total energy use.

Since the simulation model and actual hotel have different area, energy use profiles from measurements were calculated per m² of building area. As discussed above, both DHW needs and self-use in the DHW system were included in the presented measurements. Self-use includes water leakages in the pipes, circulation losses, energy use for maintaining the required temperature of DHW in the system and other consumer-independent losses in the system. Due to these losses, a DHW system is constantly using a certain amount of heat, even if there are no visitors in a hotel. Reducing self-use is an essential task in achieving efficient energy use in the buildings. Statistical data for the hotel showed that information about self-use could be obtained based on profiles of the DHW energy use in public holidays. From **Figure 2**, we can see that hourly average and variation of DHW energy use during the holidays is very small. This phenomenon could be explained by the fact that on holidays, the hotel was closed for visitors. Consequently, the DHW energy use in the hotel in these days mostly caused by self-use in the system.

Accordingly, it was proposed to consider the average profiles of DHW energy use during the public holidays as a way to assess self-use in DHW system of the hotel. Average profiles of energy use on holidays evaluate the share of energy use for self-use of DHW system. The identified percentage of the energy use for self-use in the hotel constituted 39.15% of the average DHW annual energy use.

Comparison of DHW energy use in the standards and measurement data in the real hotel

"ISO 18523-1:2016: Energy performance of buildings" provides reference domestic hot water usage for different types of rooms. Based on ISO 18523 and EnergyPlus model, DHW energy use profiles for the typical hotel were obtained. "SN/TS 3031:2016: Energy performance of buildings. Calculation of energy needs and energy supply" is a national standard in Norway. Calculation of energy needs and energy supply gives recommendation on DHW profiles that should be used as input for energy demand calculation [11].

In this study, the profiles of the actual DHW energy use in the real hotel, see **Figure 2**, and the profile for the same type of building based on the standards ISO 18523, see **Figure 3**, and SN/TS 3031, see **Figure 4**, were compared. The analysis indicates the big difference between these tree types of profiles.

Compered to profiles in real hotel, **Figure 2**, the profile based on ISO 18523, see **Figure 3**, significantly overestimates the DHW energy use in the hotel. ISO 18523 shows morning and evening peaks of the DHW energy use, which occur from 6 a.m. to 10 a.m. and from 6 p.m. to 11 p.m. The peak energy use modelled based on ISO 18523 are about three times higher than those measured in the real hotel. Besides, evening peak of DHW energy use in a real hotel is not expressed as obvious as in the ISO 18523.

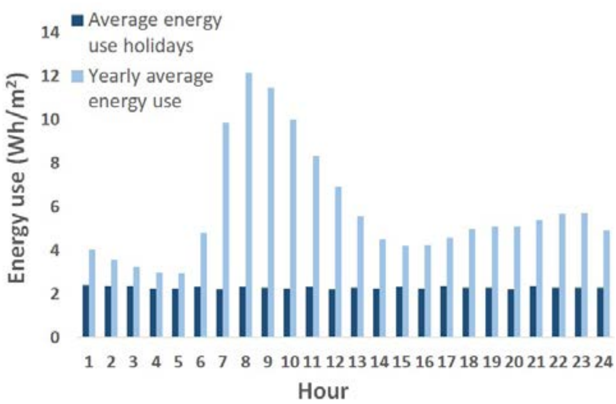

Figure 2. Profiles of hourly DHW energy use on holidays and all days in the year in the hotel.

As shown in **Figure 4**, the DHW energy use from 1 a.m. to 5 a.m. in the standard SN/TS 3031 is equal to zero. This fact means that the standard does not take in account the so-called self-use of the system. On the contrary, the actual data obtained with the help of energy meters usually contain both the system's self-use and DHW energy use by visitors. It should be noticed, that self-use of the system is responsible for the significant share of energy use in DHW tap systems (up to 40% during the year) and therefore cannot be neglected.

From the standard SN/TS 3031 profile (see **Figure 4**), we can assume that morning peak of energy use occurs from 7 a.m. to 8 p.m., and evening peak from 6 p.m. to 7 p.m. The maximum heat demand during the day is approximately 8 W/m². Meantime, from the profiles of energy use obtained from the statistical data, it was possible to notice that morning peak usually occurs from 7 a.m. to 11 a.m., and a small increase in energy use can be observed from 10 p.m. to 11 p.m. The maximum energy use during the day was approximately 12 W/m². The difference in the values of maximum energy use in considered profiles was 6 W/m², which was 30% of the total DHW use. This difference could be explained by self-use of DHW system that the standard SN/TS 3031 does not take into account. However, it could be noticed from **Figure 4**, the timing of actual peaks of energy use also does not match the information presented in the standards.

Monthly and annual DHW energy use

The simulation results from EnergyPlus with different DHW profiles as inputs were compared with the actual energy use in the hotel. Monthly energy use is given in **Figure 5** and annual energy use is given in **Figure 6**. The simulation results for the DHW energy use revealed the drawbacks of the considered standards.

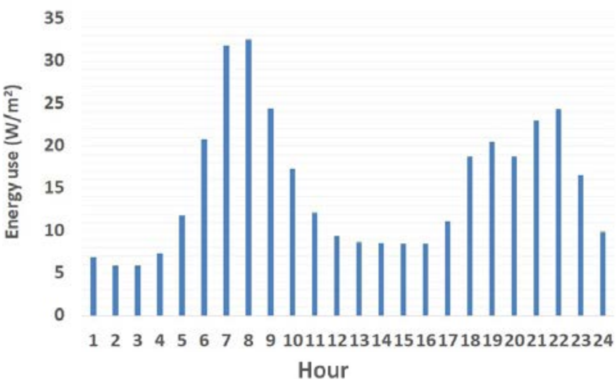

Figure 3. Hourly profile of DHW energy use of the hotel obtained based on "ISO 18523-1:2016: Energy performance of buildings".

For example, the difference between the annual DHW energy use simulated by profiles obtained from the measurements and the real total DHW energy use was approximately 10%. Meantime, the national standard, SN/TS 3031:2016, underestimated annual DHW energy use for 32% and ISO 18523-1:2016 overestimated for 2.3 times.

Simulation results indicated that the DHW energy use was responsible for significant share of the total energy use of the hotel see **Figure 7**.

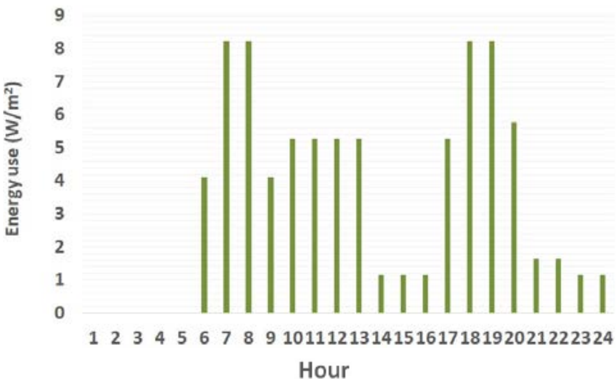

Figure 4. Hourly profile of DHW energy use according to the standard "SN/TS 3031:2016: Energy performance of buildings. Calculation of energy needs and energy supply".

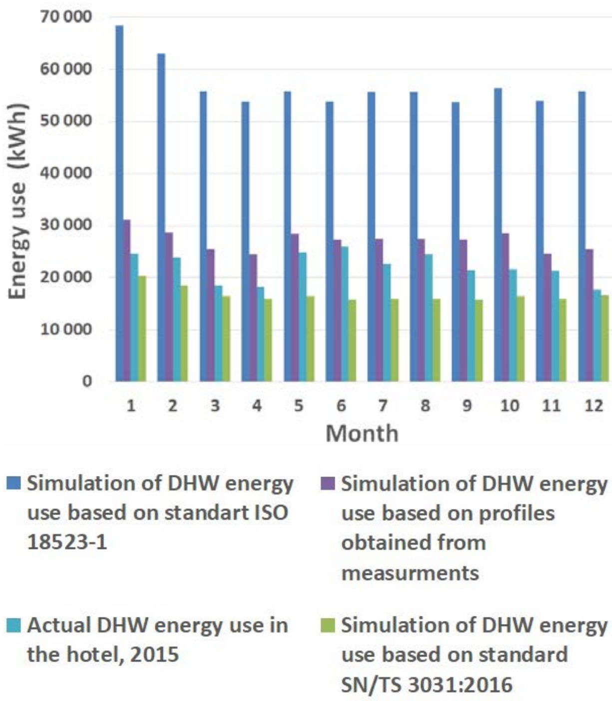

Figure 5. Simulated and actual monthly DHW energy use in the hotel.

Comparison with the DHW energy use in the real hotel revealed that simulations based on profiles obtained by measurements gave better explanation of the DHW energy use than the standards. The standard ISO 18523-1:2016 significantly overestimated the DHW energy use in the hotel in Norway. Meantime, for annual and monthly simulations of the DHW energy use, the technical specification SN/TS 3031:2016 demonstrated quite reasonable result. However, in addition to using the technical specification SN/TS 3031:2016, the assumption about self-use in DHW system should be included in calculations. Making this assumption for a real building can be problematic.

The factors that introduce uncertainty to simulations are number and types of DHW use facilities in the hotels. The presence of a restaurant, swimming pool, sauna, and gym increase DHW energy use at the hotel. The profiles given in the standards are usually too simplified. These profiles were created for certain categories of buildings such as hotel, offices, school, etc. However, even within one type of buildings, DHW energy use can behave differently. For example, studies showed that specific DHW use in large and luxury hotels is much higher than in a regular one [4]. Therefore, there is a need to develop more aggregated profiles, which will take into account the main factors that influence DHW energy use. It should be emphasized that these profiles should be based on accurate and up-date statistical data from real buildings and reliable methods of processing available information.

Conclusion

DHW systems play essential role in achieving efficient energy use in buildings. For this reason, evaluation of DHW energy during simulations should be representative and corresponds to real energy use in buildings. The DHW profiles are the basis for simulation of DHW systems performance. Moreover, analysis of DHW energy use profiles is a powerful instrument for gaining knowledge about DHW system operation.

In this article, the EnergyPlus model from the DOE Large Hotel model was adjusted according to Norwegian regulations and requirements. For analysis of the DHW energy use in the hotel, it was considered few different scenarios with various profiles used as input. Profiles obtained based on measured DHW energy use in the real hotel, profiles derived from international standard ISO 18523-1, and the national standard SN/TS 3031:2016 were used in this study. The comparison of the standards revealed the significant difference between hourly DHW energy use obtained by measurement and standards. Besides, the timing of actual peaks of energy use does not match the information presented in the standards. Implementation of the EnergyPlus model indicated that simulations based on profiles obtained by measurements gave better explanation of the DHW energy use than using the standards. Simulations based on ISO 18523-1:2016 overestimated the annual DHW energy use approximately two time and peak energy use three times. Meantime, the national standard SN/TS 3031:2016 showed better result. However, the standard SN/TS 3031:2016 does

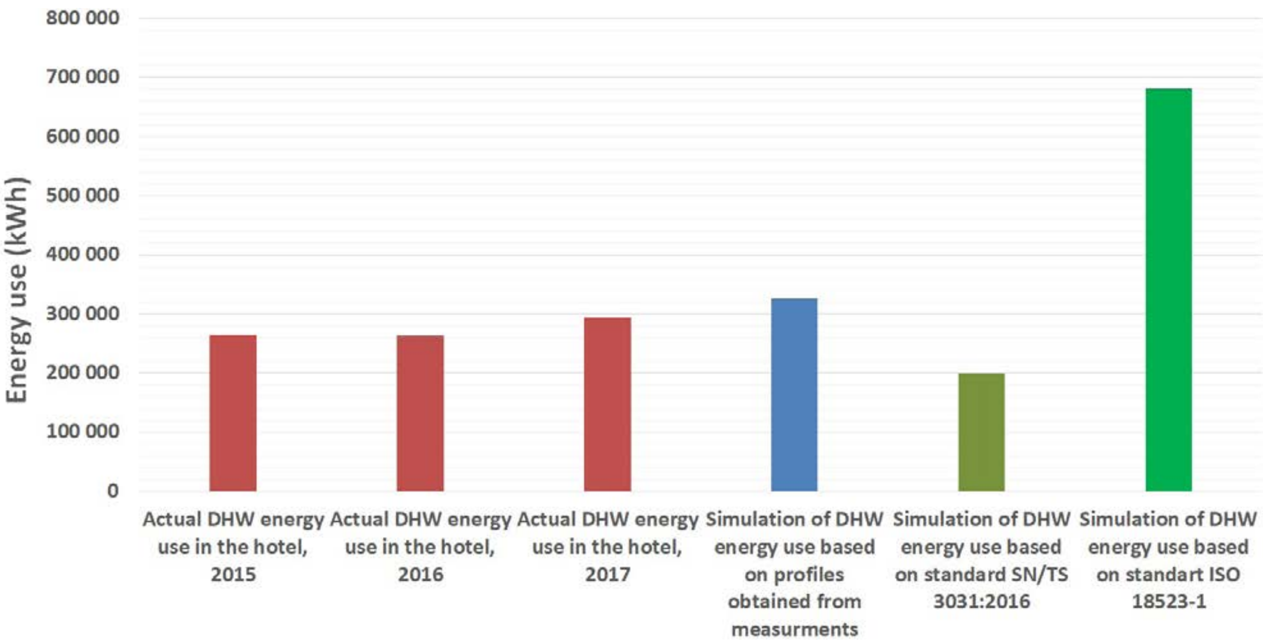

Figure 6. Simulated and real yearly DHW energy use in the hotel.

not take in account self-use of DHW system. Therefore, information given in this standard should be supplemented by estimation of self-use of DHW system in the building. At the same time, profiles which are based on actual measurements, allowed us to obtain the most reliable results. The difference between yearly DHW energy use simulated by profiles obtained from measurements was approximately 10%. ■

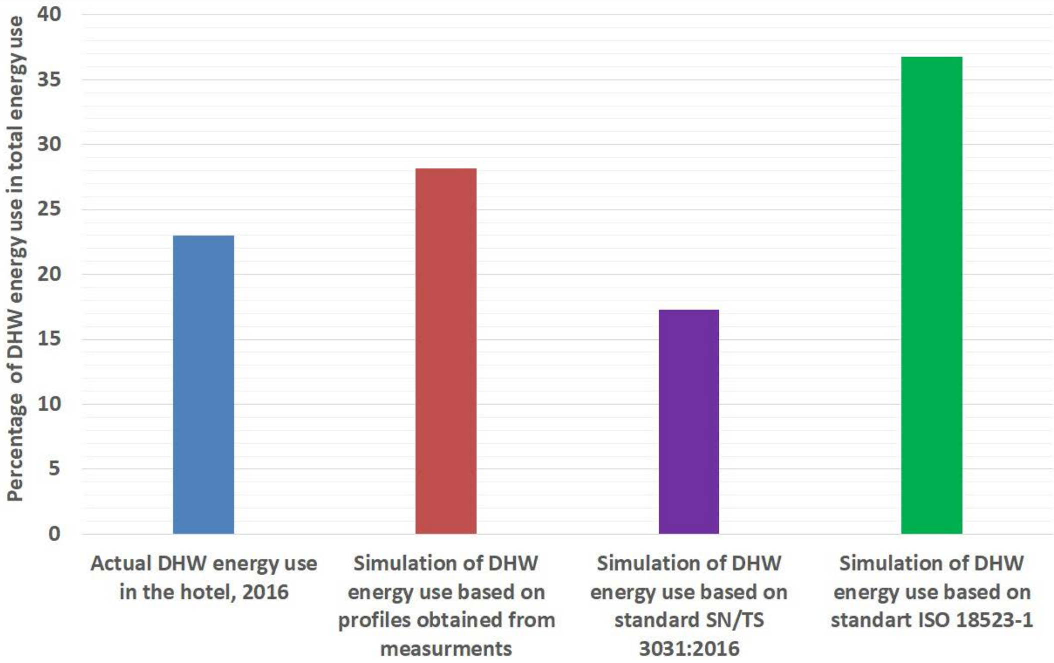

Figure 7. Percentage of DHW energy use in total energy use of the hotel.

Acknowledgement

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AixOCAT – Introducing a Library for Building Automation and Control Systems

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Nowadays, the building sector faces an increasing complexity in the design and operation of building energy systems. Hence, a proper implementation of the building automation and control systems (BACS) for such systems is time consuming and expensive. In order to reduce the implementation effort, a structured control development with reusable program code is desirable. Although current commercial control libraries are available, they raise considerable costs and provide only limited interoperability with further software. Hence, and because of the complexity, the restricted amount of time and little proper support, especially small- and medium-sized companies are limited in their capabilities of implementing BACS. In order to support the implementation of control algorithms, we propose an open source library for building automation software based on the OSCAT library. This article shows the library's general usability and the workflow for the implementation of control algorithms in BACS using the example of a control loop in a recently constructed building. The library, the examples and the workflow could become a major contribution to the construction of intelligent and energy efficient buildings.

Keywords: building automation and control systems, programmable logic controller (PLC), control algorithm, open-source library, object-oriented programming

Building automation and control systems are considered a vital ingredient of healthy, energy-efficient and comfortable buildings. In this field, there is a large variety of use cases with different requirements [1]. The common engineering process of BACS, however, is often inefficient and results in building energy systems that have a high potential for performance improvement [1,2]. These deficiencies result from a lack of a commonly accepted concepts for the creation of building automation software, leading to a very heterogeneous building stock [1,3]. Due to the large differences between individual buildings, it is challenging to apply intelligent algorithms such as automatic fault detection and diagnosis or model predictive control [3], which are considered vital concepts for high-performance buildings.

A freely available library containing modules and best practice examples for future automation software projects could greatly support engineers to improve BACS and building operation. In this work, we present an open-source library for automation software compliant with the IEC 61131 standard to enable efficient development of automation code that is both reliable and enables the application of advanced control and operation analysis.

The AixOCAT library

In order to increase the quality of building automation projects and at the same time reduce the engineering effort, we identified the goals listed below and designed the AixOCAT library [4] accordingly. It provides both code templates and best practice examples that follow the principles.

We aim to

1. achieve high re-usability of code and thus reduce engineering effort
2. increase reliability of technical building equipment and test benches
3. support extendibility of automation systems
4. enable interoperability, especially with cloud-based applications

Re-usability and reliability

The AixOCAT library contains code templates that provide typical functionality for building energy systems and test benches. We have integrated most of the open-source code by the Open Source Community for Automation Technology (OSCAT) [5]. The OSCAT library contains many useful modules for building automation that could be reused in a variety of projects. Moreover, AixOCAT is an open-source library, meaning that various contributors write and review code, report software bugs and request further developments. Therefore, the automation community contributing to the library will be able to bundle expertise and thus ensure reliable automation projects as required in goal 2.

Extendibility and Interoperability

We follow a modular design approach to ensure extendibility and interoperability as described in goal 3 and 4: The library mainly contains Programming Organization Units (POUs) implemented in Structured Text (ST) according to IEC 61131-3 standard. These POUs are mostly Function Blocks (FB), which transform several inputs into several outputs. In order to allow for an object-oriented programming style and thus extend the FB functionality with properties and methods. The software application TwinCAT [6] is one example we tested that allows to use these extended FBs for programming real-time controllers.

Using FBs, we structure the programs mainly according to physical subsystems in the energy system such as "air handling unit" (AHU) or "concrete core activation" (CCA). For further structuring, we propose an operation mode-based approach. In this context, an operation mode is a collection of pre-defined actuator commands or set-points for field devices. The transitions from one operation mode to another are based on pre-defined conditions. These can be error states or temperature thresholds [7].

In order to support extended interoperability, one operation mode can be dedicated to external control applications. It can thus allow connection to control algorithms that may be hosted outside the actual automation system, e.g. on a virtual machine, to send control commands to the controller. In this case, the actuator commands and set points are not pre-defined but generated in the external application. In the event of a communication loss, a transition to a local operation mode always ensures a secure system operation.

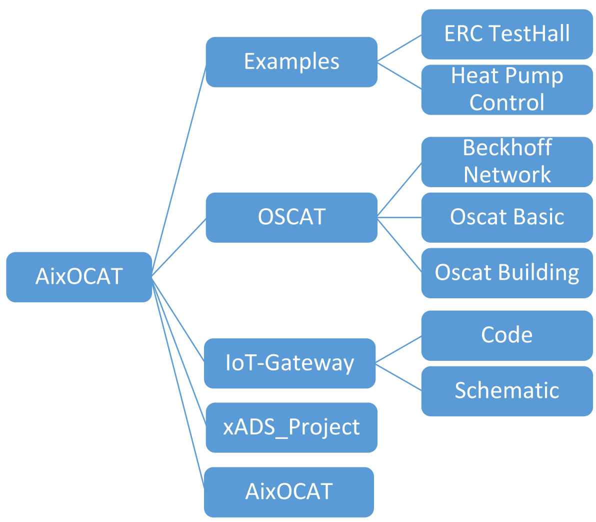

Figure 1. Current structure of the library.

An important research application is the hardware-in-the-loop method, in which a real-life controller is coupled to virtual technical building equipment represented by a simulation model. For that end, AixOCAT provides interfaces for Modelica, an object-oriented multi-physics modelling language. The application uses the Automation Device Specification (ADS) to exchange data with the PLC.

Collaborative development

We aim for a flexible, open and well-organised development of the library, which is available to the public on GitHub [8]. We propose a work flow for non-restricted but efficient contribution to the library. This work flow defines basic requirements such as programming style, documentation and issue tracking. Moreover, new developments and code enhancements are done in separate branches, ensuring that the master branch remains stable and usable by the community. A so-called "pull request" requires another contributor to review the newly added code and to merge the reviewed code into the master branch.

Use Case - ERC Test Hall

For demonstrating the use of the library and its benefits, we present a real-life project, namely the ERC test hall in Aachen, Germany, as a representative example for laboratory and machine halls. The facility consists of two hall parts with an area of 630 m² and 360 m², respectively, for test beds and an additional area with five office rooms and a total area of 90 m². The test hall is equipped with an AHU, a CCA and ceiling panel heaters (CPH) as well as chilled beams within the office rooms. Moreover, the energy system contains external after heaters and coolers. Using the example of the CCA, we demonstrate the functionality of the AixOCAT library.

Control Strategy

The required hot water for AHU, CCA and the decentralized after heaters is supplied by a heat distributor. As described in the previous section, the library especially supports PLC programming by providing object-oriented programs for BAS. For instance, the CCA comprises a conventional admixing circuit consisting of a pump, a mixing valve as well as four temperature sensors and a control unit. **Figure 2** shows the developed object-oriented representation of the CCA as a class diagram in the unified modelling language (UML).

The components are designed as interfaces, which are implemented and mapped according to the communication interfaces of the physical components. By using this structure, basically any admixing circuit is described in the same way while following our objectives of re-usability, extendibility and interoperability.

Details and Results

As described above, the modules of the hydraulic circuit are interfaces, which can be implemented in various ways: In the test hall, we implemented

1. the temperature sensors as PT100 (including conversion of integer to temperature),
2. the valve as (0)2-10 V device for both actual and set position (including conversion between integer value and opening percentage),
3. the pump as BACnet device,
4. the control unit as a mode-based control that regulates the mixing supply temperature via proportional-integral-derivative (PID) control.

In the auto-mode of the control unit, the set temperature is determined in an ambient air heating curve. This value is compared to the actual temperature and a PID controller generates the actuating signal to the mixing valve, whereas the pump generates a constant pressure increase.

The entire code for the described modules of the admixing circuit can be found in the library. **Figure 3** shows a plot of the supply temperature for the CCA as well as the temperature at the distributor. The supply temperature was set to 22 °C. The plot shows that the oscillating distributor temperature is compensated quite well by the admixing circuit.

Beside the CCA, the induction units, the preheater, reheater and the cooler of the AHU are also realized by admixing circuits, hence the above described code for the hydraulic circuit only needs to be linked to their physical sensors, pumps and valves.

Conclusions

We introduced an open-source library that we published to support the engineering of building automation and control systems. We present the library structure and demonstrate its usability in the control system of a real-life building.

As many deficiencies in the building stock result from a lack of a commonly accepted concepts for the creation of building automation software, we identified requirements for the library to enable three main ideas:

- Re-usability and reliability,
- Extendibility and Interoperability and
- Collaborative development.

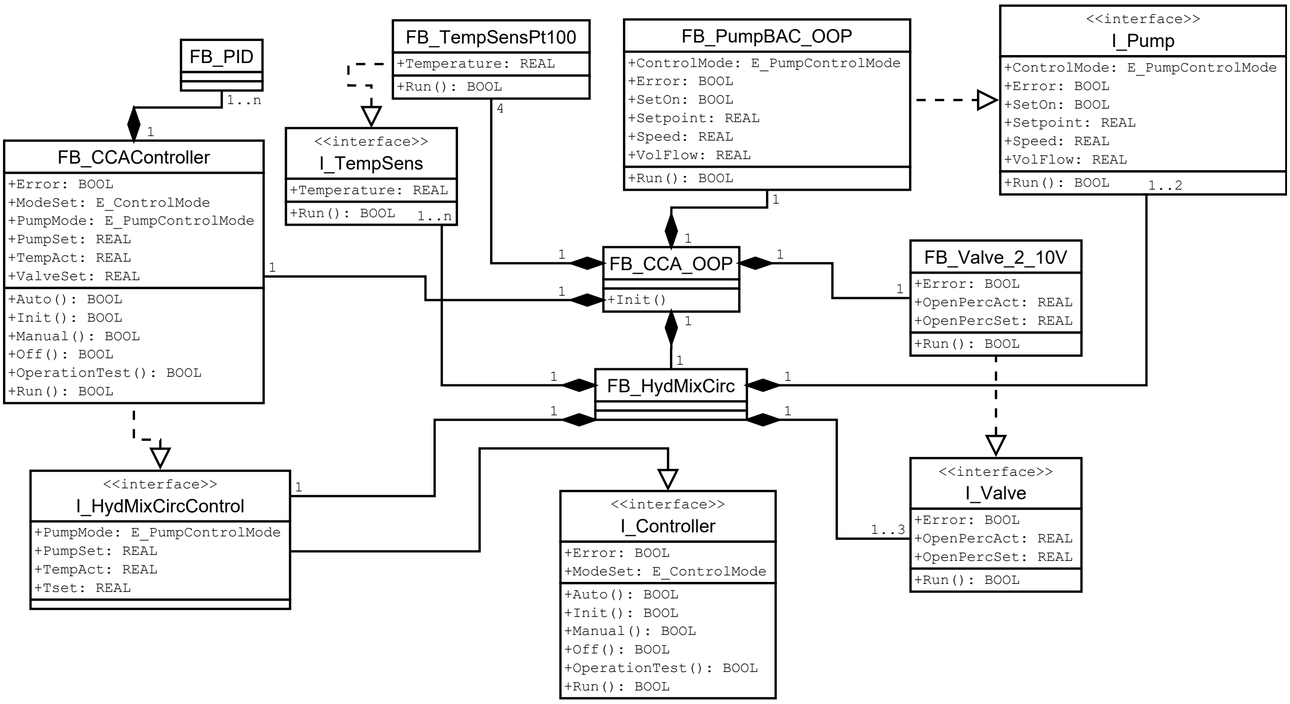

Figure 2. UML diagram of the CCA automation system; standard property gets and set methods are omitted for clarity.

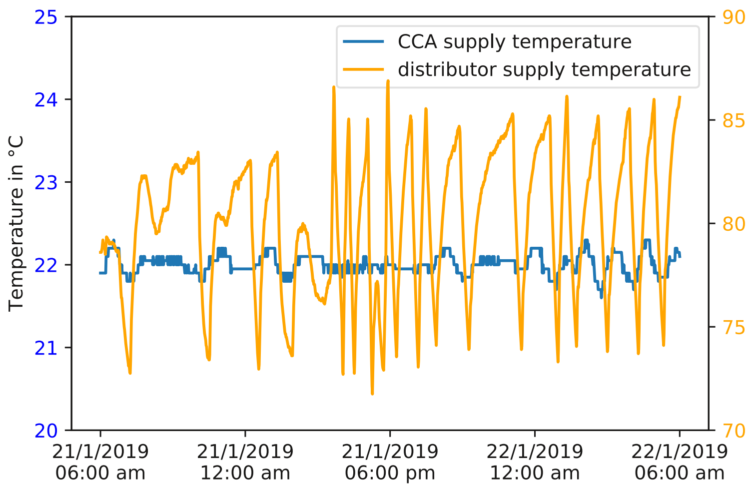

Figure 3. Plot of the CCA supply temperature and the distributor temperature in the considered hall for a duration of 24 h; the considerable oscillation of the distribution temperature is sufficiently compensated by the simple PID control.

The library is based on these ideas and, due to the open-source development, enables the building automation community to collaborate on the standardization of the engineering process.

The library will constantly be improved and is available on GitHub [4]. ■

Acknowledgement

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Rehabilitation of the Utility Spaces and Boiler Room – Monnaie Royal Theatre

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Keywords: central heating, dry- coolers, renovation, high volume boilers, energy efficient, BMS, water quality

Abstract

The building used for workshops and administrative services at the Monnaie Royal Theatre in Brussels was subjected to complete renovation, to conform to fire safety regulations and be more energy efficient. This was achieved by renovation of the infrastructure of installations: central heating and cooling, water supply, and gas pipes, electrical power and control, fire detection, lighting and BMS integration.

Introduction

The concept shows the stages of rehabilitation of a heating and cooling system for a monument building, the Royal Theater of Monnaie in Brussels, Belgium, as well as the problems encountered and the solutions found in order to ensure a low-energy efficient system. The energy efficiency concept provides a powerful and cost-effective framework for reducing greenhouse gas emissions, fuel consumption, and operating costs.

Control and monitoring are provided by the BMS (Building Management System) system, which intervenes in the modulation and adjustment of four high-volume condensing boilers: three 850 kW heating boilers, a 100 kW ACM boiler, a 300 kW chiller, two 195 kW dry-cooler units, all pumps, and auxiliary control devices.

Water quality is a problem addressed in the paper in light of the requirements of preserving existing installations and protecting newly installed boilers.

The execution work has two stages:

- Stage I. - centralized administration of the technical spaces - the distribution of the theater
- Stage II. - connection of the second building through a technical and passage tunnel, crossing under a pedestrian street – the connection of the central installations with the terminal equipment inside the theater (for 13 central air treatment units).

Data about the building complex

Location and landmark

The address is Place de la Monnaie – 1000 Bruxelles, for the theatre building and for the administrative and workshop building it is 23, rue Léopold , and 41 rue Fossé aux Loups (**Figure 1**, **Figure 2**, **Figure 3**).

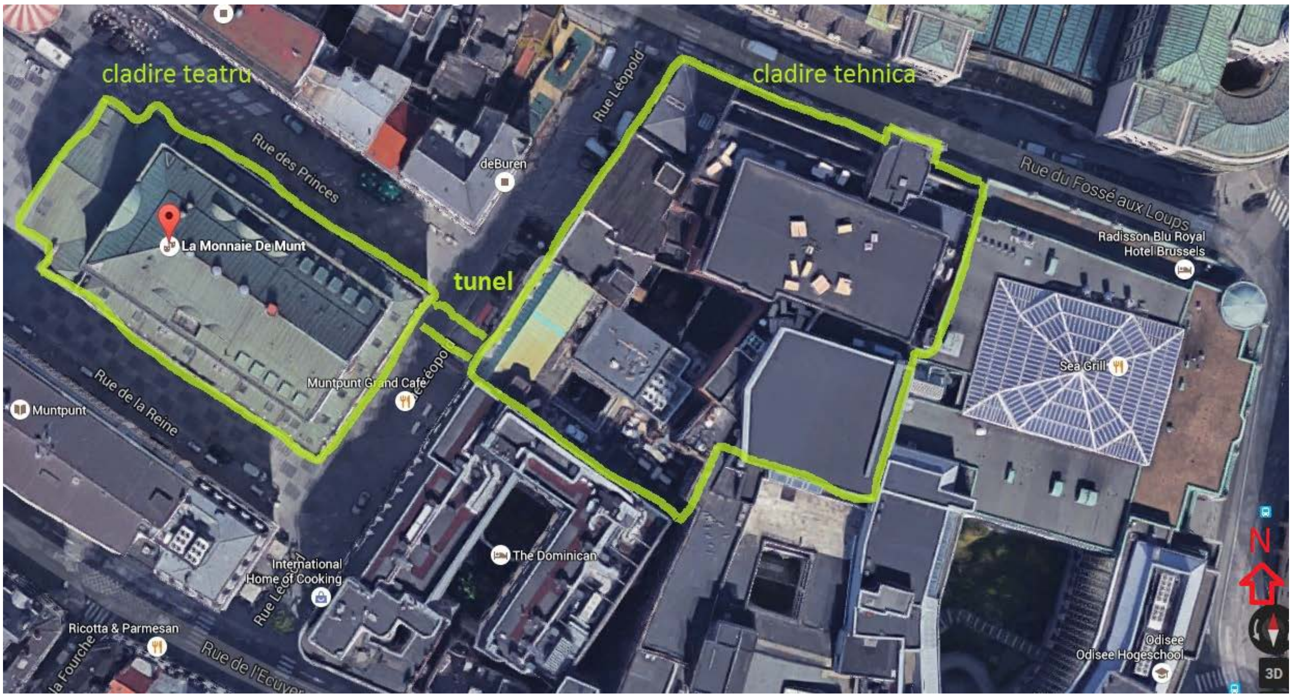

Figure 1. Location of theatre and technical building.

Figure 2. Technical building façade at 23, rue Léopold.

Figure 3. Technical building façade at 41 rue Fossé aux Loups.

The first Grand Theater was opened in 1700. In 1819, it was however demolished and rebuilt at the current location by the french architect Louis-Emmanuel Damesne on the site of the former 'Herberge van Oistervant' mint ('La Monnaie' is the French word for 'coins'). It was considered one of the most beautiful theatres outside Italy. But by January 21, 1855, a serious fire reduced to ashes the entire building. The new Theatre of the Mint reopened its doors in 1856.

In **1985** The Department of Public Works decided to renovate the building for technical, safety and aesthetic reasons. In **2000** there was the Inauguration of the New Monnaie workshops in the ancient Vanderborght buildings and the neo-classical building at no. 23 Leopold street just behind 'La Monnaie'

There were two more renovation campains one between 2003-2007 and the other between 2015 – 2017 to better conform to the new fire safety regulations.

Utilities

Initial heating and cooling facilities

The base station in the basement had 30-year-old equipment, namely 2 boilers with atmospheric burner on gaseous and oil fuel, developing a 2 x 764 kW thermal capacity, a 600 liter day tank for oil fuel, a hydraulic separator, two WILO circulation pumps on each boiler, a manifold of DN300 with 10 circuits and 3 expansion vessels of 500 litres each.

There was a secondary station in the basement with 2 boilers of 240 kW each, two expansion vessels (2 x 300 litres), a manifold collector, pumps, three - way valves for workshops and the administrative area. The radiator pipeline distribution was made up of steel joint with copper in an advanced state of decay.

Design brief and contractual requirements

Design theme [1]:

- Dismantling of existing installations
- Heating for 3 administrative buildings, workshops and theater with 4th floor thermal plant on the roof and two basement substations for workshops and administrative offices
- Replacement of domestic hot water distribution, pumps, valves, inserting two new heat exchangers
- Water softening station
- A new split type cooling system: made up of a chiller and two drycooler machines for the theater building
- A BMS for monitoring, control and adjustment
- Power supply and indoor gas distribution

Heating system

- 3 x 850 kW HOVAL gas fired condensing boilers, of large water volume, support the overall heating system
- 1 x 100 kW HOVAL condensing boiler for domestic hot water production
- GRUNDFOS variable speed pumps
- PNEUMATEX pressure maintenance systems
- Gas exhaust chimney
- Ventilation intake for combustion process
- Two solutions were discussed:
- **Version 1**: gas condensing boilers without large water content, constant speed pumps, hydraulic pressure separator (BEP)
- **Version 2**: gas condensing boilers with large water content so that the minimum water flow required to be as low as zero, and variable speed pumps

The second solution was implemented due to the high energetical efficiency [1, 3-5,7,8].

Boiler room heat source

The three boiler units work together in a "cascade system" because of multiple benefits:

- High turndown capability when only one boiler is required
- Flexibility with footprint allowing installation in irregular spaces
- Increased reliability with heat provided by several boilers
- Service and maintenance is simplified
- Smaller boilers can be maintained by a single engineer on site
- Simple spare part management
- Different rated outputs can be cascaded and control boilers by priority, delivering excellent efficiency; in the example shown in **Figure 4** the capacity used is 83%.

From the BMS perspective, if there is no circulation of water in the pipes , the flow switches on the boiler return pipe change color from black to a red impulse. If the boilers are in authorised mode, they change color from black to green, if one of them is in alarm, it becomes a red impulse.

The prescription of boiler input ratio can be changed by switching off the auto/manual switch and selecting manual input and enter the value in the numeric field.

Boiler room main manifolds
There are four main distribution circuits (**Figure 5**):

- CC1.1 – Theatre
- CC1.2 – Administrative offices
- CC1.3 – Workshops
- CC1.4 – Domestic hot water production

Each circuit is equipped with two centrifugal pumps, a lead and a backup. The operation between the pumps is systematically altered to achieve equal wear using timed alternation - where the lead and backup pumps are switched by an automatic timer controlled by the BMS.

As in the case of the other boilers, the BMS display works the same way.

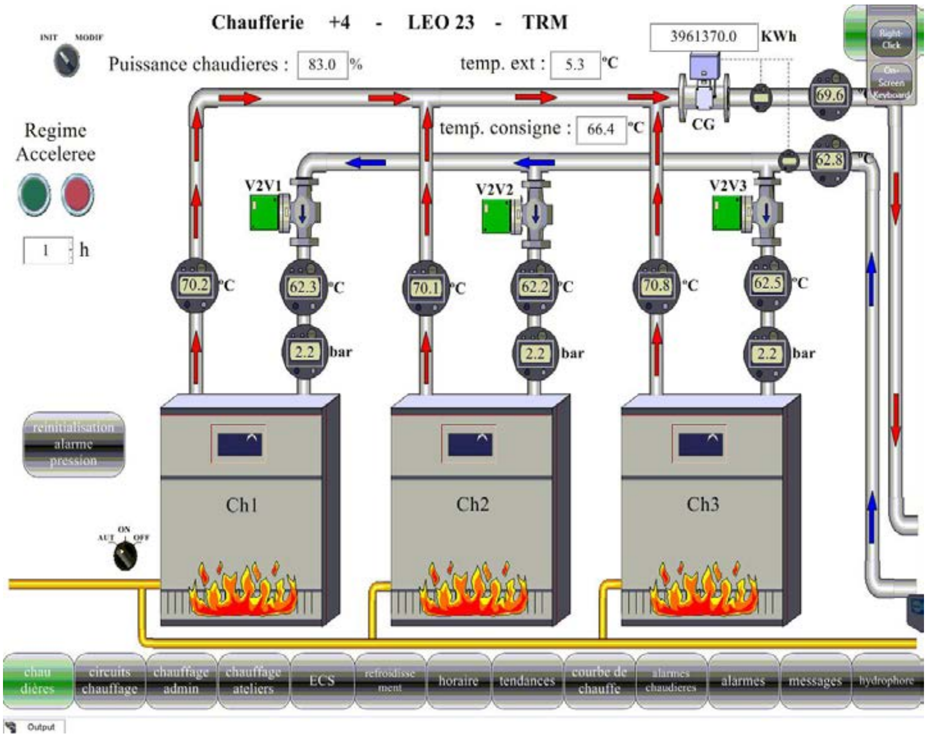

Figure 4. Heating system diagram – boilers.

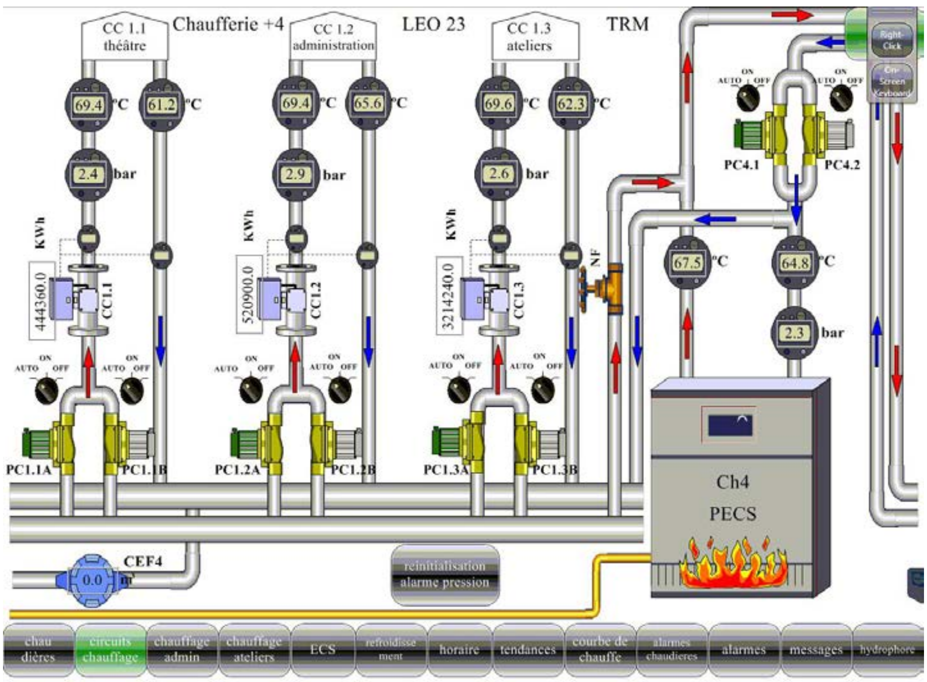

Figure 5. Heating system diagram – main manifolds.

Connection to the theatre building – CC1.1

In order to connect the heat source with the terminals in the theatre building, an underground tunnel was devised to house (**Figure 6**):

- 2 heating DN100 distribution pipes (CC1.1),
- 2 cooling water DN125 pipes
- 2 domestic hot water DN65 pipes
- ventilation ducts

The construction of this tunnel was the final stage in the installation project. It was a cumbersome endeavour because the site contained archaeological artefacts and they had to be carefully moved and evalued, street access was closed off. The tunnel between the Monnaie theatre and its workshops measures sixteen metres, under Leopold street.

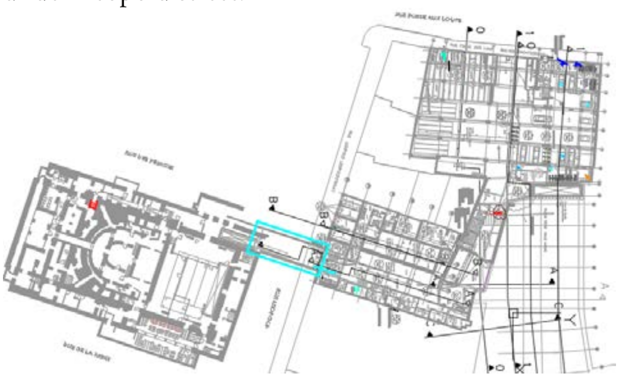

Figure 6. Underground tunnel for CC1.1.

Site works consist of the tunnel (unearthing, walls, soil and ceiling) and the installation of technical connections (ventilation, heating, electricity, water, Internet) between both buildings and reconstruction of the rail and waterways network.

Administrative offices Substation 1 – CC1.2

Substation 1 is located in the basement in a separate room, and houses two manifolds supply/return DN 100 for heat circuit distribution to all the office radiators and to an air handling unit heater battery, and the water softening station.

Workshops Substation 2 – CC1.3

Substation 2 is located in the basement in a separate room, and houses two manifolds supply/return DN 300 for heat circuit distribution to all the workshop radiators and to an air handling unit heater battery.

Every circuit is equipped with a balancing valve, a pump, two temperature sensors placed on the supply and return pipes and a pressure sensor on supply.

Hot water production station – CC1.4

The reservoir VT1 (**Figure 7**) with a 1000 litre capacity is connected to the main manifold (the secondary source) and the smaller 100 kW condensing boiler as a primary source of heated water. The temperature in the reservoir must be at least 60°C. This inhibits

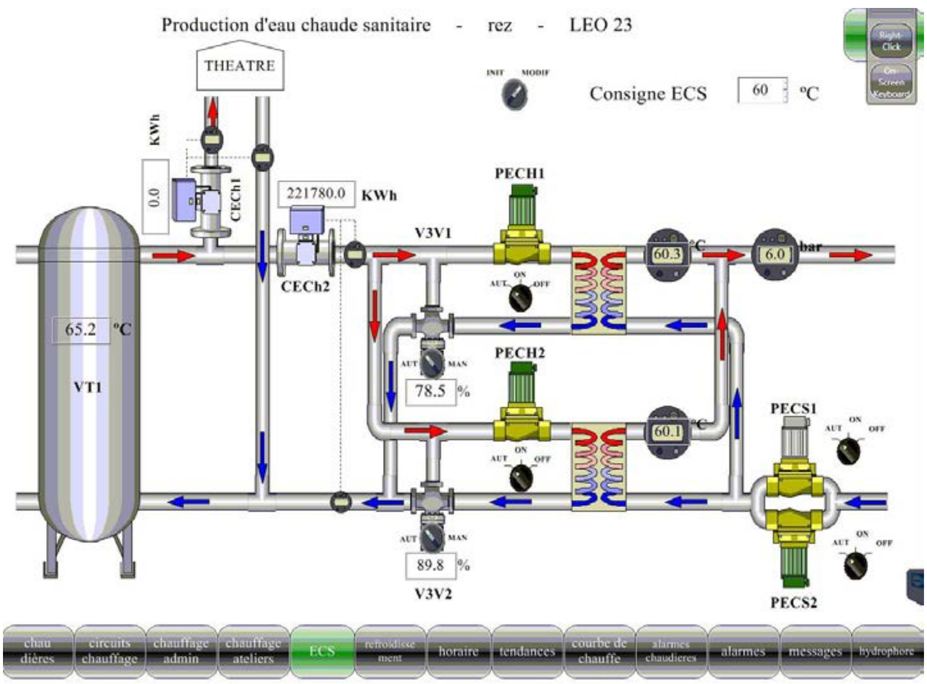

Figure 7. Heating system diagram – domestic hot water.

Legionella and other bacteria to develop. Both thermostatic regulating valves on the primary circuit of the heat exchanger ensure a temperature of 45°C on the secondary side of the exchanger. Between one and three o'clock at night, the "Légionnelle function" is active, and the temperature of water goes up to 65°C.

The hot water station composed of 2 plate heat exchangers, 2 primary pumps, 2 recirculating pumps, valves, 3-way thermo static valves, expansion vessels and accessories.

The problem of water treatment

We have the following premises:

- **design requirements**: the design theme required the washing of the old heating system with trisodium phosphate (Na_3PO_4) to ensure an anticorrosion protection film as well as pH and hardness and conductivity measurement
- **boiler supplier**: requires very low conductivity -thus demineralization of water throughout the system, in the new and the old plant in order not to affect the stainless steel / aluminum of internal boiler exchanger

Thus, there is a contradiction between the design requirements to protect the anticorrosion facility with a trisodium phosphate film (Na_3PO_4), i.e. adding salts in water and the supplier's requirements to have a demineralised thermal agent according to **VDI 2035**.

In order to evaluate the actual situation as well as possible and 4 samples were collected for analysis from 4 different locations:

- softened water station,
- water from the central heating system
- substation 1 - substation 2

Observations

1. Conductivity is determined by the presence of salts, namely the presence of sodium salts, i.e. NaCl (sodium chloride) used to regenerate the ion exchanger (cationite).
2. The softening system does not change the conductivity of the treated water because there is only a substitution of calcium ions with sodium ions on the ion exchanger, therefore the conductivity cannot fall below 800 µS / cm.
3. The presence of phosphates in the circuit is determined by traces of trisodium phosphate (Na_3PO_4), used in the flushing stage which is beneficial as it results in the formation of a protective layer against corrosion of iron phosphates on the inner surface of the pipes and heating elements.

Cooling system

The cooling system comprises:

- 2 x 195 kW "silent" cooling tower units located on the roof on the 4th floor
- chiller with a cooling capacity of 300 kW
- 2 expansion vessels with variable pressure membranes on the distribution to dry coolers
- 2 expansion vessels with variable pressure diaphragm on chiller distribution
- variable speed twin (double) pump
- 500 liter buffer tank

The BMS display controls the pumps of the evaporator and condenser and to see the temperatures of both tower and chiller circuits. The BMS link can also start or close two dry coolers together. A switchflow sets off an alarm if there is no circulation of water in the evaporator circuit and the pumps are working.

Table 1. Analyses were performed for conductivity, PH and salts.

No.	Analysis	UM	H_2O after treatment	H_2O Boiler plant	H_2O CC1.2	H_2O CC1.3
1	Conductivity	µS/cm	801	1030	1038	1077
2	pH	unit. pH	7,65/8,00/8,44	6,78/7,54/7,77	7,50/8,05/8,18	9,38/9,89/9,68
3	Na^+	mg /L	180±5	275±5	265±5	250±5
4	K^+	mg /L	0,5±0,2	1,0±0,2	1,0±0,2	1,0±0,2
5	Ca^{2+}	mg /L	19±1	< 0,2	< 0,2	< 0,2
6	Mg^{2+}	mg /L	2,6±0,2	< 0,2	< 0,2	< 0,2
7	PO_4^{3-}	mg /L	3±5	31±5	31±5	30±5

Energy consumption

Figure 9 shows the registered thermal energy consumption related to the heating system during a period of 30 days (from 15.12.2018 – 14.01.2019). Heat meters on general and secondary branches of installation provide valuable data needed for billing and optimisation of the network performance. The flow is measured using bi-directional ultrasound based on the transit time method, with proven long-term stability and accuracy. All circuits for calculating and measuring are collected on a single board, providing a high level of measuring.

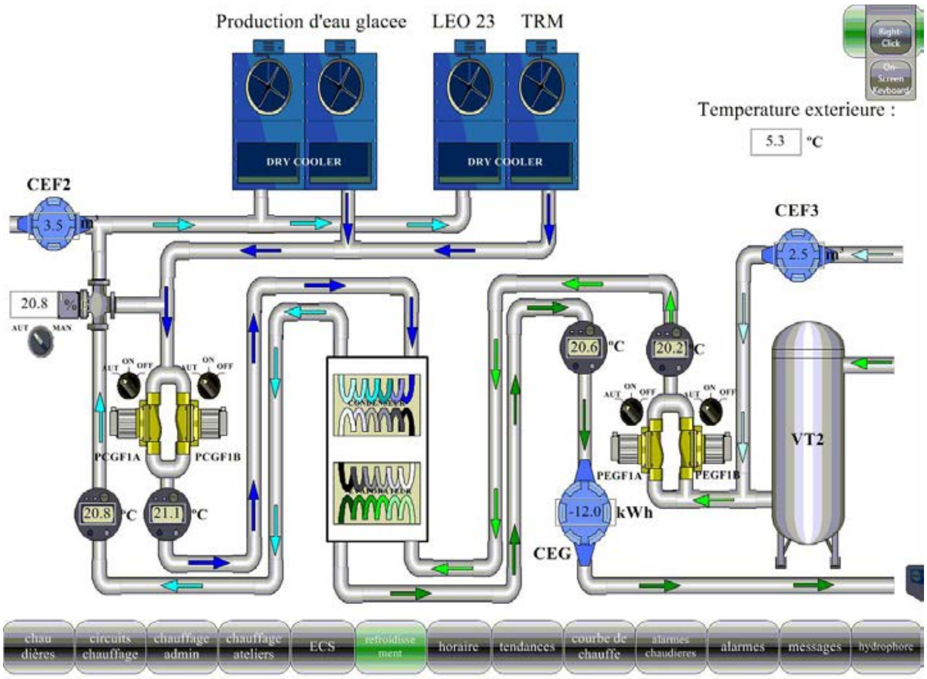

Figure 8. Cooling system diagram.

The green graph is the variation of outside temperature. The red graph is the variation of thermal energy consumption. The high spikes are at the beginning of each day are the energy boosts when the boilers are turned on. Then the graph is pretty stable. The black graph is the calculated moving average for the thirty days.

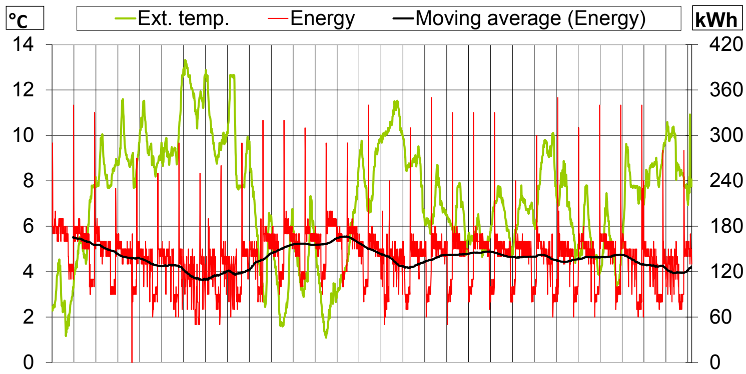

Figure 9. Thermal energy consumption graph.

Conclusions

Rehabilitation of monument buildings implies both consolidation, modernization, replacement, but also energy efficiency [9], [10]. All together are a difficult task due to the restrictions resulting from the building typology. This problem is present and as presented in the paper it is a very fine balance between the choice of the technical solution, the equipment, the routes and the connection between the circulation of the thermal agents from different areas of the installation. ■

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The H2020 project GEO4CIVHIC

– Most Easy, Efficient and Low Cost Geothermal Systems for Retrofitting Civil and Historical Buildings

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Abstract

The market of Ground Source Heat Pumps needs to be increased and one of the barriers is represented by the use of this technology in the retrofit of buildings in urban environments. For this purpose, the H2020 project GEO4CIVHIC has been funded and is currently running. The project develops several solutions for shallow geothermal energy in the retrofit environment, based on the building type, climate and the geological conditions of the underground and considers all aspects of the geothermal system (drilling methodology, ground heat exchangers, grouting, heat pumps). The main objectives are:

- identify and where missing develop modular solutions in drilling (machines and methods) and installing (narrow and reduced spaces), heat exchangers types, heat pumps and other renewable energy/storage technologies, heating and cooling terminals with the focus on each type of built environment (civil and historical);
- generate and demonstrate the easiest to install and cost-effective geothermal energy solutions using and improving existing and new tools.
- Demonstrate the environmental respect and the reduction of CO_2 emissions in the atmosphere

More efficient ground heat exchangers and cheaper drilling methodologies/machines adapted to the built also narrow environment like the historical centers will be realised. This approach will bring to an easy applicability in the building refurbishment presenting different constraints, to reduce the overall drilling cost in the given geological conditions, to fit in different levels of retrofit (partial or deep). For better meeting the different needs of the retrofitted buildings 6 prototypes of heat pumps will be developed and built up, from high temperature heat pumps (when heating terminals are maintained) up to plug & play solutions (for deep retrofit), thus reducing the retrofit costs.

The association of the innovations with different tools like a Decision Support System will enable to find the best solution for each combination of building type/climate/geology to be chosen. Moreover, the design tools will reduce overall engineering costs, avoid design mistakes and form the basis for a major dissemination effort. Application tools will help the users for different practical aspects.

The new solutions in the project will be demonstrated in 3 pilot facilities, in 4 real demonstration sites (warm, mild warm, mild cold and cold climates) and in 12 virtual sites. Demonstrations go from partial to deep renovations and include historical buildings.

The H2020 project started in April 2018, lasts 4 years with an overall budget of 8.36 M€, accounting 19 partners from 10 countries.

1 Introduction

The building retrofit market today barely reaches 1 % of the actual building stock [1]. In addition, the interventions are of shallow nature in the majority of the buildings. The Energy Transition initiative of the European Commission is focusing on increasing the retrofitting of the building stock from the current 1 % level to 3 % and to shift the nature of the interventions towards deep retrofits. The Energy Efficiency call topics EE-10-2016 (accelerated and cost-effective deep renovation) and EE-11-2016 (overcome deep-renovation barriers) are the steps in this direction. The present call topic is one further step of many in research and innovation to increase shallow geothermal applications in buildings in any kind of constrains, internal (high temperature terminals) and external (narrow or difficult to attain free spaces). The revision and implementation into legislation of the EPBD, the Energy Efficiency Directive and the Renewable Energy Directive by the EC, coupled with financial support mechanisms (e.g. tax reductions for deep retrofits, premiums for renewable energy systems) will contribute as well.

The application of shallow geothermal installations in the built environment is not well developed [2] at today. The main barriers are:

1. higher upfront investments compared to other conventional solutions like condensation gas boilers for heating and direct expansion systems for cooling;

2. difficulties of cost effective and environmentally friendly drilling in the built environment;

3. need to change Heating and Cooling (H&C) terminals in order to adequate performance from heat pumps, particularly in historical buildings;

4. low levels of awareness on the techniques and its advantages, reluctance to risks and/or lack of experience amongst the designer and operators (architects, installers, building owners) in the ultra-conservative building industry.

To overcome the above barriers, the total investment cost of geothermal systems has to decrease compared to alternative solutions. The high drilling cost needs to be tackled. Drilling with highly efficient but heavy and large drilling machines is difficult and often impossible in the built environment, in particular in the historical centers. The use of smaller, less powerful machines leads to even higher drilling costs.

Increasing the thermal efficiency of the Ground Source Heat Exchangers (GSHEs) is another way to reduce the total length of GSHEs to install. Ample research in this field has been done [3], [4] and is ongoing as part of the H2020 projects Cheap-GSHPs [5], GEOTeCH [6] and GEOCOND [7]. These developments have to be integrated and/or taken one step further. Development of the Heat Pumps (HPs) towards a higher efficiency with any kind of terminals and lower costs should also contribute to the decrease of the total investment or the increase of the overall efficiency. HPs with good performance at higher temperatures avoid the need to replace all or part of the heating terminals [8], [9]. Hybrid heat pumps, i.e. dual source (air to water and water-to-water) HPs can reduce further the total length of GSHE needed [10]. The combination with other Renewable Energy Sources (RES) as solar could improve the return on investment [11] [12]. Shallow geothermal systems are more complex to realize than conventional solutions, in particular when barriers and constraints are present. Critical aspects include correct design, adequate performance in operation and costs for the installation. Providing tools, training material/support to designers, instruct installers and operators facilitate the realization of geothermal installations, reduces costs, improve the awareness and overcome reluctance towards this technology.

The project aims at reducing these gaps and increase the operating efficiency making shallow geothermal one of the standard applications in retrofitting. The stable nature of geothermal as a renewable energy source, the ability of heating/cooling with only one system and the higher residual value of buildings retrofitted with this technology are additional key factors for investors who are focusing on the long-term value of retrofits.

The main goal of GEO4CIVHIC proposal is to tackle all of the above-mentioned areas by developing and demonstrating more easy to install in any reality and more efficient GSHEs, using drilling machine innovations tailored for the built environment and developing or adapting HPs and other hybrid solutions for retrofits through a holistic engineering, construction and controls approach.

The present paper presents the general aspects of the GEO4CIVHIC project showing the initiatives and the proposed results in the project.

2 Methods

The overall methodology of GEO4CIVHIC follows a holistic approach with the activities grouped by type and organized in a logical sequence from research over innovation to demonstration and evaluation. The communication, dissemination and exploitation runs in parallel over the four other phases. The all-important development of the innovations and tools is tackled in the second phase. First, the basis for driving these innovations and for monitoring the project progress and results is researched.

Once the developments have been realized the project moves into an extensive demonstration phase. Field tests of the key innovations are followed in a third phase by pilots, full case demonstrations and virtual case studies. Upon results evaluation, a solid basis is built for market exploitation supported by training events, workshops and dissemination activities.

The consortium partners cover all the important aspects and areas in the value chain of shallow geothermal plants. The overall work and single tasks have been organized such that partners work along the main innovation themes in multi-disciplinary groups.

This approach maximizes their knowledge, expertise and synergies for the benefit of the project innovations. phases are shown in more detail below.

2.1 Phase 1: Preliminary cost analysis and barriers identification

Barriers for geothermal plants in retrofit projects of existing buildings need to be known to drive the innovation and the subsequent exploitation. They are usually not only of economic or technical but also social, cultural and legislative nature. The entire partnership is involved in this task. The partners closest to the stakeholders (architects, SME's, industry) use their contacts and networks.

Geothermal maps have and are being developed at different scales in European, National and Regional projects. The "drillability", understood as the eligibility of the soil for the best drilling method and the best heat exchanger to use, is not included. In GEO4CIVHIC this key factor will be added to the maps and guides for later use in the decision making and the performance evaluation process (including the traditional drilling methods and the improved technology developed in the project).

Information about the cost and performance of heating/cooling plants, including shallow geothermal ones, is needed to set quantified key performance indicators for the innovations' evaluation and to support business models. These plants depend on the energy demand profile of the building, the heating/cooling terminals and for geothermal also on the soil. These demand profiles will be generated via modelling of different building types, building structures, climates and undergrounds to cover the European market. This is then followed by a cost and efficiency study.

2.2 Phase 2: Technological Innovations and Tools

The innovation activities in this phase follow respectively a hardware (drilling, borehole heat exchangers, heat pumps) a middleware (BEMS) and a software track (decision support, engineering tools, app's, controls).

The drilling method, already developed in Cheap-GSHPs for unconsolidated soils, will be improved using a more powerful and efficient rotation-vibration drilling head mounted on a compact drilling machine. This to enable to use this technology in all types of unconsolidated soil and even soft rock. A new head and the corresponding drilling rig are developed jointly. The drilling rig design will also address the barriers (compactness, weight, flexibility) and the reduction of non-productive times. The latter will be done by

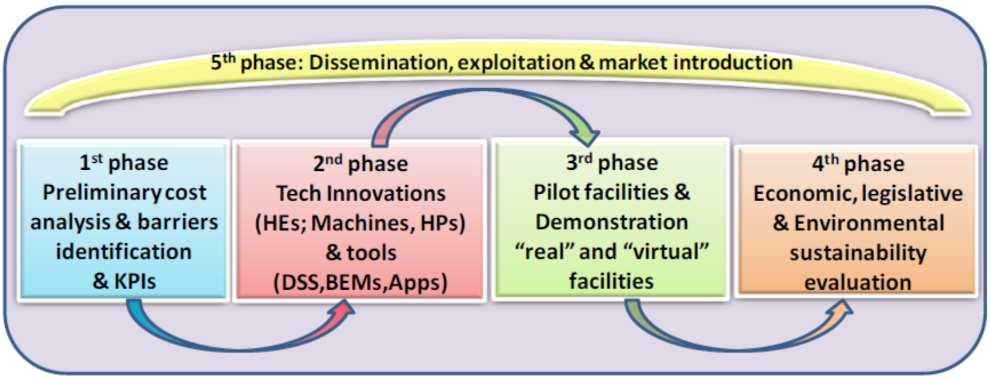

Figure 1. The five phases of the project GEO4CIVHIC.

semi-automated operator support equipment for fast mounting/dismounting of shafts/casings and heat exchanger's installation.

The efficiency and cost of co-axial heat exchangers can be improved, building on the developments already realized in Cheap-GSHPs. The powerful drilling head allows to increase the external diameter but the potentially negative implications on drilling speed and depth need to be verified as well as the impact in thermal performance (laminar vs. turbulent geothermal fluid flow) and pump size/consumptions. An optimization exercise, also with performance data from Cheap-GSHPs, is foreseen. Other improvements to study are new tube materials (plastics) and grouts (conductivity), which will come from the project GEOCOND; in fact, different new grouting and pipe plastic materials are being developed aimed at further increasing efficiency and decreasing operating costs of GSHP solutions.

Four new HPs will be developed based on the analysis of possible HVAC solutions in new and retrofitted buildings for meeting high and low temperature with one or two sources. Another HP faces the trend in the market to move to smaller-size heat pumps suitable for the retrofitted buildings with low energy demand (nZEB, ZEB or PEH). A compact geothermal heat pump, easy to install and to integrate in existing buildings, will be developed. Finally, a low temperature HP with mid-term low GWP fluid will be also developed.

The development of a middleware solution regards the connection between the HPs and the other RES like solar thermal, PV or wind and allows the interaction and coordinated control of these technologies. For this purpose, a development of intelligent control algorithms, in connection with BEMS, will be made, in order to increase the overall efficiency of the installations. The last track is about ICT tools. The Web based Decision Support tool and the engineering tools to size the GSHEs will be based on the tools developed in Cheap-GsHPs and will be improved during GEO4CIVHIC. The repository with solutions for drilling, heat exchangers, HPs is built in first period of the project using the knowledge and experience from the partners in each of their areas of expertise. The tool will then be adapted for any kind (civil and historical) retrofitted building applications.

Moreover the "drillability" guide and geothermal maps will be carried out for helping users in the selection of the most appropriate drilling method and heat exchanger choice.

2.3 Phase 3: Demonstration in "real" and "virtual" demonstration facilities

The demonstration phase is the moment of truth, where the innovations have to be checked and tested. A cascade of test and demonstration sites is set up, having specific innovations to validate. The pilot facilities are sites where specific innovations are tested and improved, while demonstration facilities are sites where buildings are retrofitted and the GSHP solutions of GEO4CIVHIC are installed. In the Figures below the 3 pilot facilities and the 4 demonstration facilities are shown with the related innovations descriptions. The pilot facilities are intended to check and test some specific technologies which are developed during the project (3 prototypes of HPs, 3 co-axial solutions, innovative materials and better coupling with RES). The demonstration facilities are supposed to be used to check the retrofit (shallow or deep) of the buildings with installation of 4 different prototypes of HPs (different also from pilot facilities) and two different solutions of co-axial pipes. Overall 7 prototypes of HPs will be developed, 3 types of co-axial and one type of very shallow GSHEs will be developed and tested.

In both pilot and demonstration facilities monitoring campaigns will take place and models will be run in order to have a better understanding of the problem

Pilot facility n. 1 (CNR), Italy
3 innovative small size HPs, together with novel co-axial pipes solutions

Pilot facility n. 2 (TECNALIA), Spain
Innovative small size HP + RES and testing/optimization of BEMS

Pilot facility n. 3 (UPV), Spain
Very shallow heat exchangers, special grouting and new materials for pipes

Figure 2. The three pilot facilities which are used in the project.

by tuning them and finding general results (e.g. not influenced by the actual climatic conditions but referenced to average climatic conditions). Results of real demonstration facilities will give not only the performance of the proposed solutions, but also the installation costs and the possible problems in using the drilling machine and the installation of the GSHEs. Costs and problems also of the building retrofit will be useful information to look at.

Demonstration facility 1
Malta (warm)
Co-ax GSHE + HP
prototype n. 1

Demonstration facility 2
Italy (mild warm)
Co-ax GSHE + HP
prototype n. 2

Demonstration facility 3
Belgium (mild cold)
Co-ax GSHE + HP
prototype n. 3

Demonstration facility 4
Ireland (cold)
Co-ax GSHE + HP
prototype n. 4

Figure 3. The four real demonstration facilities which are used in the project

During the development and demonstration of the new technologies, risk assessments will be made in parallel and coupled back to the development teams.

Beside the real demonstration facilities there are 12 virtual demonstration facilities. In these sites retrofit of buildings have been planned or realized or will be in progress. The innovations of GEO4CIVHIC will not be installed, but will be sized and a feasibility study will be carried out. The owner could at a later stage implement the developed solutions since substantial parts of the engineering work will have been done. At the same time, the costs and renovation problems in the building will be used for enlarging the data base of solutions and cost-benefit analyses.

2.4 Phase 4: Economic, legislative and environmental sustainability evaluation

After the demonstration phase sufficient information is available to evaluate the cost and efficiency impact of the different developed solutions. Material costs, production, assembly and installation costs are known by now and can be extrapolated towards larger scale application. The benefits and also the environmental impact can be defined using LCA and LCCA methodologies demonstrating how these technologies are environmentally friendly and strongly help in the reduction of the CO_2 in the atmosphere.

Several consortium partners have been participating in previous projects on shallow geothermal systems covering standards, regulative and legislative aspects. They will make conformity verifications and possible recommendations on the integration in standards and regulations for these new technologies.

2.5 Phase 5: Dissemination, exploitation and market introduction

The fifth pillar phase, comprises all the horizontal, supporting activities of the project. It regards the broad and attractive sensitization, communication and deployment activities aimed at reaching different kinds of stakeholders and SME's along the supply chain. Awareness is one of the main barriers for shallow geothermal systems next to the high upfront capital cost.

Dissemination and Exploitation take place during the whole project where the GEO4CIVHIC solutions will be used for specifically targeted exploitation activities by the consortium with different actions and events during and after the end of the project.

Moreover, the training material available during the project will provide precious available material, not only related to the results of the GEO4CIVHIC project, but also to the most recent important innovations realised during the last European projects where some partners were involved. This material will fundamental to increase familiarity with heat exchangers types and installation, heat pumps, controls and, as a consequence, can remove fear. The big industrial representative in the consortium makes possible to develop a realistic and complete exploitation plan for each step in the chain. An exercise on the financial incentives, most probably not well known by many stakeholders, will provide an additional support to the business plans.

Also, the options to link up with regional structural fund initiatives on RES need to be included in this modelling exercise. Finally, the cluster with the other successful projects presents an opportunity to include in the hybrid plant configurations the latest developments in the other renewable heating and cooling technologies.

3 Building types examined in the project

In this paragraph particular reference to the building types which are going to be analysed in real and virtual cases will be shown in order to make stakeholders better understand the problem of retrofitting buildings and to provide suitable heating and cooling by means of GSHPs.

It has to be underlined that the key problem to be solved in the project is to provide more suitable solutions for retrofit of buildings in urban areas. The key point of GEO4CIVHIC is to look at both existing and historical buildings with different types of renovation, i.e. shallow retrofit or deep retrofit.

For this purpose, on one hand the problem will be examined by using archetypes in order to generalize results (see another paper proposed at CLIMA 2019), on the other hand the real and virtual cases will provide feed-back on the applications of the proposed solutions and on the real costs, i.e. costs for retrofitting the envelope, the HVAC costs and GSHP costs.

As already mentioned, 4 real cases and 12 virtual cases are being analysed in the project. So far the data collection of the buildings are ongoing and for some of them some preliminary energy modelling has been carried out.

As could be seen in the next table, the 16 cases are subdivided in: existing buildings and historic buildings. Defining historic buildings is not always clear and simple. I a very simplified way a building can be considered historical when it has been constructed 50 years back in the past. So we have defined existing buildings built after 1960 and historic buildings the ones built before, even if exceptions may occur. As can be seen there is a good variety of buildings as for the age, being 7 existing buildings and 9 historic buildings.

A further analysis has been carried out considering also the climatic conditions based on the classification carried out in Cheap-GSHPs project [13]. The subdivision has been carried out into: Warm (W),

Table 1. Description of the real and virtual demonstration sites and subdivision among age and climate: Warm (W), Mild Warm (MW), Mild Cold (MC), Cold (C).

		Age		Climate			
	Location	**Existing**	**Historic**	**W**	**MW**	**MC**	**C**
Real	Malta		X	X			
	Italy		X		X		
	Belgium	X				X	
	Ireland		X				X
Virtual	Greece	X		X			
	Spain		X	X			
	Romania	X			X		
	Romania	X			X		
	Italy		X		X		
	Croatia		X		X		
	Germany		X			X	
	Belgium		X			X	
	Ireland		X				X
	Switzerland	X					X
	Spain	X		X			
	Holland	X				X	
		7	**9**	**4**	**5**	**4**	**3**

Mild Warm (MW), Mild Cold (MC), Cold (C) climates. As might be observed in Table 1, the subdivision among climates is also consistent, dealing with all possible solutions from dominant heating cases to dominant cooling cases, passing through balanced cases. As a matter of fact, there are 3 cold climates, 4 mild cold climates, 5 mild warm climates and 4 warm climates.

The work which is being carried out is providing and will provide a huge amount of information which needs to be set up in a well-organized data base which needs to be robust and consistent with the other data sets coming from the other tasks. All information will be used for the costs and environmental analysis which will be ready almost at the end of the project.

4 Conclusions and discussion

The present paper shows the general methodology which lays below the project GEO4CIVHIC which is one of the biggest research activities in the next three years in the frame of shallow geothermal energy. The project deals with the retrofit of buildings in urban areas and aim at providing technologies suitable for very narrow places with important barriers of different kind. All the developments will go in four main directions:

- novel types of GSHEs and drilling technologies;
- novel types of heat pumps dealing with low and high temperature solutions and with one or two sources;
- middleware solutions for enhancing the coupling between GSHP solutions and RES;
- software solutions for helping designers in sizing and designing GSHP technologies and to provide more awareness to stakeholders through software and apps;
- reduction of the CO_2 emission in the atmosphere in a future sustainable production of energy.

The project lasts until March 2022, hence results will be ready in the next future. The main purpose of the present paper is to show also the real and virtual building cases which are going to be analysed in the project to have a wider overview of the project and its potentialities.

Most of the technologies which are going to be developed in GEO4CIVHIC have to be protected for patent potential applications and hence no further details can be provided so far for prototypes and machines which are going to be developed and produced. ■

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Assessment of Indoor Environmental Quality (IEQ) in offices and hotels undergoing deep energy renovation – The Aldren Method


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Energy renovation of the European building stock is crucial for achieving the reduction of CO_2 emissions. The emissions associated with the buildings are estimated to amount as much as 35% of the total CO_2 emissions. This action is essential in mitigating climate change and its effects. The conversion rate of building stock into environmentally friendly low-energy alternative is however still quite low in Europe and remains at the level not higher than 1% to 2% annually (Artola et al., 2016). This conversion rate cannot underpin the very ambitious targets set by the European Commission regarding the reduction of energy use and non-fossil fuel energy production, as well as the overall intention for quick decarbonization of building stock in Europe. The rate at which new buildings are erected cannot produce sufficiently high CO_2 reduction. Improving the energy performance of the existing buildings through their deep-energy renovation seems, therefore, at present to be the most efficient method for achieving decarbonization of building stock. The rate at which renovations are made must consequently be much higher than today.

Among different impediments of the low conversion rate of European building stock into buildings with low-energy use is the cost of performing the renovation and the long period for the return on the investments necessary to perform the renovation – there are financial benefits resulting from low energy use in buildings, but they are relatively low compared to investments required to improve the energy performance of a building. Additional justification and incentives for energy renovation of buildings, not only related to the environmental impact and energy use, are therefore required to boost the renovation rates far above the present low rates. Besides, straightforward and transparent procedures are required to support the energy renovation of buildings. They will secure that the intended energy savings are reached, that they are properly communicated and monetized and that no other risks exist that will limit the expected benefits from the renovation process.

To address the matters mentioned above the project ALDREN has been conceived and launched in 2017. The project was granted by the European Commission within the Horizon 2020 Programme (aldren.eu). ALDREN stands for "Alliance for Deep Energy Renovation". The main objective of ALDREN is to develop the operational methodology for advancing energy renovation of buildings; offices and hotels are the target buildings. The major elements (modules) of ALDREN methodology comprise the development of:

- a European harmonized energy performance rating, offering comparability and transparency across the EU;
- an energy performance verification protocol to enhance confidence ("you got what has been promised"), building value and management tools;
- a health and well-being assessment framework offering the integration of indoor air quality, comfort and health in the scope of deep energy renovation;
- and a method for financial valuation of both energy and non-energy benefits the latter comprising, for example, an increased building value or productivity in renovated buildings.

All these elements are embraced in the Building Passport and are additionally used to produce the Renovation Roadmap. They respectively collect and present all information regarding the energy performance of a building and energy renovation process, as well as provide recommendations and alternative solutions for the most effective, successful and financially healthy and beneficial energy renovation process. The elements of ALDREN methodology presented above are developed so that they can be used as stand-alone modules, but of course, the overall intention of ALDREN is that they are used together forming the so-called ALDREN method for deep-energy renovation. The method is expected to create a enough incentive to increase the rate at which renovations are carried out. Besides, this method is additionally expected to become a backbone of EVCS, the European Voluntary Certification Scheme, which has been proposed and considered by the Energy Performance of Building Directive (EPBD) (2010) as a market-driven vehicle to boost the energy renovations in the non-residential building sector entailing as much as 25% of the gross building floor area in Europe. Finally, it is believed that ALDREN method will become sufficiently attractive and straightforward so that it can be adopted partially or entirely by any other certification scheme already in use. The structure of ALDREN indicating the consolidation with EVCS is shown in **Figure 1**.

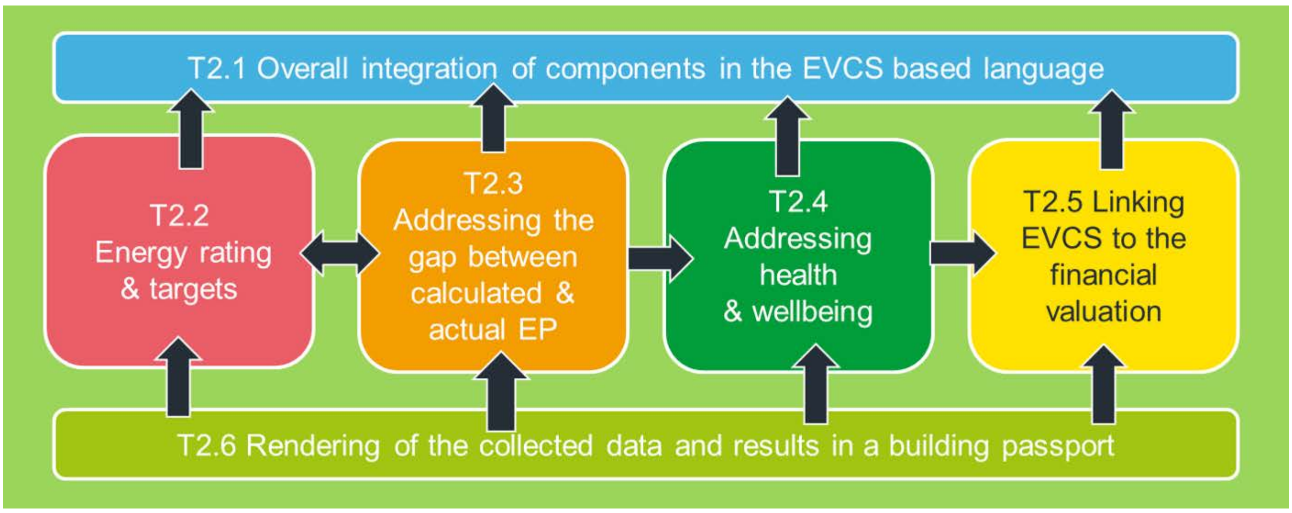

Figure 1. ALDREN in a nutshell, six tasks for consolidation and adaptation of an EVCS (European Voluntary Certification Scheme) based common language.

As indicated by the above bullet points, one of the elements of ALDREN method for the deep-energy renovation of offices and hotels is the development of a protocol for assessment of indoor environmental quality (IEQ) in building undergoing the energy renovation. One reason for the inclusion of this module in the ALDREN method is the direct requirement of EPBD (2010). EPBD is mandating that "*Member States should support energy performance upgrades of existing buildings that contribute to achieving a healthy indoor environment*" and that each long-term renovation strategy shall encompass "*an evidence-based estimate of expected energy savings and wider benefits such as those related to health, safety and air quality*". Another reason why the assessment of IEQ was included is that it allows estimating the potential additional benefits resulting from the renovation process that are not related to reduced energy use. They include among others the improved IEQ conditions in a building that has undergone energy renovation compared with the condition prior to renovation, improved well-being, comfort, health and productivity of building occupants, the increased market value of a building, lease renewal or time needed to lease the space, and alike. The subsequent economic benefits of these improvements are expected to be several times higher than those resulting from reduced energy (e.g., Wargocki and Seppanen, 2006). These additional benefits, often called non-energy benefits, create a powerful argument and incentive to perform energy renovation because their inclusion results in significantly lower pay-back times of the investments and because the resulting profits can be achieved much quicker and can be much higher than those that are associated only with lowering of energy use.

There are different protocols used to quantify IEQ in buildings including both the objective measurements of the components of IEQ, i.e., parameters describing the thermal, acoustic and luminous (visual) environment and air quality, and the subjective ratings of building occupants providing among others the information on their satisfaction with IEQ. However, no standard protocol exists describing, for example, the minimum number and type of measurements that need to be carried out to evaluate IEQ adequately in buildings. Consequently, rather than adopting one of the existing approaches for measuring IEQ, it has been decided that ALDREN should develop the protocol for assessing IEQ in buildings that undergo energy renovation with the focus on offices and hotels which are the target building typologies of ALDREN. This protocol should be applicable in buildings prior to and after the energy renovation is completed. It has additionally been decided that such protocol should not differ considerably from the measuring protocols that are already in use, especially it should not differ much from the protocols proposed by different schemes that are used for providing the sustainability certification of buildings; it was feared that too original and unconventional protocol might limit its use in practical applications. It was also decided that ALDREN protocol for IEQ measurements should only include objective measurements. Although subjective measurements have many advantages and provide information that cannot be obtained by the objective measurements, e.g., building occupants can express directly whether they are satisfied with IEQ or not, the use of subjective measurements was troublesome and ambiguous. An important argument justifying this opinion was that there is no standard questionnaire that can be proposed and applied for rating IEQ by building occupants. Another valid argument was that there are too many factors that can impact and/or modify the responses of occupants and that it is difficult to control them well and make the proper adjustments when the occupant ratings are analysed. Consequently, the ratings of IEQ made by occupants in different buildings may not be comparable, which would breach the original intentions and objectives of ALDREN.

To assist the process of developing the protocol for assessing IEQ in buildings undergoing energy renovation, the methods for assessing IEQ proposed by various certification schemes were examined and summarized. It was done mainly to learn which IEQ parameters are measured when buildings are given the sustainability certificate. An inventory of parameters used to characterize IEQ in different certification schemes was made (Wei et al., 2019), and some results are shown in **Table 1**. To make this inventory, thirteen green building (GB) certification schemes were examined, among which nine were European and four non-European ones. Because the ALDREN project is addressing the European building stock, the summary mainly focused on GB schemes developed in European countries because they were expected to accord with EU regulations, standards, climate and with European traditions for construction, building culture and heritage. Some GB schemes developed in non-European countries were also included in the summary because they are used globally, and thus also in Europe. Only the information available for public that could be retrieved from the documents posted on the certification schemes webpages was used to create this summary; the standards referred to by surveyed GBs were not examined. The focus was on indicators used to assess IEQ in offices and hotels. However, if no specific information for these types of buildings was provided, the indicators recommended for any types of buildings were retrieved from GB schemes.

Nineteen indicators characterizing thermal environment were identified. Among them, the most commonly used ones were Predicted Mean Vote (PMV), Predicted Percentage Dissatisfied (PPD), room operative temperature, room air relative humidity, and air speed. Twenty indicators characterizing acoustic environment were identified. Among them, the most commonly used ones were ambient noise and reverberation time. Thirty-nine indicators characterizing IAQ were identified. Among them, the most commonly used ones were ventilation rate and concentration of total volatile organic compounds (TVOC), formaldehyde, carbon dioxide (CO_2), carbon monoxide (CO), particulate matter (PM10 and PM2.5), ozone, benzene, and radon. Twelve indicators characterizing luminous (visual) environment indicators were identified. Among them, the most commonly used ones were illuminance level, daylight factor, and spatial daylight autonomy.

The summary of IEQ indicators was used to select IEQ parameters that should be included in the protocol for assessing IEQ in buildings undergoing energy renovation that is proposed by ALDREN. Not all parameters listed in **Table 1** were selected, and this table does not include all parameters that were eventually included in the measuring protocol. The method for rating of IEQ in buildings proposed by ALDREN contains both the measuring protocol for the selected IEQ parameters as well as the rating of overall IEQ level using a new IEQ index called ALDREN TAIL index, in short TAIL. The measuring protocol and an index allow thus repeatability, comparability as well as similar standard rating metric, all originally called for in the proposed ALDREN method.

TAIL is shown in **Figure 2**. TAIL stands for the thermal (T), acoustic (A) and luminous (L) environment, and indoor air quality (I), the four cardinal components characterizing IEQ. Each component is assessed separately, and the quality of each component is provided by TAIL. The quality level is depicted by different colors, green standing for high quality, yellow for medium quality, orange for moderate quality, and red representing low quality. TAIL also provides information on the overall quality level of the indoor environment. This level depends on the quality of the four components of IEQ: T, A, I and L. The overall quality is expressed by the Roman numbers, I standing for high quality, II for medium quality, III for moderate quality,

***Table 1.** IEQ indicators commonly used by Green Building certification schemes.*

IEQ indicator	Level(s)	HQE	OsmoZ	BREEAM	KLIMA	DGNB	LiderA	BES	ITACA	WELL	LEED	CASBEE	NABERS
Thermal environment													
PMV	x		x	x	x				x	x			x
PPD	x		x	x	x					x			
Air relative humidity					x	x	x	x				x	x
Operative temperature	x				x	x		x		x			
Air speed		x			x		x	x					x
Acoustic environment													
Ambient noise		x	x	x	x			x		x	x		x
Reverberation time	x	x	x	x		x		x		x	x		
Indoor air quality													
Ventilation rate	x	x	x	x		x		x	x	x	x	x	x
TVOC		x	x	x	x	x		x		x	x		x
Formaldehyde	x	x	x	x	x	x		x		x	x		x
CO_2	x		x		x			x		x	x		x
CO		x	x					x		x	x		x
PM_{10}	x	x	x							x	x		x
$PM_{2.5}$	x	x	x							x	x		
Ozone		x	x					x		x	x		
Visual (luminous) environment													
Illuminance level	x			x			x	x		x	x	x	
Daylight factor	x	x	x	x		x			x			x	
Spatial daylight autonomy	x	x	x							x	x		

and IV for low quality. These levels match the quality levels prescribed by the standard EN16798-1 (2019), one of the standards supporting EPBD (2010).

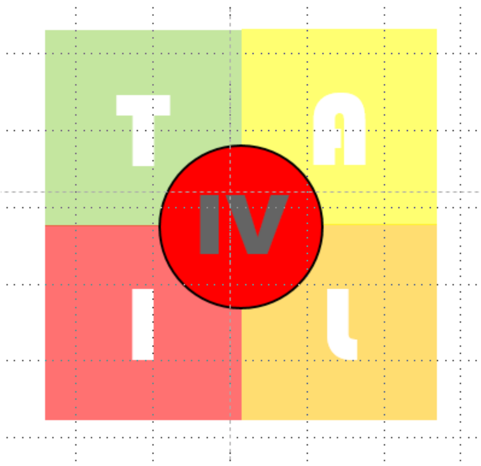

Figure 2. ALDREN TAIL index, in short TAIL.

The quality levels of the components of TAIL are determined by performing measurements of different parameters characterizing IEQ. Twelve parameters are selected: temperature for rating the quality level of T, sound level for A, ventilation rate, concentration of CO_2, formaldehyde, PM2,5, radon and benzene, relative humidity and visible mold level for I, and illuminance level and daylight factor for L. The measured values are compared with the reference values, and then their quality levels are determined. The reference values are set either to match the standard EN16798-1 (2019) or the WHO Air Quality Guidelines (2006, 2010). The detailed protocol for measuring the selected twelve parameters was developed, including the selection and a minimum number of measuring points, details regarding the accuracy of instrumentation, as well as analysis of measuring results.

Ten parameters used to characterize IEQ are measured. Visible mold is assessed by visual inspection, and the daylight factor is assessed by simulations. The protocol recommends the measurements and assessments in seasons with extreme conditions, which for most European regions comprises at least heating (winter) and non-heating (summer) season. Simulation of some IEQ parameters have been considered as a supplement or to replace the measurements. However, simulations require many assumptions, especially in the case when the original information regarding the construction materials used in the existing building undergoing renovation is unknown. Consequently, it was felt that performing measurements would provide a more accurate estimate of the actual IEQ level in a building. In addition to that, it is worth mentioning that many IEQ parameters simply cannot be simulated at present.

The measuring protocol and the index developed by ALDREN are currently subjected to testing and preliminary validation. Testing is made during pilot measurements carried out by ALDREN project in existing buildings that have undergone energy renovation. The index is reviewed by the project partners and different building stakeholders. Consequently, the index and the protocol presented in this article are not in their final version - they can still be revised and supplemented if the project continues its activity that is scheduled to end in the spring of 2020. There are few additional parameters considered for measurements and few protocol modifications, including the method for determining the overall IEQ level. ■

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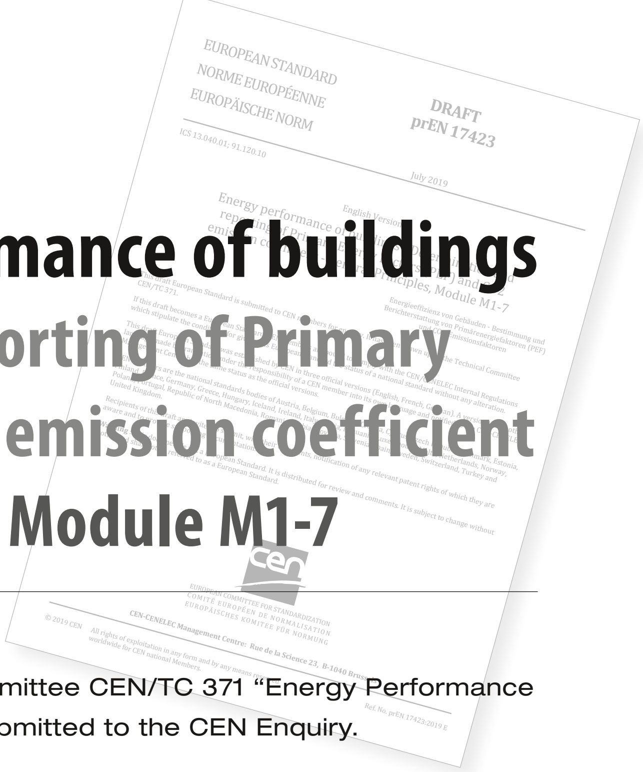

prEN 17423 Energy performance of buildings – Determination and reporting of Primary Energy Factors (PEF) and CO_2 emission coefficient – General Principles, Module M1-7

Author: **JAAP HOGELING**, Chair CENTC 371 Program Committee on EPBD

This draft standard has been prepared by Technical Committee CEN/TC 371 "Energy Performance of Buildings project group", this document is currently submitted to the CEN Enquiry.

Regarding the scope of this standard:
The current draft standard provides a transparent framework for reporting on the choices related to the procedure to determine PEFs [1] and CO_2 emission coefficients [2] for energy delivered to and/or exported by the buildings as described in EN ISO 52000-1:2017. Exported PEFs and CO_2 emission coefficients can be different from those chosen for delivered energy. This standard can be considered as a supporting/complementing standard to EN ISO 52000-1, as the latter requires values for the PEFs and GHG Emissions factors to complete the EPB calculation.

This draft standard is part of a series of standards aiming at international harmonization of the methodology for the assessment of the energy performance of buildings (EPB standards) and specifies the choices to be made to calculate the PEF(s) and CO_2 emission coefficients related to different energy carriers. The standard can be adapted to different time steps (annual, monthly, hourly) with the scenarios used for energy use and energy delivered. As for other EPB standards for the correct use of this document, a normative template is given in Annex A to specify choices.

The target group of this standard are all the users of the set of EPB standards and especially national standardization experts or building authorities who are in charge of defining the PEFs and CO_2 -emission coefficients.

Choices related to PEF and CO_2-emission factors are also dealt with in other standards (e.g: EN ISO 52000-1, EN 15316-4.5). In the future, all choices are expected to be summarized in one document. Therefore, chapters of other documents have been copied into this document to make a consistent document and provide a better understanding.

Annex A (normative) provides a template to report only the main methodological choices that have an impact on PEF and CO_2 emission coefficient values. No mandatory quantitative reporting of data is requested. These choices are described in Clause 6.

Informative general formulae defining the PEF for different configurations (e.g. one main energy carrier, multi energy input systems, multi energy output systems, exchanges with other perimeters) have been added included for better understanding. These general formulae do not have an impact on PEF and CO_2 emission factors but contribute to a better understanding. Related informative data reporting tables show a possible structure of resumed data reporting towards are more common structured quantitative reporting. It has not been decided yet to make the formulae and reporting tables normative.

This prEN has been published for enquiry, the enquiry closes 2019-10-17, which means in practise that your National Standard Body has to receive your comments before the 1^{st} of October 2019 to be able to process them according CEN rules. We encourage our readers to consult their NSB for access to this draft standard. ■

[1] PEF: For each delivered or exported energy carrier, there are three PEF, related to different energy contents of the energy carrier, to be assessed: Non-renewable PEF (fP;nren); Renewable PEF (fP;ren); Total PEF (fP;tot);

[2] The CO_2 emission coefficient shall be expressed in kg of CO_2 per kWh of the related energy carrier. The CO_2 emission coefficient can also include the equivalent emission of other greenhouse gases (e.g. methane, water vapour). To be more precise, it should be specified by adding "equivalent" (e.g. CO_2 eq).
The emission factors shall be coherent with the choice of referring to gross or net calorific value.

First highlights of the 2019 European Elections

Author: **REBEKA MARŠNJAK**, EU Policy and International Relations Officer

Possible political dynamics of the new 9th legislative term

On 2 July the newly elected European Parliament was officially constituted and the term of the 9th legislature has started. During these elections, 751 Members of Parliament (MEPs) were elected from 190 political parties in 28 member states, with the higher percentage of the new MEPS (61%) and 3% more women MEP representatives (final 40%) as from the last elections in 2014 (37%). Currently, the new Parliament consist of seven political groups, some of the MEPs are listed as non-aligned.

In the past months, the political parties elected the new President of the European Parliament, who became David Maria Sassoli, an Italian MEP since 2009, who was re-elected also this year on "*Partito Democratico*" list for a third term. His presidency of the European Parliament will run for two and a half year, until January 2022.

* https://www.europarl.europa.eu/resources/library/media/20190716RES57231/20190716RES57231.pdf

However, the EPP (European People's Party) continues leadership as the biggest political group at the European Parliament, followed by the S&D (Socialists and Democrats) as second and the Renew Europe (former ALDE party) on the third place. Notably, this year's elections brought higher number of members of populists and nationalistic oriented parties, which can lead to additional challenges when seeking for consensus and pushing for ambitious targets in order to reach energy transition and other climate agendas. In times, when we need political stability to push forward all policies that need the strong leadership during their implementation, it will be much depending on political dynamics within European institutions.

First woman to lead the European Commission for the next five years

On 16th July, the European Parliament confirmed Ursula von der Leyen as a new President of the European Commission with 383 members voted in favour, 327 against and 22 abstentions, a little more than 50% of Parliaments members.

Ursula von der Leyen will take her office on 1 November 2019 for a five-year term. She was member of the German Bundestag since October 2009, following as Federal Minister of Labour and Social Affairs and currently holding the position of Federal Minister of Defence since December 2013. Being a licensed physician, she also holds a degree in economics and medicine. She is married and has seven children.

As a new President-elect, she is a less known political figure at European level and appeared unexpectedly as a new candidate from the EPP political group, who was not taking part as a "*Spitzenkandidat*", which costed many disagreements from different political groups at the European Parliament. During the long lasting hear-ings at the plenary session in Strasbourg, Ursula von der Leyen presented her political guidelines* for a five years term 2019-2024.

Climate action proposals and European green deal were not strong enough to convince all political groups to reach a higher majority support

Putting carbon neutrality into law during the first 100 days, developing the transition fund and making EU executive leadership more flexible and inclusive with proposing the nomination of the two executive vice presidents, new President-Elect summarised the main political priorities of her presidency:

1. A European Green Plan: towards reduction of 55% of CO_2 emissions by 2030, based on social, eco-nomic and environmental assessment.
2. To facilitate the transition of the above-mentioned plan, she proposes a "Transition Plan" via Sus-tai-nable Europe investment Plan and new forms of climate bank. Therefore, she also wants to im-ple-ment a carbon border tax and extend the Emissions Trading System.
3. An economy that works for people with a special focus on private-public fund specialising in Initial Public Offerings of SMEs.
4. A Europe that fits the digital age (legislation for a coordinated European approach on the human and ethical implications of Artificial Intelligence).
5. Protecting European way of life (proposing the new Pact on Migration).
6. A stronger position of EU in the world.
7. A new push for European democracy (improving lead candidate system, more inclusive leadership).

The Greens, the fourth largest political group remained unconvinced on the new President-Elect's green agenda, which by their opinion seems ambitious but with no concrete action tools to reach them. At the same time, nationalists, populists and the centre right (EPP) parties were accusing von der Leyen to seek too much consensus with progressive lefties parties in the European Parliament.

On the other hand, progressive parties such as Socialists and Democrats (S&D) were still unhappy on not putting forward one of the Parliament-approved Spitzenkandidaten as Commission President, which by their opinion clearly did not respect the "voice of voters". At the same time, they wanted more concrete actions to tackle European democracy and details on how to respond to citizens' demands. The representa-tives of the new "Renew Europe" political group - which is the successor of the ALDE group that existed from 2004 until 2019 - welcomed her agenda and called for a real pro-European leadership. In addition to that, for the purpose of the European elections 2019, the Renew Europe gathered together ALDE and Macron's "En Marche" political group which started under the new name for the 9th legislative term. According to the opinion of many, the nomination of von der Leyen strengthens Macron's position in Europe, which seems to be an excellent political move for Macron to continue his vision of European Union.

Therefore, Ursula's initial political party EPP welcomed her political priorities and strived for innovative, fair and mostly ecological Europe.

Nationalists and populist parties had a common opinion on not seeing any convincing vision for Europe. Thus, they were welcoming new climate ambitious targets, transition fund and a bank for sustainable investments, which might be a good sign of support when targeting climate transition proposals.

What follows next…

The Member states' heads of governments already started with sending their official proposals for members of the Commission. Hearings of candidates will take place from 30 September to 8 October in the Parliament's committees. The vote on the full College of Commissioners is scheduled for mid-October. Once the European Commission is elected by the Parliament, the Commission will be formally appointed by the European Council, acting by a qualified majority.

Nevertheless, the arising questions, will Mrs von der Leyen be able to conquer hardly reached majority of support when it comes to seek the support for proposed policies? Will she be able to build bridges and make execute leadership as much inclusive? And the most important, will the new Commission's presidency provide measures and tools to fully reach climate and energy targets and strengthen the European market to support various sectors through the energy and climate transition.

What to implement better from the previous legislation term?

The coming 5 years will be crucial to facilitate a successful green transition, which will depend on well-maintained mobilisation of not only public but also private investments, having an effective circular economy, and providing integrated and functional European energy market. The EU needs to increase energy efficiency and the renewables share in all sectors, reduce our dependence on outside sources, provide the infrastructure and invest in long term solutions in the future.

As we are entering this new legislative mandate, circular economy will be one of the leading topics, therefore the industrial vision is vital for Europe to remain leader of the global energy transition. With the increasing demand for product efficiency, sustainable production and commitment to circular economy, it is important to facilitate financial support and cooperation between enterprises and linkage between various sectors. A major legislative challenge will be a common European strategy on gas and new gas regulation.

In the building sector, implementing the EPBD via the national energy plans continues to be a "hot" topic in member states. In parallel, a new Smart Readiness Indicator (SRI) is under development and is currently under consultation as part of the second SRI study. A delegated act on its implementation supposed to be ready for adoption by the end of this year.

REHVA will monitor all priorities on the political agenda, and impact on policy developments that relate directly to the HVAC and buildings sector. Main observations will be published regularly in the digital REHVA policy news** channels and on "freshly" created REHVA blog www.rehva.eu/blog. ■

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CONFERENCE

REHVA BRUSSELS SUMMIT 4-5 November 2019

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

Delivering healthy, zero-carbon buildings by 2050?

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

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

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

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

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

SESSION 2 – Building performance certification to bridge the finance gap

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

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

SESSION 3 – HVAC product efficiency & drinking water systems

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

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

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

Registration to the sessions and to the side events is mandatory. Below, you may find the registration fees.

Event	Fee
REHVA Dinner, Sofitel Le Louise Hotel, Brussels	85 € (exl. VAT)
REHVA Conference *"Delivering healthy, zero-carbon buildings by 2050?"*	Free, but mandatory registration

If you would like to register for the summit, please go on: www.rehva.eu/events/details/rehva-brussels-summit-2019 and follow the instructions for registration. ■

REHVA is taking a part in setting up the Indoor Environmental Quality Global Alliance in a strong cooperation with global partners

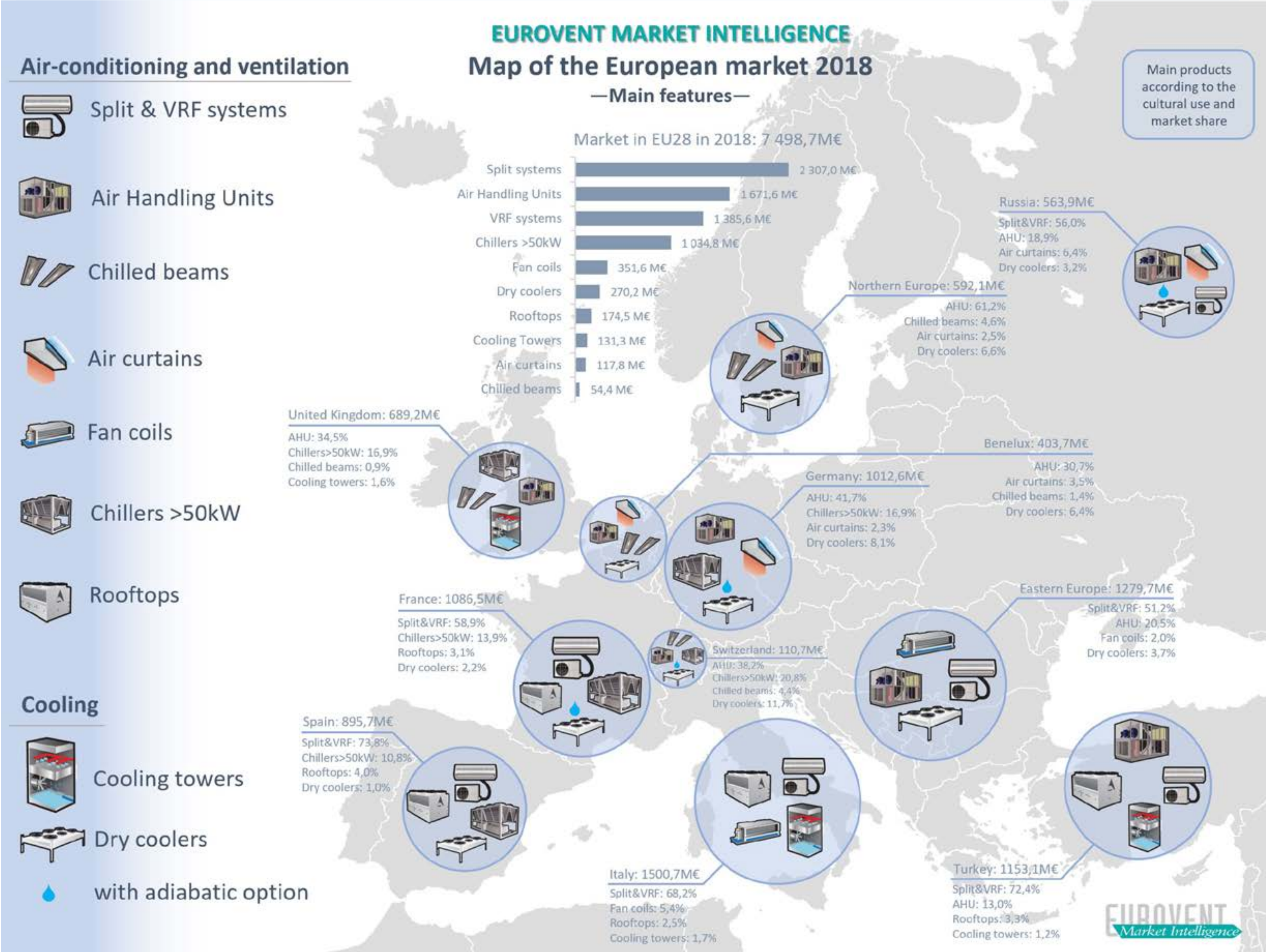
A brand-new global entity named Indoor Environmental Quality Global Alliance (IEQ-GA) is a result of cooperation in supporting the advocacy and exchange of indoor environmental information in buildings all over the globe.

https://ieq-ga.net/

Therefore, the six founding full members (AIHA, AIVC, AiCARR, ASHRAE, IAQA, ISHRAE and REHVA), are bringing together professionals from various disciplines linked to indoor environment, whom will work together to create a common message of policy agendas and advocacy positions, research and other information that can be put into practice to provide related standards, codes, and guidelines or other means of dissemination to support health and indoor environmental quality in buildings sector.

IEQ-GA office will be in Brussels, Belgium where the first year of the IEQ-GA secretariat will be held by REHVA. The main activities describe the participation in relevant committees and organisations to foster the aim of the association in promoting the research and educational exchange of the indoor environmental quality. Thus, participating in the activities to influence and to advocate on the importance of the healthy environment of the buildings. However, it is crucial that cooperation with various stakeholders, member states and other global partners is based on managing the knowledge and sharing to various layers internationally, and to expand their activities while attracting new members and stakeholders to join and apply new possible developments in the indoor environmental quality field.

The official announcement of the final establishment of this global alliance is going to be held during the AIVC conference in October 15-16th. ■



25 years of Eurovent Market Intelligence!

Eurovent Market Intelligence (EMI), the European Statistics Office for the HVAC&R market, has just published the results of its studies for 2018 sales in Europe, Middle East and Africa (EMEA), based on the data collected from a large number of industry manufacturers. To mark this occasion, our team interviewed the Eurovent Market Intelligence (EMI) team.

EMI team. From left: Manager **Yannick Cotrelle**, Analyst **Inna Collet** and Analyst **Anaïs Hamon**.

How are the 2019 collections going?

Yannick Cotrelle: The 2019 collections have been a success once again this year, with more than 300 participants with an increase of 9% in comparison with last year. In addition to this representation, the timeline of data was also the order of the day, the results have never been delivered this early before, around the start of March for most of the programmes.

Inna Collet: Among the collections that were the most successful, you can find the usual programmes, such as chillers and air handling units (AHUs), however also pool dehumidifiers that have enjoyed an exceptional increase of 26% with close to 20 participants. Moreover, this programme will be the subject of a redesign in 2020 to conform with the needs of the manufacturers.

What new features is EMI offering in 2019?

Anaïs Hamon: Previously, you could only view the results of the collections in tables, which you could see on our website or download as an Excel file. Now, our participants also have access to geographical maps and dynamic, interactive graphs. This means that not only do they change depending on what you select (country, product segments, etc.), but you can also click directly on the graph to update the map or on the map to update the graphs. Given that you can also view your market share, rank or even the evolution of the market, this allows sales managers to animate presentations by basing them directly on this new tool.

Have you also launched new programmes?

Yannick Cotrelle: EMI has strengthened its expertise in the air conditioning market by launching new collections of statistics on VRF and Split System sales. These have brought together more than twenty companies, among whom are the leaders of the three main countries of production: Daikin (Japan), Midea (China) and Samsung (South Korea). This has already allowed us to identify trends in VRFs, like the market position of models with capacity above 50 kW, or again the growing success of cassette-type interior units.

Where does Eurovent Market Intelligence rank in comparison to other market data suppliers, such as consulting firms?

Yannick Cotrelle: In a way, we are complementary. We differ from traditional consulting firms in that we cannot divulge the market share of a company nor its commercial strategy. In effect, our figures are based on the sales data declared directly by the manufacturers, they are treated as strictly confidential and without this commitment to confidentiality, EMI would not exist. Conversely, our market data is a lot more detailed – it draws on statistics tables that combine several thousand data points per country – and most representative of the market, currently no other body exists with the same coverage rate as ours.

Anaïs Hamon: We also provide quarterly results on chillers, fan coils, AHUs and rooftop units markets and we have seen growing interest in this subject from manufacturers. While five years ago manufacturers represented only 56% of our participants in the annual collections, today this figure has reached 74%; which is not negligible given that, in the meantime, our total number of participants has also grown.

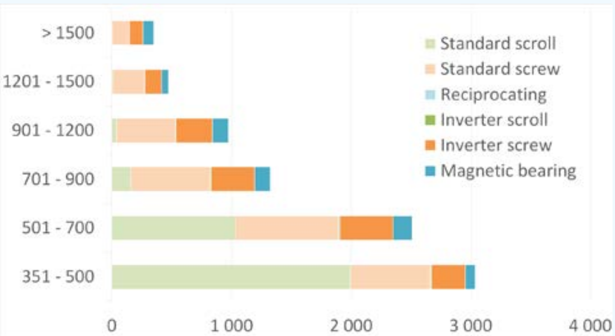
What are the projects for 2020?

Inna Collet: It is still too early to make a decision about the new collections that will be launched in January, but one thing is certain, we will continue to prioritise the improvement of our online tools, with greater flexibility in terms of data extraction and more choices and interaction in terms of visualisation. We will also try to strengthen our representation of regions at the periphery of the European Union, such as Russia, Turkey and India. That's why we will attend several exhibitions in March 2020 like Acrex in Delhi and Climate World in Moscow, and the next Eurovent Summit will take place from 22 to 25 September 2020 in Antalya in Turkey.

The HVAC&R Market in the EMEA Region in 2018

Chillers

The chiller market (including reversible) in the European Union reached 2.2 billion euros in 2018, with a 5% increase in units with a capacity greater than 50 kW in comparison with the previous year. With regard to the market for units with a capacity lower than 50 kW, the market continues to be dominated by reversible heat pumps and is predominantly in France, Germany and Italy with a total of 228,000 units sold in these three countries. Moreover, we find the same trio of



Chiller market in Europe in 2018
– split by compressor for units above 350 kW.

countries at the top of the table for units with a capacity of more than 700 kW, with a total of 1,231 units sold.

In terms of refrigerants used, the market continues to be largely dominated by R410A and R134a. New refrigerant blends (like R-513a) and HFOs (like R-1234ze), which have grown rapidly in comparison with 2017, however still only make up 1% of the units sold in Europe. In terms of air-cooled units, the standard compressors are generally scroll-type for capacities up to 700 kW and screw-type for higher capacities, with a transition point of using an inverter at 200 kW. In terms of water-cooled units, the scroll to screw tipping point is at 500 kW for standard compressors, while for inverter compressors, the market starts at 200 kW, almost equally shared between inverter screws and those with magnetic bearing.

The IT Cooling sector

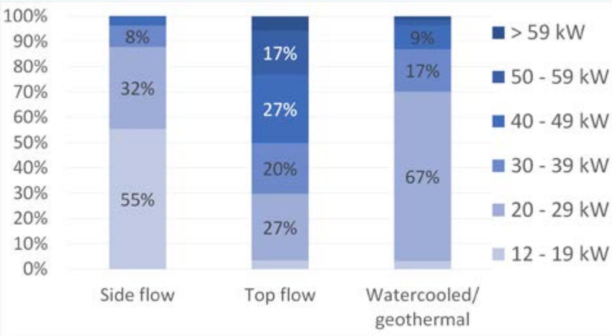
The IT Cooling market rose to 427 million euros in the EMEA region in 2018, comprising 58% room air conditioners (also called CRAC – Computer Room Air Conditioners), 19% self-contained air conditioners (row and rack coolers), 10% mobile TLCs and 13% AHUs. The biggest markets are – by order of size – Germany with 63.1 million euros, the United Kingdom with 53.2 million euros, France with 32.1 million euros and Italy and Russia with 24 million euros each. In the European Union, the growth of CRAC and RACK units has been slightly negative, whereas TLC and AHU units have experienced an increase of about 10%.

In the room air conditioner market, we noted two distinct trends: the first is, for chillers, a constant increase in units with capacity over 150 kW (their number has more than doubled since 2015) and the second is, for direct expansion units, an upwards trend for modulating compressors. Paradoxically, since 2016 we have also seen a downwards trend for units with indirect integrated free cooling, which could be explained by competition from evaporative cooling in this sector.

Variable refrigerant flow air conditioning systems (VRF)

The VRF market reached 216,135 units sold in Europe in 2018, representing an increase of around 7% in comparison to 2017. The principal markets in Europe are, in order of size, Turkey (despite the decrease recorded this year), France, Italy and Spain, totalling 108,744 units. Northern Europe still lags far behind with only 1,327 units sold in 2018. The largest increases were in Portugal and Romania, with an increase of more than 30%, whereas the largest decreases were in Norway and Lithuania, with declines of around –30%.

In terms of the market segmentation, we saw an increase in high-capacity VRFs with units with a capacity of more than 50 kW rising from 11.2% in 2017 to 14.1% in 2018. This trend went together with a predominance of top flow units, which comprised around 60% of the units sold. As for interior units, the market remains oriented towards cassette units (42%), then duct units (30%) and wall units (21%), even though significant variations exist across countries.



VRF market in Europe in 2018
– split by type of units and capacity range.

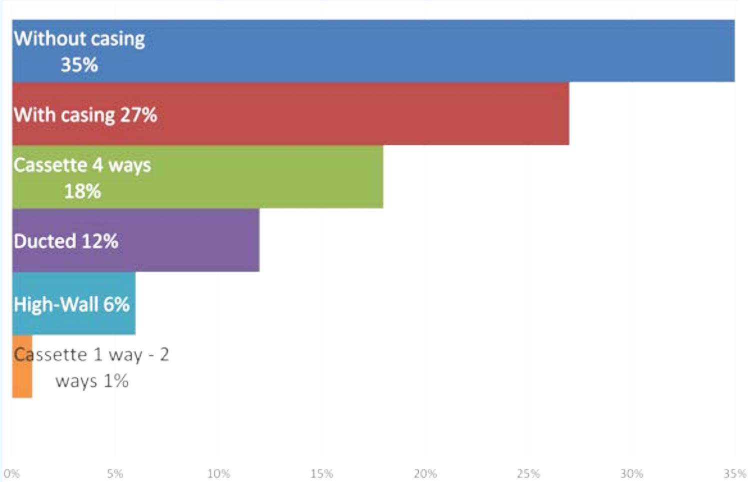
Residential heat recovery ventilation units

The market reached 408.8 million euros in 2018 in the European Union, to which an additional 43.3 million euros should be added for Norway and 8.68 million euros for Switzerland. Of the units sold in Europe, 29% had a flow rate of less than 100 m^3/h and 38% had a flow rate of more than 250 m^3/h. In terms of energy class, most were Class A, accounting for 82% of units sold. Class A+ still only represents 5% of the market. In terms of the type of heat recovery, very specific types are popular in certain countries, such as in Germany with more than half of the exchangers are ceramic (for small decentralised units with alternating flow), Norway with 93% of the exchangers are rotary (in severe cold, the rotary movement prevents frost from forming, which would negatively impact energy performance) and France with 88% of units are equipped with counter-flow heat exchangers.

Fan coil units

The fan coil market was relatively stagnant in Europe between 2017 and 2018, levelling off at about 1.35 million units. This is due partly to the sharp decline in Turkey (–24.9%) and, to a lesser extent, the decrease in Russia (–7.1%). By contrast, the EU experienced an increase of +4.6%, mainly explained by large increases in Spain and the United Kingdom (+6.5% and +13.1% respectively) and by a stable Italian market (+2.4%). It is also worth noting that Portugal is the European country that experienced the largest increase between 2017 and 2018, with an increase of more than 40%, which allowed this country to reach 15,900 units in 2018.

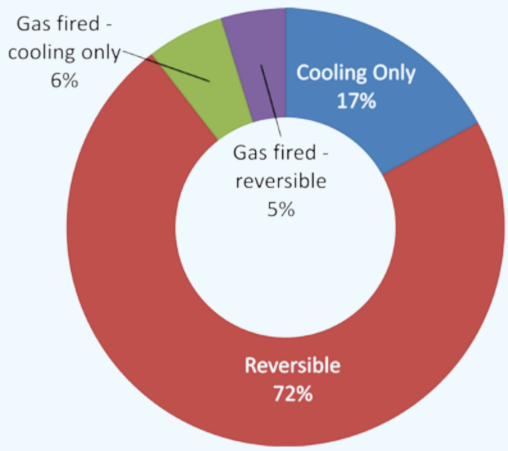
The most dynamic types of fan coils were 'cassette' and 'wall' models, as well as '4 pipe' units. Their large increase has, however, not inverted the market distribution, which remains, for the most part, dominated by '2 pipe' units (73% of models). From a design point of view, fan coils with and without casing still represent 30% of the market respectively and 'cassette' and "ducted" models share the remaining market.



Fan Coil Units market in 2018 by type of technology
– total Europe.

Rooftop units

The European rooftop unit market experienced a decrease of more than 12% in 2018, amounting to about 11,500 units sold in Europe. Turkey remained dominant with 2,100 units sold in 2018, representing an increase of +4%. Despite declining by –15.3%,



Rooftops market in 2018 by type of technology in Europe, Africa and Levant.

–17.4% and –6.1% respectively, France, Italy and Spain remain the next three largest European markets, each with more than 1,500 units sold.

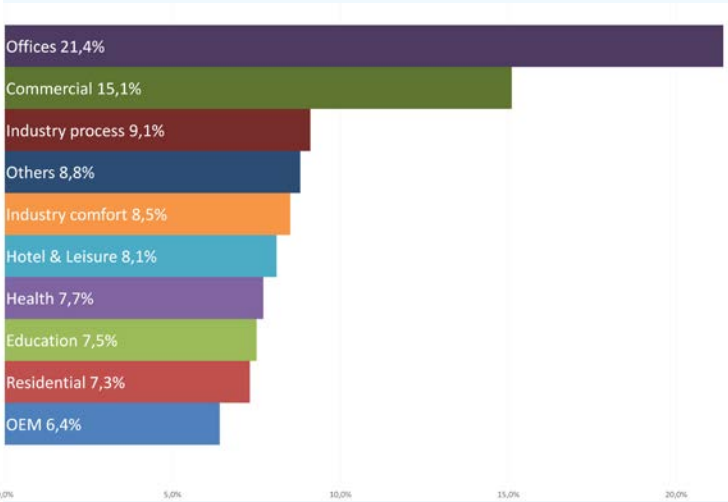
Medium capacity units, between 17 and 120 kW, represent three-quarters of sales in Europe. Reversible rooftop units remain the preferred type in Europe, with about 70% of the market. Cooling-only units also seem to have gained ground, accounting for almost 17% of sales.

Air handling units

The European air handling units market reached 2.1 billion euros after a small increase in 2018 (3.3%). This increase came mainly from four of the biggest European markets: Germany, which remains the leader with 422 million euros (+0.9%), followed by Northern Europe with 362 million (+3.8%), Eastern Europe (261 million, +14%) and Turkey (149 million, +11.1%). By contrast, we saw a decline in sales in Russia and the CIS (129 million euros, –14%) and the United Kingdom (237 million euros, –10.7%).

On the application side, the European market is dominated by new units, representing 62% of sales, with the remaining 38% being replacements. Furthermore, we have noted the use of air handling units predominantly in offices (21.4%) and in the commercial sector (15.1%).

It is also worth noting that air handling units with integrated controls represent two-thirds of sales in Europe and 'compact' units seem to have gained ground, as they constitute almost 60% of sales today.



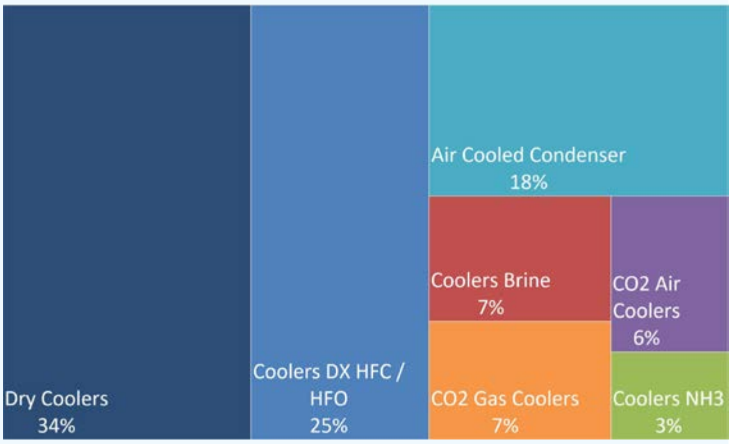
AHU market in 2018 by type of application – total Europe.

Heat exchangers

The European market continued to grow in 2018, reaching around 940 million euros, of which about 3% were adiabatic. This increase has been driven by the main European markets: Germany, Italy, France and Spain, which recorded growths of around +10%.

Air-cooled heat exchangers continue to gain ground and represent 34% of the market in this year. The rest of the market is composed of evaporative coolers (35%), condensers (18%) and CO_2 gas-air heat exchangers (13%).

The heat exchangers market is dominated by commercial refrigeration (39%), followed by industrial and comfort applications, with 26% and 21% of the market respectively. It is worth noting that the trend is significantly in favour for new heat exchangers (63%) to that of replacement (37%).



Heat Exchangers market in 2018 by type of technology – total EMEA.

Chilled beams

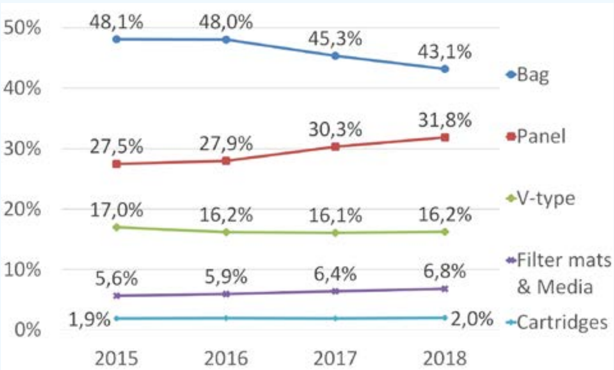
The chilled beams market has once again decreased – by 6% this year – falling to 54.4 million euros in 2018. This decrease was spurred by the countries that traditionally represented the bulk of the market, such as Sweden, the United Kingdom and France. These countries, with a market share of 51% in the EU, saw declines of –5% for Sweden and –30% for the United Kingdom, as a result of Brexit. Other regions, like Italy, Belgium and the Baltic countries also recorded negative movements. Conversely, Denmark, Spain and, outside of the EU, Switzerland and Russia have also benefited from increases of more than 40%.

Active chilled beams, which constitute 93% of sales, remain the most used in Europe. Among these, 76% are integrated and 24% are autonomous.

Air filters

The growth in air filters in the EMEA market subsided in 2018, with total sales of around 950 million euros. The two biggest countries, Germany and France, who jointly represent 40% of the market, recorded a slight decrease of around –2%, whereas the United Kingdom and Italy increased by 4%.

In terms of filtration category, the most used filters were of the ePM1, ePM5 and ePM10 categories, even though the trend is clearly downwards as they fell from 61% of the market in 2014 to 52% in 2018. In terms of the design, bag filters continue to dominate the market, even though they showed a downwards trend in favour of panel filters, with 43.1% and 31.8% respectively of the market share in 2018.



Split of the Air filters market in EMEA by type of design.

Cooling towers

The European cooling towers market grew by 16% in 2018 to reach 131.3 million euros. Five countries represent two-thirds of the European market: Germany, Italy, France, the United Kingdom and Poland. All of these countries have seen an increase in their sales, the highest being recorded in Poland where the growth reached 25%.

Outside of the European Union, the biggest markets were the Arabian Peninsula (around 20 million euros), Turkey (about 14 million euros) and Russia (almost 9 million euros). However, the market only increased in Russia between 2017 and 2018, whereas the Arabian Peninsula and Turkey experienced a significant decrease in their sales.

Open cooling towers were the most popular in most European countries. Only the Baltic countries, Belgium, France and Romania preferred closed circuit towers.

As in previous years, more than 60% of the European market constituted low capacity units, those with fewer than 10 cells. Large capacity towers, with more than 50 cells, are used occasionally in projects in Europe, whereas they are more common in other geographical zones, like the Arabian Peninsula.

Air curtains

The air curtain market experienced an increase of 6% in 2018 and reached 83,000 units sold. Air curtains are mainly widespread in Northern Europe, where there are around 1,900 inhabitants per unit sold. In other European countries however, there are around 5,000 inhabitants or more per unit sold. Outside of the European Union, Russia and other CIS countries (the Commonwealth of Independent States) constitute one of the most significant markets with sales exceeding 230,000 units in 2018, due to stricter regulations.

In the European Union, 91% of air curtains were sold in the design, commercial and retail markets, whereas only 9% were destined for industry and cold rooms.

Electrically heated air curtains are the most popular in the European Union and represent almost half of the market. Air curtains with water heating constitute around 28%, whereas 20% do not provide heat. Units with refrigerant remain less popular for the moment and have a market share of around only 2%.

Pool dehumidifiers

The single-flow pool dehumidifiers market declined by 15% in 2018 in the EMEA zone, representing a little more than 7,100 units sold. This decline, observed in all the regions of the EMEA zone, was particularly pronounced in Italy, Spain, Portugal and Turkey. France and Germany still constitute the principal single-flow markets with almost 40% of sales.

In contrast, the double-flow market saw its sales increase by 20% and reached more than 5,300 units sold. The increase is between 1 and 20% in all of the EMEA zone countries, with the exception of Northern Europe and the United Kingdom and Ireland region, where sales decreased by between 8 and 10%. ■

REHVA
Federation of European Heating, Ventilation and Air Conditioning Associations

MEMBERS

Network of 27 European HVAC Associations joining 120 000 professionals

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Exhibitions, Conferences and seminars in 2019-2020

Exhibitions 2019

3-5 September	ISH Shanghai & CIHE	Shanghai, China	https://www.hk.messefrankfurt.com/content/ishs_cihe/shanghai/en/visitors/welcome.html
2-5 October	ISK-SODEX 2019	Istanbul, Turkey	www.sodex.com.tr/en
21-23 November	REFCOLD	Hyderabad, India	http://www.refcoldindia.com/
4-6 December	50th int HVAV&R congress and exhibit	Belgrade, Serbia	http://kgh-kongres.rs/index.php/sr/

Conferences and seminars 2019

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

Exhibitions 2020

27-29 February	ACREX	New Delhi, India	http://acrex.in/home
10-13 March	SHK Essen	Essen, Germany	https://www.shkessen.de/branchentreff/

Conferences and seminars 2020

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

The AIVC was created in 1979 as the 5^{th} project of the IEA Technical Collaboration Programme on Energy in Buildings, called annex 5. Originally called the AIC (Air Infiltration Centre), the focus has moved to a more global view on indoor climate and energy efficiency and therefore the name was changed in Air Infiltration and Ventilation Centre. At present, there are 17 member countries (Australia, Belgium, China, Denmark, France, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Republic of Korea, Spain, Sweden, UK and USA).

The deliverables of the AIVC are technotes, Ventilation Information Papers, contributed reports, newsletters, webinars, workshops and conferences. This year, the 40^{th} AIVC conference will be held in Ghent (Belgium) in conjunction with the 8^{th} TightVent conference and the 6^{th} venticool conference. It is also the intention to have at this conference the public legal launch of the Indoor Environmental Quality Global Alliance (www.ieq-ga.net).

The Ghent conference will include keynote presentations, long and short oral presentations with posters as well as 12 topical sessions:

Session 01: 40 years of AIVC

Session 02: Bedroom ventilation, IAQ and sleep

Session 03: Better implementation of ventilative cooling (cooling of buildings using outside air as main source) in national building standards, legislation and compliance tools

Session 04: Controlling moisture for improved IAQ

Session 05: EPBD 2018/844/EU Article 19a feasibility study on the "inspection of stand-alone ventilation systems"

Session 06: EBC Annex 68 - Design and Operational Strategies for High IAQ in Low Energy Buildings

Session 07: EBC Annex 78 - Supplementing Ventilation with Gas-phase Air Cleaning, Implementation and Energy Implications

Session 08: EBC Annex 80 - Resilient Cooling

Session 09: Integrating uncertainties due to wind and stack effect in declared airtightness results

Session 10: Model based control and concepts for ventilation systems

Session 11: Performance-based assessment methods for ventilation systems

Session 12: IEA EBC Annex 79: What information do we need for occupant-centric building design and operation?

More information can be found on:
www.aivc2019conference.org ■

ACREX India 2020
27 - 29 February 2020
IEML • GREATER NOIDA • DELHI NCR

Organized by
ISHRAE

Event Producer
NÜRNBERG MESSE

ACREX India 2020, South Asia's Largest HVAC&R Event, promises to build sustainable future

ACREX India, **the most credible representative of the South Asian HVAC & R Industry**, organised by Indian Society of Heating, Refrigerating and Air Conditioning Engineers (ISHRAE) and produced by NürnbergMesse India, gears up at an augmented pace for the 21st Edition to be held in the National Capital Region, New Delhi on February 27-29, 2020. Keeping up with the high standards of national and international participation, there shall be exhibitors and visitors from over 25 countries including Belgium, China, Czech Republic, Egypt, France, Germany, Italy, Japan, Korea, Malaysia, Saudi Arabia, Singapore, Spain, Switzerland, Taiwan, the Netherlands, UAE, UK, Ukraine and USA. While corporations like Climaveneta S.P.A, Clivet S.P.A, Güntner Gmbh and many more have opened their offices in India, several international brands like Lu-Ve S.P.A, Fujian Snowman Co. Ltd, Prihoda S.R.O, Infraca, etc., have been regularly doing business and are working towards setting up their India operations or JVs.

ACREX India 2020 – Building a Sustainable Future Together

ACREX India 2020 will also present a live exhibit titled "*Shudh Vaayu Deergh Aayu*" (translated to English as: Clean air, long life) on IAQ which shall focus on advanced techniques of designing new homes that now feature mechanical systems that support and accentuate natural ventilation. The exhibit will demonstrate that how, through mechanical means and through HVAC systems, one can remove or dilute indoor airborne pollutants coming from indoor sources; and how it reduces the level of contaminants and improves the IAQ.

"As we showcase this exhibit to architects, builders, home-owners and policy makers in the government sector, we can help improve the lives and health of our fellow citizens by advocating for formulation of suitable policies and guidelines. The special SVDA Pavilion, will have 20 IAQ brands with their products in an exclusive show-and-tell form of exhibit. We also plan some dedicated lectures and papers on this theme to provide a holistic approach to the initiative. A power-packed delegation of international association heads during ACREX India 2020 the largest international exhibitor presence to date will ensure that India and ACREX India is aggressively promoted internationally." says **Sushil K. Choudhury**, Chairman ACREX India 2020.

Insightful Seminars & Workshops will be held by industry experts on topics ranging from energy efficiency, healthy buildings, indoor air quality, refrigerants, to IoT; along with engaging sessions by international associations like U.S. Green Building Council, REHVA (Federation of European Heating, Ventilating and Air-conditioning Associations), CEEW (Council On Energy, Environment and Water) s, AAR (Association of Ammonia Refrigeration), IAQA (Indoor Air Quality Association) & ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers).

Commenting on the opportunities that ACREX India offers, Ms. **Sonia Prashar**, Chairperson of the Board and Managing Director, NuernbergMesse India quoted "The Indian HVAC &R market is quickly racing to surpass the USD 6 Billion mark in the next five years making it imperative for every manufacturer in the international market to vie for a space in the Indian sub-continent. ACREX India 2020 creates a valuable platform for all connected to the HVAC & R industry to reach relevant stakeholders and decision makers."

High potential opportunities in the Indian market

India HVAC market is expected to reach USD 5.9 billion by 2024, registering a CAGR of 9.86 per cent during the forecast period. The development be ascribed to expanding number of tall buildings, shopping malls and shopping centers, and hypermarkets in level II urban communities, as well as on-going smart-city projects in the nation. Growing infrastructure-based developments, technological advancements & increasing tourism activities, extreme climatic conditions, rising disposable income, growing construction activities in both commercial and residential sectors, coupled with various government initiatives aimed at improving energy efficiency are some of the other major factors expected to aid this surge.

Growth Drivers

- Direct Expansion of HVAC market in India in 2016 accounted for USD 3.34 Billion, the same trend to continue over the next five years.
- Increasing demand for HVACs from rapid infrastructure development activities through major residential complexes, hotels, office spaces, amusement and recreation spaces.
- Surging medical tourism and expanding IT & ITeS sector.
- Value share of commercial sector in India HVAC market projected to increase from 27.87% in 2016 to 28.75% by 2022.

Key Highlights: Concurrent Events at ACREX 2020

- **Curtain Raiser** – the exclusive precursor event & networking platform for CEOs, leading developers, architects, consultants & officials from international associations, organized by ISHRAE & Sanhua India.
- **ACREX Awards of Excellence** - paneled by a jury of industry experts to award products and services across categories like innovation, green buildings, energy saving, green products, building automation, product with technology developed in India and Indoor Air Quality.
- **aQuest** - unique competition organized by ISHRAE and powered by HITACHI to connect with the **Student community.**
- ACREX Hall of Fame - the new industry benchmark to honour iconic projects in India, instituted by ISHRAE and Powered by Danfoss.

A powerful duo: ACREX India 2020 along with FSIE 2020

Fire & Security India Expo will be held concurrent to ACREX India at the IEML, New Delhi Region as the platform for passive, active and organizational Fire safety, security management, organized by NürnbergMesse India & Fire & Security Association of India (FSAI). In FSIE 2020, 150+ national & international exhibitors will present their latest products and technologies to an increased audience of about 10 000 qualified visitors.

About ISHRAE

The Indian Society of Heating, Refrigerating and Air Conditioning Engineers (ISHRAE), founded in 1981 at New Delhi by a group of eminent HVAC&R professionals, has over 12,000 HVAC&R professionals as members and 7,500 student-members. Operating from 41 Chapters & sub chapters across the country with its headquarters in Delhi, ISHRAE is led by a team of elected officers, working on a voluntary basis, and collectively called the Board of Governors. Website: www.ishrae.in

About NürnbergMesse Group

NürnbergMesse is one of the 15 largest exhibition companies in the world, with around 120 national and international exhibitions and congresses and approx. 40 sponsored pavilions at the Nuremberg location and worldwide. Every year, about 35,000 exhibitors (international share: 44%) and up to 1.5 million visitors (international share of trade visitors: 26%) participate in the own, partner and guest events of the NürnbergMesse Group, which is present with subsidiaries in China, North America, Brazil, Italy and India. The group also has a network of about 50 representatives in over 100 countries.

Website: www.nuernbergmesse.de, www.nm-india.com

For more information on ACREX, visit www.acrex.in

ISHRAE

REFCOLD INDIA
21 - 23 NOVEMBER, 2019
Hitex Exhibition Centre, Hyderabad

NÜRNBERG MESSE

Refrigeration and cold chain industries in the Indian Subcontinent anticipate massive surge in business with REFCOLD India 2019

REFCOLD India 2019: November 21–23, 2019

- The platform to showcase latest innovations as future drivers for refrigeration industry
- Major end-users of Indian cold chain industry like AL-Kabeer (India's largest meat exporter), Bulk Drugs Manufacturers Association of India, GADRE Premium Seafood (India's largest premium seafood exporter) endorse REFCOLD India 2019
- Various subsidy schemes made available by the Government of India through MoFPI, NHB, NHM, APEDA and other bodies for boosting industry operations

REFCOLD India, South Asia's largest cold chain and refrigeration event, is the blooming destination for innovation in products and services, training and education and business networking for the entire food industry. Over 15,000 decision makers and innovators from retail, food service, processing, production, distribution, logistics, and transportation representing frozen, refrigerated, ambient and fresh operations would attend the most prime convention pertaining to their industry.

This year's REFCOLD India would take place at Hyderabad, Telangana on November 21–23, 2019. The state of Telangana boasts of a robust infrastructure, international airport, 4 food parks, 146 industrial parks, 27 SEZs and 2 Agri-export zones, thereby making it the *perfect destination to bring the entire sector under a single roof and work towards the common goal.*

Over the course of three days at *REFCOLD India, exhibition, seminars and workshops* will combine to deliver the most valuable and comprehensive business-to-business networking event, serving the perishables industry with opportunities to connect with key buyers that produce, handle, store, transport or are involved in the distribution of perishable products. Two principal highlights of the event are:

- *REFCOLD Business Summit* – aims to provide great business opportunities to exhibitors to connect with top industry buyers.
- *REFCOLD Innovation Hub* – platform for exhibitors and partners to showcase their innovations which has power to transform the Cold Chain and Refrigeration Industry.

OVERVIEW OF INDIAN MARKET: Opportunities and Challenges

The Cold Chain & Refrigeration Market in India is expected to reach $658.59 Bn by 2022. The transformation of traditional perishables business through integrated cold-chain solutions would have a great impact on the market scenario and overall growth, in a country where 60% of the population is currently employed in agriculture.

Along with a plethora of promises, this sector also comes with certain challenges. Fragmentation of warehouses and third-party logistics delay the operational efficiency, hence *integrated logistics solutions* for end to end supply chain becomes imperative. Cold chain network configuration is a science and needs to be handled with care and responsibility. To transform these shortcomings into opportunities, the experts need to realign – right from the space & network modelling, logistics, and valued facilities to match cold chain requirements.

Through efficient operations, one can steer the opportunities in the current market, which are plenty, as the demands are very promising and the expected growth at CAGR of 13–16% provides great momentum for existing and new players.

Key Growth Drivers

- Through Cold Chain Logistics, distribution goes far and wide and in larger volumes, resulting into higher demand and consumption of dairy, meat, poultry and marine foods
- By 2020, the Indian Dairy industry is expected to double to $ 140 bn
- By 2020, Indian Food and Retail market is projected to touch $ 828.92 bn
- 100% Foreign Direct Investment allowed in multi-brand retail business of locally sourced processed food
- Growth in Pharma products
- The projects identified under Ports & Shipping Industry – *The Sagarmala Programme* - is expected to mobilize over 61.6 bn of infrastructure investment

More Concurrent Events at REFCOLD India

- *REFCOLD Emerson Awards Night* – The award night hosted by ISHRAE along with Emerson to honour *innovative & outstanding energy efficient projects* in the Cold Chain and Refrigeration Industry.
- *Daikin Global Poster Competition* – the aim is to provide a platform to *national and international students to demonstrate their innovative research*.
- *REFCOLD Entrepreneur's Conclave* – Creating an ecosystem for entrepreneurship through this conclave by industry experts.
- *REFCOLD BIZ QUIZ – Technical and entertaining Business Quiz for HVAC & R Professionals* to display their knowledge of technical and business domains

Way forward for the Indian Cold Chain Industry

The cold chain industry has evolved over the years and has played an indispensable role to preserve, extend and ensure the high shelf life of products like fresh agricultural produce, seafood, frozen food, photographic films, chemicals, and pharmaceutical drugs, ultimately boosting the Indian economy. The major driving force behind the growth of cold chain facilities in India is the growth of the end-user industries.

The answer to timely delivery to the user industries including quick service restaurants, pharmaceutical industry, processed food industry and organised retail sector lies in the right product, in the right quantity, condition and price to the right customer at the right place. This is an art, completely dependent on the science of inclusive and accurate planning & decision making.

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Website: www.nuernbergmesse.de, www.nm-india.com

For more information, visit www.refcoldindia.com

ACREX India 2019
HALL 1
28 February - 2 March 2019
South Asia's largest Exhibition on Air Conditioning
bfa
BUILD FAIR ALLIANCE
ISHRAE

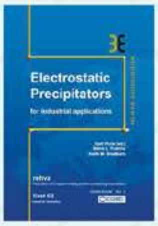
REHVA

Federation of European Heating, Ventilation and Air Conditioning Associations

EUROPEAN GUIDEBOOKS

No.01: DISPLACEMENT VENTILATION IN NON-INDUSTRIAL PREMISES

No.02: VENTILATION EFFECTIVENESS



No.03: ELECTROSTATIC PRECIPITATORS FOR INDUSTRIAL APPLICATIONS

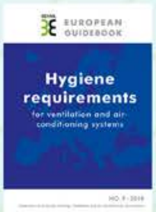
No.04: VENTILATION AND SMOKING

No.05: CHILLED BEAM APPLICATION GUIDEBOOK

No.06: INDOOR CLIMATE AND PRODUCTIVITY IN OFFICES

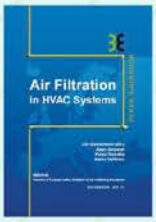
No.07: LOW TEMPERATURE HEATING AND HIGH TEMPERATURE COOLING

No.08: CLEANLINESS OF VENTILATION SYSTEM



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

No.10: COMPUTATIONAL FLUID DYNAMICS IN VENTILATION DESIGN



No.11: AIR FILTRATION IN HVAC SYSTEMS

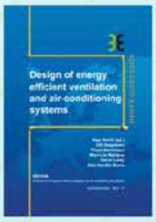
No.12: SOLAR SHADING

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

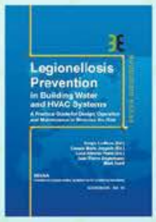
No.14: INDOOR CLIMATE QUALITY ASSESSMENT

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

No.16: HVAC IN SUSTAINABLE OFFICE BUILDINGS



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



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

No.19: MIXING VENTILATION

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

No.21: ACTIVE AND PASSIVE BEAM APPLICATION DESIGN GUIDE

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

No.23: DISPLACEMENT VENTILATION

No.24: FIRE SAFETY IN BUILDINGS

No.25: RESIDENTIAL HEAT RECOVERY VENTILATION

No.26: ENERGY EFFICIENCY IN HISTORIC BUILDINGS

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

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

No.29: QUALITY MANAGEMENT FOR BUILDINGS